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EXECUTIVE COMMITTEE
SCIENTIFIC COMMITTEE ON OCEANIC RESEARCH
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President:

Dr. Marie-Alexandrine Sicre
CNRS, LOCEAN
Tour 46-00, 5eme étage
4 place Jussieu
75252 Paris Cedex 05
FRANCE
E-mail: Marie-Alexandrine.Sicre@locean-ipsl.upmc.fr

Secretary:

Prof. Paul G. Myers
Department of Earth and Atmospheric Sciences
1-26 ESB, University of Alberta
Edmonton, Alberta T6G 2E3
CANADA
pmyers@ualberta.ca

Past President:

Prof. Peter Burkill
Mount Clogg Farm
Shaugh Prior
Plymouth PL7 5HA
UNITED KINGDOM
E-mail: peter.burkill@plymouth.ac.uk

Vice-Presidents:

Dr. David Halpern
14030 Crest Way
Del Mar, CA 92014
USA
david.halpern@jpl.nasa.gov

Dr. Sinjae Yoo
2670, Iljudongro
Gujwa-eup, Jeju 63349
SOUTH KOREA
Email: sjyoo@kiost.ac.kr

Prof. Jing Zhang
Graduate School of Science and Engineering
University of Toyama
Toyama 9308555
JAPAN
jzhang@sci.u-toyama.ac.jp

Ex-Officio Members:

Dr. Patricia Miloslavich (IABO)
GOOS BioEco Project Officer
University of Tasmania
Institute for Marine and Antarctic Studies
Private Bag 129
7001 Hobart TAS
AUSTRALIA
Email: pmilos@usb.ve

Prof. Trevor McDougall (IAPSO)
The School of Mathematics and Statistics
University of New South Wales
Sydney NSW 2052
AUSTRALIA

Prof. Joyce Penner (IAMAS)
Climate and Space Sciences and Engineering
Climate & Space Research Building
University of Michigan
2455 Hayward Street
Ann Arbor, MI 48109-2143
USA

Co-opted Members:

Nuria Casacuberta Arola
ETH Zurich
Otto-Stern-Weg, 5
HPK G23
Zurich 8093
SWITZERLAND
ncasacuberta@phys.ethz.ch

SCOR Secretariat:

Edward R. Urban, Jr., Executive Director
College of Marine and Earth Studies
Robinson Hall
University of Delaware
Newark, DE 19716
USA
Tel: +1-302-831-7011
E-mail: secretariat@scor-int.org

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**PROCEEDINGS
OF THE
SCIENTIFIC COMMITTEE ON OCEANIC RESEARCH**

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SCOR
College of Earth, Ocean and Environment
003 Robinson Hall
University of Delaware
Newark, DE 19716 USA
Tel: +1-302-831-7011, Fax: +1-302-831-7012, Internet: secretariat@scor-int.org
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SCOR Proceedings, Volume 55
REPORT OF THE 2019 ANNUAL SCOR MEETING

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2019 SCOR ANNUAL MEETING

Toyama, Japan
23-25 September 2019

1.0 OPENING

1.1 Opening Remarks and Administrative Arrangements

Jing Zhang welcomed participants on behalf of the Japanese SCOR Committee. She noted that a metal tumbler is available for each participant, so that the use of plastic can be reduced. Marie-Alexandrine Sicre, SCOR President, also welcomed participants and asked each to introduce themselves.

Sicre continued by noting members of the SCOR community that had died in the past year and summarized their scientific contributions (see https://scor-int.org/AnnualMeetings/2019_SCOR_Meeting/Tab_1.pdf) and involvement with SCOR:

- Wallace Broecker was a Full Member of SCOR WG 20 on Radiocarbon Estimation of Primary Production and of SCOR WG 44 on Ocean-Atmosphere Materials Exchange.
- Keith Hunter was a Full Member of SCOR WG 80 on Role of Phase Transfer Processes in the Cycling of Trace Metals in Estuaries and Co-chair of SCOR WG 109 on Biogeochemistry of Iron in Seawater.
- Angus McEwan was a Member of SCOR/IOC Committee on Climate Change and the Ocean and a Nominated Member from Australia.
- Walter Munk was a Full Member of SCOR WG 96 on Acoustic Monitoring of the World Ocean.
- Rengaswamy Ramesh was a Full Member of SCOR WG 117 on Synthesis of Decadal to Millennial Climate Records of the Past 80ky.
- Bert Semtner was a Full Member of SCOR WG 107 on Improved Global Bathymetry.

1.2 Approval of the Agenda

Additions or modifications to the agenda as distributed may be suggested prior to approval of the final version. The only change was to move the InterRidge presentation from Thursday to Wednesday, right after WG discussions, because Jerome Dymant needed to leave before Thursday.

1.3 Report of the President of SCOR

The SCOR President, Marie-Alexandrine Sicre, briefly reviewed her activities for SCOR since the SCOR Annual Meeting in September 2018 in Plymouth, UK. Sicre was invited to contribute to the Sustainable Blue Economy conference held in Kenya (26 to 28 November 2018); she gave an introductory presentation in the Science and Research Symposium. In December 2018, Sicre represented SCOR at a GEOTRACES-PAGES workshop on the use of isotopes for paleoceanography organized in France. In mid-April to mid-June 2019, Sicre worked with Peter Burkill and Paul Myers to recruit a new Executive Director for SCOR; Patricia Miloslavich was selected. On 19-23 June 2019, she participated in the second IMBeR Open Science Conference

in Brest, France and the following meeting of the IMBeR Scientific Steering Committee. Following the IMBeR meetings, Sicre represented SCOR (with Ed Urban) at the IOC General Assembly, which had a large focus on the UN Decade of Ocean Science for Sustainable Development. She plans to represent SCOR at a regional Indian Ocean planning workshop for the UN Decade. IOC acknowledged progress in the second International Indian Ocean Expedition (IIOE-2) and encouraged support to 2025. During the past year, Sicre also participated in monthly conference calls by the Ocean Knowledge Action Network Development Team.

1.4 Report of SCOR Executive Director

The Executive Director, Ed Urban, reported on his activities for SCOR since the 2018 SCOR Annual meeting, and on the current condition of SCOR. Urban noted that at least three SCOR working groups contributed to community white papers published in the special section of *Frontiers in Marine Science* related to the OceanObs'19 meeting. Four ASLO eLectures were published in the *Limnology and Oceanography* eLecture journal from WG 146 on Radioactivity in the Ocean, 5 decades later (RiO5). In terms of outreach from SCOR, there has been an increase in the number of individuals receiving SCOR emails, and followers on Twitter and Facebook; there is little overlap between recipients of SCOR emails and tweets. The Webpages for SCOR WGs are being improved with pictures and not-technical explanations related to the groups' work. SCOR has reserved a double booth at Ocean Sciences 2020, where there will be software demonstrations from SCOR WGs and projects. Urban reported that the percentage of females involved in SCOR activities is slowly increasing, while the percentage of developing country scientists on SCOR groups has remained constant. The Irish SCOR Committee now tweets, which might be a good approach for other national SCOR committees. The SCOR Visibility Committee distributed a survey on SCOR visibility and legacy. The Executive Committee will consider the results of the survey and recommendations from the Visibility Committee before the 2020 SCOR Annual Meeting.

1.5 Appointment of an *ad hoc* Finance Committee

The SCOR Constitution requires that a Finance Committee be appointed at every SCOR meeting. It must consist of at least three members of SCOR who are not members of the Executive Committee. The Finance Committee reviews the administration of SCOR finances during the previous fiscal year and the current year, and will propose a budget for 2020 activities and dues for 2021. Members of the 2019 Finance Committee approved by the Executive Committee were Riitta Autio (Finland), Peter Croot (Ireland), Ilka Peeken (Germany), and Song Sun (China-Beijing). The Committee reported to the meeting under agenda item **8.3**.

1.6 2020 Elections for SCOR Officers

The SCOR President and all three Vice-President positions are open for nominations for the 2020 elections. Two of the Vice-Presidents, Jing Zhang and Sinjae Yoo, are eligible for a second term; at least one new Vice-President will be needed. The Nominating Committee needs to be balanced in terms of discipline, geography, and gender. Nominations will be due four months before the next SCOR Annual Meeting. Two months before the 2020 Annual Meeting, the

Nominating Committee will send a slate to all countries; unless at least three countries object, the slate is automatically approved to be elected at the end of the next meeting. Peter Burkill asked for volunteers to serve on the Nominating Committee for the 2020 elections.

2.0 WORKING GROUPS

2.1 Current Working Groups

The Executive Committee Reporter for each working group (or a member of the group) presented an update on working group activities and progress, and made recommendations on actions to be taken.

2.1.1 WG 142 on Quality Control Procedures for Oxygen and Other Biogeochemical Sensors on Floats and Gliders

The group produced four documents by WG members that directly related to the terms of reference of the group, and group members contributed to other BGC-Argo cookbooks. The group had excellent interactions with Argo, although their work is also relevant to gliders. The group was disbanded earlier in 2019.

2.1.2 WG 143 on Dissolved N₂O and CH₄ measurements: Working towards a global network of ocean time series measurements of N₂O and CH₄

Ed Urban reported that since the 2018 SCOR Annual Meeting, group members led a workshop on methane and nitrous oxide in October 2018 at Lake Arrowhead, California, USA, funded by the U.S. Ocean Carbon and Biogeochemistry (OCB) program. The group also participated in preparation of a white paper for OceanObs'19¹ and another reporting on their intercomparison activity.² The group's request to extend its term until the 2019 SCOR Annual Meeting to complete activities underway, was approved at the SCOR Annual Meeting in Plymouth. Finally, they are preparing standard operating procedures (SOPs), which they hope to complete by the end of 2019. The group will be disbanded when the SOPs are completed.

2.1.3 WG 145 on Chemical Speciation Modelling in Seawater to Meet 21st Century Needs (MARCHEMSPEC)

Marie-Alexandrine Sicre reported that members of the group received a three-year grant from the U.S. National Science Foundation and the UK Natural Environment Research Council to conduct research related to the group's work. The group has enlisted the help of several national laboratories in its work and is also cooperating with the Joint Committee on Seawater on pH issues (see **agenda item 4.3**). The group has two additional peer-reviewed papers in preparation. It will hold its final meeting on 16 February 2020 at the 2020 Ocean Sciences Meeting in San Diego, Calif., USA. The group has proposed a tutorial and a special session at Ocean Sciences, and will provide an opportunity at the SCOR booth to test software on which the group is working. Sicre recommended that the group be maintained until they complete their terms of reference. Ed Urban noted that SCOR asks working groups to finish in 3-4 years, but sometimes

¹Bange, H.W., et al. 2019. A Harmonized Nitrous Oxide (N₂O) Ocean Observation Network for the 21st Century. *Frontiers in Marine Science*, 2 April 2019, <https://doi.org/10.3389/fmars.2019.00157>.

²Wilson, S.T., et al. 2018. An intercomparison of oceanic methane and nitrous oxide measurements. *Biogeosciences* 15:5891–5907. <https://doi.org/10.5194/bg-15-5891-2018>

they take longer. Funding was approved for the group's 2020 meeting.

2.1.4 WG 147: Towards comparability of global oceanic nutrient data (COMPONUT)

Michio Aoyama, co-chair of WG 147, presented an update of its status and progress. The group held an editorial meeting on 7-10 July 2019 at the Scripps Institution of Oceanography to work on the nutrient analysis portion of the GO-SHIP manual and on international nutrient intercalibration exercises. The revised document has been published on the Web (see <https://www.oceanbestpractices.net/handle/11329/1023>). There are now five lots of certified reference materials (CRMs) available. Peter Burkill asked about inter-comparisons of nanomolar-level nutrient concentrations in the open ocean. Aoyama replied that the working group has received requests about this and could perhaps work towards nanomolar CRMs, but it would need more accurate measurements. There are questions of the homogeneity of low-level CRMs. The group is planning more inter-comparisons in 2021, beyond the life of the working group. Aoyama will organize the next intercomparison exercise, and the team will provide CRMs for the next exercise. It was agreed that the group has completed its terms of reference and should be disbanded.

2.1.5 WG 148 on International Quality Controlled Ocean Database: Subsurface temperature profiles (IQuOD)

Paul Myers reported on the status and progress of WG 148. The group produced a peer-reviewed paper this year, on an algorithm for estimating which XBT instruments were used in measurements, based on metadata available.³ The group will meet for the final time as a SCOR WG on 28 October-1 November 2019 in Brest, France. It was agreed to postpone disbanding of the group until the 2020 SCOR Annual Meeting, without extra funding. Ed Urban noted that the International Oceanographic Data and Information Exchange (IODE) of IOC has also supported the group.

2.1.6 WG 150 on Translation of Optical Measurements into particle Content, Aggregation & Transfer (TOMCAT)

Peter Burkill reported on the status and progress of WG 150. Members of TOMCAT (with members of WG 154) were involved this year in shaping a Community White Paper on Observational Needs as part of OceanObs'19.⁴ The group has a special issue of *Frontiers in Marine Science* open, which currently has 10 papers submitted on novel methodology to modelling and other topics. The group is also preparing a literature review of particles in the ocean. Burkill apologized that there was no report from the group in the background book. The chair produced a report, but Burkill requested some revisions before distributing. In terms of capacity building, the group is planning a training course on analytic methods in marine biogeochemistry in South Africa, which may be held in conjunction with a working group meeting. SCOR asked the group to add an Associate Member from a developing country. Burkill recommended that SCOR approve funding in principle, but ask for a clarification of the group's plan and leave it to the SCOR Executive Committee to make the final decision. This recommended was accepted by meeting participants.

³Palmer, M.D., et al. 2018. An Algorithm for Classifying Unknown Expendable Bathythermograph (XBT) Instruments Based on Existing Metadata. *Journal of Atmospheric and Oceanic Technology* 35:429-440.

⁴Lombard, F., et al. 2019. Globally consistent quantitative observations of planktonic ecosystems. *Front. Mar. Sci.* 6:196. <https://doi.org/10.3389/fmars.2019.00196>

2.1.7 WG 151: Iron Model Intercomparison Project (FeMIP)

Núria Casacuberta-Arola reported on the status and progress of WG 151. The group did not meet in person this year, but made progress on each of its terms of reference virtually using email and Slack. An open-access article is being drafted related to practices for minimum complexity representations of the iron cycle in models (TOR #1). The group is targeting specific models and types of parameter fields. They are drafting a table with the main physiological processes that should be included in models that include iron. They are planning to use a single model (GENIE) for the comparisons and are waiting for the availability of the group member who will do the simulations. The group has submitted a proposal for a session at Ocean Sciences 2020 related to the goals of the group. They plan to meet on 16 February 2020, in conjunction with Ocean Sciences.

Salvatore Aricò mentioned that this group is relevant to a Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) working group on geo-engineering. It would be useful to have some cross-fertilization between WG 151 and the GESAMP group. WG 151 is also relevant to some IOC activities on carbon sequestration. Bob Duce added that the GESAMP group is active and has produced a comprehensive report. Ed Urban noted that Philip Boyd is co-chair of the GESAMP geo-engineering group and a member of WG 151, so this should create a good linkage.

2.1.8 WG 152 on Measuring Essential Climate Variables in Sea Ice (ECV-Ice)

Daiki Nomura, co-chair of WG 152, reported on its status and progress. The group is trying to compile various biological and chemical data from sea ice and publish synthetic reviews based on these data. An Antarctic synthesis review was published in the *Journal of Geophysical Research*.⁵ The group is interested in gas fluxes between the air and sea, through sea ice. It is comparing air-sea CO₂ fluxes by two methods and is finding two orders of difference in eddy covariances; they may need to remove moisture for the method to work properly. The group has held annual meetings in 2017 (USA), 2018 (Switzerland), and 2019 (Canada). The group held an intercalibration exercise in February 2019 and published several peer-reviewed articles.⁶ The group met on 16-18 August 2019 in Winnipeg, Canada. This will be the group's last full meeting with SCOR funding. After SCOR funding is completed, group members will conduct intercomparisons in an air-sea-ice chamber in 2020, and will conduct the same experiment on northern Hokkaido (Japan) or at Cambridge Bay (Canada) in May 2021, to focus on primary production, light, gas in sea ice, and flux. Unlike Hokkaido, which has thinner and warmer sea ice, Cambridge Bay has colder and thicker sea ice.

⁵Meiners, K.M., Vancoppenolle M., et al. 2018. Chlorophyll-a in Antarctic land-fast sea ice: A first synthesis of historical ice-core data. *Geophysical Research: Oceans*, 123, 8444-8459, <https://doi.org/10.1029/2018JC014245>

⁶ Butterworth, B.J. and Else, B.G.T. 2018. Dried, closed-path eddy covariance method for measuring carbon dioxide flux over sea ice. *Atmos. Meas. Tech.* 11:6075-6090, <https://doi.org/10.5194/amt-11-6075-2018>

Campbell, K., Mundy, C. J., Juhl, A. R., Dalman, L. A., Michel, C., Galley, R. J., Else, B. E., Geilfus, N. X., and Rysgaard, S. 2019. Melt Procedure Affects the Photosynthetic Response of Sea Ice Algae. *Front. Earth Sci.* 7:21. [doi:10.3389/feart.2019.00021](https://doi.org/10.3389/feart.2019.00021)

Meiners, K.M., et al. Chlorophyll-a in Antarctic land-fast sea ice: A first synthesis of historical ice-core data. *Geophysical Research: Oceans* 123:8444-8459, <https://doi.org/10.1029/2018JC014245>.

Roukaerts, A., D. Nomura, F. Deman, H. Hattori, F. Dehairs, and F. Fripiat. 2019. The effect of melting treatments on the assessment of biomass and nutrients in sea ice (Saroma-ko lagoon, Hokkaido, Japan). *Polar Biology* 42(2):347–356, <https://doi.org/10.1007/s00300-018-2426-y>

A meeting participant commented that the plan to integrate data and make the data archive open to public will be important. Lisa Miller, a Full Member of WG 152, added that data synthesis is a responsibility of the BEPSII working group, which is a former SCOR group that has continued. Phoebe Lam, co-chair of the GEOTRACES project, added that the GEOTRACES community is working on inter-comparisons of trace metal measurements in sea ice. Ilka Peeken, another Full Member of WG 152, added that the group is making good progress, dealing with its tasks well and working together well. Mitsuo Uematsu, co-chair of the Ocean Knowledge Action Network, asked if groups like this contributed directly to the IPCC Special Report on Ocean and Cryosphere. Ed Urban responded that SCOR is not contributing directly, but scientists in the working group may have. The group requested permission to spend its remaining US\$8,000 to help support participants at the next meeting of the group or to participate in an intercalibration experiment. It was decided that the group should inform SCOR who they would like to support for which purpose and the Executive Committee will decide later whether to approve the funding.

2.1.9 WG 153 on Floating Litter and its Oceanic Transport Analysis and Modelling (FLOTSAM)

Victor Martinez, a Full Member of WH 153, provided an update of WG 153's status and progress. He thanked Jing Zhang for the invitation to give the public lecture on 22 September, before the SCOR meeting. This group participated in a white paper on marine litter for OceanObs'19, published in *Frontiers in Marine Science*.⁷ There was a breakout group at OceanObs, which Ed Urban reported was well attended. Several other articles are in review or in preparation, including one on observation requirements for remote sensing of marine litter. WG 153 met most recently in Utrecht, The Netherlands on 6-9 May 2019, with 23 in-person and 5 remote participants, including some Ph.D. students. The group has proposed a session at Ocean Sciences 2020. The group is mainly focused on modeling litter distributions, but there are also remote sensing and bio-optics components. Martinez admitted that the percentage of women in the group is lower than desirable, although one of the vice-chairs is female. The Website has been updated for dissemination purposes. In the next year, the group will continue its review of physical processes and extend it to sampling methods, and will do a review of marine pollutants in the Arctic. For the group's 2020 meeting, they are considering meeting in Russia or Japan; a decision will be made by early October 2019. Martinez expressed his hope that remote sensing of litter could become associated with remote sensing of ocean color.

Salvatore Aricò asked the extent to which plastics is a focus of the working group. Martinez responded that plastics are a core to the group's activity, as the majority (~70%) of debris is plastic. Aricò suggested a collaboration with the GESAMP WG 40 on Sources, Fate and Effects of Plastics and Micro-plastics in the Marine Environment, which was renewed recently, although their focus is different. Ed Urban noted that WG 153 will submit a proposal to the Lounsbery Foundation for a larger meeting associated with third meeting of the group. Martinez noted that the group is in discussions about funding for outreach in developing regions. Peter Burkill asked if the group has used the remote sensing historical record to look at changes in floating litter in gyres over recent decades, to study how oligotrophic gyres have been impacted by anthropogenic material. Martinez responded that there are areas of accumulation, including gyres, which can be

⁷Maximenko, N., et al. 2019. Towards the Integrated Marine Debris Observing System. *Front. Mar. Sci.* doi: [10.3389/fmars.2019.00447](https://doi.org/10.3389/fmars.2019.00447)

monitored with satellite remote sensing, but there is a question about whether the quality of older remote sensing would allow historical analysis. Robert Duce asked whether WG 153 is focused on micro- or macro-plastics. Martinez answered that the group is both dealing with both.

Funds were approved for WG 153 activities in 2020.

2.1.10 WG 154 on Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (P-OBS)

Patricia Miloslavich provided an update about the status and progress of WG 154. A subgroup of the group met in Villefranche-sur-Mer, France, in November 2018 to finalize a draft section for the GO-SHIP Manual, summarizing existing technology that could be incorporated into GO-SHIP cruises to measure plankton-relevant parameters, the relevant best-practice documents, associated costs and effort, and to organize its 2nd in-person meeting, in conjunction with OceanObs'19. The group reported to GO-SHIP's annual meeting in conjunction with OceanObs. WG 154 is also contributing to a discussion of the U.S. Ocean Carbon and Biogeochemistry group on adding biological measurements to GO-SHIP and BGC-Argo. As part of the group's development of recommendations, it is discussing ocean biological measurement best practices and has compiled a list of approaches to measure plankton and how feasible they would be to install on GO-SHIP cruises. Preliminary comments from GO-SHIP requested that WG 154 refine the scientific questions that would be addressed by each measurements and what sort of data repository is available for each. The group participated (with WG 150) in a community white paper for OceanObs'19 (see footnote 4). The work of the group has been parceled out to subgroups; the subgroup leaders met in November 2018. Unfortunately, the Continuous Plankton Recorder (CPR) is not feasible to deploy on GO-SHIP cruises because of ship speed and the frequent stops made on GO-SHIP cruises. The group's Terms of Reference #1, #4, and #5 have been completed. TORs #2 and #3 are in progress. TOR #6 has not yet been started. Victor Martinez asked if there is any mechanism within SCOR for working groups to work together on topics of mutual interest. The observing platforms used by WG 154 would be of interest to WG 153. Marie-Alexandrine Sicre responded that there is no formal mechanism, but individual scientists in the different groups can initiate contact.

Funding was approved for 2020 activities of WG 154.

2.1.11 WG 155 on Eastern boundary upwelling systems (EBUS): diversity, coupled dynamics and sensitivity to climate change

David Halpern presented an update about WG 155. The group is working on a review paper about knowledge of EBUS systems, a second paper on EBUS models, a summer school (May 2020 in Dakar, Senegal) and open science meeting (2021 in Lima, Peru), a data portal, and a data and monitoring needs report. Their next meeting is planned to occur in conjunction with the summer school in Dakar. Halpern stated that he was not very optimistic about the group's progress, based on its annual report. The group has held one in-person meeting in mid-June 2018 and two conference calls, mainly to organize the 2020 summer school. The group is working on a review article. Group members were co-authors of a community white paper for OceanObs'19, but this was not mentioned in the group's annual report. The group is in its second year now. The group is supposed to be linked to the CLIVAR EBUS Research Focus, without duplication, but there was no update about that linkage. Halpern suggested that the group proceed with its work

and that SCOR ask for additional information about the group's work to assess the group's progress better.

Salvatore Aricò commented that there is a need to discriminate between the importance of the topic and how EBUS might be changing—which is important because of linkages to Sustainable Development Goals and food security—and comments on this particular working group. Aricò noted that there was a summer school organized by the CLIVAR EBUS Research Focus in Trieste earlier this year. The CLIVAR and SCOR groups are complementary. Ed Urban noted that at least one member of WG 155 is also a member of CLIVAR group. A meeting participant noted that the URL given in the WG report is not working. John Clayton (IMBeR) noted that most of the activities listed in the WG 155 report were done in collaboration with CLIVAR and that WG 155 and the IMBeR EBUS group are basically the same. Peter Burkill suggested that SCOR hold WG 155's funding until they can satisfy the SCOR Executive Committee reporter's questions satisfactorily. This approach was agreed.

2.1.12 WG 156 on Active Chlorophyll fluorescence for autonomous measurements of global marine primary productivity

Sinjaee Yoo reported on the status and progress of WG 156. The group met for the first time in June 2019 for five days, including intercomparison experiments, and has made a good start on many of its terms of reference. In particular, the group's intercomparisons conducted in June will be used to produce a best-practices document related to active chlorophyll fluorescence measurements. Early-career scientists were involved in the intercomparisons. Group members will verify some of the best practices in the next 6 months, before producing a manual in eBook format. TOR #1 is largely complete; TOR #2, production of a best practice document for getting low-level data from different instruments, is underway. TOR 3, 4, 5 – initiated; TOR 6 – not yet started, to be initiated in years 3-4; TOR 7—knowledge sharing and outreach—is ongoing. In the coming year, the group will be involved in some field campaign deployments of fluorometers, hold its second meeting in conjunction with Ocean Sciences 2020, and submit a proposal to enhance capacity. WG 156 has very ambitious goals, but seem to be making good progress. Funding was approved for the group's 2020 meeting.

2.1.13 WG 157: Toward a new global view of marine zooplankton biodiversity based on DNA metabarcoding and reference DNA sequence databases (MetaZooGene)

Patricia Miloslavich reported that WG 157 will hold a symposium (see <https://metazooogene.org/symposia>) and its first meeting on 13-14 September 2019 in Gothenburg, Sweden. Work has begun on an open-access data portal for barcode data and metadata, and a review paper on which this information will be based. The second WG meeting will be held in conjunction with Ocean Sciences 2020 in San Diego, Calif., USA. Miloslavich noted that Ann Bucklin, WG 157 chair, won outstanding achievement award from the International Council of the Sea (ICES) this year. Funding was approved for the group's 2020 meeting.

2.2 Working Group Proposals

2.2.1 Roadmap for a Standardised Global Approach to Deep-Sea Biology for the Decade of Ocean Science for Sustainable Development (DeepSeaDecade)

Patricia Miloslavich presented the proposal and a summary of comments from national SCOR committees. In general, national SCOR committees considered the proposal to be timely because it would contribute to the UN Ocean Decade of Ocean Science for Sustainable Development, which recognizes the deficit of deep-sea data and the impact of this deficit on sustainable management of the ocean. More information about biodiversity and ecosystems of the deep sea are needed, particularly with the growing interest in deep-sea mining activities. The working group could provide a framework for a coordinated, international effort to increase our knowledge of deep-sea ecosystems, and could encourage and enable the development of new knowledge and understanding of a poorly understood component of the ocean system. However, some national SCOR committees did not find this proposal more timely than the other proposals. Standardization of deep-sea biology techniques is urgently needed, and the group should make it possible to develop a focused dialogue within the community to agree on standards and methods used to address the questions identified, and ensure future research efforts are integrated and inclusive. Standardization could help make sampling more efficient and comparable among surveys. However, it was not clear what a SCOR working group would add to existing deep-sea activities, such as the International network for scientific investigation of deep-sea ecosystems (InDEEP), Deep Ocean Stewardship Initiative (DOSI), and the Deep Ocean Observing Strategy (DOOS). The group's work will help facilitate coordination of future data acquisition, and contribute to capacity development and training. However, all of the deliverables (i.e., summary publications and white papers) could be accomplished without a SCOR working group and this kind of group could be supported by IOC or some other UN body. The terms of reference are generally appropriate, but are perhaps too broad and generic TOR #2 has already been addressed in part by other recent EU projects (e.g., AtlantOS, ATLAS, iATLANTIC) and DOOS activities. A large part of the diversity in the deep ocean is microbial, which is apparently not considered at all in this proposal. The proposal is strongly benthic focused, whereas recent work suggests that the biggest data gaps are for meso-pelagic species. In this context, some more specific examples of how Argo would be used for informing meso-pelagic or benthic studies would be informative. The membership has good gender balance (5 females and 5 males), but only two members from developing countries (Mexico and South Africa). There are no Asian or South American scientists proposed among the Full Members, only as Associate Members. The proposed membership seems to be dominated by senior researchers. It is geographically diverse yet some major nations in deep sea research (Russia, China, Japan, Germany) are not represented.

The Japanese SCOR Committee did not give the proposal high priority, as it felt the terms of reference were extremely vague and the geographical distribution of proposed members too oriented to North America and Western Europe. Environmental DNA (eDNA) methods are now advanced, but there was no mention of these in the proposal. The UK SCOR Committee felt that the proposal is “must fund”. It is timely given the UN Decade. It has high priority for ocean science and SCOR. There is no such existing forum. The issue of the geographic balance of members and other issues can be addressed if the proposal is approved. The Dutch SCOR Committee rated the proposal as “must fund”, higher than for C-GRASS. IOC was positive about the proposal, despite comments about how to improve it. IABO didn't feel like the proposal

addressed all the needs and issues related to the deep sea and that the proposed membership could be improved. The Canadian National Committee for SCOR rated the proposal behind the CBIOS proposal. The Korean SCOR Committee rated the proposal as “do not fund”. A major goal of the proposal was to develop an observational strategy, which many other groups are also doing, so SCOR resources would be better used in other areas less supported by other organizations. The Polish SCOR Committee strongly supported the proposal. It is interested in the approach and methods that will be developed, which will be useful for developing countries. The group’s work can be complementary to other efforts. Salvatore Aricò (IOC) noted that the deep ocean has been identified by a number of stakeholders as an important frontier from the point of view of the need to come up with an integrated map that includes life in the deep, ecosystems, metabolic features of those ecosystems, and industrial and science access to the deep sea. Some initiatives exist (e.g., OBIS contains records from the Census of Marine Life), but these could be linked to the working group. There is a need for the kind of work that this group proposed, for the UN Decade.

The reviews by national SCOR committees before the meeting yielded 12 “must funds”, three “may funds”, and four “do not funds”. The proposal was selected as one of two to start in 2020.

2.2.2 Marine Species Distribution Modelling in the global ocean (MSDM-GO)

Joyce Penner summarized the proposal, as well as comments from national SCOR committees. National SCOR committees thought the proposed membership wasn’t well balanced in gender composition and had inadequate representation from Asia and developing countries. The proposed membership does not include some key people who are working with marine species distribution models (MSDMs). The proposal needs to better present why this is a compelling issue and why the scientific community needs improved management of MSDMs. What does it mean in practice to improve best practices and standards? The proposal didn’t justify well that a best practices document will solve the problem that some standards already exist, but people don’t follow them. How would having a best practices document encourage the following of the best practices identified? The proposal needs a better discussion of what is intended with regard to the massive open online course (MOOC), and how it would be implemented, financed, and maintained after the working group’s term is completed. Some description should be provided about how the group would look at species diversity in different regions. The proposal should describe connections to other global research initiatives, such as the Integrated Marine Biosphere Research (IMBeR) project.

The review by national SCOR committees yielded 5 “must fund” rankings, 8 “may fund” rankings and, 6 “do not fund” rankings. The proposal was not approved.

2.2.3 DIagnoSis of Carbon in the Ocean: Variability, uncERtainty and the Coasts (DISCOVER-C)

Trevor McDougall presented the proposal and a summary of national comments related it. National committees noted that this is an important issue for ocean science and for SCOR because CO₂ fluxes affect not only the physical climate but also marine ecosystems (through acidification). Solving methodological issues should have a large positive effect. However, the group might not merit SCOR funding because the amount of the present discrepancy of the ocean CO₂ uptake seems modest; why worry about a 5% (of the global release of CO₂)

imbalance? The proposed Working Group would be duplicative of other projects underway. That is, the issue of patchy data coverage is well known, so how would a Working Group solve this issue? The statistical approaches for filling in data-sparse data areas do not need a Working Group to implement. However, the land-based sink is actually calculated as a residual between the known emissions and the amount taken up by the ocean. Also, if it is possible to determine the ocean sink more accurately (for relatively little cost) then it is probably worth the effort. That is, while 5% may sound like a small amount of uncertainty in some fields of science, if it is possible to reduce this 5% to say 2%, this would benefit society. The proposal needs to explain the potential benefit better. Regarding the perceived duplication of effort, a SCOR Working Group can bring important and different aspects than from other groups, possibly speeding things up and aiding in the adoption of new methodologies. Any re-submission needs to spell out why this new type of approach may not occur without a SCOR Working Group.

The Australian SCOR Committee ranked this proposal higher than the DeepSeaDecade proposal due to obvious importance of uptake of CO₂ fluxes, compared to things happening in the deep ocean. The UK SCOR Committee ranked this proposal as its top “must fund” because it is timely, highly relevant for the UN Paris agreement and SDG 13, and relevant to knowledge gaps related to ocean acidification and effects on marine life. This is a highly important subject area to address important areas of uncertainty. A focused working group would help narrow and reduce uncertainty. The terms of reference were clear and the proposed membership appropriate. The capacity building aspects were addressed well. The Korea SCOR Committee also ranked this proposal as its top pick. The proposal has been improved since last year. The Japanese SCOR Committee ranked the proposal as its 2nd highest priority. Improving air-sea CO₂ fluxes could improve understanding of the ocean carbon sink. They liked the idea of using the link to numerical models with observing system simulation experiments (OSSEs), to find key areas to reduce uncertainty. This approach seems to be feasible. The German SCOR Committee also ranked this proposal highest. The proposed work is extremely timely and valuable, and fits with grand challenges identified by other organizations. The proposed links with developing countries and other organizations could be improved. The U.S. SCOR Committee had a more mixed review. It agrees with the importance of the issue, but not that this is the most important proposal under consideration. There are many scientists in the United States working on this topic. If there is a gap in Arctic data, more specialists on carbon in the Arctic should be involved. IOC expressed that this is a very important proposal and will fill some data gaps. The Canadian National Committee for SCOR noted that the top experts are proposed as members, so the group is likely to be successful although, as noted by the U.S. committee, there is a lack of Arctic expertise. SOLAS ranked this proposal as its top one, for obvious reasons. SOLAS was quite impressed with the proposed membership and its diversity, given how complicated and specialized this problem is. David Halpern noted that the orbital carbon observatory and GOES satellites are not yet at the accuracy we want, but are moving in that direction. The Irish SCOR Committee ranked this proposal in the middle. Biogeochemical Argo and carbon satellites might address seasonal aspects, even if there are accuracy issues. The group did not propose links to IMBeR and SOLAS. The China-Beijing SCOR Committee ranked the proposal as “do not fund”. CO₂ is very important; but compared to other proposals, not as key for SCOR funds.

The review of the proposal yielded 8 “must funds”, 8 “may funds”, and 3 “do not funds”. The proposal was not funded.

2.2.4 Changing Biotic-Sediment Interactions in the Ocean Seabed (CBIOS)

Sinjaee Yoo presented the proposal and a summary of review comments from national SCOR committees. The proposal covers a wide range of disciplines from climate science to benthic ecology, but does not specify how to integrate these components to achieve the proposed terms of reference. The proposal discusses models, for example, to predict future changes based on historical models, but only mentions conceptual models, without any details. The proposal should have discussed what type of conceptual models would be used, and how they would be developed. The proposed membership is okay, except perhaps that some regions (e.g., South America) are not represented. In terms of disciplinary representation, more sedimentologists should be involved, also maybe statisticians and modelers.

From national committees, four ranked the proposal as “must fund”, 8 ranked it as “may fund”, and 6 ranked it as “do not fund.” The proposal was not funded.

2.2.5 Coordinated Global Research Assessment of Seagrass System (C-GRASS)

Peter Burkill presented the proposal and a summary of comments from national SCOR committees. This proposal had the highest ranking, with 8 “must funds”, 8 “may funds”, and only 2 “do not fund”. As with the other proposals, national SCOR committees expressed a variety of opinions. IABO expressed that seagrasses are a key global environmental system, as reflected in the development of an essential ocean variable (EOV) for seagrasses. IABO found this proposal most compelling of the proposals, because of the importance of this ecosystem. The Japanese SCOR Committee strongly supported IABO’s comments, as seagrass plays a key role in coastal ecosystems and many are endangered by climate change. Common data protocols and easy data access are crucial. However, the German SCOR Committee did not think that seagrasses were relevant to global ocean science, whereas the U.S. SCOR Committee found it less compelling than other proposals. Several national committees found the proposal very relevant to the “blue economy”, important to the developing world, and providing links to UN SDG 14 and the Global Ocean Observing System (GOOS). The U.S. SCOR Committee felt there the bottleneck is the lack of data from the developing world, which this group will not have enough funding to address. The German SCOR Committee was concerned whether the proposed group was excluding key participants. A significant issue is knowing the trends in abundance and biodiversity. There are many data uncollated in many places, which is why this group wants to make data comparable, including by the use of common nomenclature, so that existing data are more easily used. The available data need to be put it a single location so they can be used in the future by local policy makers. The UK SCOR Committee rated this proposal as the second most important. The resubmitted proposal is improved from last year. As the German SCOR Committee noted, the role of seagrasses in the global carbon cycle is mostly irrelevant; the important issue is the high productivity fueled by seagrass ecosystems in terms of coastal fisheries. Seagrasses are a key habitat and it will be very important for the group to develop practical procedures to help developing countries access databases and use available data. IAPSO agreed it is nice to make data access easier for scientists in developing countries. Victor Martinez noted that there are remote sensing applications for seagrass ecosystems, so a standardized approach, with common protocols, would be great for remote sensing. Knowing about the color of seafloor with seagrass will help with to know the color of the overlying water. The Irish SCOR Committee also noted remote sensing with drones is a new approach that can be used for seagrass ecosystems. The China-Beijing SCOR committee ranked the proposal as “must

fund”. The issue is not only important for developing countries; it is crucial for coastal regions worldwide in terms of fish recruitment and coastal productivity.

Eight national SCOR committees ranked the proposal as “must”, 8 as “may fund”, and two as “do not fund”. The proposal was selected for funding.

2.2.6 Integration of international ocean acidification research at CO₂ seeps (InterSEEP)

Paul Myers summarized review comments from national SCOR committees, which were generally positive. There were questions about upscaling, as well as scientific areas potentially missing. The Australian SCOR Committee rated the proposal as “must fund” and noted that increasing ocean acidification (OA) is a major threat to marine ecosystems and that recent studies of shallow marine CO₂ seeps offer an opportunity to address these knowledge gaps on local scales as a natural analogue for high-CO₂ conditions on a global scale. The research community on CO₂ seeps remains fragmented internationally. There is an opportunity for SCOR to establish a new global network of researchers working on CO₂ seeps that would significantly increase our understanding of the global impacts of OA on marine ecosystems. The proposed group would initiate a new global research community to coordinate interdisciplinary studies. The terms of reference address the key requirements and tasks for a newly established international research community on CO₂ seeps. The proposed members of the group, including some from developing nations, seem to be highly qualified to lead this effort. The Canadian National Committee for SCOR rated the proposal as “do not fund”. They agreed that the community is fragmented and needs to be brought together, but perhaps it is too early for SCOR support for such a group. The suggested work plan doesn’t seem like a great use of time for face-to-face meetings. The Chilean SCOR Committee rated the proposal as “may fund” and noted that there is a growing body of research using organism-level or ecosystem-level responses to natural variability in CO₂, pH, and other carbonate parameters. However, they thought it would be a mistake from a conceptual and practical standpoint to focus only on CO₂ seeps, and not more broadly to include other natural analogs of OA conditions. The small spatial scale of such systems intrinsically limits their usefulness when considered alone. The China-Beijing SCOR Committee rated the proposal as “may fund”. The proposed work is relevant to SDG 14. They suggested adding members and terms of reference related to plankton. The Finnish SCOR Committee rated the proposal as “must fund” and thought the proposed work is very timely, as the atmospheric carbon dioxide concentration has already achieved a level to cause observable changes in seawater chemistry and biota. A consensus in the OA seep community might lead to a more coherent and applicable OA database. However, the terms of reference are not detailed enough and the membership needs competent and strong marine chemical and physical participation. The French SCOR Committee rated the proposal as “may fund”. While CO₂ seeps have been studied for several years, there is at present a critical need to coordinate efforts to standardize the data produced, archive the data correctly, develop best practices, etc. However, despite their high potential, these sites are often poorly utilized because of poor determination of the carbonate system or a lack of basic knowledge of site ecology. Training new scientists, archiving datasets correctly, and publishing best practices for CO₂ seeps are of high priority. A SCOR working group would be an appropriate mechanism for the proposed activities and the terms of reference are sufficient to cover the needs in this field. All the members are recognized experts in their fields and the group proposes efforts to expand to developing countries. The Year

1 meeting seems overly ambitious. The German SCOR Committee ranked the proposal as “do not fund”. The topic is timely, but it is not clear that the topic is significant globally. The community is small enough that the coordination could be done at international conferences. It was unclear if harmonization of data schemes can be established in just a few meetings or if proposed expertise is sufficient. The Indian SCOR Committee thought the proposal was timely and a high priority for science and SCOR, that a SCOR working group would be an appropriate mechanism, and that the proposed terms of reference and membership were appropriate.

The Irish SCOR Committee rated the proposal as “may fund”. They agreed with previous comments. TOR #2 is way too broad and there are existing best practices documents (TOR #5). It is unlikely that seeps are representative of all marine ecosystems under high-CO₂ conditions. There is no mention in the proposal of links to the SOLAS or IMBeR projects, or how the outcomes of this group would be communicated to the wider SCOR community. The Italian SCOR Committee also ranked the proposal as “may fund”. The general theme of ocean acidification and climate change response studies in a natural environment is important and timely. The general theme of the group is relevant, but the focus is limited. The terms of reference need to be more specific in terms of the goals and products. The Japanese SCOR Committee rated the proposal as “may fund”. It is timely in principle, but is still immature and not properly focused yet. CO₂ seep studies are just one of many OA research topics. The hydrothermal seeps around the world are each unique ecosystems, so a working group such as proposed could be effective to integrate data and research findings. In terms of the proposed membership, it would be good to include a marine geochemist/chemical oceanographer. The group would publish a database in the PANGAEA system, but there is no review process for PANGAEA. The Korean SCOR Committee ranked the proposal as “do not fund” because they were not certain if the seep analysis would actually lead to a better forecast/outlook of the effects of global change in ecosystem because effects at seeps might not be generalizable to the global ocean. It would be helpful to see a plan for how the work of this group could be generalized to a variety of environments under ocean acidification. The Polish SCOR Committee rated the proposal as “must fund” because ocean acidification effects have been insufficiently recognized. The problem is important, so the proposal is timely.

The South African SCOR Committee ranked the proposal as “must fund”, because it is a very high priority to understand these seep’s contribution to the CO₂ problem the ocean faces. The proposal includes a well-developed capacity-development workshop plan. The Swedish SCOR Committee rated the proposal as “may fund”. The group would use an innovative approach to address the effects of ocean acidification. Creating a network of sites and standardizing methods would be timely. The main drawback to the group’s approach is that the pH gradients in the vicinity of the seeps are often very steep both in time and space. This may not reflect the long-term changes that marine organisms will have to adapt to due to effects related to global change. The UK SCOR Committee also ranked the proposal as “may fund”. The timeliness of the proposal is not clear. There is a lot of activity on ocean acidification in other formats, although there is no forum specifically on OA in CO₂ seep communities. It is not clear if CO₂ seeps are a good analogy for OA in the global system. Organisms in these settings have had time to adapt, which differs from the rest of ocean. The U.S. SCOR Committee thought the proposal was timely because it has broad implications for understanding increasing acidification of ocean waters and the impact of this process on marine organisms. Seeps could represent one of the best

analogs for studying future ocean conditions. Improved and reliable measurement of ocean carbonate chemistry is a priority of the ocean sciences community and for SCOR. The topic is relevant to UN Sustainable Development Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development. The inherent international nature of the problem aligns well with the SCOR working group model. The primary goals of capacity building in developing countries and codifying of best practices are important. IODE is relevant to this group. The SOLAS project expressed that this project is important, but the proposal was not as convincing as for DISCOVER-C. IABO rated the proposal as “may fund”, important for carbon cycle and acidification, but the membership is limited to biologists, and missing chemists and geologists

Seven national committees ranked the proposal as “must fund”, 9 as “may fund”, and 4 as “do not fund”. The group was not funded.

3.0 LARGE-SCALE SCIENTIFIC PROGRAMS

SCOR currently sponsors five large-scale research projects; four of them are co-sponsored by other organizations. Each project has its own scientific steering committee (SSC) to manage the project. SCOR and other co-sponsors are responsible to oversee the projects, which they do primarily through responsibility for the project SSC memberships and terms of reference, although sponsors also oversee the results of the projects’ activities. Any proposed changes in membership or terms of reference are considered by the SCOR Executive Committee, in partnership with other co-sponsors, throughout the year. The SCOR Secretariat oversees the use of grant funds provided to the projects through SCOR. SCOR uses solely grant funds for IMBER, SOLAS, and GEOTRACES, but is providing SCOR support for IQOE and IIOE-2 until they are self-supporting.

3.1 GEOTRACES

Phoebe Lam, co-chair of the GEOTRACES Scientific Steering Committee, presented an update about GEOTRACES activities and progress. (Andrew Bowie is the other co-chair.) Lam reminded participants that the GEOTRACES mission is to identify processes and quantify fluxes that control the distributions of key trace elements and isotopes (TEIs) in the ocean, and to establish the sensitivity of these distributions to changing environmental conditions. Scientists from approximately 30 nations have been involved in the project, which is designed to study all major ocean basins. The GEOTRACES Science Plan was published in 2006, and Intermediate Data Products (IDPs) have been released in 2014 and 2017; the next IDP is planned for 2021. The 2017 IDP has been downloaded 2,655 times. GEOTRACES is working on a new data portal to make it easier for PIs to input data and for the GEOTRACES Standards and Intercalibration Committee, and Data Management Committee to fulfill their responsibilities in relation to each dataset submitted.

One hundred fifteen GEOTRACES cruises have been completed so far, including GEOTRACES section cruises and cruises related to GEOTRACES process studies. The United States and China have completed section cruises since the 2018 SCOR Annual Meeting, and Australia, Germany,

and The Netherlands completed process study cruises.

To date, 1,270 peer-reviewed papers have resulted from GEOTRACES cruises and process studies. The project's synthesis strategy is to synthesize as they go, rather than waiting until the end of the project. GEOTRACES convened a [joint workshop with PAGES](#) in December 2018 on the implications of GEOTRACES observations for paleoceanography, one of GEOTRACES's three main themes to help synthesize GEOTRACES results so far.

Lam presented the following GEOTRACES science highlights:

- The circulation loop in the North Atlantic and Arctic oceans depicted by artificial radionuclides
- Gulf Stream Eddies are fertilizing the Western Atlantic Ocean
- New estimates of replacement times for elements in the ocean

The GEOTRACES Data Management Committee and SSC met in Hobart, Tasmania on 7-11 September 2019. The SCOR review of GEOTRACES is nearing its completion and results will be presented after Lam's presentation by Robert Duce, a co-chair of the GEOTRACES Review Panel. Lam emphasized that a key goal of the project is to produce freely available data products during the life of the project.

GEOTRACES continues to be active in capacity building. Technical information has been disseminated in the form of recommendations for nations developing a trace metal-clean sampling system, in a document developed by Greg Cutter, past co-chair of the GEOTRACES Standards and Intercalibration Committee. This document provides useful advice on the purchase of sampling bottles, clean lab design, etc. and is available at <http://www.geotraces.org/science/geotraces-activities>. GEOTRACES also sponsored the following training activities: GEOTRACES Workshop in Israel (Kaplan Symposium), hands-on workshop on using IDP2017 data with Ocean Data View, and 2nd GEOTRACES Summer School. The 6-day Summer School is scheduled for 23-28 September 2019 in Cadiz, Spain, on board of *Intermares* School Ship. Forty students from 17 countries will participate; 104 applications were received from students in 28 countries. The course will include lectures, student presentations, practical sessions, and field sampling on board the ship. The third GEOTRACES Summer School is planned to be held in Germany in summer 2021.

Following Lam's presentation, Robert Duce presented the results of the SCOR review of GEOTRACES. This is the first of SCOR reviews of its major projects. The Review Panel included 10 members, with Duce and Colin Devey as co-chairs. Duce was the SCOR Executive Committee Report when GEOTRACES was approved by SCOR in 2007 and Devey was the Reporter in 2018 when the Review Panel was set up. As inputs to the review, GEOTRACES was asked a set of questions about project history and achievements and a questionnaire was sent to the GEOTRACES email list. The response to the survey was low, but those who answered were very positive about GEOTRACES. The project's outreach and capacity building have been effective at expanding the number of laboratories worldwide that can analyze trace elements and isotopes in the ocean. The project has been very open and inclusive for young, female and developing country scientists in significant ways. GEOTRACES has particularly revolutionized

understanding in the following areas:

1. Changes in the paradigm of iron cycling in the ocean
2. The cadmium:phosphate relationship
3. The coupling between zinc and silicon
4. Development of new tools for constraining rates of TEI cycling
5. Imbalances in oceanic budgets of some trace elements

The GEOTRACES Review Panel concluded that GEOTRACES is an excellent project. The panel made 11 recommendations to GEOTRACES based on input received and discussions among panel members. The draft report was given to the GEOTRACES SSC to check for factual errors and misunderstandings in the text before the presentation at the SCOR meeting. A few changes were made to the report, which will be transmitted to the SCOR Executive Committee in final form before the end of 2019 and then to the GEOTRACES SSC, requesting a response to the recommendations. David Halpern commented that the legacy of the datasets should be preserved with a full copy at more than one site. Phoebe Lam acknowledged the importance of this issue.

3.2 Surface Ocean – Lower Atmosphere Study (SOLAS)

Lisa Miller, chair of the SOLAS SSC, made a presentation about SOLAS activities since the 2018 SCOR meeting, which have included the SOLAS SSC Meeting, held in April 2019 near Sapporo, Japan and the SOLAS Open Science Conference, held in Sapporo immediately before the SSC meeting.

The vision of SOLAS is “to achieve quantitative understanding of the key biogeochemical-physical interactions and feedbacks between the ocean and atmosphere, and of how this coupled system affects and is affected by climate and global change.” SOLAS has developed five themes to pursue its vision:

1. Greenhouse gases and the oceans
2. Air-sea interface and fluxes of mass and energy
3. Atmospheric deposition and ocean biogeochemistry
4. Interconnections between aerosols, clouds, and marine ecosystems
5. Ocean biogeochemical controls on atmospheric chemistry

SOLAS is also pursuing some integrating topics (e.g., upwelling systems, polar oceans, Indian Ocean) and topics related to science and society (e.g., impacts of ship-plume emissions on ocean biogeochemistry, blue carbon, open-ocean stewardship). The SOLAS International Project Office (IPO) is funded until the end of 2020, so the process of renewing or moving the IPO is underway. SOLAS also has a regional project office that is expiring in 2020.

Miller showed the network of projects and organizations with which SOLAS interacts. The U.S. Ocean Carbon and Biogeochemistry (OCB) program established a Subcommittee on Ocean-Atmosphere Interactions, which will convene a scoping meeting for U.S. research on ocean-atmosphere interactions in early October.

The SOLAS Implementation Strategy is a “living”, Web-based document, currently in Version 2. It details activities and events that directly address SOLAS science, and provides information about established working groups and planned developments. Some years ago, SOLAS replaced its newsletter with “event reports” that document events convened by SOLAS. For example, Event Report #16 that reported on the 2019 Biogeochemical Exchange Processes at Sea-Ice Interfaces (BEPsII) meeting (see https://www.solas-int.org/files/solas-int-2019/3%20Publications/Event%20Reports/SOLAS%20event%20report_Issue16.pdf).

Miller noted that SCOR supported four early career scientists from developing countries to participate in the 2019 SOLAS Open Science Conference (OSC), which attracted 190 participants from 30 countries. The 2019 OSC was held in Sapporo, Japan, on 21-25 April 2019. The next SOLAS OSC will potentially be held in Cape Town, South Africa in 2022.

SOLAS has significant activities related to remote-sensing techniques applied to SOLAS science. In June 2016, SOLAS and the European Space Agency (ESA) co-sponsored a workshop on “Harnessing remote sensing to address critical science questions on ocean-atmosphere interactions” in Frascati, Italy. A peer-reviewed paper was produced from the meeting.⁸ In May 2019, SOLAS sponsored a session at the ESA Living Planet symposium, in Milan, Italy. A special issue of *Remote Sensing* will be produced from the symposium, with a deadline of August 2020. A remote sensing workshop in Asia is being planned for spring 2021 to better entrain Asian space agencies.

SOLAS has encouraged development of the Helmholtz International Ocean-Atmosphere Network: A new SOLAS Time Series in Cabo Verde. It will build on the existing time-series stations and infrastructure at Cabo Verde.

SOLAS has been encouraging discussions of the scientific aspects of climate intervention. SOLAS issued a Statement on Geoengineering on the SOLAS Website (see <http://www.solas-int.org/statement-on-geoengineering.html>) and held a Geoengineering Workshop on 21 April 2019 in conjunction with the 2019 SOLAS OSC. Outcomes of the workshop include positive debate, emphasis on “safe operating space”, potential linkages with modelling, and a white paper to be prepared on specific SOLAS science needed to inform decision making. There is a critical need to gather scientific evidence on the feasibility and risks of marine geoengineering to guide regulation of research. SOLAS has been sponsoring activities to review the effects of shipping on inputs of materials to the atmosphere. A review paper was produced from a SOLAS-sponsored workshop.⁹ A proposal was submitted to the Belmont Forum proposal on global shipping: Linking policy and economics to biogeochemical cycling and air-sea interaction (ShipTRASE). In terms of governance, SOLAS stimulated a review of global conventions and treaties with air-sea interface implications and convened a session on “The apparent mismatch between science and policy at the air-sea interface”.

⁸Neukermans, G., Harmel, T., Galí, M., Rudorff, N., Chowdhary, J., Dubovik, O., Hostetler, C., Hu, Y., Jamet, C., Knobelspiesse, K., Lehahn, Y., Litvinov, P., Sayer, A.M., Ward, B., Boss, E., Koren, I. and Miller, L.A., 2018. Harnessing remote sensing to address critical science questions on ocean-atmosphere interactions. *Elem Sci Anth*, 6(1), p.71. DOI: <http://doi.org/10.1525/elementa.331>

⁹Endres, S., et al. (2018) A New Perspective at the Ship-Air-Sea-Interface: The Environmental Impacts of Exhaust Gas Scrubber Discharge. *Front. Mar. Sci.* 5:139. doi: 10.3389/fmars.2018.00139

Upcoming SOLAS activities include the following:

- October 2019: IMBER-SOLAS-IOCCP-GCP-CLIVAR-WCRP-IOC meeting on Ocean Carbon (and related topics), Paris, France.
- October 2019: OCB Workshop on Ocean-Atmosphere Interactions: Scoping directions for U.S. research, Sterling, USA.
- December 2019: CATCH annual meeting, Berkeley, USA.
- February 2020: SOLAS-sponsored session at the Ocean Sciences Meeting, San Diego, USA.
- April 2020: SOLAS Scientific Steering Committee annual meeting, Santiago, Chile.
- April 2020: SOLAS South America workshop, Valparaiso, Chile.
- April 2020: SOLAS-sponsored session(s) at the annual European Geophysical Union meeting, Vienna, Austria.
- May 2020: 8th International Symposium on Gas Transfer at Water Surfaces, Plymouth, UK.
- August 2020: BEPSII annual meeting, Hobart, Australia.
- June 2021: 8th international SOLAS Summer School, Cape Verde.

Robert Duce mentioned that information about micro-plastics entering ocean from the atmosphere (i.e., microplastics in snow) suggest that this component could be quite significant. This topic will be examined at the GESAMP geo-engineering workshop. There are good links between SOLAS and GESAMP working groups. Sinjae Yoo noted in relation to the proposed Asian workshop on remote sensing in 2021, the Korean space agency will launch its 2nd geostationary satellite in late 2020 or early 2021. This might be a good opportunity to approach them about a meeting in Korea. Yoo will provide contact information to Lisa Miller. Victor Martinez noted that rivers and atmospheric transport are important for micro-plastic input to ocean. Joyce Penner commented that IAMAS has a cloud and precipitation commission, with interests in geo-engineering, and also an aerosols, clouds and precipitation project. It would be good for SOLAS and IAMAS to be in contact about this. Lisa Miller noted that there is little governance for air over open waters and even coastal waters.

3.3 SCOR/POGO International Quiet Ocean Experiment (IQOE)

Ed Urban reported on the progress of IQOE, which is the first international research project on ocean acoustics and bioacoustics.

IQOE can be described as involving two fundamental areas of activity:

1. documenting ambient sound levels in ocean at frequencies important for marine organisms, including variability over time and space; and
2. bringing together existing information and developing new information on effects of sound on marine organisms.

IQOE was developed with the premise that this experiment should not add sound to ocean. The project promotes the use of passive acoustic methods, focuses on ambient sound, comparing noisy and quiet areas, and takes advantage of observational opportunities in areas scheduled or

predicted to become quieter or noisier. For example, the Ports, Humpbacks, Y Soundscapes In Colombia (PHYSIC) project endorsed by IQOE is doing a before-after control-impact (BACI) study to examine the effects of port development on humpback whales on the Pacific coast of Colombia. PHYSIC is currently establishing a pre-construction baseline of human sources of sound and sounds from humpback whales.

Science of IQOE also can be described in terms of 5 fundamental questions:

1. Have human activities affected global ocean soundscape compared with natural changes over time?
2. What are current levels and distribution of sound in ocean?
3. What are trends in sound levels across global ocean?
4. What are current effects of anthropogenic sound on important marine animal populations?
5. What are potential future effects of sound on marine life?

The project is still ramping up its activities, through its working groups, which are conducting many of the project's implementation activities. The working groups currently active include (1) Acoustic Measurement of Ocean Biodiversity Hotspots, (2) Arctic Acoustic Environment, (3) Data Management and Access, (4) Marine Bioacoustical Standardization, and (5) Standardization. Most of the working groups met in 2019, in conjunction with a major bioacoustics meeting in The Hague. IQOE has endorsed 7 projects so far, including two new ones in the past year.

The IQOE Website was designed by the same company that designed the SCOR Website. Besides regular project information, the IQOE Website includes

- **Aquatic Acoustic Library:** Searchable literature database to more than 4,600 documents
- **Database of passive acoustic systems**
- **Acoustic Data Portal:** access to national archives to acoustic data
- **Portal to Marine Animal Sounds Website**

In the past year, IQOE made progress in several areas. IQOE worked to get acoustics included in the OceanObs'19 conference, by contributing to a Community White paper on "Observing the Oceans Acoustically",¹⁰ and presentation an overall IQOE poster and a poster by the IQOE WG on Arctic Acoustic Environment. IQOE sponsored development of a special issue of *ECO Magazine* focused on ocean sound.¹¹ IQOE established a new working group on Marine Bioacoustical Standardization, to complement the work of the WG on Standardization, which is concerned mainly with physical acoustics.

The Alfred Wegener Institute in Bremerhaven, Germany has advertised to hire a Data Scientist and Data Engineer for ocean acoustic data. (The deadline was 31 August 2019.) These people would help IQOE with its data management task. IQOE will work with the GOOS Biology and Ecosystems Panel to convene an implementation workshop for the Ocean Sound Essential Ocean

¹⁰<https://www.frontiersin.org/articles/10.3389/fmars.2019.00426/full>

¹¹https://scor-int.org/IQOE/IQOE_Article_ECO_Magazine.pdf

Variable (EOV), which is the responsibility of IQOE. IQOE is working to develop new funding sources for work of the working groups and the IQOE Science Committee.

The German SCOR Committee representative mentioned an Arctic observing project with lots of acoustics, conducted by scientists at the Alfred Wegener Institute. John Claydon remarked that he has some contacts in the community associated with sound (passive) for spawning around coral reefs, who might want to collaborate. Ed Urban asked for contacts.

SCOR approved 2020 support for IQOE.

3.4 SCOR/Future Earth Integrated Marine Biosphere Research (IMBeR) project

John Claydon, IMBeR Executive Officer, made a presentation about IMBeR, which aims to promote ocean sustainability under global change for the benefit of society. It evolved from the Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) project. The *IMBeR Science Plan & Implementation Strategy 2016-2025* describes three Grand Challenges:

- Grand Challenge I: Understanding and quantifying the state and variability of marine ecosystems
- Grand Challenge II: Improving scenarios, predictions, and projections of future ocean-human systems at multiple scales
- Grand Challenge III: Improving and achieving sustainable ocean governance

IMBeR science is being implemented by regional programs, working groups, and endorsed projects. IMBeR activities include conferences, workshops, IMBIZOs, summer schools, and the Interdisciplinary Marine Early Career Network. IMBeR hopes to impact policy and governance, increase ocean literacy, positively change human behavior, and increase capacity for IMBeR-related science worldwide. Two thousand scientists, from 80 countries, are involved in IMBeR. More than 1,000 publications have resulted from the project so far.

IMBeR supports five regional programs:

1. Ecosystem Studies of Subarctic & Arctic Seas (ESSAS)
2. Eastern Boundary Upwelling Systems (EBUS). EBUS is a SCOR WG and collaborates with the Climate and Ocean - Variability, Predictability, and Change (CLIVAR) project and SOLAS
3. Integrated Climate & Ecosystem Dynamics (ICED)
4. Sustained Indian Ocean Biogeochemical & Ecological Research (SIBER), co-sponsored by Indian Ocean GOOS
5. Climate Impacts on Oceanic Top Predators (CLIOTOP)

IMBeR supports four working groups: (1) Human Dimensions Working Group, (2) Continental Margins Working Group (a collaboration with Future Earth Coasts), (3) SOLAS-IMBeR Ocean

Acidification, and (4) the new Integrated Ocean Carbon Research group, a collaboration with IOCCP, IOC, SOLAS, and the Global Carbon Project.

Claydon presented some highlights of IMBeR-related science from the past year:

- Observing Great Whales from Space—Research related to the ICED regional program demonstrated that at least four large whale species could be detected using imagery from the WorldView -3 satellite: Cubaynes, H.C., P.T. Fretwell, C. Bamford, L. Gerrish, and J.A. Jackson. 2018. Whales from space: four mysticete species described using new VHR satellite imagery. *Marine Mammal Science* 35:466-491. <https://doi.org/10.1111/mms.12544>
- Krill (*Euphausia superba*) have moved and contracted southwards in response to warming seas—Research from the ICED regional program reviewed 90 years of observations of krill, showing changes in distribution, sizes, densities, and levels of recruitment: Atkinson, A., S.L. Hill, E.A. Pakhomov, V. Siegel, C.S. Reiss, V. Loeb, D.K. Steinberg, K. Schmidt, G.A. Tarling, L. Gerrish, and S.F. Sailley. 2019. Krill (*Euphausia superba*) distribution contracts southward during rapid regional warming. *Nature Climate Change* 9:142-147 DOI: 10.1038/s41558-018-0370-z
- Effects of warming oceans on marine top predators and their food webs—Research related to the CLIOTOP regional program found that oxygen minimum zones, expanding because of ocean warming, affect the food chains of three species of tuna: Pethybridge, H., C.A. Choy, J.M. Logan, V. Allain, A. Lorrain, N. Bodin, C.J. Somes, J. Young, F. Ménard, C. Langlais, and L. Duffy. (2018) A global meta-analysis of marine predator nitrogen stable isotopes: Relationships between trophic structure and environmental conditions. *Global Ecology and Biogeography* 27(9):1043-1055.
- Lack of consensus among marine scientists as to what constitutes a “Regime Shift”—Research related to the Human Dimensions Working Group found that, although regime shifts are a key concept in marine science and management, there is no consensus for defining regime shifts: van Putten, I., F. Boschetti, S. Ling, and S.A. Richards. 2019. Perceptions of system-identity and regime shift for marine ecosystems. *ICES Journal of Marine Science*. fsz058 <https://doi.org/10.1093/icesjms/fsz058>

The Marine Data Hub is a product resulting from the IMBeR IMBIZO 5 “Critical Constraints on Future Projections of Marine Systems” workshop (see <https://ccdatahub.ipsl.fr/>). The hub provides access to ecological, physical, biogeochemical and societal datasets for global models.

Since the 2018 SCOR Annual Meeting, IMBeR has convened the following meetings:

- 8th China-Japan-Korea IMBeR Symposium
- 4th CLIOTOP Symposium
- 2nd IMBeR Open Science Conference (OSC)

The IMBeR OSC was held in Brest, France on 17-21 June 2019. It featured 27 sessions and 10 workshops, and an early-researcher day. Five hundred seventy-nine individuals participated, of which 53% were female and 46% were early-career researchers and students. One feature of the OSC was an Early Career Researcher Day and the launch of the IMBeR Interdisciplinary Marine

Early Career Network. Claydon noted that organizing an open science conference is a huge amount of work, especially without a corporate management company, in reference to the GEOTRACES Review Panel recommendation about open science meetings.

Upcoming events include the following:

- Experiencing China – Dialog on the Maritime Silk Road: 10-13 October 2019 at East China Normal University, Shanghai, China
- ESSAS Annual Science Meeting - “Linking past and present marine ecosystems to inform future fisheries and aquaculture”: 1-3 June 2020 in Sapporo, Japan
- ClimEco7 – 22-29 June 2020 in Cabo Verde
- 1st IMBeR West Pacific Symposium: 2020 in Thailand
- IMBeR IMBIZO 6

The IMBeR Scientific Steering Committee (18 members) met most recently in Brest, France in June 2019, immediately following the 2nd IMBeR Open Science Conference on 23-27 June 2019. IMBeR is considering responses to its request for bids for moving its International Project Office, which will happen in 2020.

Peter Burkill asked how IMBeR was planning to get more African involvement in the project. Claydon responded that they will use the ClimEco7 event in Cabo Verde to help, but will also link to east African local organizations. Marie-Alexandrine mentioned that some people in Tanzania might be good contacts. Lisa Maddison added that making new connections with African institutions is an IMBeR goal. When IMBeR planned a summer school in Ghana, there was high-level support, but they had difficulty getting local volunteers to support the meeting, so they had to move the school to Indonesia. Sicre noted that WG 155 is planning a summer school in Dakar. Patricia Miloslavich stated an interest in IMBeR’s early career program. It might be possible to network across all early-career scientists involved in all SCOR working groups and projects. Miloslavich offered to suggest names for IMBeR expansion in South America. Nick D’Adamo (IOC) offered to provide links for the IMBeR West Pacific event in Thailand.

3.5 SCOR/IOC/IOGOOS Second International Indian Ocean Expedition (IIOE-2)

Peter Burkill and Nick D’Adamo reported on the progress and plans of IIOE-2. The goals of IIOE-2 is to advance our understanding of the Indian Ocean and its role in the Earth System in order to enable informed decisions in support of sustainable development and the well-being of humankind. SCOR has helped support the first three annual meetings of the IIOE-2 Steering Committee. The 3rd International Indian Ocean Science Conference was held on 11–15 March 2019 at Nelson Mandela University (NMU) in South Africa. The conference was attended by more than 100 participants from 21 countries. An aim of this conference was to bring the Second International Indian Ocean Expedition (IIOE-2) community into the region to promote the research being undertaken by Western Indian Ocean (WIO) institutions in IIOE-2. The IIOE-2 Steering Committee met in conjunction with the conference and adopted a simpler management structure.

Burkill summarized some of the scientific results resulting from IIOE-2 endorsed cruises so far:

- **Global Warming:** The Indian Ocean is central to the control of the global climate. The southern Indian Ocean is warming faster than any other part of the global ocean, twice the rate of the Pacific Ocean and about 50% faster than the Atlantic Ocean. Given these observations, the focus is now on understanding the mechanisms involved in the Indian Ocean's warming. There are at least two hypotheses that need to be investigated: (1) the Indonesian Throughflow from the Pacific Ocean has increased, bringing more warm Pacific water into the Indian Ocean and/or (2) westerly winds over the equatorial Indian Ocean are becoming stronger, strengthening downwelling conditions, leading to the warming of the upper ocean. The latter is linked to Madden-Julian Oscillations (see next bullet) and the Indian Ocean Dipole, which itself has teleconnections with the Pacific Ocean. This is of huge societal relevance, as more than 40% of the world's population live in countries prone to cyclones, floods, and droughts around the Indian Ocean. It is vital to understand how the climate affects people and their livelihoods.
- **Madden-Julian Oscillation (MJO):** The MJO increases intense winds in a small area of the eastern Indian Ocean. In December to April, three trillion tons of water is transported from the Pacific Ocean every 30 days or so, resulting in a sea level change of about 4 cm. The transport of water affects the ocean's heat budget, motion of the Earth, and day length, which can affect the accuracy of the Global Positioning System (GPS).¹²

IIOE-2 has motivated special journal issues in *Deep-Sea Research II*, *Biogeosciences*, *Acta Oceanologica Sinica*, and the *Journal of Marine Systems*. For *Deep-Sea Research II*, two special issues have been published so far, and two additional special issues are planned. These volumes bring together a diverse body of contemporary Indian Ocean research motivated by IIOE-2 and others. The first volume includes 12 papers and the second volume includes 13 papers, and there are 6 additional manuscripts in various stages of review and revision, which will go into a third volume. These papers cover a wide range of topics in marine geology and physical, chemical, and biological oceanography. Additional submissions are being actively solicited for the third volume. The fourth volume will be focused on papers from a recent Australian IIOE-2 cruise along 110°E; seventeen papers have been identified for this volume. IIOE-2 also communicates about the project through a monthly newsletter, quarterly publication (*Indian Ocean Bubble-2*), and the IIOE-2 Website (www.iioe-2.incois.gov.in).

SCOR has been interacting with the Western Indian Ocean Marine Science Organization (WIOMSA) over the past several year, and increased interactions could help implement IIOE-2 and increase SCOR visibility in Africa.

IIOE-2 will contribute to the International Indian Ocean Science Conference 2020 on 16-20 March 2020 in Goa, India. The IIOE-2 Steering Committee will meet in conjunction with the conference.

Nick D'Adamo emphasized that having SCOR's collaboration has been intrinsically important to IOC, IOGOOS and to the wider IIOE-2 constituency. Looking to the future and to maintaining this relationship and support, both SCOR's high-level scientific imprimatur and its important

¹²Rohith et al. <https://www.nature.com/articles/s41467-019-09243-5>

financial support is fundamentally important to IIOE-2. It is essential for IOC and IOGOOS to continue to advocate to organizations to continue their support for SCOR's important contributions. The support from IOC and IOGOOS is provided in the form of administrative support, support staff time, and cash budgets of the two Joint Project Office Nodes in Perth, Australia and Hyderabad, India. For the Perth Node, this means the equivalent annually of 1 to 1.5 FTEs at executive and senior level, and full administrative office and financial management hosting, as well as operational cash support from IOC and its collaborating Perth sponsors on the order of \$20-25K per year. The Perth Node was able to host and sponsor the first full IIOE-2 Steering Committee meeting in 2017, with supplementary cash from local sponsors of around \$15,000. This benefited all of the scientists who came to Perth for that meeting. The Joint Project Office was also able to broker the same sort of support for the other two Steering Committee meetings held in Jakarta and Port Elizabeth in 2018 and 2019, respectively, again providing support for the IIOE-2 Steering Committee and connecting them with local scientists, including early career scientists and those from scientifically less equipped countries. IOC also supports the IIOE-2 via the time and Paris IOC Headquarters-based administrative support relating to its Executive Secretary, Vladimir Ryabinin, as Co-Chair of the Steering Committee. For the India Node and its hosting linked to IOGOOS, the total personnel time is at least as much as the staffing of the Perth Node. The Indian facility manages the IIOE-2 Website, communication products, data and information, operational coordination and other elements of running the IIOE-2. IOGOOS and its aligned Indian JPO Node was also able to broker hosting of the international 2015 science conference and associated IIOE-2 launch. This will be repeated in an even bigger way in March 2020 in Goa when the second major science conference and the IIOE-2 Steering Committee and related alliances are again hosted by our Indian collaborators with high-level Indian Government support.

For IOC and IOGOOS, having this explicit and visible relationship with SCOR is critical to being able to show that these organizations leverage support from SCOR.

IIOE-2's future is bright, especially given that the scientific community enthusiastically indicated its support to continue to implement, at least until 2025, the IIOE-2 Science Plan for which SCOR led the development. The support of the scientific community has already been complemented by IOC's and IOGOOS's own committed organizational support. The Science Plan will obviously need to be examined at the project mid-term to align it scientifically with any developments in the science, and SCOR's role in any realignment will be critical. Future IIOE-2 science should take into account the development of the UN Decade of Ocean Science for Sustainable Development. Comparing the IIOE-2 framework of scientific themes and resulting project initiatives that have already arisen, it is clear that many of SCOR's working groups align with them.

IIOE-2 is already being seen as a model on which to base other potential oceanic multi-disciplinary initiatives under the UN Decade. For example, scientists from the Pacific Ocean region are starting to look closely at IIOE-2's history, sponsorship, and governance models.

SCOR should be reassured that the support it has already yielded excellent benefits in terms of building scientific cooperation and facilitating science that aligns strongly with SCOR's scientific priorities. The science highlights brochure that Peter Burkill referred to in his

presentation and the growing body of scientific achievements through IIOE-2 is testament to what has already been and can continue to be achieved. IOC recognizes that the allocation of SCOR funds is competitive, so any support that SCOR provides will continue to be respected and highly valued by IOC and IOGOOS.

Burkill presented a request of US\$15,000 for the 2020 meeting of the IIOE-2 Steering Committee, as for past annual Steering Committee meetings. SCOR approved 2020 financial support for IIOE-2 as well as continued sponsorship of IIOE-2 for the 2021-2025 period.

Hal Batchelder asked if each cruise is endorsed. Peter Burkill responded that each Principal Investigator applies for endorsement, which is normally granted, if a set of conditions is met. Nick D'Adamo noted that the IIOE-2 Website has a snapshot of all cruise tracks. Paul Myers commented that there is less known about the Indian Ocean than about the Arctic Ocean. Lisa Miller asked if there had been a call for session proposals. SOLAS may have missed it. Is there a framework for side events? SOLAS would like to have a presence at the conference.

4.0 INFRASTRUCTURAL ACTIVITIES

4.1 IOC/SCOR International Ocean Carbon Coordination Project

Masao Ishii, co-chair of the IOCCP Scientific Steering Group (SSG), presented an update of the project status and plans. Ishii reminded participants of IOCCP's terms of reference (see <http://www.ioccp.org/index.php/about-us/tors>) before discussing how the project is addressing them. The IOCCP SSG has 10 members, with subject area responsibilities for Underway CO₂ Observations, Ocean Interior Observations, Time Series Efforts, Ocean Acidification, Nutrients, Oxygen, Instruments and Sensors, Data and Information Access Services, Data Synthesis Activities, Framework for Ocean Observing, and Global Climate Observing System. The IOCCP SSG also serves as the Biogeochemistry Panel of the Global Ocean Observing System.

IOCCP has led and been involved in several capacity-building activities in the past year, addressing TOR #7. The major activity led by IOCCP was the "Training course on a suite of biogeochemical sensors", which was held on 10-19 June 2019 at the Sven Lovén Centre for Marine Infrastructure, in Kristineberg, Sweden. This was a beginner-level course for early-career scientists (see <http://www.ioccp.org/2019-training-course>). The course featured 16 instructors and 27 students (18 female and 9 male) from a pool of 136 applicants. Some training materials used in the course could be made available more broadly; discussions are ongoing with Ocean Teacher Global Academy and Ocean Best Practices to do this. The course will be offered biennially, if sufficient funding is available.

IOCCP staff assisted with the AtlantOS "Underway and Sensor CO₂ Data and Metadata QC Procedures" training workshop, held in Sopot, Poland on 1-3 April 2019. The purpose of this workshop was to promote data sharing and quality control through SOCAT. There were 10 students and 3 lecturers involved and there is a demand for similar workshops in other regions.

IOCCP also supported the Global Ocean Oxygen Network (GO2NE) Summer School on 2-8 September 2019, in Xiamen, China. IOCCP co-sponsored the event and provided two of the

instructors. Forty PhD students and early-career scientists participated, with 16 instructors. The focus was on oxygen measurements in a theoretical framework, plus practical sessions on laboratory experiments, field work, modelling and special sessions on communication, ethics, and engagement with stakeholders. See <https://mel.xmu.edu.cn/summerschool/go2ne/Program.html>.

IOCCP continues to support data synthesis of inorganic carbon EOVS products, through support to the Surface Ocean CO₂ Atlas (SOCAT) project and Global Ocean Interior Carbon Data Analysis Project (GLODAP). SOCATv2019 was released on 18 June 2019 with 25.7 million quality controlled surface ocean fCO₂ data from 1957 to 2019. The project is still without sustained funding. GLODAPv2.2019 was released during the 1st AtlantOS International Symposium. Data from 116 new cruises were added since the previous version of GLODAP. The 2019 dataset included 840 cruises and more than 1.1 million bottle sample analyses from 1972 through 2017.

IOCCP is encouraging the development of several data portals. The Global Ocean Acidification Observing Network Data Portal (<http://portal.goa-on.org/Explorer>) will include metadata on ocean acidification-relevant observations. The metadata can be filtered by region, platform, EOVS, etc. and the portal makes it possible to visualize available time-series data. An Oxygen Data Portal/Synthesis Product (for Deoxygenation) is in the scoping and design phase. The aim is to include all oxygen data from all relevant platforms. IOCCP is engaged in building the framework in terms of aims, end users, structure, funding sources, community coordination, etc. IOCCP is hosting the Oxygen Data Platform Scoping workshop in November 2019 in Sopot, Poland. IOCCP is also promoting the development of a Marine BGC Global Data Assembly Centre (GDAC). Developments are ongoing and funding was secured in Europe and in the United States. Future GDAC partners (NOAA PMEL and BCDC at the University of Bergen) signed a Memorandum of Understanding and will apply to become IODE Associated Data Units. Partnership with IODE will help bridge the gap between SOCAT and GLODAP efforts, and the nationally focused IODE data management. A series of meetings will be held in 2020 to advance this idea.

In relation to its work at the GOOS Biogeochemistry (BGC) Panel, coordination and communication efforts related to oxygen observations are in progress. IOCCP has prioritized addressing three BGC EOVS over the next several years, for particulate matter, nitrous oxide, and dissolved organic carbon. Also, for the Ocean Colour EOVS, implementation activities will continue to be a joint venture of the International Ocean Colour Coordinating Group (IOCCG) and GOOS Panels. IOCCP's main role is to curate the Ocean Colour EOVS Specification Sheet.

IOCCP facilitates closer partnerships between the observing community and the modelling community:

- Surface Ocean pCO₂ Mapping intercomparison (SOCOM) is collating various methods to interpolate pCO₂ data in space and time. Outputs are used in the annual assessment of global carbon budget by Global Carbon Project (GCP), together with those from forward Ocean BGC models. SOCOM is contributing to GCP's 2nd Regional Carbon Cycle Assessment and Processes (RECCAP2). See <http://www.bgc-jena.mpg.de/SOCOM/>.

- Toward Ocean BGC Data assimilations—The IOCCP office contributed to a book “New Frontiers in Operational Oceanography” published as an outcome of the 2017 GODAE OceanView International Summer School including Chapter #6 on “Biogeochemical In-situ Observations – Motivation, Status and New Frontiers” and Chapter #22 “Marine Biogeochemical Modelling and Data Assimilation for Operational Forecasting, Reanalysis and Climate Research”. IOCCP has developed close links with the leaders of the Marine Ecosystem Analysis and Prediction Task Team in Ocean Predict: Katja Fennel (Dalhousie, Canada) and Marion Gehlen (LSCE, France)
- Connection with CMIP6—IOCCP SSG members participated in “Synthesis and Intercomparison of Ocean Carbon Uptake in CMIP6 Models Working Group and Workshop” in Washington, D.C. in December 2018: <https://www.us-ocb.org/cmip6-wg/>.
- Integrated Ocean Carbon Research (IOCR)— SOLAS-IMBeR Joint Carbon Group #1 (surface) and #2 (interior) disbanded in April 2017. IOCR is aiming to form a new international ocean carbon research framework that fulfills the entire value chain of the ocean carbon research from coordination of observations through knowledge provisions to the public, stakeholders, and policymakers. IOCCP hosted some meetings (e.g., a side event during ICDC10 in August 2017) and discussed with delegates from SOLAS, IMBeR, WCRP, GCP as well as IOC about this issue. At the 51st session of the IOC Executive Council in June 2018, IOC endorsed taking on a coordinating role in the area of ocean carbon research through the set-up of a working group in partnership with IOCCP, SOLAS, IMBeR, and the GCP in support of the UN Decade of Ocean Science for Sustainable Development and Agenda 2030. The workshop will held on 28-30 October 2019 in Paris, included the invited participants recommended from each organization and project.

The Global Climate Observing System (GCOS) requested IOCCP’s direct involvement for the ocean component of the carbon budget theme, rather than working through the Ocean Observing System for Climate (OOPC). It is necessary to harmonize biogeochemistry EOVS and ocean biogeochemistry Essential Climate Variables (ECVs). This work would contribute to the next GCOS Implementation Plan. In terms of short-term engagement, one of IOCCP’s Co-Chairs attended the GCOS All Panels Meeting and provided input via OOPC. For long-term engagement strategy, IOCCP SSG members need to commit to GCOS processes.

IOCCP contributed to the development of the methodology to report SDG Indicator 14.3.1, approved by the IOC-UNESCO Executive Council, related to minimizing the impacts of ocean acidification. IOCCP members and staff contributed to at least 8 different community white papers for OceanObs’19.

The next IOCCP SSG meeting will be held on 13-15 November 2019 in Sopot, Poland.

David Halpern presented the results of the SCOR/IOC Review of IOCCP. The review has been going on for 12 months and is almost completed. Our colleagues in the IPO project office in Sopot, Poland were very helpful in the review, in responding to questions from the Review Panel. The Review Panel was created with the approval of SCOR and IOC. The Panel requested the following information from IOCCP:

- Accomplishments, costs, etc. over the past five years 2012-2017 (since IOCCP established its International Project office in Poland) and the expectations for 2018-2023.
- Evolution of IOCCP since its beginning.
- List of publications supported by IOCCP since 2012.
- IOCCP capacity-building activities since 2012.
- Coordination/interaction of IOCCP with other projects/organizations (e.g., SOLAS, IMBeR and Future Earth) since 2012.
- Geographic distribution of individuals involved in and benefitting from IOCCP activities/products/services since 2012.

The Panel found that IOCCP has established itself as a project that helps the international ocean science community address important issues of science, measurements, and the availability and use of ocean carbon and other biogeochemical data. IOCCP has been instrumental in the production of several important products and implementation of significant activities:

- Surface Ocean CO₂ Atlas (SOCAT)
- Global Ocean Data Analysis Project (GLODAP)
- Global Ocean Acidification Observation Network (GOA-ON)
- GOOS Biogeochemistry Panel and Contributions to the Global Climate Observing System (GCOS)
- Standards and Intercalibration for Nutrient Measurements
- Dissolved Oxygen Observations
- Capacity Building

The Review Panel made 8 recommendations. An overall theme of the review is that the office is understaffed for the amount of work it is doing and should not take on more responsibility without more staff and funding.

The draft report was sent to the IOCCP SSG co-chairs to identify any factual errors and misunderstandings. The co-chairs asked for clarification of a few items.

Masao Ishii responded to the review comments that the IOCCP Scientific Steering Group will seriously consider the review comments during its next meeting. He agreed with the difficulty in getting funding and the necessity to prioritize activities. It is always difficult to decide whether to cut off activities if new interesting activities appear. Salvador Aricò (IOC) thanked the Review Panel members. Perhaps IOCCP should delegate some bits and pieces of its work to other organizations, and look for synergies and collaborations. Phoebe Lam (GEOTRACES Co-chair) asked how these reviews are going to be used, whether they will be published, and whether they will be provided to ICSU/ISC. Ed Urban responded that ICSU only asked that SCOR establish a process, not that SCOR send the results of the reviews to them, so there is no plan to do so, unless asked for evidence that their recommendation to SCOR was implemented. Peter Burkil asked if GEOTRACES and IOCCP would like SCOR to make the reviews public. David Halpern recommended that if any action were taken to publicize the results of the IOCCP review, SCOR should not unilaterally decide what to do, given that the review was conducted jointly with IOC. The review report will be sent to the IOCCP project office jointly from both organizations. Trevor McDougall commented that it would be dangerous to put the reviews on the SCOR

Website, as they could constrain future reviews. David Halpern agreed. Phoebe Lam agreed that there would be no benefit from publishing the reviews. Ed Urban agreed. In some ways, these project reviews are analogous to reviews of peer-reviewed papers. SCOR expects to receive thoughtful consideration of review recommendations, but not necessarily implementation of each recommendation. Salvador Aricò noted that it would be very useful if the official findings of the review can be officially sent to IOC so it can trigger responses. Ed Urban suggested that it might be useful to make some statement on the project and/or SCOR Websites that the projects were reviewed and received positive comments and some recommendations. Phoebe Lam responded that GEOTRACES would not mind making the document that GEOTRACES submitted to the Review Panel available on the GEOTRACES and/or SCOR Web sites.

4.2 GlobalHAB

Elisa Berdalet, GlobalHAB SSC Chair, made a presentation about the status and plans of the GlobalHAB project. She reminded participants that the overall goal of GlobalHAB is to improve understanding and prediction of HABs in aquatic ecosystems, and management and mitigation of their impacts. The mission of GlobalHAB includes

- Foster international coordination and cooperative research to address the scientific and societal challenges of HABs, including the environmental, human health and economic impacts, in a rapidly changing world.
- Serve as a liaison between the scientific community, stakeholders and policy makers, informing science-based decision-making.

GlobalHAB work is related to several other projects and GlobalHAB seeks to cooperate when interests with other projects intersect. GlobalHAB receives financial support from IOC, in-kind support from the SSC members' institutions, and external contributions for particular activities. The U.S. National Science Foundation provided support for GlobalHAB until 31 August 2019. The GlobalHAB Scientific Steering Committee (SSC) acknowledged the financial and logistic support received from SCOR during the 2015-2019 period. The funds made possible the 3 meetings of the GlobalHAB SSC, representation of the GlobalHAB at international meetings, publications completing the work of the former SCOR/IOC GEOHAB project, and the first phase of the implementation of the GlobalHAB Science Plan (2016-2020). The most recent meeting of the GlobalHAB SSC was held at the Laboratoire d'Océanographie de Villefranche (LOV) in Villefranche-sur-mer (France) on 10-11 April 2018. Since then, SSC members have worked on implementation of GlobalHAB by communication through email and virtual meetings of small groups. GlobalHAB members attending the International Conference on Harmful Algae in October 2018 in Nantes, France held an opportunistic meeting and convened a session on "Networking activities around HABs: GlobalHAB, Global HAB Status report, ICES-WGs and other initiatives."

The GlobalHAB Science Plan is being implemented through activities addressing the scientific questions formulated in each of the 12 Themes of the program. GlobalHAB has endorsed projects related to GlobalHAB interests, including on bioinformatics, innovative technologies for the early detection of HAB threats, and human health implications of HABs. GlobalHAB SSC members have been active in capacity building in their regions. For example, the following

activities in the Western Pacific region were conducted by IOC WESTPAC: (1) Scientific Diving for Marine Benthic Dinoflagellates Sampling and Processing held in September 2018, Phuket, Thailand and (2) Training course on Applying analytical method for detecting Ciguatoxins (CTXs) in fish held in April 2018 in Nha Trang Vietnam. GlobalHAB held a meeting with the Global Ocean Oxygen Network (GO2NE) to explore the linkage between high-biomass HABs and anoxia. GlobalHAB SSC members participated in the development of a community white paper for OceanObs'19.¹³ GlobalHAB has nearly completed a guide for managers regarding control of cyanobacterial blooms.

GlobalHAB has several activities planned for the coming year:

- **17-19 October 2019.** Economic Aspects of HABs Workshop. In Victoria, BC, Canada at 2019 PICES Annual Meeting.
- **8-11 October 2019.** Fish-killing Algae Workshop. Puerto Varas, Chile
- **Fall 2019.** Emerging threats on human health in Europe due to climate change.
- **January 2020.** Special issue in *Harmful Algae* on HABs and climate change
- **Summer 2020.** Scientific Summary for Policy Makers on HABs and climate change
- **May 2020.** HAB Modelling Workshop. Glasgow, UK
- **8-12 June 2020.** Symposium on in situ observations of HABs
- **2020.** Best practice guidelines for the study of HABs and climate change
- **On-going.** Global Harmful Algal Bloom Status Report. IOC
- **On-going.** Implementation of Global Ciguatera Strategy (IOC, FAO, IAEA, NOAA, GlobalHAB)
- **New GlobalHAB Theme:** Open Science Meeting on *Sargassum* Blooms.
- **Workshop and a Summer school on analysis and interpretation of genetic data on HABs species.**
- **A PCR/qPCR *Gambierdiscus* identification workshop**
- **A 2nd International Conference on Ostreopsis Development, including ecology, toxicology, health and economy issues**
- **A harmful species (*Gambierdiscus*, *Ostreopsis*, *Prorocentrum*, cyanobacteria) sampling workshop** is under exploration with different Spanish institutions in the Canary Islands in 2020 - early 2021.

In terms of management, GlobalHAB needs to obtain a minimum of secretariat support, to follow-up with endorsed projects, communicate about GlobalHAB, update the GlobalHAB Website, and keep track of the publications mentioning GlobalHAB (EndNote library). In terms of project funding, IOC will continue support. Even though NSF support of GlobalHAB has ended, SCOR could help identify institutions or international programs and alliances that would help support GlobalHAB. Can SCOR identify a particular topic of interest by SCOR to be addressed by GlobalHAB? Are there opportunities for SCOR working groups on HAB topics? Is there potential for collaborative projects with IMBER, SOLAS, or GEOTRACES? GlobalHAB needs core funding to continue implementation of the project.

¹³<https://www.frontiersin.org/articles/10.3389/fmars.2019.00250/full>

Ed Urban mentioned that SOLAS has listed harmful algal blooms as a potential interest and he commented at the SOLAS SSC meeting that they should discuss this with GlobalHAB. Elisa Berdalet responded that yes, she and Lisa Miller had discussed cooperation between projects at this meeting.

4.3 IAPWS/SCOR/IAPSO Joint Committee on Seawater (JCS)

Trevor McDougall presented an update about the Joint Committee on Seawater. This group was formed to continue the work of SCOR/IAPSO WG 127 on Thermodynamics and Equation of State of Seawater, which developed the Thermodynamic Equation of State-10 (TEOS-10). JCS does not meet annually as a full group. Instead, individual members represent the group at other meetings. For example, in 2017-2019, six JCS members attended the 2017 IAPWS Annual Meeting in Kyoto, Japan (2-7 Sept. 2017) and three members attended the 2018 Ocean Sciences meeting (Portland, 1 Feb. 2018). However, at five-year intervals, JCS hold full meetings in conjunction with the International Conference on the Properties of Water and Steam, most recently in Sept. 2018, in Prague, Czech Republic. JCS recommended to SCOR, IAPSO, and IAPWS that JCS continue as an activity sponsored by these organizations, that the JCS Terms of Reference remain unchanged for the next cycle, and that the membership of the various JCS task groups, which are largely independent of one another, be increased slightly to assist them in their work. These recommendations were accepted by JCS sponsors. The JCS has been responsible for continued implementation of TEOS-10, as well as conducting experimentation and modeling for proper description of seawater properties in models. The JCS has been working with SCOR WG 145 in terms of pH and its effects on trace metals and other components of seawater.

Peter Burkill asked about the future of the JCS and whether it will continue as a standing committee. McDougall answered yes, especially since the group is inexpensive for SCOR, only costing a few thousand dollars most years. TEOS-10 is now incorporated in most standard modeling software. Funding was approved for 2020 for the group.

4.4 SCAR/SCOR Southern Ocean Observing System (SOOS)

Louise Newman, SOOS Executive Officer, made the SOOS presentation remotely. SOOS is a joint initiative of SCOR and the Scientific Committee on Antarctic Research (SCAR). The project is its 8th year. It is managed by an International Project Office (IPO), which is hosted in Hobart, Australia by the Australian Research Council's Antarctic Gateway Partnership. The IPO is financially supported by the University of Tasmania and a set of international sponsors. The SOOS Mission is "to facilitate the collection and delivery of essential observations on variability and change of Southern Ocean systems to all international stakeholders, through design, advocacy, and implementation of cost-effective observing and data delivery systems."

SOOS carries out its work through the SOOS Scientific Steering Committee and its Executive Committee, a Data Management Committee, Regional Working Groups (Indian Ocean, West Antarctic Peninsula, Ross Sea, Amundsen/Bellingshausen seas, Weddell Sea/Dronning Maud Land), Capability Working Groups (SOFLUX, ATWG, CAPS, OASIIS, OSD), and Task Teams (eEOVs, AUV).

With the additional of the Weddell Sea/Dronning Maud Land working group in the past year, SOOS now has circum-Antarctic coverage. Each Regional Working Group is responsible to determine key gaps in observational coverage in their region, standardize methods, ensure data discoverability and delivery, “design” a regional observing system, and coordinate field activities, share resources, and align projects. The working groups use workshops to achieve their goals and several are planned for the coming year.

Capability Working Groups (CWGs) develop important capabilities for SOOS, such as developing and implementing new technologies and methods; improving observational design, efficiency, and coverage of observing systems; building new coordination networks towards enhanced observations; and developing data discovery and delivery tools. CWGs include the following:

- SOFLUX (Southern Ocean Fluxes)
- CAPS (Censusing Animal Populations from Space)
- ATWG (Acoustic Trends WG)
- POGO-OASIIS (Observing the ocean beneath Antarctic Sea Ice and Ice Shelves)
- OSD (Observing System Design)

Key tools and products include SOOSmap (an online data discovery tool), DueSouth (database of upcoming expeditions to the Southern Ocean), and documents that defining observational priorities, such as the community white paper produced for the OceanObs’19 conference¹⁴ (led by SOOS) and the SOOS Science Plan. SOOSMap is delivered by EMODnet Physics and provides direct links to data, where possible. New SOOSMap layers most recently delivered include CCAMLR Ecosystem Monitoring sites, CPR Survey data, Micro- and Macro-plastics, Krill Survey data (KRILLBASE), Penguin Colony count data (MAPPPD), and sea-ice core chlorophyll data.

The SOOS SSC met most recently in Korea on 16-18 May 2019, hosted by the Korean Polar Research Institute (KOPRI). SOOS thanked SCOR and SCAR for their continued support of the annual SOOS SC meetings, and acknowledged the 3-year commitment of funds by SCOR for the SOOS SSC meetings (2019-2021). This long-term commitment is important for SOOS’ forward planning and ability to leverage additional support.

Key activities over the coming year(s) include the following:

- Continue to make progress with the 5-Year Implementation Plan (2016-2020), including consolidation of key products and building working group networks
- Coordinate a review and update of the SOOS Science Plan based on the priorities identified in the OceanObs’19 community white paper
- Report on achievements of the 5-year Implementation Plan, and coordinate development of the new 5-Year Implementation Plan (2021-2025)
- Organise the 2020 SOOS annual meeting, to be held in Hobart, Australia alongside the SCAR2020 Open Science Conference in August 2020

¹⁴<https://www.frontiersin.org/articles/10.3389/fmars.2019.00433/full>

SOOS will represent SCOR at the annual meeting of the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) meeting on 21 Oct.-1 Nov. 2019.

Miloslavich stated that she is pleased that funding solutions have been found for the next three years and is impressed with the progress of the DueSouth web portal. David Halpern asked what the dots of different colors on SOOSMap mean. Newman responded that the different colors indicate different types of data. Juan Fierro (Chile) asked why there were fewer dots along the coast of Argentina versus the coast of Chile. Newman responded that the dots on the map depend on what data are publicly available. Newman noted that they are discussing how to link/point GEOTRACES data on SOOSMap.

4.5 Changing Ocean Biological Systems (COBS)

Patricia Miloslavich updated meeting participants about the progress of this group, which is transforming from a SCOR working group (WG 149) to a SCOR infrastructural project. The major achievement in 2018/2019 was the development and launch of a Web-based multi-driver Best-Practice Guide (BPG) to fulfill WG 149's ToR #4. This BPG is available at <https://meddle-scor149.org/> and comprises three components: (1) decision support for design, (2) MEDDLE (Multiple Environmental Driver Design Lab for Experiments) experimental simulator, and (3) a library of video tutorials. A handbook is available to step users through the BPG (<https://doi.org/10.25959/5c92fdf0d3c7a>). COBS is conducting outreach in collaboration with other groups working in multiple drivers (e.g., GOA-ON, GO2NE, IMBER, IOC-Ocean Sciences); it organized a workshop and hosted a session at the IMBER 2019 Ocean Science Conference. COBS is building bridges with disparate disciplines (e.g., eco-toxicology, epigenetics, paleo-oceanography) through several approaches, including the Ocean Global Change Biology Gordon Research Conference and associated Gordon Research Seminar for early-career scientists. Mentoring of early-career scientists in the design process for complex multiple-driver manipulation experiments also occurred through a course hosted by the International Atomic Energy Agency in May 2019 in Monaco. The group is forging close links with the proposed IOC WG on Multiple Stressors (Boyd and others are having regular video-conferences with Salvatore Aricò), and is working with IOC to develop a Guide for Policy-makers on multiple drivers to form part of the UN Decade on Ocean Science of which multiple drivers will be a key theme. There is a perspective article in review at *Nature Climate Change* entitled “Novel experimental frameworks are essential to reveal the rules shaping ocean global change biology”

Plans for the coming year include the following actions:

- Member rotation to inject some new ideas and energy into the group
- Revision of the original ToRs
- Raise awareness of the availability of the Web-based BPG (national, regional and international presentations and 1-day workshops), including 30-minute tutorial sessions at 2020 Ocean Sciences at the SCOR Booth
- Resources for tutorials will be made available to COBS and interested parties
- Further develop the Web-based guide as a valuable educational resource

- Continue to work closely with IOC on developing multiple drivers activity for the UN Decade
- Upload of additional video tutorials onto COBS YouTube site (linked into the Web-based BPG)
- Seek constructive criticism through a portal in the Web-based BPG site

Salvador Aricò (IOC) noted that COBS is relevant for ecosystem management and multiple stressors, for the UN Ocean Decade, which will likely need this type of science. For now, IOC is delaying the creation of an IOC group on this topic, to see how COBS evolves. Ed Urban noted that it is unsure how long NSF will provide funding, although the current funding runs until 31 August 2021. He added that WG 149 raised \$30-40K beyond what SCOR provided, which shows what WG members can achieve. Hal Batchelder noted that there are issues with making YouTube videos available in China. Patricia Miloslavich responded that it is an open question how to deal with this issue. John Claydon (IMBeR) responded that the IMBeR Regional Project Office in China uses an equivalent video-sharing platform to deal with this issue.

5.0 CAPACITY-BUILDING ACTIVITIES

The papers related to SCOR's capacity-building activities were available in the background for the meeting (https://scor-int.org/Annual%20Meetings/2019_SCOR_Meeting/Tab%205.pdf), but were not presented, due to a full schedule of other presentations.

5.1 SCOR Committee on Capacity Building

The Committee worked by email this year, evaluating two sets of requests for travel support for ocean science meetings and applications for the 2019 SCOR Visiting Scholars Program. An article about SCOR's capacity-building activities was published in *Scientia* magazine (see <https://www.scientia.global/from-coast-to-coast-building-capacity-in-ocean-science/>). SCOR approved funding for the committee's 2020 activities.

5.2 SCOR Visiting Scholars

SCOR began a program in 2009 to enlist the services of ocean scientists from the SCOR community, from both developed countries and developing countries, both recently retired and active, to teach short courses and to provide more extended on-site education and mentorship at developing country institutions. Six SCOR Visiting Scholars were approved for 2019, to work in Angola, Argentina, Brazil, Ecuador, and Mauritius. Ed Urban and Sophie Seeyave (POGO Executive Director) submitted a publication to *Oceanography* magazine describing the SCOR Visiting Scholars program and POGO Visiting Professors program; the publication is being revised for resubmission. The number of Visiting Scholars approved each year has increased from 1 in 2009 to 6 in 2019. The 6 SCOR Visiting Scholars approved in 2019 will be supported by US\$7,500 from the U.S. National Science Foundation, \$5,000 from the main SCOR budget, \$1,975 from the Committee on Capacity Building's budget, and \$525 from crowd-funding. This is the first year that SCOR Visiting Scholars were sent to Angola and Mauritius. The call for applications for 2020

Visiting Scholars will be made after the SCOR Annual Meeting in Toyama. We will attempt to increase the crowd-funding portion in 2020.

5.3 POGO-SCOR Visiting Fellowships for Oceanographic Observations

SCOR and POGO have been cooperatively funding this program since 2001. As the POGO Members had to be consulted on this year's budget expenditure at POGO's annual meeting at the end of January 2019, the announcement was posted on 6 March 2019, with a closing date of 30 April 2019.

A total of 29 valid applications were received this year (exactly the same number was received in 2018). Applications were received from 18 countries (15 countries in 2018). The highest number of applications (5) was received from India. With the combined available budget from POGO and SCOR, 5 candidates were selected, from Cameroon, Cote d'Ivoire, India, Iran and South Africa. The applications were screened independently by a committee of four, with representation from SCOR, POGO, and partners of POGO (including host supervisors of fellows from 2018). In making their selection, the committee considered the following factors:

- quality of the application;
- relevance of the application to the priority areas identified in the fellowship announcement;
- evidence that the training will lead to improved sustained observations in the region, or improved applications of such data;
- evidence that the training would lead to capacity-building with potential lasting impact on regional observations; and
- the need to maximize regional distribution of the awards.

POGO and SCOR commend the efforts of all the supervisors and colleagues at the various host institutions who agreed to devote time and energy required for the training. The program would not have been viable without such efforts from prominent scientists and their teams.

5.4 NSF Travel Support for Developing Country Scientists

SCOR has received support from the U.S. National Science Foundation (NSF) since 1984 to provide funding for SCOR capacity building activities. Most of the funds are used for travel grants for scientific meetings, although a portion is used for SCOR's contribution to the POGO-SCOR Fellowship Program and the SCOR Visiting Scholars program. Travel grants are awarded to ocean scientists from developing countries and the former Soviet Union, Eastern Europe, and other countries with economies in transition, to enable them to attend international scientific meetings. A new three-year grant was approved in July 2017, running from 1 August 2017 to 31 July 2020. The amount of the award from NSF is \$75,000 per year. A proposal for renewal of the grant will be submitted to NSF in early 2020.

About 77% of the grant funds are devoted to supporting the travel of scientists from developing countries and countries with economies in transition to ocean science meetings. The SCOR Committee on Capacity Building evaluates requests from meeting organizers for such support

several times each year. After a meeting is approved, the organizers run a selection process and propose individual recipients for support. The PI checks the names of proposed recipients to ensure they are from eligible countries and have not received similar support from SCOR in the past two years. Priority is given to applicants who are presenting a paper or poster at the meeting or to those who have some special expertise or regional knowledge to bring to a workshop or working group. Preference is also given to younger scientists. In general, care is taken to ensure that the recipients of SCOR/NSF funds are active scientists. If travel grant recipients are informed that their support comes from SCOR and that it is made possible through NSF funding. Requests are received throughout the year and the SCOR Committee on Capacity Building considers new requests between meetings. Forty-three students and scientists from 13 countries were supported during the reporting period to attend 12 scientific meetings and summer schools. The third year of funding in the current grant was awarded by NSF in 2019.

5.5 Research Discovery Camps at the University of Namibia

SCOR has supported “Research Camps” at the University of Namibia Henties Bay campus for the past 6 years, through funding from the Agouron Institute and more recently through funding from the Simons Foundation. The 6th Camp was held on 28 April-24 May 2019. These camps have brought together graduate students, post-doctoral fellows, and instructors from Namibia, other African countries, and other countries of the world to learn ocean science through doing research together. The camps bring together resources from the University of Namibia, the national fisheries agency, participants, and the Agouron Institute and Simons Foundation.

6.0 RELATIONS WITH INTERGOVERNMENTAL ORGANIZATIONS

6.1 Intergovernmental Oceanographic Commission (IOC)

Marie-Alexandrine Sicre and Ed Urban attended the IOC Executive Council meeting in June 2019 to represent SCOR. At that meeting, SCOR expressed support for considering the second International Indian Ocean Expedition (IIOE-2) as a component of the UN Decade of Ocean Science for Sustainable Development. SCOR and IOC co-fund several activities: IIOE-2 (see item 3.5), IOCCP (see item 4.1), and GlobalHAB (see item 4.2).

Salvatore Aricò reminded meeting participants that 2021 will be the official start of the UN Decade, which will run until 2030. He stated his hope that the UN Decade would be a true action decade, not only a paper event. He noted that this will not be an ocean decade, but an ocean science decade, to take ocean science to the next level. The UN Decade should produce new science to achieve important societal outcomes:

- A clean ocean
- A healthy and resilient ocean
- A predicted ocean
- A safe ocean
- A sustainable productive ocean
- A transparent and accessible ocean

The UN Decade is being managed by a 19-member Executive Planning Group (EPG). The main tasks of the EPG are to provide advice on the form and structure of the UN Decade, including governance arrangements; support the drafting of Implementation Plan for the UN Decade, to be considered by the UN General Assembly; and engage with and consult relevant communities. The next meeting of the EPG will be in January 2020 at UNESCO Headquarters in Paris. One of the EPG's short-term tasks that will be of most interest to SCOR is the Science Plan Task Group, which will

- “carry out an assessment of the gaps in ocean science and knowledge with respect to societal and sustainable development needs, and in particular identify where current scientific efforts have the biggest potential to be scaled up, building on the contribution of new technologies;
- promote the importance of the science-policy interface (for example, EU projects have a science-policy interface panel) and the importance of co-designed research involving other stakeholders and decisions-makers;
- develop guidelines for interacting with science programmes: explain the balance between the top-down and bottom-up approach, define the threshold of acceptance for the scientific projects, provide a template to enabling planners to assess scientific proposals in a systematic way, evaluate if those emblematic themes are the same as the R&D priority areas and societal outcomes and if not to list these topics. These elements should be integrated in the strategic paper to be used when engaging communities such as ICES, PICES for them to know how they can engage; and
- prepare a high-level science plan (outline and consultations), and review and update the implementation plan on a regular basis.”

The Science Action Plan will be created based on inputs from regional and thematic workshops, inputs from science and stakeholder consultations, and contributions of existing science plans/organisations. It will ensure involvement of early-career professionals and good gender representation. The 1st UN Decade Global Planning Meeting was held on 13-15 May 2019 in Copenhagen, Denmark. This meeting included 250 participants from 50 countries, with all the main ocean basins represented. The meeting was structured with 6 panels and 6 working groups (organized around the 6 Decade societal outcomes), 4 cross-cutting theme panels, and 2 side events. Following the Global Planning Meeting will be a series of regional meetings, representing each ocean basin. A second Global Planning Meeting and Stakeholder Forum will be held in early 2020. The UN General Assembly will consider the Implementation Plan in late 2020. David Halpern asked Aricò to elaborate on the Science Plan Task Group for the UN Decade. Aricò responded that this group, led by Martin Visbeck, is a subset of the Executive Planning Group. Presently, its members are all members of the Executive Planning Group. The group is presently providing input on for the outline of the UN Decade Science Plan, but the process will eventually be opened.

Aricò next noted activities involving close cooperation and coordination between IOC and SCOR: HABs (GlobalHAB program), time series (an outcome of SCOR WG 137), de-oxygenation (Xiamen Summer School, August 2019), multiple stressors (an outcome of SCOR WG 149), and Eastern Boundary Upwelling Systems (EBUS) (in cooperation with SCOR WG 155). Other IOC activities that may be of interest to SCOR include ocean acidification (SDG

14.3.1), nutrients (SDG 14.1.1a), plastics (SDG 14.1.1b), Blue Carbon, and Integrated Ocean Carbon Research.

6.2 Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP)

GESAMP WG 38 on Atmospheric Input of Chemicals to the Ocean convened two workshops at the University of East Anglia (UEA) in Norwich, United Kingdom from 27 February through 2 March 2017. The topics of the two workshops were (1) Impact of Ocean Acidification on Fluxes of Atmospheric non-CO₂ Climate-Active Species and (2) Changing Atmospheric Nutrient Oceanic Solubility. So far, these workshops have resulted in four published peer-reviewed papers, with five additional papers in preparation. SOLAS has supported the group with intellectual advice and people.

WG 38 would like to submit a proposal to NSF through SCOR for a workshop to assess the impact of the atmospheric transport of nutrients in sub-Saharan Africa to the Indian Ocean, with special reference to ocean productivity. The workshop would be held in South Africa and the total cost would be about US\$100,000. WMO has already committed \$40-50K. David Halpern suggested that national space agencies might be interested and willing to contribute funds. Ed Urban added that trace element chemists at Stellenbosch University might be willing to provide lectures. Marie-Alexandrine Sicre asked whether ocean circulation be a key player, since there is a productivity gap between Africa and Madagascar. Duce responded that this may be the case. This is an open question that will require more modelling; this workshop would be of value to local scientists, even if it demonstrates no atmospheric impact.

6.3 North Pacific Marine Science Organization (PICES)

Hal Batchelder, PICES Deputy Executive Secretary, gave an update about PICES, which is an intergovernmental scientific organization established in 1992 to promote and coordinate marine scientific research in the North Pacific Ocean and adjacent seas to advance scientific knowledge of the area and its living resources. PICES currently has six member nations: Canada, Japan, People's Republic of China, Republic of Korea, the Russian Federation, and the United States. PICES' vision is "to engage scientists in trans-disciplinary multi-national collaborations to further our collective understanding of the North Pacific's natural systems and enhance ecological and social resilience of our coasts and oceans." PICES structure includes

- a Governing Council (2 National Delegates from each of 6 countries) that approve budgets, manages the organization, and sets strategic direction
- a Science Board composed of the chairs of 7 committees and 1 science program, which sets scientific priorities and provides recommendations to the Governing Council
- Expert Groups on many different topics, which carry out specific tasks/activities/analyses/reports
- a Scientific Steering Committee for its current integrated science program (FUTURE)
- a small Secretariat, hosted by Canada at DFO's Institute of Ocean Sciences

Even though PICES is an intergovernmental organization, many academic scientists are involved. Its agenda is driven from the bottom up by participating scientists, through the PICES Science Board. PICES has a broad subject area span, including climate science, lower trophic levels, fish, marine mammals and birds, contaminants and, recently, a human dimension component. Publications are a major output for PICES, including peer-reviewed journal articles and special issues, PICES Scientific Reports (records of Expert Groups and findings), Special Publications (e.g., Ecosystem Status and Trends Reports, Methods handbook, targeted advice (e.g., Cohen Report to the Government of Canada and the FERRRS Report to the U.S. government; ADRIFT project on the impacts of tsunami debris – in progress), and the PICES Community Newsletter.

PICES' major current research program is FUTURE - Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems. This program ties together much of the other work of PICES. The research themes of this program include the following:

1. What determines an ecosystem's intrinsic resilience and vulnerability to natural and anthropogenic forcing?
2. How do ecosystems respond to natural and anthropogenic forcing, and how might they change in the future?
3. How do human activities affect coastal ecosystems and how are societies affected by changes in these ecosystems?

PICES and SCOR have been cooperating since PICES was created. PICES has been helpful in regionalizing several international SCOR projects. SCOR and PICES have provided capacity building support for each other's activities, and have cooperated more broadly in capacity building. Hal Batchelder serves as a liaison to the SCOR Committee on Capacity Building. Ed Urban noted that the Guide to Best Practices for Ocean CO₂ Measurements is a good example of collaboration among SCOR, PICES, and IOC.

7.0 RELATIONS WITH NON-GOVERNMENTAL ORGANIZATIONS

7.1 International Science Council

The International Science Council (ISC) was launched in June 2018 and has since been focused on establishing a new governing structure. The SCOR Executive Committee and SCOR Executive Director continue to work on actions to respond to the ICSU review of SCOR.

7.1.1 Scientific Committee on Antarctic Research (SCAR)

SCOR and SCAR currently co-sponsor the Southern Ocean Observing System (SOOS). SCAR is developing a new set of Scientific Research Programs, to be formally approved at the XXXVI SCAR Delegates meeting in Hobart, Australia in 2020. SCAR's mission focuses on advancing research, understanding, and education on Antarctica and the Southern Ocean. SCAR also provides independent and objective scientific advice and information to the Antarctic Treaty System and other management bodies, and provides the main international exchange of Antarctic information within the scientific community. SCAR celebrated its 60th anniversary in 2018.

SCAR approved three Programme Planning Groups in 2018, each of which has a significant ocean component: (1) Integrated Science to Support Antarctic and Southern Ocean Conservation (Ant-ICON), (2) Antarctic Ice Sheet Dynamics and Global Sea Level (AISSL), and (3) Near-term Variability and Prediction of the Antarctic Climate System (AntClimnow). SCAR noted the excellent relationship with SCOR co-sponsoring SOOS and the value of SOOS continuing work in developing its regional groups.

7.2 Affiliated Organizations

7.2.1 International Association for Biological Oceanography (IABO)

Patricia Miloslavich, IABO President, updated SCOR meeting participants about IABO, which was established in 1964 under the International Union of Biological Sciences. The goals of IABO are to

- Promote the study of marine biology, biological oceanography, and other related sciences
- Promote interdisciplinary communication between marine biologists and other ocean stakeholders by organizing and supporting international forums
- Encourage international networking and collaboration between organizations and individuals with similar aims and interests
- Recognize and award outstanding accomplishments in marine biodiversity science

IABO functions through three task groups, on (1) Science, (2) Recognition, and (3) Communication. The chairs of these three groups, plus the President, Past-President, and Secretary, serve as the IABO Executive Committee. All the groups coordinate their work to produce the World Conferences on Marine Biodiversity. IABO held its General Assembly at the 4th World Conference on Marine Biodiversity in Montreal, Canada on 13-16 May 2018. The World Conferences on Marine Biodiversity are the major focal assembly for sharing research outcomes, management and policy issues, and for discussions of the role of biodiversity and biodiversity conservation in sustaining ocean ecosystems. The 5th WCMB will be held on the 13-16 December 2020 and will be hosted by the University of Auckland under the auspices of IABO. A new IABO Executive Committee was elected, including Patricia Miloslavich as the new IABO President and Suchana Chavanich (Thailand) as the new IABO Secretary.

The 1st Carlo Heip Award recipient was Prof. Carlos M. Duarte, Director of the Red Sea Research Center and Tarek Ahmed Juffalli Chair in Red Sea Ecology of King Abdullah University of Science Technology of the Kingdom of Saudi Arabia. The Carlo Heip award is awarded to individuals who have demonstrated exemplary leadership in marine biodiversity science. The next award recipients will present a plenary talk at the next World Conference on Marine Biodiversity. Nominations close on 1 December 2019. IABO is cooperating with other international organizations—including the Global Ocean Observing System (GOOS), the Ocean Biographic Information System (OBIS), Marine Biodiversity Observation Network (MBON), and World Register of Marine Species (WoRMS)—to build a unified and globally consistent ocean observing system that includes biological measurements.

The IABO email list is MARINE-B, with 1,350+ subscribers. This is IABO's main communication mechanism, whose purpose is to provide news and relevant information related to biological oceanography, and marine biology and biodiversity, including funding, jobs and study opportunities, relevant papers and reports, conferences, etc. After 55 years, IABO is considering how to refresh its image and logo.

Peter Burkill commented that it is good to see IABO doing so well, given its condition some years ago.

7.2.2 International Association for Meteorology and Atmospheric Sciences (IAMAS)

Joyce Penner, IAMAS President, presented an update of IAMAS activities. The IUGG General Assembly was held in Montreal, Canada on 8-18 July 2019, at which IUGG celebrated its 100th anniversary. Much of the annual activity of IAMAS focused on this event and Penner became IAMAS President at the IUGG General Assembly. The new IAMAS Bureau consists of

- President – Joyce Penner (USA)
- Secretary General – Steve Ackerman (USA)
- Vice-President – John Burrows (Germany)
- Vice-President – Mary Scholes (South Africa)

The work of IAMAS is to increase understanding of atmospheric phenomena, and encourage Earth observation and monitoring, weather and climate modeling, study of climate variability and change on the Earth and other planets, and next-generation education. IAMAS does this through 10 commissions:

1. Atmospheric Chemistry and Global Pollution
2. Atmospheric Electricity
3. Climate
4. Clouds and Precipitation
5. Dynamic Meteorology
6. Meteorology of the Middle Atmosphere
7. Ozone
8. Planetary Atmospheres and their Evolution
9. Polar Meteorology
10. Radiation

IAMAS is exploring whether to set up a new Tropical Meteorology Commission. IAMAS helped its parent, the International Union of Geology and Geodesy, celebrate its 100th Anniversary with a special celebration on 10 July 2019. Six outstanding speakers covered many aspects of atmospheric research. More than 900 attendees from IAMAS contributing to 100 symposia and 32 joint sessions, where IAMAS was lead of 61 joint sessions. The 2021 IAMAS Assembly will be conducted jointly with IAPSO and IACS in Busan, Korea on 18-23 July 2021. IAMAS is seeking an early-career scientist to work with the Bureau on planning and promotion of IAMAS and they have recommended that the IAMAS Commissions also appoint early-career scientists on their leadership panels. Discussions about the future of IAMAS started at the plenary in Cape

Town, South Africa in 2017, followed by an extended discussions at the Bureau meeting in Cambridge in April 2018. A strategic plan was adopted by the Executive Committee in Montreal in mid-2019. Lisa Miller asked if the draft strategic plan will be posted on the Web; Penner responded that it would be. David Halpern commented that he was intrigued by the IAMAS early-career medal; besides age, what are the selection criteria? Penner responded that outstanding research record is a requirement. The fields covered by IAMAS are wide, so nominations are accepted from commissions and members at large, Robert Duce commented that it is nice to see IAMAS moving into the 21st Century.

7.2.3 International Association for the Physical Sciences of the Oceans (IAPSO)

Trevor McDougall, IAPSO President, presented an update about IAPSO. IAPSO's primary goal is to promote "the study of scientific problems relating to the oceans and the interactions taking place at the sea floor, coastal, and atmospheric boundaries insofar as such research is conducted by the use of mathematics, physics, and chemistry." IAPSO works through 1) biennial scientific assemblies; 2) working groups; 3) commissions; 4) services and 5) website information. IAPSO makes special efforts to involve scientists and students from developing countries in its activities.

The principal IAPSO activity in 2018 was to prepare for the IUGG 2019 General Assembly (GA) that was held in Montreal, Canada, from 8 to 18 July 2019. IAPSO scientific sessions at the IUGG GA were held from 9 to 14 July and included 11 IAPSO symposia (216 oral presentations and 94 posters) and 5 IAPSO-led Association Joint symposia (111 oral presentations and 51 posters). IAPSO also co-sponsored 12 Joint symposia led by another Association (189 oral presentations and 104 posters). The program details can be found on the Assembly's website: <http://www.iugg2019montreal.com/p.html>. The GA was attended by about 4,000 participants, of which 359 registered as IAPSO. IAPSO highlights during the GA included the following:

- The Union Lecture "The Ocean's Role in Atmospheric Carbon Dioxide Changes During Ice Age Cycles" given by Prof. Karen Kohfeld (Simon Fraser University, Canada);
- The 2019 Prince Albert I lecture "Decadal variability in the ocean CO₂ sink" given by Prof. Corinne Le Quéré (University of East Anglia, United Kingdom), who was awarded the Prince Albert I Medal in connection with the lecture;
- The 2019 Early Career Scientist (ECS) Medal in Physical Oceanography talk "Overturning variability with observations" given by Gerard McCarthy (Maynooth University, Ireland);
- The 2019 ECS Medal in Chemical Oceanography talk "Nitrogen fixation across scales" given by Mar Benavides (Mediterranean Institute of Oceanography, France).

IAPSO also awarded the Eugene Lafond Medal, which is awarded to a developing world scientist who gave a notable paper at an IAPSO sponsored or co-sponsored symposium since the previous award. The 2019 Eugene LaFond Medal was awarded to Mr. Rohith Balakrishnan, for his oral presentation entitled "Basin-wide sea level coherency in the tropical Indian Ocean driven by Madden-Julian oscillations" delivered on 11 July 2019 within the IAG-IAPSO joint symposium on "Monitoring Sea Level Changes by Satellite and In-Situ Measurements." IAPSO is now organizing the IAPSO-IAMAS-IACS Joint Assembly in Busan, South Korea, from 18 to 23 July 2021. A first planning meeting was held in Montreal, involving IAPSO, IAMAS, and IACS officers. Information about the conference will be posted at www.baco-21.org.

An important initiative during 2018 was the establishment of the IAPSO Early Career Scientist Working Group. As one of the leading international associations in ocean physics and chemistry, IAPSO provides a significant platform for early-career scientists to network and integrate into the ocean science community. The group was established at the end of January 2018, chaired by Alejandra Sanchez-Franks (UK) and co-chaired by Malin Ödalen (Sweden). The first IAPSO ECS networking event was organized on 9 July 2019, during the IUGG 2019 General Assembly. About 30 young scientists participated. The email address iapso.ecs@gmail.com is active to subscribe to the WG. The Term of References of this group are available on the IAPSO website (<http://iapso.iugg.org/working-groups29.html>).

IAPSO sent out a call in early September 2019 to fund IAPSO Best Practice Study Groups; they expect to fund one of these per year. An IAPSO Best Practice Study Group will address an issue whose resolution will assist in the conduct of oceanographic research. These groups will document alternatives for measuring and analyzing data, developing processing software, or developing modelling systems. The relative strengths and weaknesses of alternative methods will be documented. Each Best Practice Study Group will receive up to US\$10,000 towards the costs of a meeting.

Joyce Penner asked if IAPSO has ever thought of changing its name, since chemistry is involved in some IAPSO topics. McDougall answered that this was discussed many times, but in the end IAPSO decided that physical sciences includes physical chemistry.

7.3 Affiliated Programs

7.3.1 InterRidge - International, Interdisciplinary Ridge Studies

Jerome Dymet, InterRidge co-chair, presented about InterRidge progress. InterRidge is following its Third Decadal Plan (2014-2023). Principal members include China, France (host – double contribution), and Norway, which contribute US\$25,000 per year. Regular members include Canada, Germany, India, Italy, Japan, Korea and the United Kingdom, which pay \$5,000 per year. Corresponding members (paying no annual fees) include Australia, Brazil, Chile, Mauritius, New Zealand, Philippines, Poland, Portugal, Russia, South Africa, and the United States.

InterRidge activities include the following:

- Working Groups organize workshops and produce reports, which is a major way the international community is involved in InterRidge. InterRidge WGs are similar to SCOR WGs in terms of activities and tenure, but receive a smaller amount of funding per group. An example is SCOR-InterRidge WG 135 on Hydrothermal Energy Transfer and its Impact on the Ocean Carbon Cycles which published its second and final publication in 2019.¹⁵ Two new WGs were approved in 2018: (1) Working Group on Mid-Ocean Ridge

¹⁵Le Bris, N., M. Yücel, A. Das, S.M. Sievert, P.P LokaBharathi, and P.R. Girguis. 2019. Hydrothermal energy transfer and organic carbon production at the deep seafloor. *Front. Mar. Sci.*, 18 January 2019, <https://doi.org/10.3389/fmars.2018.00531>

Islands and Seamounts and (2) Working Group on Seafloor Massive Sulfides along Mid-Ocean Ridges. SCOR provided support for several developing country scientists to attend the first meeting of the first of these working groups.

- Other international meetings and scientific activities
- Serving as a scientific voice to international agencies such as the International Seabed Authority (ISA) and international organizations such as SCOR
- Code of Conduct for responsible research at hydrothermal vents—InterRidge created this code in recognition of the increased level of research in these unique ecosystems (<http://interridge.org/IRstatement>).
- InterRidge Vent Database—InterRidge maintains a database (<http://vents-data.interridge.org/>), with a total of > 700 records of confirmed or inferred active vent fields in the database.
- Cruise Information to promote the exchange of information, technologies, and facilities among international research groups
- InterRidge Info (biweekly e-mail)
- InterRidge actions for early-career scientists include fellowships (up to US\$5,000 and bursaries to join cruises (up to \$2000). InterRidge also keeps track of spare berths on research cruises that might be filled by early-career scientists, and fellowships and job opportunities.

SCOR and InterRidge co-sponsored a meeting on "Mid-Ocean Ridges and Other Geological Features of the Indian Ocean" on 14-16 November 2018, in Goa, India. This meeting aimed to encourage involvement of the scientists involved in marine geology and geophysics the second International Indian Ocean Expedition (IIOE-2). The workshop attracted 128 scientists. Ten international and 17 young scientists from India were supported with travel awards. Thirty oral presentations were included in 7 thematic sessions and 42 posters presented at a "Poster Talk" session. SCOR and InterRidge supported the organization of the meeting and allowed students, young scientists, or other scientists to participate by covering travel costs.

Some key priorities for InterRidge in the coming year are to ensure the transition of the Office to a new host country; open new InterRidge Working Groups (perhaps in biology); organize an InterRidge Theoretical Institute in October/November 2019; attract member countries, communities, individual scientists by new projects, and participate in the current debate on deep-sea mining and the protection of the environment by giving stakeholders and the public access to the most up-to-date scientific information

Ed Urban noted that marine geology/geophysics experts will be involved in the 2020 Indian Ocean conference. Peter Burkill emphasized the importance of such scientists in the second International Indian Ocean Experiment. Dymant added that InterRidge is also seeking to create a digital atlas for mid-ocean ridges of the Indian Ocean; he would like to see a small working group formed to make use of Indian Ocean transits to solve simple geological problems. Salvatore Aricò noted two ways in which InterRidge is relevant to UN actions. First, the UN Decade is likely to include an element related to ocean mapping, including bathymetry and life in the deep ocean. Second, the UN is working on a new convention related to Biodiversity Beyond National Jurisdictions.

7.3.2 International Ocean Colour Coordinating Group (IOCCG)

Sinjaee Yoo reported that IOCCG was established in 1996 to promote communication and co-operation between the space agencies and the ocean-color user community. IOCCG has affiliated to SCOR since its early years. IOCCG has a broad international role for science and capacity building related to ocean color. It provides a forum for national space agencies to interact with each other and with the scientific community involved in ocean color research and observations. SCOR assists IOCCG with grants from NASA and regularly provides travel support for early-career scientists from developing countries to participate in IOCCG events.

IOCCG has a system of working groups that produce scientific monographs to advance the field of ocean color observations from satellites. The current groups include the following:

- Working Group on Earth Observations in Support of Global Water Quality Monitoring (Chair: Arnold Dekker, Paul DiGiacomo and Steven Greb)
- Joint GlobalHAB/IOCCG WG on Harmful Algal Blooms (Chair: Stewart Bernard).
- Uncertainties of Ocean Colour Remote Sensing (Chair: Frédéric Mélin)
- Intercomparison of Atmospheric Correction Algorithms Over Optically-Complex Waters (Chair: Cédric Jamet).
- Role of Ocean Colour in Biogeochemical, Ecosystem and Climate Modelling (Chair: Stephanie Dutkiewicz).
- Long-Term Vicarious Adjustment of Ocean Colour Sensors (Chair: Christophe Lerebourg).

IOCCG working groups produce monographs, 17 in number so far (<https://ioccg.org/what-we-do/ioccg-publications/ioccg-reports/>). IOCCG created a Protocol Series with four volumes completed so far and two open for comment: (1) Volume 1.0 - Inherent Optical Property Measurements and Protocols: Absorption Coefficient; Volume 2.0 - Beam Transmission and Attenuation Coefficients: Instruments, Characterization, Field Measurements and Data Analysis Protocols; (3) Volume 3.0 - Protocols for Satellite Ocean Color Data Validation: In situ Optical Radiometry (In Press); and (4) Volume 4.0 - Inherent Optical Property Measurements and Protocols: Best Practices for the Collection and Processing of Ship-Based Underway Flow-Through Optical Data (see <https://ioccg.org/what-we-do/ioccg-publications/ocean-optics-protocols-satellite-ocean-colour-sensor-validation/>).

Another important IOCCG activity in recent years have been the biennial International Ocean Colour Science meetings, which are open meetings designed to bring together the international ocean color community to discuss important issues related to their science. The fourth International Ocean Colour Science meeting took place in Busan, South Korea in April 2019. More than 250 researchers from 29 different countries participated.

IOCCG ran several different capacity-development activities in 2018-2019:

- IOCCG Summer Lecture Series—The fourth installment took place at the Laboratoire d’Océanographie de Villefranche (LOV, France) from 25 June to 6 July 2018. The courses provide advanced training in bio-optics and ocean color, specifically on current critical issues in ocean color science. A total of 131 applications were received, of which

22 students from 15 different countries were selected. SCOR sponsored three students to attend the training course (from South Africa, India and Nigeria), which was gratefully acknowledged. All the lectures were video recorded and are available on the IOCCG Website, together with the PowerPoint lecture presentations (see <http://ioccg.org/what-we-do/training-and-education/ioccg-sls-2018/>).

- An international ocean color remote sensing training course in Hangzhou, China in October 2019. This course was organized by IOCCG, in conjunction with EUMETSAT and the Second Institute of Oceanography, State Oceanic Administration, China (SIO/SOA). The course included training on the Sentinel-3 OLCI marine data stream, introducing participants to the latest satellite data available from EUMETSAT, as well as training on the SatCO₂ marine satellite data online analysis system.

Paul Myers noted that there seems to be no new IOCCG reports since 2015. Yoo replied that the slide only showed a subset; the most recent report was published in 2018. Patricia Miloslavich noted that the GOOS ocean color EOVS group is working with IOCCG. Elisa Berdalet added that it has been nice for GlobalHAB to continue its collaboration with IOCCG.

7.3.3 Global Alliance of CPR Surveys (GACS)

Peter Burkill provided an update about GACS progress. The most recent GACS meeting was held in November 2018 at the Marine Biological Association of the UK (Plymouth, UK). Sonia Batten led a GACS paper on “A global plankton diversity monitoring program” published in *Frontiers in Marine Science*.¹⁶ The next annual GACS meeting will be in November 2019 in Hobart, Tasmania. This will include a one-week training program on the CPR for technicians from South Africa and Brazil. Dr. Sanae Chiba is promoting the use of GACS indicators through the Biodiversity Indicators Partnership. GACS is included as an operating network for the GOOS Biology and Ecosystems Panel, and two GACS members are members of the Panel. There is a training workshop this year to help India initiate Southern Ocean CPR work.

What does GACS get from SCOR? They should consider whether to drop their SCOR affiliation if they are not benefiting. Ed Urban responded that benefits from affiliation with SCOR include visibility and opportunities to apply for SCOR developing country travel support.

8.0 ORGANIZATION AND FINANCE

8.1 Membership

8.1.1 National Committees

Ed Urban reported that the SCOR Executive Committee discusses on a regular basis how to recruit new nations to participate in SCOR. The SCOR President recently sent letters to institutions in Estonia, Kenya, and Oman to determine their level of interest in forming national SCOR committees. Discussions are underway with several other countries, including Portugal.

¹⁶Batten, S.D., R. Abu-Alhaija, S. Chiba, M. Edwards, G. Graham, R. Jyothibabu, J.A. Kitchener, P. Koubbi, A. McQuatters-Gollop, E. Muxagata, C. Ostle, A.J. Richardson, K.V. Robinson, K.T. Takahashi, H.M. Verheye, and W. Wilson. 2019. Global Plankton Diversity Monitoring Program. *Front. Mar. Sci.*, <https://doi.org/10.3389/fmars.2019.00321>

8.2 Publications Arising from SCOR Activities

SCOR projects and working groups have produced many publications in the past year. Several SCOR working groups have special issues or significant papers under development, which will appear in the next year. The list of working group publications from the past year is available in the background book for the SCOR meeting at https://scor-int.org/Annual%20Meetings/2019_SCOR_Meeting/Tab%208.pdf.

8.3 Finances

The SCOR Executive Committee approved a Finance Committee consisting of Riitta Autio (Finland), Peter Croot (Ireland), Ilka Peeken (Germany), and Song Sun (China-Beijing). This committee will conduct its work during the SCOR meeting and will report on (1) the 2018 Audit report, (2) recommendations of revisions to the 2019 SCOR budget, (3) recommendations for the 2020 SCOR budget, and (4) recommendations for dues levels in 2021. Peter Croot presented the report on behalf of the ad hoc SCOR Finance Committee:

- **Final 2018 Report and 2018 Audit Report:** Discretionary income derived from membership dues amounted to US\$379,000, plus income from the U.S. National Science Foundation, foundations, and partner organizations (\$97,000) for a total discretionary income of \$476,000. Discretionary Expenses were for SCOR working groups (\$108,000), other science activities (\$88,000), and administrative expenses (\$309,000), for a total of \$505,000. The cash balance at the end of 2018 was \$220,000. SCOR requires maintenance of a cash balance of least \$100,000, so this requirement was met. The Finance Committee recommended SCOR to accept the 2018 financial report and meeting participants approved this recommendation. The Finance Committee reviewed the auditor's report of 2018 finances. The auditor found no accounting discrepancies (and found SCOR a low-risk auditee). The Auditor's report was in accordance with SCOR financial report, and there are no special remarks in the Audit to consider. The Finance Committee recommend acceptance of the 2018 statements and the recommendation was accepted by meeting participants.
- **Revised 2019 Budget:** The 2019 discretionary income budgeted at the 2018 SCOR Annual Meeting in Plymouth was \$466,730. It was recommended that this be reduced to \$462,511, due to more complete knowledge of 2019 income. SCOR is on target to receive the budgeted dues by the end of the 2019. The expected expenses for working group meetings is about \$63,000 less than budget, primarily because four groups did not meet. Croot showed a chart of working group spending over time and noted that total working spending over time amounts to 70% of budget. Miscellaneous scientific activities were slightly under budget and administrative expenses were about \$50,000 less than budgeted. Due to the underspending in all categories, the budgeted loss of \$161,000 was reduced to about \$46,000, leaving the newly budgeted ending balance at the end of 2019 of about \$174,000, above the SCOR required level of \$100,000. The Finance Committee recommended approval of the revised 2019 budget and meeting participants approved it.
- **Proposed 2020 Budget:** The proposed 2020 budget included about \$5000 more in discretionary income than the revised 2019 budget. The 2020 budget also included \$15,000 each for 10 working groups and a partial budget for an 11th working group. The

proposed 2020 budget for miscellaneous scientific activities was about \$5000 lower than in the 2019 revised budget and administrative expenses about \$25,000 higher in 2020 than in 2019. Overall, discretionary expenses would be about \$70,000 higher in 2020 than in 2019. Assuming a 75% underspend by working groups in 2020, this budget would result in an ending balance of \$102,000, still above the minimum balance required by SCOR. The Finance Committee recommended approving the proposed 2020 SCOR budget and the meeting participants agreed. This budget assumes funding for two new SCOR working groups in 2020.

- **2021 dues for national SCOR committees:** The Finance Committee recommended that SCOR continue its practice of raising dues by 3% each year for 2021 dues, over 2020 dues levels. Meeting participants agreed to this increase.

Peter Burkill asked for more details about the crowd-funding item in the income for the 2019 revised budget. Ed Urban replied that these funds were for the SCOR Visiting Scholars program. We receive some funding each year from a request to the SCOR email list. We will continue this crowd-funding approach because it does not take much effort, and provides some visibility. In previous crowd-funding appeals, most contributions have come from former Visiting Scholars, so this indicates positive feelings about the program from them.

Burkill asked the incoming Executive Director if she is also happy with the proposed budget. Patricia Miloslavich replied affirmatively. Urban added that there are conservative assumptions in the budget, to be safe. Marie-Alexandrine Sire asked again if participants approved the entire report from the Finance Committee and meeting participants agreed.

9.0 SCOR-RELATED MEETINGS

9.1 SCOR Annual Meetings

9.1.1 2019 SCOR Annual Meeting: Toyama, Japan

Marie-Alexandrine Sire and Ed Urban thanked the Japanese SCOR Committee for the excellent meeting arrangements and social events. Urban presented gifts to Jing Zhang, who supervised the preparations for the meeting and raised local support, and to Chie Ueda, who led the logistical team.

9.1.2 2020 SCOR Annual Meeting: Guayaquil, Ecuador

Patricio Hidalgo Host, Director of the Ecuadorian Naval Oceanographic Institute made a presentation about the arrangements so far for the 2020 SCOR Annual Meeting. The meeting will be held at the Naval Officer's Club facility. The invitation to SCOR has been extended from the Ecuadorian Ministry of Defence. Hidalgo acknowledged that the Japanese SCOR Committee set a high standard for local hosts. The month of September would be fine for the meeting, and the local hosts will adapt the dates to meet SCOR's needs. It was agreed that Ed Urban would do a Doodle poll of Executive Committee members to select the best dates.

9.1.3 2021 SCOR Annual Meeting: Busan, Korea

Sinjaee Yoo presented information about the 2021 SCOR Annual Meeting, which will be held in Busan, Korea. He noted that it would be necessary to avoid the Korean Thanksgiving holiday (the 2nd biggest holiday in Korea) on 18-22 September 2021 and the Busan International Film Festival (the dates for 2021 are still uncertain). Paul Myers asked if it would be possible to link with the IAPSO/IAMAS/IACS Assembly. Urban replied that the dates for that assembly are 18-23 July 2021 and that would be too early in terms of getting working group proposals reviewed and making other arrangements. When SCOR has met in conjunction with IAPSO assemblies in the past, there have usually been few people who attend both meetings (besides the IAPSO President), so there is little benefit to meeting together to try to increase interactions or to reduce the carbon footprint of the meetings.

9.1.4 Future SCOR Annual Meetings

Ed Urban reminded participants that the SCOR Executive Committee welcomes invitations for SCOR Annual Meetings after 2021.

Appendix 1 Participants

LIST OF PARTICIPANTS

SCOR Executive Committee:

President:

Marie-Alexandrine Sicre (NM)

CNRS, LOCEAN

Tour 46-00, 5eme étage

4 place Jussieu, 75252 Paris Cedex 05

FRANCE

Marie-Alexandrine.Sicre@locean-ipsl.upmc.fr

Secretary:

Paul Myers (NM)

Department of Earth and Atmospheric Sciences

1-26 ESB, University of Alberta

Edmonton, Alberta T6G 2E3

CANADA

pmyers@ualberta.ca

Past-President:

Peter Burkill (NM)

Drake Circus

Plymouth University

Plymouth PL4 8AA

UNITED KINGDOM

Email: peter.burkill@plymouth.ac.uk

Vice Presidents:

David Halpern (NM)

Jet Propulsion Laboratory

4600 Oak Grove Drive

MS 183-501

Pasadena, CA 91109

USA

david.halpern@jpl.nasa.gov

Sinjaee Yoo (NM)

2670, Iljudongro

Gujwa-eup, Jeju 63349

SOUTH KOREA

sjyoo@kiost.ac.kr

Jing Zhang (NM)

Graduate School of Science and Engineering

University of Toyama

Toyama 9308555

JAPAN

jzhang@sci.u-toyama.ac.jp

Ex-Officio Members:

Patricia Miloslavich (IABO)

Project Officer GOOS Biology & Ecosystem Panel

Universidad Simon Bolivar / AIMS

PMB No. 3

Townsville, Queensland, 4810

AUSTRALIA

pmilos@usb.ve

Trevor McDougall (IAPSO)

School of Mathematics and Statistics

University of New South Wales

Kensington 2052

AUSTRALIA

Phone: +61407518183

trevor.mcdougall@unsw.edu.au

Joyce Penner (IAMAS)

3588 Plymouth Road #165

Ann Arbor, MI 48105

USA

penner@umich.edu

Co-opted Members

Nuria Casacuberta Arola

ETH Zurich

Otto-Stern-Weg, 5

HPK G23

Zurich 8093

SWITZERLAND

ncasacuberta@phys.ethz.ch

SCOR Secretariat:

Ed Urban

SCOR Secretariat

003 Robinson Hall

College of Earth, Ocean, and Environment

University of Delaware

Newark, DE 19716

USA

Email: ed.urban@scor-int.org

Other Participants:**Michio Aoyama**

Ten-nodai 1-1-1, Tsukuba, 305-8572
Ibaraki
JAPAN
michio.aoyama@ied.tsukuba.ac.jp

Salvatore Aricò

UNESCO/IOC
Head of Ocean Science Section
Paris 75007
FRANCE
s.arico@unesco.org

Riitta Autio (NM)

Agnes Sjöbergin katu 2
Helsinki FIN-00790
FINLAND
riitta.autio@ymparisto.fi

Harold (Hal) Batchelder

8624 Bourne Terrace
North Saanich, BC V8L 1M1
CANADA
hbatch@pices.int

Elisa Berdalet

Institute of Marine Sciences (CSIC)
Passeig Maritim de la Barceloneta, 37-49
Barcelona 8003
SPAIN
berdalet@icm.csic.es

John Claydon

IMBeR International Project Office
Institute of Marine Research
Bergen 5004
NORWAY
john.claydon@hi.no

Peter Croot (NM)

Earth and Ocean Sciences, Quadrangle Building
National University of Ireland Galway
Galway H91 TK33
IRELAND
peter.croot@nuigalway.ie

Nicolino D'Adamo

70 Jones Street
Stirling 6021
AUSTRALIA
nick.dadamo@bom.gov.au

Dejun Dai

No.6 Xianxialing Road
Qingdao 266061
CHINA
djdai@fio.org.cn

Lennart De Nooijer

Landsdiep 4
Den Hoorn 1797 SZ
NETHERLANDS
ldenooijer@nioz.nl

Robert Duce

145 Pioneer Passage
Bastrop, TX 78602
USA
robertduce@hotmail.com

Jerome Dymont

IPGP, 1 rue Jussieu
Paris 75005
FRANCE
+33695063425
jdy@ipgp.fr

Juan Fierro

Errazuriz Echaurren 254, Playa Ancha
Valparaíso 2340000
CHILE
jfierro@shoa.cl

Ruoying He

2800 Faucette Blvd
Raleigh, NC 27695
USA
rhe@ncsu.edu

Patricio Efrain Hidalgo Vargas

Av. 25 de Julio - Vía Puerto Marítimo - Base Naval
Instituto Oceanográfico de la Armada
Guayaquil 090114 Guayas
ECUADOR
patricio.hidalgo@inocar.mil.ec

Masao Ishii

Meteorological Research Institute
1-1 Nagamine, Tsukuba 305-0052
Ibaraki
JAPAN
mishii@mri-jma.go.jp

Chan Joo Jang (NM)

385 Haeyang-ro
Youngdo-gu, Busan 49111 Gyeonggi-do
SOUTH KOREA
cjjang@kiost.ac.kr

Burton Jones

King Abdullah University of Science and
Technology
Thuwal, Makkah 23955-6900
SAUDI ARABIA
burton.jones@kaust.edu.sa

Dong-Jin Kang

KIOST
Hayang ro 385
Busan 49111
SOUTH KOREA
djocean@kiost.ac.kr

Intae Kim

KIOST
385, Haeyang-ro, Yeongdo-gu
Busan 49111
SOUTH KOREA
ikim@kiost.ac.kr

Kaoru Kubokawa

3-26-2, Akabanedai, Kitaku
Tokyo 115-0053
JAPAN
kubokawa22@gmail.com

Phoebe Lam

University of California, Santa Cruz
1156 High St.
Santa Cruz, CA 95064
USA
pjlam@ucsc.edu

Qian Liu

Key Lab of Marine Chemistry Theory and
Technology
Ministry of Education
Qingdao 266100
CHINA
liuqian@ouc.edu.cn

Lisa Maddison

IMBeR International Project Office
Institute of Marine Research
Bergen 5004
NORWAY
lisa.maddison@hi.no

Victor Martinez Vicente

Plymouth Marine Laboratory
Prospect Place, The Hoe
Plymouth PL1 3DH, Devon
UNITED KINGDOM
vmv@pml.ac.uk

Hanna Mazur-Marzec

al. Marszałka Piłsudskiego 46
Gdynia 81-378
POLAND
+48 609419132
biohm@ug.edu.pl

Lisa Miller

Institute of Ocean Sciences
CP 6000
Sidney V8L 4B2
CANADA
lisa.miller@dfo-mpo.gc.ca

Daiki Nomura

3-1-1, Minato-cho
Hakodate 0418611
JAPAN
daiki.nomura@fish.hokudai.ac.jp

Ilka Peeken (NM)

Am Handelshafen 12
Bremerhaven 27570
GERMANY
ilka.peeken@awi.de

Song Sun (NM)

7 Nanhai Road, IOCAS
Qingdao, Shandong 266071
CHINA
sunsong@qdio.ac.cn

Xiaoxia Sun

No. 7 Nanhai Road
Qingdao 266071 Shandong
CHINA
xsun@qdio.ac.cn

Emily Twigg

U.S. National Academies
500 Fifth St NW
Washington, DC 20001
USA
etwigg@nas.edu

Mitsuo Uematsu

Center for Environmental Science in Saitama (CESS)
914 Kamitanadare
Kazo, 347-0115, Saitama
JAPAN
uematsu@aori.u-tokyo.ac.jp

Chau-Ron Wu

Dept. of Earth Sciences, Natl. Taiwan Normal Univ.
88, Section 4 Ting-Chou Road
Taipei 11677
TAIWAN
cwu@ntnu.edu.tw

Toshio Yamagata (NM)

3173-25 Showa-machi, Kanazawa-ku
Yokohama, Kanagawa 236-0001
JAPAN
+81-45-778-5502
yamagata@jamstec.go.jp

Wei Zheng

No.6 Xianxialing Road
Qingdao 266061
China
zhengwei@fio.org.cn

Fang Zuo

IMBeR Regional Project Office
East China Normal University
Shanghai 200062
CHINA
fzuo@sklec.ecnu.edu.cn

NM = Nominated Member

Appendix 2 Agenda

1.0 OPENING

1.1 Opening Remarks and Administrative Arrangements	<i>Zhang, Sicre, Urban</i>
1.2 Approval of the Agenda	<i>Sicre</i>
1.3 Report of the President of SCOR	<i>Sicre</i>
1.4 Report of SCOR Executive Director	<i>Urban</i>
1.5 Appointment of an <i>ad hoc</i> Finance Committee	<i>Sicre</i>
1.6 2020 Elections for SCOR Officers	<i>Burkill</i>

2.0 WORKING GROUPS

2.1 Current Working Groups	
2.1.1 WG 142 on Quality Control Procedures for Oxygen and Other Biogeochemical Sensors on Floats and Gliders	
2.1.2 WG 143 on Dissolved N ₂ O and CH ₄ measurements: Working towards a global network of ocean time series measurements of N ₂ O and CH ₄	<i>Urban</i>
2.1.3 WG 145 on Chemical Speciation Modelling in Seawater to Meet 21st Century Needs (MARCHEMSPEC)	<i>Sicre</i>
2.1.4 WG 147: Towards comparability of global oceanic nutrient data (COMPONUT)	<i>Aoyama, Sicre</i>
2.1.5 WG 148 on International Quality Controlled Ocean Database: Subsurface temperature profiles (IQuOD)	<i>Myers</i>
2.1.6 WG 150 on Translation of Optical Measurements into particle Content, Aggregation & Transfer (TOMCAT)	<i>Burkill</i>
2.1.7 WG 151: Iron Model Intercomparison Project (FeMIP)	<i>Casacuberta-Arola</i>
2.1.8 WG 152 on Measuring Essential Climate Variables in Sea Ice (ECV-Ice)	<i>Nomura, McDougall</i>
2.1.9 WG 153 on Floating Litter and its Oceanic Transport Analysis and Modelling (FLOTSAM)	<i>Martinez Vicente, Myers</i>
2.1.10 WG 154 on Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (P-OBS)	<i>Miloslavich</i>
2.1.11 WG 155 on Eastern boundary upwelling systems (EBUS): diversity, coupled dynamics and sensitivity to climate change	<i>Halpern</i>
2.1.12 WG 156 on Active Chlorophyll fluorescence for autonomous measurements of global marine primary productivity	<i>Yoo</i>
2.1.13 WG 157: Toward a new global view of marine zooplankton biodiversity based on DNA metabarcoding and reference DNA sequence databases (MetaZooGene)	<i>Miloslavich</i>
2.2 Working Group Proposals	
2.2.1 Roadmap for a Standardised Global Approach to Deep-Sea Biology for the Decade of Ocean Science for Sustainable Development (DeepSeaDecade)	<i>Miloslavich</i>
2.2.2 Marine Species Distribution Modelling in the global ocean (MSDM-GO)	<i>Penner</i>
2.2.3 DIagnoSiS of Carbon in the Ocean: Variability, uncERtainty and the Coasts (DISCOVER-C)	<i>McDougall</i>
2.2.4 Changing Biotic-Sediment Interactions in the Ocean Seabed (CBIOS)	<i>Yoo</i>
2.2.5 Coordinated Global Research Assessment of Seagrass System (C-GRASS)	<i>Burkill</i>
2.2.6 Integration of international ocean acidification research at CO ₂ seeps (InterSEEP)	<i>Myers</i>

3.0 LARGE-SCALE SCIENTIFIC PROGRAMS

- | | |
|----------------------------------------------------------------------------------|-------------------------|
| 3.1 GEOTRACES | <i>Lam, Duce</i> |
| 3.2 Surface Ocean – Lower Atmosphere Study (SOLAS) | <i>Miller, Penner</i> |
| 3.3 SCOR/POGO International Quiet Ocean Experiment (IQOE) | <i>Urban, Halpern</i> |
| 3.4 SCOR/Future Earth Integrated Marine Biosphere Research | <i>Claydon, Burkill</i> |
| 3.5 SCOR/IOC/IOGOOS Second International Indian Ocean Expedition (IIOE-2) | <i>D’Adamo, Burkill</i> |

4.0 INFRASTRUCTURAL ACTIVITIES

- | | |
|---------------------------------------------------------------------|----------------------------|
| 4.1 IOC/SCOR International Ocean Carbon Coordination Project | <i>Ishii, Halpern</i> |
| 4.2 GlobalHAB | <i>Berdalet, Yoo</i> |
| 4.3 IAPWS/SCOR/IAPSO Joint Committee on Seawater (JCS) | <i>McDougall</i> |
| 4.4 SCAR/SCOR Southern Ocean Observing System (SOOS) | <i>Newman, Miloslavich</i> |
| 4.5 Changing Ocean Biological Systems (COBS) | <i>Miloslavich</i> |

5.0 CAPACITY-BUILDING ACTIVITIES

- | | |
|--------------------------------------------------------------------------|--------------|
| 5.1 SCOR Committee on Capacity Building | <i>Urban</i> |
| 5.2 SCOR Visiting Scholars | <i>Urban</i> |
| 5.3 POGO-SCOR Visiting Fellowships for Oceanographic Observations | <i>Urban</i> |
| 5.4 NSF Travel Support for Developing Country Scientists | <i>Urban</i> |
| 5.5 Research Discovery Camps at the University of Namibia | <i>Urban</i> |

6.0 RELATIONS WITH INTERGOVERNMENTAL ORGANIZATIONS

- | | |
|---------------------------------------------------------------------------------------------------------|------------------------|
| 6.1 Intergovernmental Oceanographic Commission (IOC) | <i>Sicre, Arico</i> |
| 6.2 Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) | <i>Duce</i> |
| 6.3 North Pacific Marine Science Organization (PICES) | <i>Batchelder, Yoo</i> |

7.0 RELATIONS WITH NON-GOVERNMENTAL ORGANIZATIONS

- | | |
|----------------------------------------------------------------|--------------|
| 7.1 International Science Council | <i>Sicre</i> |
| 7.1.1 Scientific Committee on Antarctic Research (SCAR) | <i>Myers</i> |

- 7.2 Affiliated Organizations**
- 7.2.1 International Association for Biological Oceanography (IABO) *Miloslavich*
 - 7.2.2 International Association for Meteorology and Atmospheric Sciences (IAMAS) *Penner*
 - 7.2.3 International Association for the Physical Sciences of the Oceans (IAPSO) *McDougall*
- 7.3 Affiliated Programs**
- 7.3.1 InterRidge - International, Interdisciplinary Ridge Studies *Dyment, Zhang*
 - 7.3.2 International Ocean Colour Coordinating Group (IOCCG) *Yoo*
 - 7.3.3 Global Alliance of CPR Surveys (GACS) *Burkill*
- 7.4 Other Organizations**
- 7.4.1 Partnership for Observation of the Global Oceans (POGO) *Halpern*

8.0 ORGANIZATION AND FINANCE

- 8.1 Membership** *Urban*
- 8.1.1 National Committees
- 8.2 Publications Arising from SCOR Activities** *Urban*
- 8.3 Finances** *Finance Committee, Urban*

9.0 SCOR-RELATED MEETINGS

- 9.1 SCOR Annual Meetings**
- 9.1.1 2019 SCOR Annual Meeting: Toyama, Japan *Zhang*
 - 9.1.2 2020 SCOR Annual Meeting: Guayaquil, Ecuador *Hidalgo-Vargas, Miloslavich*
 - 9.1.3 2021 SCOR Annual Meeting: Busan, Korea *Yoo*
 - 9.1.4 Future SCOR Annual Meetings *Urban*
- 9.2 Locations of Past SCOR Annual Meetings**
- 9.3 SCOR-Related Meetings Since the 2018 SCOR Annual Meeting and Planned for the Future**

Appendix 3

Proposal for a Working Group on Coordinated Global Research Assessment of Seagrass Systems (C-GRASS)

1. Summary

Seagrasses provide the foundation of submerged coastal grassland ecosystems around the world but are threatened by human activities, with substantial declines in global cover over the last century. Seagrasses provide multiple valuable ecosystem services, particularly in the developing world. Yet obtaining an accurate understanding of seagrass status, trends, and responses to global change has been challenging due to the fragmented nature of available data. The time is opportune to solve these problems. Building on a recently completed Community White Paper and initial workshops to organize global seagrass researchers, we propose a series of SCOR workshops to collate and analyze existing data toward a scientific synthesis of the drivers and trajectories of seagrass ecosystems under global change, and to provide a framework for future coordinated observation and research on seagrass systems. Our Working Group (WG) engages a diverse community, spanning the globe and fields of technical expertise to: (1) collate and analyze existing data to publish an open-access scientific synthesis of current status, trends, and drivers of change in global seagrass systems; (2) establish common protocols and best practices for seagrass data collection, curation, and sharing, collated in a multi-media handbook of accepted protocols and best practices; (3) integrate seagrass data collection into international, open-access portals, with common frameworks for data vocabulary, metadata, management, and service to stakeholders; and (4) integrate ongoing seagrass monitoring and research into a global community of practice that incorporates diverse data types and informs diverse end users.

2. Scientific Background and Rationale

2.1. Global status of seagrass ecosystems

Seagrasses provide the foundation of submerged coastal grassland ecosystems around the world. They are among the most productive natural habitats on land or sea (1), store substantial quantities of carbon, and provide humanity with fishery habitat, coastal protection, erosion control, and other services (2). Seagrass nutrient cycling services alone have an estimated value of nearly \$2 trillion per year (3), and Indonesian seagrass meadows provide fishery nursery areas that contribute an estimated 54% to 99% of daily protein intake for local communities (4).

Seagrasses also serve as early warning indicators of anthropogenic perturbations in the coastal zone due to their sensitivity to changing water quality and fishing activities (5).

Seagrass habitats are threatened worldwide by human activities: a recent synthesis estimates that almost 30% of seagrass global cover has been lost over the last century (6) and 22 of the world's 72 seagrass species (31%) are in decline (2, 7), a trend widely considered a global crisis (8).

Recognizing this, the Global Ocean Observing System (GOOS) has proposed seagrass cover and composition as one of seven Essential Ocean Variables (EOVs) defined by societal importance as reflected in reporting requirements for numerous international conventions and agreements that shape policy responses to global change (9).

Despite their importance, developing coordinated systems for observing seagrass status and trends has been challenging for several reasons. First is the fragmented nature of available in situ data. Data on seagrass systems are collected by numerous local and regional monitoring programs, and by two global programs: Seagrass-Watch (10, 11), SeagrassNet (12). These networks, together with the Smithsonian's newer MarineGEO program, have engaged hundreds of scientists and thousands of citizens in collecting data. But such programs often have different objectives, methods, and target variables, making inter-comparison and synthesis difficult. A second challenge is that field sampling is biased geographically, concentrated in North America and western Europe around major scientific organizations. As a result, syntheses of seagrass occurrence rely heavily on interpolation of expert knowledge and low-resolution point-based occurrence sampling, whereas seagrass extent is difficult to quantify and resolution is low in the regions where seagrasses are most diverse such as the western Pacific.

2.2. New opportunities in seagrass science and conservation

We are now poised to overcome these historical challenges, as illustrated by several recent developments. These include production of a consensus Community White Paper outlining criteria for a coordinated global seagrass observing system (13), convening of the International Seagrass Experts Network (ISEN)¹⁷, an upcoming GOOS workshop to draft implementation plans for seagrass and mangrove observing, and participation in this WG of leaders of the two major global seagrass networks, Seagrass-Watch (WG member McKenzie) and SeagrassNet (WG member Short). Recent field initiatives have focused on seagrasses in the rich and understudied territories of southeast Asia and the coral triangle, including by members of this Working Group: Ambo-Rappe, Cullen-Unsworth, Fortes, Nordlund, Prathep, and Unsworth. While Africa remains poorly documented, WG member Uku is an authority in that region. This work promises to significantly expand geographic coverage of seagrass knowledge in understudied areas.

Additional opportunities to assemble a geographically comprehensive and well resolved understanding of global seagrass systems come from innovations in remote sensing; engagement of citizen scientists in field data collection; and community consensus around the need for standardization of protocols and data management (13). Our proposed working group (WG) aims to integrate and coordinate remote sensing and in situ sampling programs toward a more powerful scientific synthesis of global seagrass distribution and ecosystem characteristics. The WG will then extend this synthesis by coordinating seagrass ecosystem researchers worldwide toward consensus on comparable approaches for collecting and organizing data on seagrass cover, composition, and ecosystem characteristics. The WG will have the secondary benefit of providing a scientific and operational foundation to advance seagrass cover and composition as an Essential Ocean Variable (1).

2.3. Rationale for a SCOR working group

We propose a series of SCOR workshops that engage a diverse community of scientists and stakeholders to achieve the following goals: (1) collate and analyze data to produce a synthesis of the current status, trends, and drivers of change in global seagrass systems; (2) establish common protocols and best practices for seagrass data collection, curation, and sharing; (3) integrate existing and ongoing seagrass data collection into open-access portals, using a common schema; and (4) integrate existing seagrass monitoring and analysis into a unified, global community of practice. The proposed workshops will establish the community to continue the process into the future, and several participating institutions are committed to supporting achievement of the long-term goals.

Over the last few years seagrass researchers around the world have recognized the need for a more coordinated global response to understanding and publicizing seagrass degradation and have begun to coalesce around a shared vision for achieving this (8, 13). The time is ripe for a new global assessment of seagrass ecosystems. Achieving such a synthesis requires engaging expertise in seagrass physiology, field ecology, biogeochemistry, remote sensing, database architecture, geospatial science and mapping, social science, and digital knowledge product development and service. The proposed WG, and our large network of collaborators, spans this expertise. Foundations have been laid by incorporating seagrass cover as an Essential Ocean Variable by the Global Ocean Observing System (9), engaging the global community in the consensus Community White Paper (13), and formation of the ISEN.

The primary bottlenecks to a global seagrass database are comparability of protocols and accessibility of data. We will make rapid progress on the first of these as leaders of both major seagrass networks and the MarineGEO program are full members of this group (McKenzie, Short, Duffy). An achievable first step is to establish a public metadata portal to summarize what seagrass data exist and who holds them. We will then work to make as much of this data as possible accessible and will incorporate new data as they become available.

¹⁷See: <http://unseagrass.org/>

Candidate protocols and best practices have been developed, vetted, and formalized by Seagrass- Watch, SeagrassNet, the *Zostera* Experimental Network (14), MarineGEO¹⁸, and other programs, providing a foundation for a global community of practice. Under the right conditions, satellite remote sensing (15) and lightweight drone technology (16) can obtain high-resolution maps of seagrass distribution and resolve variation in abundance, offering promise in linking regional and global-scale cover mapping, and validating these with strategically sited *in situ* measurements.

We will evaluate the capabilities of remote sensing to conduct regional assessments on the health and cover of seagrass communities. Satellite images collected over the past 30 years provide an basis for evaluating change, yet it is not clear how this technology can be leveraged with new unmanned airborne systems and field efforts. WG Members Muller-Karger and Dierssen bring experience in these areas to the WG.

The accessibility of shallow-water seagrass meadows and their importance to local fisheries and ecosystems makes seagrass systems prime targets for application of citizen science monitoring, as done by Seagrass-Watch and the Seagrass Spotter phone app¹⁹, co-developed by WG Member Unsworth. There is considerable potential to expand and integrate these activities. Through all these approaches, we are poised to achieve a previously unavailable synthesis of the changing distribution of global seagrass habitat, and the drivers of these trends. This process will also advance implementation of the seagrass EOVI envisioned as part of GOOS.

3. Terms of Reference

The objectives of the SCOR C-GRASS Working Group are:

Objective 1: Produce a scientific synthesis of status and trends in global seagrasses and the systems they support, via a comprehensive review of peer-reviewed and gray literature, and unpublished data, on seagrass occurrence, ecosystem characteristics, and benefits to human well-being.

Objective 2: Produce a handbook of standard protocols and best practices for collecting, curating, and sharing data on seagrass ecosystems among scientists and stakeholder groups, building on existing experience of scientists and end-users in management and conservation, and contributed to the Ocean Data Standards and Best Practices Project of IODE.

Objective 3: Promote development of standardized vocabularies for variables and data schemas specific to seagrass ecosystems, and integration of existing and new data into the Ocean Biodiversity Information System (OBIS) using the EVENT-DATA schema (17).

Objective 4: Organize an interdisciplinary community of practice to synthesize data on status, trends, and drivers of global change in seagrass ecosystems, building on and integrating existing resources.

4. Working plan

4.1. Objective 1: Produce a scientific synthesis of status and trends in global seagrass systems

The centerpiece of the Working Group will be assembling the existing global seagrass data into an updated scientific assessment, building on previous assessments of global seagrass occurrence (18). Collaboration of major global seagrass networks (WG members Short, McKenzie, Duffy) will achieve an unprecedented coordination and integration of data, knowledge, and practice.

The data will be analyzed with ocean environmental data layers and data on human activities to quantify drivers of change in global seagrass systems. The results will be published in peer-reviewed paper(s), and integrated into the UNEP-WCMC Ocean+ initiative, which maintains a database of seagrass cover and produces maps and knowledge products that directly inform decision-making (available through Ocean Data

¹⁸Available at: <https://marinegeo.github.io/seagrass.html>

¹⁹Available at: <https://seagrassspotter.org/>

Viewer20), including the *Global Distribution of Seagrasses*.²¹ The synthesis will also link in situ seagrass data to remote sensing approaches (19) and quantification of seagrass ecosystem services (WG members Cullen-Unsworth and Nordlund) (20, 21).

4.2. Objective 2: Produce a handbook of standard protocols and best practices

Agreement on comparable protocols and best practices is key to coordinating monitoring across a distributed network and ensuring that data are comparable across space and time. We will assemble and analyze core measurements and protocols for in situ survey methods (22), remote- sensing approaches (15), and sampling designs, focusing on those that are fit to purpose, i.e., selected to provide information of appropriate resolution, quality, and scale to capture seagrass trends relevant to reporting requirements of nations and decision-makers. This process is facilitated because only two large networks dominate the field and leaders of both (McKenzie, Short) are members of our WG. The Working Group will produce a multi-media handbook, linked to training videos and online resources facilitating field data collection, data management, and curation methods accepted by community consensus. These products will accelerate data collection and integration across networks by making protocols and data more accessible, and by building capacity to collect and contribute data, also adding value to existing networks (as confirmed by participation of Short and McKenzie).

4.3. Objective 3: Promote development of standardized vocabularies and data schemas

Rigorous comparison of data among programs requires a common language. The recently developed EVENT-DATA OBIS schema uses a standard Darwin Core set of terms and accommodates sampling descriptions, environmental data, and biodiversity records. The WG will develop and compile a standardized vocabulary for seagrass systems via established OBIS collaborations developed by the MBON (WG member Muller-Karger) and Smithsonian MarineGEO (WG co-lead Duffy). We will integrate a substantial body of records of seagrass cover and species composition into OBIS, notably from SeagrassNet representing 33 countries, Seagrass-Watch representing 26 countries, and the 13 sites in the MarineGEO program.

Data access and ownership are key issues in the emerging networked data ecosystem. A key first step will be a metadata portal. We will promote availability of as much seagrass data as possible, building on the Seagrass-Watch model, which involves a tiered system of data sharing that respects the ownership of raw data, while making detailed summaries available via open access portals.

Objective 4: Organize an interdisciplinary community of practice

A dynamic observing system for seagrasses requires a coordinated effort, structures to manage ongoing data input and access to maintain inter-comparability, and engagement of diverse partners across the world, disciplinary expertise, and knowledge of the needs of policy- and decision-makers. We will focus on linking the web portals and protocols of the Seagrass-Watch, SeagrassNet, the Ocean Data Viewer, and MarineGEO programs, leveraging resources already invested in them and the continuing support of their secretariat institutions. Working Group members, including the UN Environment World Conservation Monitoring Centre (UNEP- WCMC, with leadership from co-chair Weatherdon) and GRID-Arendal (Maria Potouroglou) will assist in engaging end-users of the information products from the policy community, and in developing a communications strategy. UNEP-WCMC's existing seagrass layer has been used for environmental sensitivity mapping, marine spatial planning, high-level screening of biodiversity risk, and blue carbon assessments, and its application to ecosystem-based adaptation to climate change is in progress. We expect rapid uptake of our findings in development and refinement of global blue carbon inventories and development of blue carbon markets as several WG members play advisory roles in International Blue Carbon Partnership (collaborator Peter Macreadie), the IUCN Blue Carbon Initiative (Fourqurean, Fortes, Marba), the IPCC Guidelines for National Greenhouse Gas Inventories (Macreadie), and the Coastal Carbon Research Coordination Network (Duffy).

²⁰Available at: <http://data.unep-wcmc.org>.

²¹Available at: <https://seagrasspotter.org/>

4.4. Timeline

Working Group meetings will be held in association with international conferences and we will work to leverage other funds to cover costs of participants; several participating institutions have offered financial or in-kind support. Likely venues for meetings include the 14th International Seagrass Biology Workshop (2020, Washington DC); and international Ocean Science meetings.

Month 1: Working Group meeting 1. Hone goals, assign subgroups with leads for each of the four objectives. Begin to identify data sources and tractable synthesis goals, and to assemble data and metadata (Objective 1). Draft outline of best practices (Objective 2) and data schema (Objective 3).

Month 1-12: Subgroups work on collating data, integrating into the developing data schema (Objectives 1,3), and converge on best practices for handbook (Objective 2). Integrate sample data sets into OBIS using draft schema (Objectives 1,3).

Month 12: WG meeting 2. Present draft of best practices document (Objective 2) and data schema (Objective 3) for discussion by WG. Review data assembled, outline synthesis papers, and begin intensive data analysis (Objective 1).

Month 12-24: Continue work on best practices (Objective 2) and synthesis paper(s) (Objective 4). Introduce drafts to policy end-users and incorporate feedback.

Month 24: WG meeting 3. Complete best practices handbook (Objective 2) and synthesis papers (Objective 4). Report on data integration (Objectives 1, 3), challenges, and plans.

Month 24-36: Subgroups finish work on all four objectives.

Month 36: Meeting of selected WG members, lead authors, and data architects, to synthesize results toward the Objectives, finish products, and develop plans for long-term advancement. Official launch of products.

5. Deliverables

- (1) Hold a town hall meeting at the 2020 Ocean Sciences meeting (and potentially others) to announce the Working Group effort and solicit broad input. Contributes to delivering all Objectives.
- (2) Produce a peer-reviewed scientific synthesis of status, trends, and environmental and anthropogenic drivers of change in global seagrasses and the systems they support, based on a comprehensive review of peer-reviewed and gray literature and unpublished data available in major seagrass network databases. Delivers Objective 1.
- (3) Integrate existing seagrass data, and ongoing monitoring data, into the Ocean Biodiversity Information System (OBIS) using a common data schema. Contributes to delivering Objectives 1 and 3.
- (4) Produce a peer-reviewed handbook of inter-comparable protocols and best practices for seagrass field measurements and data management, published and contributed to the Ocean Data Standards and Best Practices Project of IODE. Delivers Objective 2.

6. Capacity Building

The community of practice built through this series of working groups will be advanced into the future in several ways. First, we engage seagrass researchers and stakeholders from a diverse range of backgrounds, geographic regions, and disciplines in this common, collaborative effort. Second, we intend to develop courses with support from IODE Ocean Teacher Global Academy (OTGA) of the International Oceanographic Data and Information Exchange (IODE) to spread the protocols, best practices and synthesis tools in seagrass research to a global community. We will liaise with the OTGA program to propose an OBIS course tailored for the seagrass community, and seek support from OTGA. Third, the several seagrass observation programs, including Seagrass-Watch (McKenzie), SeagrassNet (Short), the MarineGEO program (Duffy), and the MBON (Muller-Karger) conduct training and outreach activities that will promote the best practices developed by the WG. Finally, development of the handbook and other products will also focus on

feeding information into international targets such as the UN Sustainable Development Goals and Aichi Targets, as well as the post-2020 biodiversity agenda, with leadership by UNEP-WCMC (Weatherdon) and GRID-Arendal (Potouroglou).

7. Working Group Composition

Our Working Group brings together ten Full Members (6 female, 4 male), representing 9 countries, and a range of career stages and disciplinary expertise from seagrass biology to biogeochemistry, remote sensing, fisheries, social science, and global conservation. Several Full and Associate Members are leaders in existing synthesis and coordination efforts in coastal marine and seagrass science. This diversity will help ensure that interdisciplinary products of the working group are effectively communicated to a wide audience and translated into practical applications.

7.1. Full Members

Name	Gender	Place of Work	Expertise
Emmett Duffy (co-chair)	M	Smithsonian Institution, USA	Marine ecology and biodiversity
Lauren Weatherdon (co-chair)	F	UN Environment World Conservation Monitoring Centre, UK	digital knowledge products, ocean biodiversity and spatial data
Rohani Ambo Rappe	F	Universitas Hasanuddin, Indonesia	Seagrass ecology, ecosystem services, seagrass restoration
Leanne Cullen-Unsworth	F	Cardiff University, Wales	Coupled social- ecological systems, seagrass ecosystem services
Miguel Fortes	M	University of the Philippines	Seagrass & mangrove ecology, blue carbon, policy & coastal resilience
Núria Marbà	F	Consejo Superior de Investigaciones Científicas, Spain	Seagrass ecology, global change
Len McKenzie	M	James Cook University, Australia	Seagrass status, management and sustainable use, founder Seagrass-Watch
Maria Potouroglou	F	GRID Arendal, Norway	Seagrass mapping, monitoring and ecosystem services assessment, coastal and marine policy
Fred Short	M	University of New Hampshire, USA	Seagrass ecology and restoration, founder SeagrassNet
Jacqueline Uku	F	Kenya Marine and Fisheries Research Institute	Seagrass physiology, ecology, community development

7.2. Associate Members

Name	Gender	Place of Work	Expertise
Rod Connolly	M	Griffith University, Australia	Seagrass ecosystem resilience, carbon pathways, fisheries food
Maricela de la Torre Castro	F	Stockholm University, Sweden	Social-ecological systems analysis, governance, gender, sustainable resource use, resilience
Heidi Dierssen	F	University of Connecticut, USA	Remote sensing of seagrass extent, leaf area index, carbon
Carlos Duarte	M	King Abdullah University of Science and Technology, Saudi Arabia	Marine ecology and oceanography, expertise in all aspects of seagrass ecology

James W. Fourqurean	M	Florida International University, USA	Ecosystem ecology, biogeochemistry of seagrass systems
Margot Hessing-Lewis	F	Hakai Institute, Canada	Coastal marine ecology, focusing on seagrass systems
Frank Muller-Karger	M	University of South Florida, USA	Biological oceanography, remote sensing, global change
Masahiro Nakaoka	M	Hokkaido University, Japan	Coastal ecosystem dynamics, seagrass ecology
Anchana Prathep	F	Prince of Songkla University, Thailand	Seaweed and seagrass biodiversity and ecology; coastal climate change
Richard Unsworth	M	Swansea University, Wales	Seagrass ecology, conservation, and ecosystem services, co-founder Project Seagrass

8. Working Group contributions

Rohani Ambo Rappe is a seagrass ecologist, studying ecosystem services and seagrass restoration, with expertise in the seagrass systems of the coral triangle region, the most diverse marine systems in the world.

Leanne Cullen-Unsworth is a coupled social-ecological systems analyst focusing on seagrass ecosystem services, in particular seagrass fisheries and associated food security.

Emmett Duffy is a biodiversity scientist who founded the *Zostera* Experimental Network (ZEN) and is the first Director of the Smithsonian's Tennenbaum Marine Observatories Network and MarineGEO program. He is a member of MBON, the GOOS Biology and Ecosystem panel, and is lead development of specification sheet and implementation plan for the GOOS seagrass EOv.

Miguel D. Fortes is a coastal Ecologist, and specialist on Biodiversity, ICZM and Blue Carbon, focusing on seagrasses and mangroves. His works are major additions to seagrass science and policy in the tropics and are having major impacts in applications and in development of coastal resilience in the face of climate change and other environmental uncertainties.

Núria Marbà is a seagrass ecologist focusing on assessing sustainability and integrity of coastal ecosystems and ecosystem services as well as the impact of global change.

Len McKenzie is a seagrass and coastal ecosystems ecologist working to facilitate the protection, conservation, biological diversity, rehabilitation, management and sustainable development of seagrass resources. His research focuses on status and condition of seagrass resources, the role of disturbance, and identifying thresholds of concern and investigating resilience of seagrass ecosystems. Len directs the Seagrass-Watch program, one of the two major global seagrass observing networks.

Maria Potouroglou is a biologist with extensive experience in seagrass ecosystems science and policy in several Regional Seas programmes, including the Eastern Africa, Mediterranean, North-West Pacific, Western Africa and ROPME Sea regions. She leads the scientific strategy of the first ever seagrass project in West Africa, and co-ordinates the UN Environment/GRID-Arendal convened International Seagrass Experts Network.

Fred Short is a seagrass ecologist with expertise in restoration, global seagrass mapping and monitoring, eelgrass stressors including nitrogen loading, physical impacts and climate change. He established the global seagrass monitoring program SeagrassNet and co-edited the seminal book *Global Seagrass Research Methods* (2001).

Jacqueline Uku is a marine ecologist working on seagrass systems in Kenya and recently engaged in community development projects along the Kenyan Coast. She is current President and member of the Western Indian Ocean Marine Science Association (WIOMSA), providing linkage to the member countries of the Western Indian Ocean.

Lauren Weatherdon leads development of digital knowledge products that contribute to a step- change in

global access to, and use of, ocean biodiversity information and spatial data. These products help to support the delivery of global ocean goals and targets, and to support marine spatial planning, conduct environmental impact assessments, produce ecosystem assessments, and enhance ocean literacy; she is also a member of MBON.

9. Relationship to other international programs and SCOR Working groups

This project builds on and synergizes with two initiatives already underway. First, in May 2019, UN Environment/GRID Arendal will convene an International Seagrass Experts Network to produce a report, led by member Potouroglou, highlighting the current state and threats to seagrass systems and their ecosystem services with relevance to policy. Second, in June 2019, Co-chair Duffy will co-lead a NASA-funded workshop to develop implementation plans for the GOOS seagrass and mangrove Essential Ocean Variables (EOVs). These two activities, which involve several of our members, will lay a strong foundation by identifying available data sources, conducting a qualitative review, and articulating a plan for coordinating seagrass research globally. Our proposed SCOR project will advance to the next, quantitative step by picking up where those efforts leave off: assembling, harmonizing, and analyzing the metadata and available data to produce a quantitative picture of global seagrass status, and the rates and drivers of change. A second major product will be an agreement among key seagrass constituencies around the world on terms of coordination, protocol comparability, and data sharing in future research. Together, these activities will facilitate rigorous global analyses of seagrass distribution, change, and responses to environmental and anthropogenic forcing.

The proposed WG has important relevance to several other interdisciplinary global change science efforts, and to the science-policy-society interface and communication initiatives. These other efforts are not specifically focused on seagrasses and would benefit from the research advanced by this SCOR WG on seagrasses. Among these are the following. The OceanObs Research Coordination Network is an NSF-sponsored effort to advance the integration of biological observations into ocean observing systems for societal benefit, co-led by WG member Muller-Karger. We have already submitted a Community White Paper on seagrasses to the OceanObs'19 meeting in Honolulu, Hawaii, September 2019. The Marine Biodiversity Observation Network (MBON, with WG members Muller-Karger and Duffy) is a thematic program under the Group on Earth Observations Biodiversity Observation Network or GEOBON to strengthen understanding of marine biodiversity and coordinate monitoring of associated changes over time by defining marine Essential Biodiversity Variables or EBVs. The Global Ocean Observing System (GOOS) Bio-Eco Panel (WG members Muller-Karger and Duffy) seeks to improve the availability of existing core biological variables and identify and prioritize additional cross-cutting biological and ecosystem observation needs by defining Essential Ocean Variables or EOVs for biology and to integrate these with physical and biogeochemical EOV and observing programs. Several members of the proposed C-GRASS WG are closely involved in each of these efforts and will work to integrate the WG's activities with their goals.

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Appendix 4

Proposal for a Working Group on Roadmap for a Standardised Global Approach to Deep-Sea Biology for the Decade of Ocean Science for Sustainable Development (DeepSeaDecade)

1. Summary

The deep-sea remains one of the least known parts of our planet, yet our basic ecological knowledge of this region is limited because of an historical piecemeal approach to research, and significant spatial bias in the data collected (northern hemisphere, developed nations exclusive economic zones). Fundamental ecological data forms the input parameters to all ecosystem models. Our lack of knowledge of the deep sea means it remains the 'black box' in global model simulations. The road map for the UN Decade of Ocean Science for Sustainable Development (UN DOSSD) recognises the deficit of deep-sea data and the impact of this on sustainable management of the oceans. It calls on the deep-sea science community to address this deficit under the UN DOSSD. The community have responded by identifying the key questions to be answered and the potential role of new technology in addressing those questions. What is now required is an unprecedented level of global coordination to effect a giant leap in understanding by the end of the UN DOSSD. This working group will 1) develop a global survey and sampling modular design, 2) agree methods and standards for the acquisition of biological data, including potential use of novel technologies, 3) build on the global design with habitat-specific approaches, 4) integrate developed plans with other global initiatives and 5) build global capacity for conducting deep-sea research. We will produce a series of multi-author peer reviewed papers that will form the reference point for deep-sea research for the next decade and beyond.

2. Scientific Background and Rationale

The composition and functioning of the deep sea, comprising the largest living space on Earth, is still poorly understood, with a minimal proportion of the deep seafloor sampled and investigated to date (Ramirez-Llodra et al., 2010). To most of society, the deep sea is thought of as a remote, featureless, and inaccessible space. However the combination of particular geological, physical and geochemical attributes of the deep seafloor and water column, create a set of complex habitats with unique characteristics. Each of these habitats supports faunal communities with specific physiological and behavioural adaptations to high pressure, darkness, low temperatures (or steep temperature gradients in the case of hydrothermal vents), food limitation (particularly at abyssal plains) and in some cases geographic isolation (e.g. seamounts, vents, trenches, and seeps). Deep-sea biodiversity at bathyal and abyssal depths is amongst the highest on the planet (Grassle and Maciolek, 1992; Mora et al. 2011), and in poorly sampled regions, such as the abyssal Pacific, up to 90% of species collected may be new to science (Glover et al. 2002). Our limited knowledge of very basic baseline information is the major challenge when addressing issues of biodiversity, ecosystem function, and the potential impacts of - and resilience to - human activities in the deep sea (Mengerink et al. 2014).

The United Nations Decade of Ocean Science for Sustainable Development (DOSSD) is due to commence in 2021, and we are currently in the preparation phase. The stated motivation for the decade is to reverse the cycle of decline in ocean health and create improved conditions for sustainable development of the ocean. The roadmap developed for the DOSSD recognises the deficit of biological data for the deep-sea ecosystem, and specifically calls on the scientific community to use the Decade to conduct research to understand better the deep-sea ecosystem and its functions. Deep-sea scientists have responded to this call by holding a series of international meetings. Firstly to agree to science priorities and knowledge gaps for the DOSSD (1-day meeting, Sept 2018, Monterey, USA, and follow-up meeting October 2018, Aveiro, Portugal), and secondly to explore the potential for new technology to address them (Royal Society funded meeting – Beyond Challenger Nov 2018). We now have community-level agreement on the key research questions in deep-sea science, and have identified new technologies on the horizon that may help us to address these questions.

2.1 The questions

i. What is the diversity of life in the deep ocean?

We lack fundamental ecological data for much of the deep sea. Poor knowledge of what lives there, how it is distributed from global to local 'patch' scales, as well as over environmental gradients, prevents us from establishing a baseline and knowing what is common and what is rare. Critically, fundamental ecological data form the input to **all** biological ecosystem models. Our ability to forecast how marine biodiversity will respond to environmental change and other anthropogenic pressures, depends on good base knowledge such as species distributions, physical and chemical drivers of distribution, abundance, biomass, growth rates, etc. Efforts to model species distributions to fill data gaps are currently severely limited by a lack of fundamental ecological data. Existing models are simplistic, and of questionable accuracy due to limited, and / or poor quality input

data (Davies and Guinotte, 2011; Howell et al., 2016).

ii. How are populations & habitats connected?

At present, we do not know the linkages between habitats and populations, including migration routes, ontogenetic or seasonal movement between habitats, larval dispersal pathways and genetic connectivity, or energy flow pathways in the form of trophic links and food webs. Understanding these linkages, collectively termed connectivity, is critical to effective ocean management and sustainable use. Connectivity promotes healthy and resilient populations; disruptions to the connections, for example through changes in ocean circulation patterns, can impact their persistence and population recovery after disturbance, as well as the effectiveness of Marine Protected Area networks. Understanding population connectivity is also important for our mechanistic understanding of species divergence and ultimately speciation in the ocean, and the role that physical mechanisms play in this (Cowen et al, 2000).

iii. What is the role of living organisms in ecosystem function & service provision?

We are at an early stage in understanding the role of the deep sea in provision of goods and services (for example food provision or nutrient cycling), and detail on mechanisms of delivery are scant. What are the key species/habitats involved in carbon sequestration? Are some groups more important than others? For example, we know sponges may play an important role in global Si cycling (Maldonado et al. 2005), as well as having a key role as a sink for inorganic nitrogen, surpassing that of marine sediments at equivalent depths (Hoffmann et al. 2009). To ensure the ongoing provision of those services, and to understand better marine system processes such as biogeochemical cycling, we need to identify the functional groups present, their role in ecosystem function, and how that function relates to delivery of goods and services. Again, fundamental ecological data are critical to this understanding and to our ability to bring biology into wider ecosystem models.

iv. How do species, communities and ecosystems respond to disturbance?

Understanding how the interactions and synergies play out between climate stressors and direct disturbance is essential to effective management of the deep ocean. This is an understanding that can only be gained through use of modelling approaches, and fundamental ecological data provide the input terms to such models.

2.2 The challenge

Although deep-sea science has a history of successful, international collaborative research programmes, none to date have provided the level of integration and standardisation required in order to deliver answers to the above questions. The Census of Marine Life programme made significant advances in joining-up international efforts around a common goal to understand marine ecosystems, including various deep-sea systems (e.g. seamounts, abyssal plains, continental slopes, etc.). However, the lack of an agreed common survey / sampling design and standardized methodologies among contributing projects meant that datasets could not be combined to address larger questions. Recently, there have been efforts within the deep-sea community to develop frameworks for globally consistent datasets (Woodall et al., 2018). Still, these efforts need to go further in generating a globally coherent underpinning design, and standardised methods. Only then can we hope to make the leaps in knowledge required to effectively manage the deep sea going forward, and deliver the societal outcomes identified by the DOSSD roadmap.

2.3 The need for a SCOR working group

The deep-sea science community has identified the need for a new international programme of research for the UN DOSSD that is global and inclusive. They have also identified the questions that such a programme would address. However, before any further progress can be made there needs to be a concerted effort for dialogue within the community to agree on standards and methods used to address the questions identified, and ensure future research efforts are integrated and inclusive. This requires bringing together a diverse group of researchers including deep-sea habitat specialists (seamount, vent, abyssal plain, continental slope, etc.), macro-ecologists, and process specialists (connectivity, diversity, ecosystem function, etc.). This working group will assemble a team of scientists to work jointly towards delivering an overarching plan that will form the basis of deep-sea biological research for the next decade. It will provide essential data to move towards the targets of the UN Sustainable Development Goals (in particular SD13 on Climate Action and SDG14 on Life Below Water), and it will also help inform the UN World Ocean Assessment II.

3. Terms of Reference

1. To develop a global plan for survey / sampling deep-sea ecosystems to underpin deep-sea research for the UN Decade of Ocean Science.
2. To agree on methods and standards for the acquisition of biological data, including the role of existing and novel technologies.
3. To develop habitat-specific approaches for survey / sampling the deep-sea ecosystem (following the Census of Marine Life model), that integrate the global approaches developed under ToRS 1 and 2, but allow greater specialisation.
4. To integrate ToRs 1-3 with wider efforts under the Global Ocean Observing System (GOOS) via the Deep Ocean Observing Strategy (DOOS).
5. To actively facilitate efforts to build capacity in developing nations for deep-sea science.

4. Working plan

Please see the Gantt chart provided in Appendix 1 for timing of key events associated with the UN Decade of Ocean Science for Sustainable Development, and proposed timings of SCOR working group meetings (both physical and virtual) and deliverables (draft and final). While each physical meeting will have a key focus outlined below, multiple ToRS will be discussed at each to ensure good integration of ideas both within the working group and with other UN DOSSD initiatives. The Challenger Society's Deep Sea Special Interest Group will provide funding to support an initial meeting in September 2019, and a funding application for support will be submitted to the Deep Sea Biology Society.

To address ToR 1 we will develop a coherent well-designed global survey and sampling plan, but one that is modular. The underlying principle will be that each survey / sampling module can be placed within a local, regional and / or habitat-specific context and thus be readily integrated with local, regional, research team interests. However, results from all modules can ultimately be combined to answer global scale questions, and provide 'one giant leap' for human understanding of the ocean. This plan will be developed using two in-person workshops, beginning with the Challenger Deep-Sea Special Interest Group, followed by the first SCOR working group meeting (SCOR-WG workshop 1). A virtual meeting will also be scheduled between the two workshops to develop further our ideas. The rapid timing of this ToR is important in order to interface with the UN Decade of Ocean Science's preparation phase and the finalisation of the Decade implementation plan in mid-2020.

ToR 2 is the next logical progression from ToR 1. Having agreed on a modular framework, combining data in the future will only be possible if methods are standardised. SCOR-WG workshop 2 will focus on standardisation of methods of data acquisition and processing. Building on published outputs from the Census of Marine Life (Clark et al., BLAH), a more recent workshop (Woodall et al., 2018), and a Royal Society (UK) funded meeting in Nov 2018, we will identify those measurements / samples best acquired using novel technology, and those that may be acquired using more traditional, cheaper, or more accessible technologies. Consideration of methods is important in democratising deep-sea research and enabling participation of all nations, many of whom lack access to expensive novel technologies. The outcomes of ToRs 1 and 2 will be written up as an open-access peer reviewed publication that will provide a key reference text for deep-sea science for the next 10 years and beyond, underpinning future research efforts.

ToR 3 will be developed in parallel to ToRs 1,2 and 4. We will look at habitat-specific considerations not covered by the global plan alongside the development of that plan. A sampling / survey design that works globally may not fully consider habitat-specific issues. For example, a global programme may require depth-stratified sampling of seamounts; however, a single series of depth-stratified transects on a seamount will not enable us to address seamount specific questions that may require replication on different sides of seamounts. For this ToR we will hold virtual workshops, following each of the first two SCOR workshops, for habitat-specific working groups chaired by appropriate members of the SCOR-WG to engage the wider deep-sea science community fully in the formulation of sampling plans. These virtual groupings will be advertised via the DOSI, INDEEP, Deep-Sea Biology Society and Challenger Society networks in order to reach a wide audience.

At outset, the SCOR working group will work with DOOS (via overlapping participants) to identify ways the SCOR activities advance the DOOS goals (ToR4) and develop a plan to integrate these into DOOS actions and communications. With DOOS we will focus in particular on the integration of biology with the existing deep ocean physical and biogeochemical measurement programs (e.g. ARGO, deep ARGO, BGC Argo, GoSHIP,

Ocean Sites, Observatories). Specifically, once we have established both global and habitat-specific plans, ToR 4 will review the plans against existing wider community efforts under the Global Ocean Observing System (GOOS) via the DOOS in SCOR-WG workshop 3. We will identify synergies between our plans and DOOS, ensure there is no duplication of effort, and that these different global strategies are integrated. Specifically, we anticipate key collaboration with the DOOS Essential Ocean Variable Biology and Ecosystem panel (which itself is working with the GOOS Biology and Ecosystem panel), the DOOS demonstrations projects, and with the DOSI-INDEEP/DOOS SDG 14 voluntary commitments. Critical links to the existing deep-ocean physical and biogeochemical measurement programs (e.g. ARGO, deep ARGO, BGC Argo, GoSHIP, Ocean Sites, Observatories) can also be achieved through DOOS.

ToR 5 will be partially addressed throughout the development of ToRs 1-4. The proposed working group membership draws scientists from developing nations. In addition, we will seek input from other scientists from developing nations, including early-career scientists through DOSI (in particular the DOSI working group on capacity building), INDEEP, Deep-Sea Biology Society and Challenger Society networks. We intend to consult as widely as possible on the development of deliverables to ensure broad uptake in the future. Our aim is for a truly inclusive working group. We will also hold a specific virtual workshop to develop an action plan to provide sea-going training opportunities for students from developing nations. We anticipate the action plan will consist of a statement of commitment that members of the deep-sea research community can sign-up to; a mechanism through which to advertise opportunities for students; a transparent application, assessment, and selection process; and a requirement for a short post-cruise reflection report. We will ensure engagement with similar initiatives developed under other programmes e.g. POGO.

5. Deliverables

1. An open-access peer-reviewed publication detailing a global plan for survey / sampling the deep-sea ecosystem, including use of standardised methodologies to underpin deep-sea research for the UN Decade of Ocean Science. (ToRs 1 and 2)
2. A series of open-access peer reviewed publications consisting of habitat-specific plans (following the Census of Marine Life model, and similar to German et al., 2011) to advance the global plan developed under ToRs 1 and 2 ensuring no duplication of effort with wider initiatives. (ToRS 3 and 4)
3. A research community-endorsed action plan to provide training opportunities and peer support for students from developing nations in order to broaden the research base and nurture talent (ToR 5).

6. Capacity Building

Deep-sea research, exploration and exploitation has historically been led by a small number of developed nations. This is also reflected in availability of samples, bias in available data (Fig. 6.1), and overall understanding of deep-sea ecosystems, which is currently severely limited. The least-studied parts of the deep sea are often within developing nations' EEZs and / or on the High Seas / the Area, away from the continental slopes. In addition, deep-sea research is currently conducted in a very piecemeal and poorly coordinated fashion. Individual projects tackle aspects of larger questions. The projects are often constrained by available budgets, time, and the logistics of sampling in the deep sea. There are often trade-offs made in experimental design or resolution of data against greater temporal / spatial coverage, or to provide data to satisfy multiple competing aims. While this approach has helped us continue to advance our knowledge of the deep-sea ecosystem, it has failed to make the great leaps needed to manage our ocean more effectively.

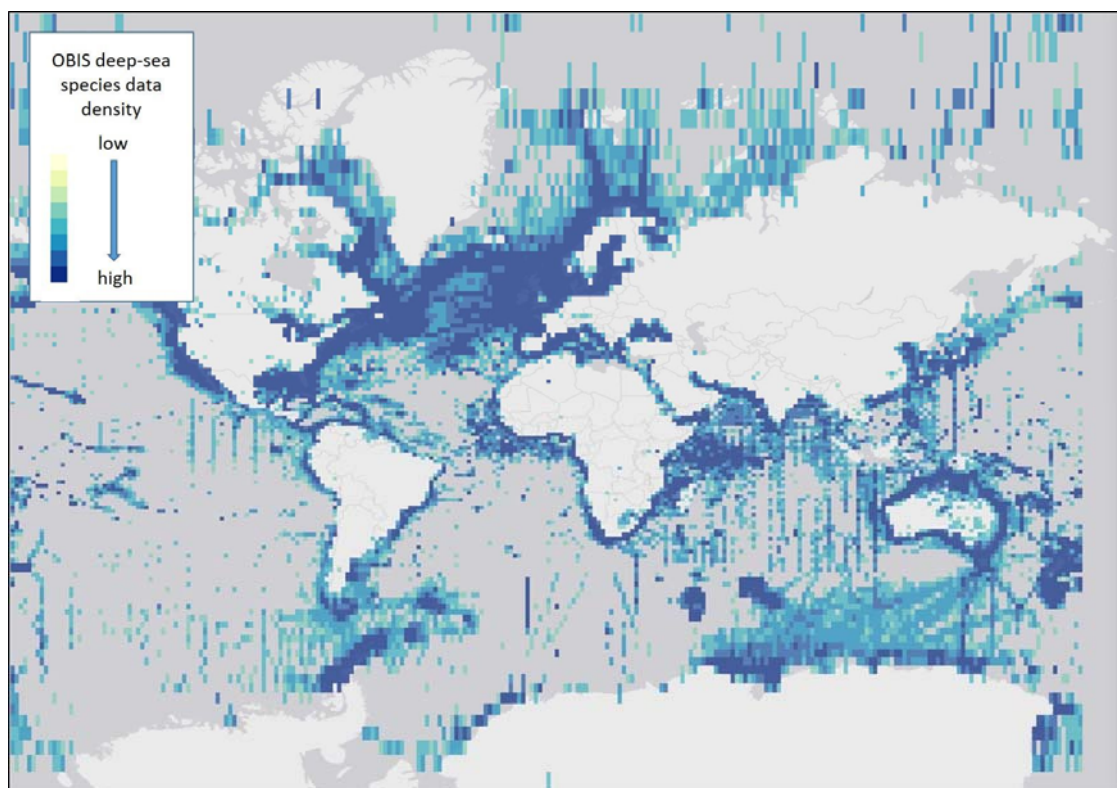


Figure 6.1 Density of deep-sea species records currently held by the Ocean Biogeographic Information System, showing clear bias in sampling effort.

International collaboration is the key to both broadening our knowledge of the deep-sea, and to make deep-sea research more accessible to scientists from all nations. This working group, through developing agreed global habitat-specific plans, will build long-lasting capacity for the research community to tackle the long-held, and unanswered, questions outlined above. The published plans will enable the global deep-sea research community to contribute to answering these long-standing questions through regional and local research programmes, in a targeted or opportunistic fashion. The modular design and standardised methodologies will enable separate programmes to adopt a particular module where it fits in with, or contributes to their project-specific research aims. Scientists working at regional scales will generate data for their own programmes, but also for the global research effort. Over the next decade, this globally coherent dataset will grow, and by the end of the decade, we will finally be able to answer the questions posed with confidence.

This working group will also significantly advance efforts to build capacity for deep-sea research in the next generation of scientists, and in developing nations. ToR 5 will specifically address the lack of opportunity for students and researchers from nations lacking in deep-sea science infrastructure to gain experience in sea-going deep-sea research. The development of an action plan to support students, early-career scientists, and researchers from developing nations to gain access to research vessel opportunities will help broaden and diversify the deep-sea research community. It will also help fulfil the aspirations of the Decade of Ocean Science. The Decade Roadmap clearly states that the Implementation Plan, to be developed by 2020, will include a plan for capacity development, training and education (R&D priority 7).

7. Working Group composition

7.1 Full Members

Name	Gender	Place of work	Expertise relevant to the proposal
Kerry Howell (co- chair)	Female	Plymouth University, UK	Deep-sea ecologist, ecological modeller, use of AI, links to DOSI, INDEEP, Challenger Society. Seamount & canyon ecology.
Elva Escobar	Female	Universidad Nacional Autónoma de Mexico, Mexico.	Biological oceanography, biodiversity, macroecology. Link to UN DOSSD executive planning group. Abyssal ecology. Regional capacity needs.
Alex Rogers	Male	REV Ocean, Norway	Marine molecular ecology, biodiversity. Links to UN and philanthropic funded programmes. Seamount Ecology
Malcom Clark	Male	National Institute for Water and Atmospheric Research, New Zealand	Deep-sea fish, fisheries. CoML lead, link to ISA. Seamounts, oceanic ridges.
Ana Hilario (co-chair)	Female	University of Aviero, Portugal	Reproductive ecology, connectivity and biogeography of deep-sea ecosystems. Vent ecology.
Paul Snelgrove	Male	Memorial University of Newfoundland, Canada.	Deep-sea benthos, biodiversity drivers and roles in sediments, links to UN BBNJ process.
Lisa Levin	Female	Scripps Institution of Oceanography, USA.	Deep-sea benthos and climate change, links to DOOS, DOSI, and IPCC
Christopher German	Male	Woods Hole Oceanographic Institution, USA	Deep-sea exploration, including innovative use of robotic vehicles and telepresence.
Kerry Sink	Female	South African National Biodiversity Institute, South Africa.	Deep-water ecology, South Atlantic, SW Indian Ocean, regional capacity needs
Roberto Danovaro	Male	Stazione Zoologica Anton Dohrn, Naples & Polytechnic University of Marche, Italy.	Deep-Sea benthos, biodiversity loss, ecosystem functions, climate change.

7.2 Associate Members

Name	Gender	Place of work	Expertise relevant to the proposal
Bhavani Narayanaswamy	Female	Scottish Association for Marine Science, UK	Deep-sea ecologist, biodiversity, effects of biological/anthropogenic inputs, continental margins, seamounts NE Atlantic, SW Indian and Arctic Oceans
Paulo Sumida	Male	University of São Paulo, Brazil.	Deep-sea ecology. South Atlantic regional capacity needs
Anna Metaxas	Female	Dalhousie University, Canada.	Biological oceanography, evolutionary ecology.
Lenaick Menot	Male	Ifremer, France.	Deep-sea ecologist. Vents, Abyss.
Nick Higgs	Male	Cape Eleuthera Institute, Bahamas.	Deep-sea biodiversity, marine observatories, whale fall. Caribbean regional capacity needs.

Eva Ramirez-Llodra	Female	Norwegian Institute for Water Research, Norway.	Deep-sea ecologist, biodiversity, connectivity. Links with DOSI, INDEEP, IUCN-CEM, Deep-sea ecosystems and mining.
Hiromi Watanabe	Female	Japan Agency for Marine- Earth Science and Technology, Japan	Deep-sea benthos, larval dispersal, population connectivity, hydrothermal vents.
Awantha Dissanayake	Male	University of New South Wales, Sydney, Australia	Ecological physiology, Experimental Biology, Climate Change.
Craig McClain	Male	Louisiana Universities Marine Consortium, USA.	Macroecology, macroevolution, biodiversity, body size, energy flow.
Javier Sellanes	Male	Catholic University of the North, Chile.	Deep-sea benthos ecology and taxonomy. SE Pacific, regional capacity needs

8. Working Group contributions

Kerry Howell (co-chair) is a deep-sea ecologist and modeller, co-proposer of the SCOR working group, co-chair of the DOSI DOSSD working group, and chair of the Challenger Deep-Sea Special Interest Group. She brings expertise in rugged terrain deep-sea habitats (seamounts, canyons, continental slopes) and various types of ecological modelling including food web, connectivity and habitat suitability modelling.

Elva Escobar contributes with knowledge in biological oceanography studying the marine biodiversity and macroecology of the seabed ecosystems in the Mexican EEZ. She is co-lead of DOSI, and a member of the IOC's Executive Planning Group for the UN DOSSD. She will ensure the working group's activities are communicated to the IOC and UN.

Alex Rogers brings expertise in biodiversity of marine ecosystems, including environmental drivers, interspecies interactions, connectivity, longer term-evolutionary processes and human impacts. He has undertaken numerous UN projects and is currently science director for REV Ocean. He will communicate the working group's plans to REV Ocean and looks for areas of shared interest.

Malcom Clark brings expertise in deep-water fish and fisheries, deep-sea ecosystems including seamount and oceanic ridges, and sampling techniques. He headed the Census of Marine Life on Seamounts, and currently sits on the Legal and Technical Commission of the International Seabed Authority.

Ana Hilario (co-chair) is a deep-sea ecologist and co-chair of the DOSI DOSSD working group and INDEEP Population Connectivity working group. She contributes with expertise on reproductive ecology, larval dispersal, population connectivity and its implications for biogeography and spatial management; as well as experience on capacity building activities in developing countries.

Paul Snelgrove brings expertise on biodiversity and ecosystem functioning in deep-sea ecosystems, and particularly seafloor environments. He has been actively involved in discussions on Biodiversity Beyond National Jurisdiction.

Lisa Levin contributes expertise on continental margin benthic ecosystems, their ecosystem services, exposure and response to climate change, and to other forms of human disturbance in the deep ocean. Through her involvement in IPCC (AR5, AR6 and Special Report on Oceans and Cryosphere), DOOS and DOSI she will identify for SCOR the major deep-ocean ecological function and service information that can contribute to ongoing climate assessment and create direct SCOR linkages to DOOS and DOSI planning and activities.

Christopher German contributes expertise in Deep Ocean exploration and, in particular, the innovative use of advances technologies to conduct that work including autonomous underwater vehicles, collaborative robotic systems and telepresence. He has experience in national and international project leadership including as Co-Chair of InterRidge, the Census of Marine Life ChEss Project, SCOR WG135 and NASA's new Network for Ocean Worlds.

Kerry Sink contributes expertise in marine ecosystem classification and assessment for the Southwest Indian, Southeast Atlantic and Southern Ocean. Kerry will provide developing country context, identify regional capacity needs and help align efforts across projects and programs.

Roberto Danovaro is a deep-sea biologist and ecologist, specialist in the assessment of the interactions between biodiversity loss and impairment of ecosystem functions and on evaluation of the impact of climate change on deep-sea habitats and ecosystems.

9. Relationship to other international programs and SCOR Working groups

There are a number of current SCOR WGs focused on standardization of methods and developing global approaches to studying marine systems (WG147 & WG143). Some current WGs are considering biology specifically (WG149), including the role of novel technologies in global efforts (WG156 & WG 157) and integrations with global programmes (WG154). While these current WGs have aspects in common with our proposed WG, none are considering the wider biological component of marine systems or the deep sea. This demonstrates the opportunity offered by our proposal.

Perhaps the most comparable SCOR WGs are historical. SCOR WG 76, approved in 1983, was focused on the ecology of the deep sea floor. As with our proposal, this WG recognized the great technical and statistical difficulties of obtaining adequate information on the deep-sea benthic ecosystem.

They proposed a critical review of the then state-of-the-art, clearly identifying what would be desirable, but at the time impracticable to do. Our proposed WG is a natural progression from where this WG concluded 36 years ago. We understand information needs, how new technology may help gather that information, and have recognised that an international programme of collaborative research is required.

SCOR WG5, the International Indian Ocean Expedition, had a single ToR: to plan and organize international co-operative exploration of the Indian Ocean. This resulted in a large-scale multinational hydrographic survey of the Indian Ocean, which took place from 1959 to 1965. It involved over 45 research vessels from 14 countries. Our proposed WG has a series of ToRs that are analogous to the single ToR of SCOR WG5. Our aim is to produce a road map for international co- operative biological research on the global ocean under the Decade of Ocean Science.

Our proposed WG has very clear links to the UN DOSSD that have been identified throughout, as well as the GOOS and DOOS initiatives. Our proposed membership includes a representative of the IOC's DOSSD Executive Planning Group, and a Co-Chair of the DOOS initiative. Their participation will ensure good communication and integration with these international programmes. The DOSSD roadmap outlines six critical societal outcomes (SO), and a further seven priority areas for research and development (R&D), which the Decade seeks to address by 2030 (Fig. 9.1). The questions that the deep-sea science community have identified (section 2.1) have direct relevance to the DOSSD SOs and R&D priority areas. Deliverables 1 and 2 of our proposed working group will specifically identify how the scientific plans developed will also address the decades SOs and R&D priorities (Table 9.1, Fig. 9.1). In addition, deliverable 3 will directly contribute to R&D priority area 7 (Fig. 9.1).

Table 9.1 How the questions identified by the deep-sea science community contribute to societal outcomes and research and development priority areas identified by the DOSSD road map.

Questions	Societal Outcomes (SO) of the Decade of Ocean Science for Sustainable Development						Research & Development (R&D) Priority Areas						
	1	2	3	4	5	6	1	2	3	4	5	6	7
i													
ii													
iii													
iv													

The six Societal Outcomes (SO) of the Decade of Ocean Science for Sustainable Development

1. A clean Ocean whereby sources of pollution are identified, quantified and reduced, and pollutants removed from the Ocean
2. A healthy and resilient Ocean whereby marine ecosystems are mapped and protected, multiple impacts (including climate change) are measured and reduced, and provision of ocean ecosystem services is maintained
3. A predicted Ocean whereby society has the capacity to understand current and future ocean conditions, forecast their change and impact on human wellbeing and livelihoods
4. A safe Ocean whereby human communities are protected from ocean hazards and where safety of operations at sea and on the coast is ensured
5. A sustainably harvested and productive Ocean ensuring the provision of food supply and alternative livelihoods
6. A transparent and accessible Ocean whereby all nations, stakeholders and citizens have access to Ocean data and information, technologies, and have the capacities to inform their decisions.

The seven Research & Development (R&D) Priority Areas

1. Comprehensive map (digital atlas) of the oceans
2. A comprehensive ocean observing system
3. A quantitative understanding of ocean ecosystems and their functioning as the basis for their management and adaptation
4. Data and information portal
5. Ocean dimension in an integrated multihazard warning system
6. Ocean in earth-system observation, research and prediction, with engagement of social and human sciences and economic valuation
7. Capacity building and accelerated technology transfer, training and education, ocean literacy.

From the Revised Roadmap for the UN Decade of Ocean Science for Sustainable Development

Figure 9.1 Societal outcomes and research and development priority areas identified in the Decade of Ocean Science for Sustainable Development roadmap.

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Appendix

Gantt chart: Timing of key points in the road map for the UN Decade of Ocean Science for Sustainable Development (light blue), and proposed timings for SCOR working group meetings (SCOR funded – black, externally funded – dark blue), virtual meetings (dark grey), ToRs (light grey), and deliverables (draft – light green, final – dark green).

Action	May-19	Sep-19	Nov-19	Dec-19/20	Mar-20	May-20	Jun-20	Aug-20	Sep-20	Nov-20	Dec-20/21	Mar-21	May-21	Jun-21	Aug-21	Sep-21	Nov-21	Dec-21/22	Mar-22	May-22	Jun-22	Aug-22
Decade global meeting #1																						
Second Executive Planning Group meeting																						
Decade global meeting #2																						
Endorsement of Decade plan by IOC																						
Official start of Decade																						
SCOR working group meetings																						
TOR 1: global plan for survey / sampling deep-sea ecosystems																						
TOR 2: agree methods and standards																						
TOR 3: develop habitat-specific approaches																						
TOR 4: integrate with wider marine observation																						
TOR 5: capacity building																						
Deliverable 1: Publication of global plan for decade of ocean science																						
Deliverable 2: Publication of habitat specific plan for decade of ocean science																						
Deliverable 3: Community-endorsed action plan for capacity building																						
SCOR-WG close																						

Full member selected relevant publications

Kerry Howell (co-chair)

- Piechaud, N., Culverhouse, P.F., Hunt, C., **Howell, K.L.** in press. Automated Identification of benthic epifauna from images using computer vision. Marine Ecology Progress Series.
- Woodall LC, Andradi-Brown, DA, Brierley AS, Clark MR, Connelly D, Hall RA, **Howell KL**, Huvenne VAI, Linse K, Ross RE, Snelgrove, P, Stefanoudis, PV, Sutton, TT, Taylor, M, Thornton, TF, Rogers AD. 2018 A Multidisciplinary Approach for Generating Globally Consistent Data on Mesophotic, Deep-Pelagic, and Bathyal Biological Communities. *Oceanography*. 31, 76-89.
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Appendix 5 Integrated Marine Biosphere Research (IMBeR) Project



Annual Report to SCOR 2018 - 2019

A. Introduction

The Integrated Marine Biosphere Research project (IMBeR) is a global environmental change research initiative co-sponsored by the Scientific Committee on Oceanic Research (SCOR) and Future Earth.

In 2016 IMBeR produced a science and implementation strategy for the next decade, underpinned by the vision, *“Ocean sustainability under global change for the benefit of society”*.

This vision recognises that the evolution of marine ecosystems (including biogeochemical cycles and human systems) is linked to natural and anthropogenic drivers and stressors, as articulated in the new IMBeR research goal to *“Understand, quantify and compare historic and present structure and functioning of linked ocean and human systems to predict and project changes including developing scenarios and options for securing or transitioning towards ocean sustainability”*.

To implement its vision and goal, IMBeR’s mission is to *“Promote integrated marine research and enable capabilities for developing and implementing ocean sustainability options within and across the natural and social sciences, and communicate relevant information and knowledge needed by society to secure sustainable, productive and healthy oceans”*.

IMBeR science aims to foster collaborative, interdisciplinary and integrated research that addresses important ocean and social science issues and provides the understanding needed to propose innovative societal responses to changing marine systems. The implementation of the IMBeR Science Plan is underpinned by the International Project Office (IPO) in Bergen, Norway sponsored by the Institute of Marine Research (IMR) and the Norwegian Research Council, and the Regional Project Office (RPO) in Shanghai, China supported by the State Key Laboratory of Estuarine and Coastal Research (SKLEC) at the East China Normal University (ECNU). The IMBeR research goal is progressed through the activities of regional programmes, working groups and endorsed projects, and is facilitated through focussed workshops (IMBIZOs), conferences and symposia, and the training of early career researchers at biennial Climate-Ecosystem (ClimEco) summer schools. [Further details at <http://www.imber.info>.]

B. IMBeR Science Plan and Implementation Strategy (2016-2025)

<http://www.imber.info/resources/images/prosjekter/imber/IMBeR-Science-Plan-and-Implementation-Strategy-2017.pdf>

The Science Plan and Implementation Strategy (SPIS 2016-2025) is developed around three Grand Challenges (GC) focussing on climate variability, global change and drivers and stressors. The qualitative and quantitative understanding of historic and present ocean variability and change (Grand Challenge I) are the bases for scenarios, projections and predictions of the future (Grand Challenge II). These are linked in Grand Challenge III to understand how humans are causing the variability and changes, and how they in turn are impacted by these changes, including feedbacks between the human and ocean systems. Priority research areas with overarching and specific research questions are identified for each Grand Challenge. The Grand Challenges are supplemented with four Innovation Challenges (IC) that focus on new and emerging topics. Specific members of the scientific steering committee are designated as “Challenge Champions” to oversee progress towards the

objectives of the Grand Challenges made by the Regional Programmes, Working Groups, Endorsed Projects, and IMBeR meetings and other activities (Figure 1).

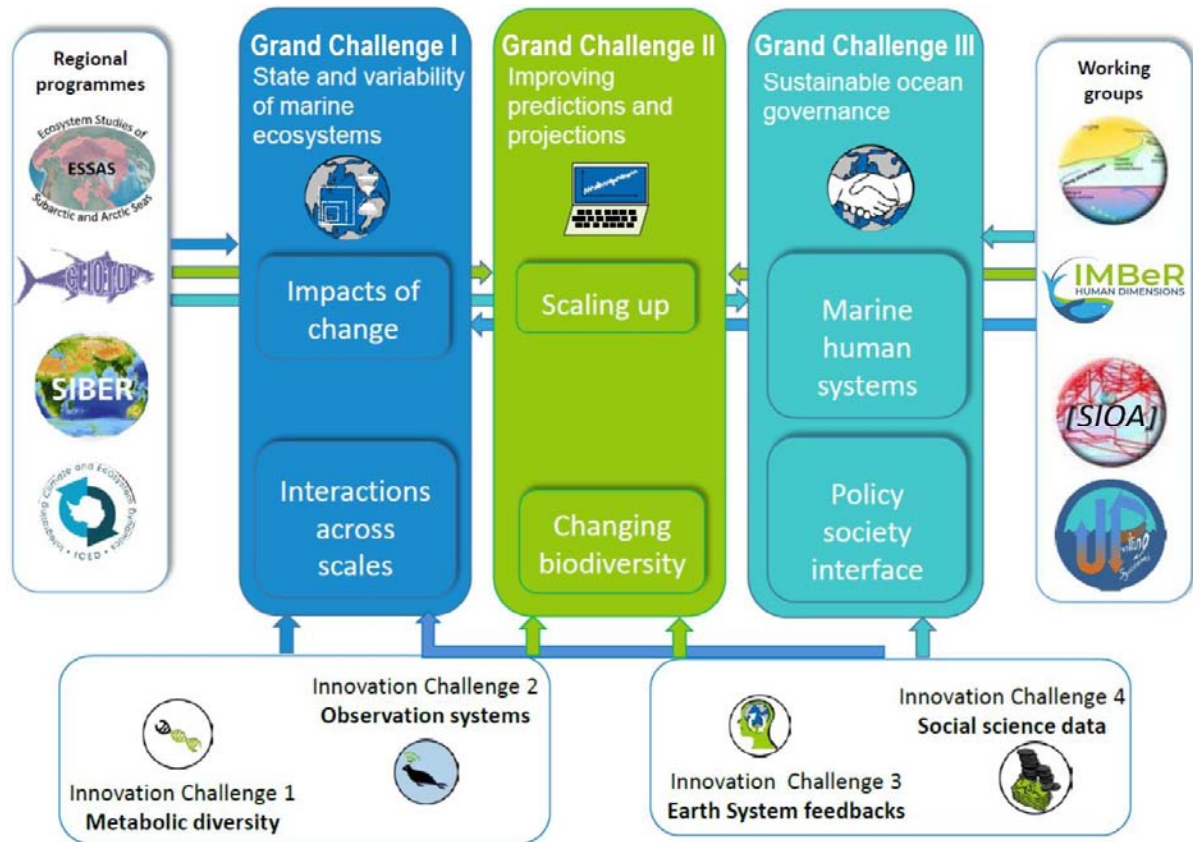
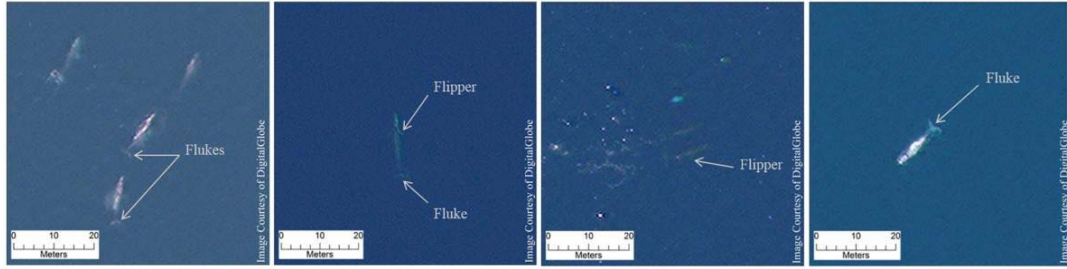


Figure 1. Contribution of the Regional Programmes, Working Groups and Innovation Challenges to the objectives of the Grand Challenges

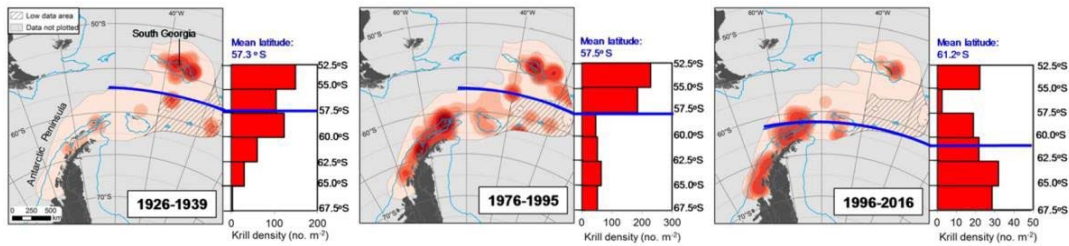
C. Selected science highlights in 2018-2019

A list of publications is given in Section K, and activities which have specifically progressed the objectives of the Science Plan are given in Section G. Here we identify a selection of studies and activities where IMBeR has contributed to the progression of fundamental knowledge in marine interdisciplinary science [For details of the figures presented, please refer to the original publication referenced]

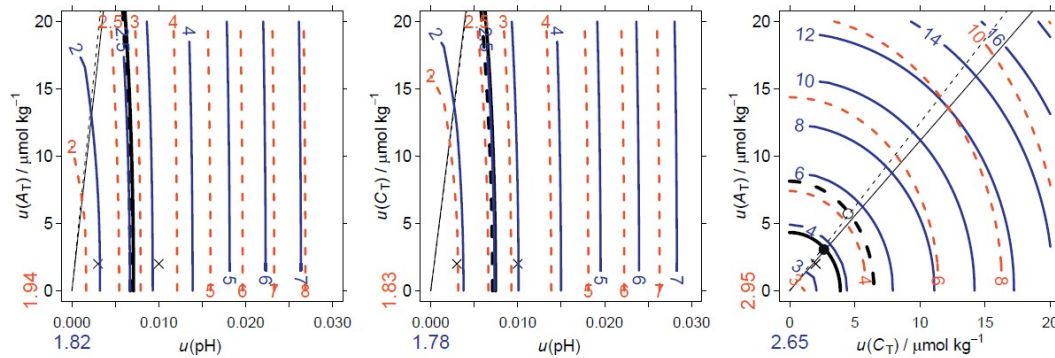
1. **Cubaynes et al (2019)** [British Antarctic Survey / ICED (IMBeR regional programme ICED – Integrating Climate and Ecosystem Dynamics)] demonstrated that advances in the resolution of satellite imagery now allow baleen whales to be identified definitively from satellite imagery. They used imagery from the WorldView-3 satellite to manually identify and count four different mysticete species: fin whales (*Balaenoptera physalus*) in the Ligurian Sea, humpback whales (*Megaptera novaeangliae*) off Hawaii, southern right whales (*Eubalaena australis*) off Península Valdés, and gray whales (*Eschrichtius robustus*) in Laguna San Ignacio. The study demonstrated that high resolution satellite imagery can be used to monitor great whales.



2. **Atkinson et al (2019)** (IMBeR regional programme ICED – Integrating Climate and Ecosystem Dynamics) have observed major shifts in the distribution of krill: over the last 90 years, **krill (*Euphausia superba*) have moved and contracted southwards in response to warming seas**. Along with changing their geographic distribution, there have also been major changes in the size of krill, their densities, and the levels of recruitment. As a keystone species in the Antarctic, these changes have major implications for the species that feed on krill, and therefore food web structure and biogeochemical cycling. These findings are invaluable for the management of both the globally important fisheries of the Antarctic and its iconic biodiversity.

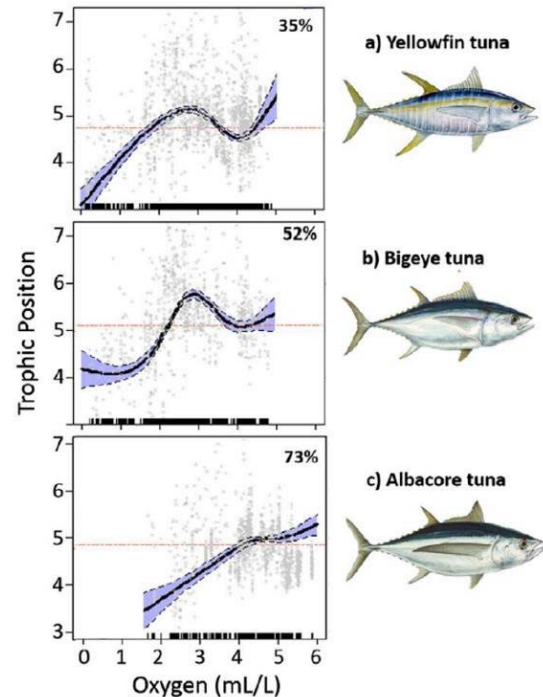


3. **Orr et al (2018)** (SOLAS-IMBeR Ocean Acidification Working Group - SIOA) developed **new tools for estimating uncertainties for calculated ocean acidification variables**. Previously, such uncertainties were seldom reported. These authors created software to propagate uncertainties and provided it as add-ons to four commonly used public packages that compute marine carbonate chemistry [CO2SYS- Excel (Visual Basic), CO2SYS-MATLAB (MATLAB), seacarb (R), and mocsy (Fortran)]. These tools along with a new type of diagram to visualise the uncertainties should allow propagating uncertainties to become standard practice for calculations of marine CO₂ system variables.

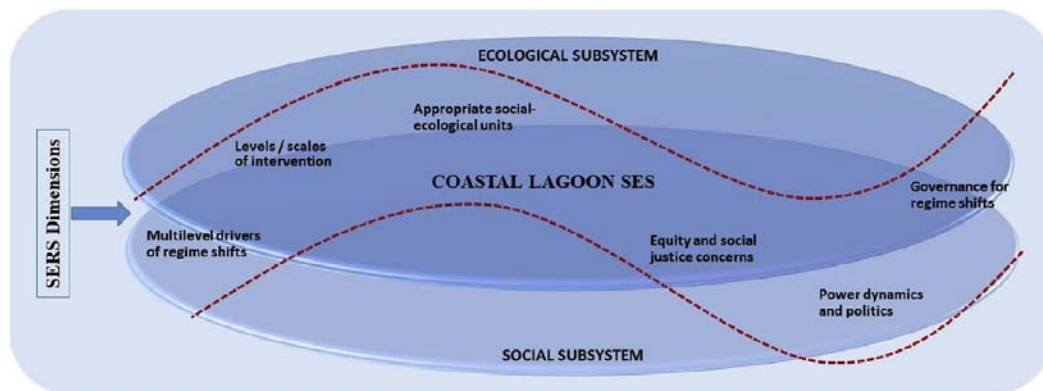


4. In one of the first global studies of its kind, using stable isotopes **Pethybridge et al (2018)** identified previously unknown **effects of warming oceans on marine top predators and their food webs**.

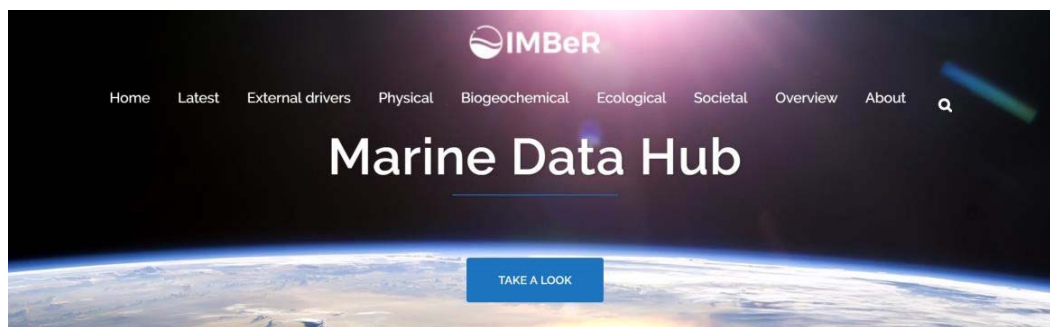
Through the network created by CLIOTOP (Climate Impacts on Oceanic Top Predators, IMBeR Regional Programme), they were able to collate samples of three species of tuna collected over a 16- year period by multiple research programmes. They found that the oxygen minimum zones – areas starved of oxygen – have a large effect on the food chain, and in the foraging behaviour of top predators, and that patterns were consistent across different regions. Because deoxygenation is a direct effect of climate change, these low oxygen zones are predicted to expand. The findings have broad implications and improve our ability to model the effects of climate change on ocean ecosystems.



5. Marine social-ecological systems are dynamic and involve many different groups of people, all with different understandings of the system, different priorities, and different visions about the future. While they all share a need to anticipate future changes, especially in the context of accelerated global change, it is difficult to combine these different actors effectively in the same process. To address this, and using the Barents Sea as a case study, **Planque et al (2019)** developed a widely applicable ‘**participatory scenario method**’ where actors develop scenarios jointly and can effectively explore the future of marine social-ecological systems.
6. In global change science, the term ‘regime shift’ is typically restricted in its use to refer to the dramatic changes in a system from one ecological state to another. However, **Nayak and Armitage (2018)** have shown that this concept needs to be broadened to include social processes. Thus, considering ‘**social-ecological regime shifts**’ helps to identify suitable management interventions and approaches to governance. The study is a further example of the growing importance of interdisciplinary research to address global change.



7. The IMBeR regional programme SIBER (Sustained Indian Ocean Biogeochemistry and Ecosystem Research) led the development of the first **Special Issue on the Second International Indian Ocean Expedition (IIOE-2)** for publication in **Deep-Sea Research II – The 2nd International Indian Ocean Expedition (IIOE-2): Motivating New Exploration in a Poorly Understood Basin, Volume 1**. This is the first compendium of scientific papers to emerge from IIOE-2 and three of the editors are/were SIBER SSC members. A second volume is in preparation and is scheduled to be published later in 2019, with contributions from SIBER SSC members.
8. The IMBeR **Marine Data Hub** was launched (<https://ccdatahub.ipsl.fr/>). The Marine Data Hub is a product arising from the IMBeR IMBIZO 5 *Critical Constraints on Future Projections of Marine Systems* workshop. The hub links ecological, physical, biogeochemical and societal data sets for global models. It raises awareness of high quality data products, and encourages exchange.

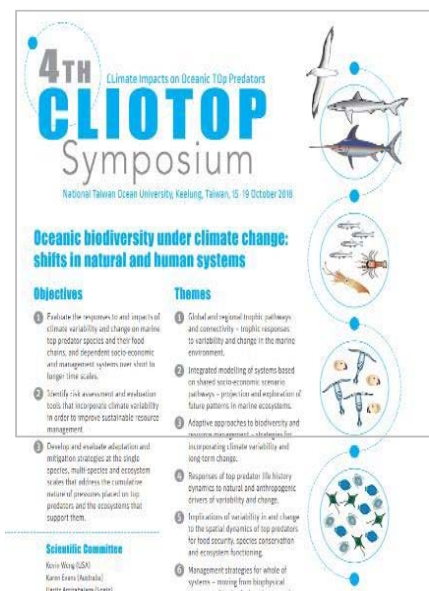


9. **Future Oceans2** – the 2nd IMBeR Open Science Conference (OSC) – was held in Brest, France, 17-21 June 2019. The meeting was attended by 553 delegates, with 27 Sessions and 10 Workshops, 549 Oral Presentations, 194 Posters, and an Early Career Researcher Day during which IMECaN (the IMBeR Interdisciplinary Marine Early Career Network) was launched.



10. The **Fourth CLIOTOP Symposium – Oceanic biodiversity under climate change: shifts in natural and human systems** – was successfully held in Keelung, Taiwan, 15-19 October 2018. This was attended by most CLIOTOP SSC members and the IMBeR International Project Office staff and drew good attendance, particularly from across Asia, a regional area where CLIOTOP has been working on expanding its network of collaborators. The conference was especially well attended by early career researchers and students.

11. **ClimEco6** (IMBeR Summer School) was held at the Gadjah Mada University in Yogyakarta, Indonesia, 1-8 August 2018. The theme of the summer school was “**Interdisciplinary approaches for sustainable oceans**” and participants were provided with practical ways to deal with the challenges arising from working across social and natural science disciplines. There were 59 participants from 19 countries.



12. Regional Programmes

Brief descriptions of the Regional Programmes and their major activities over the last year are presented below. Further details on their activities can be found in Section G. *Implementation of the IMBeR Science Plan*.

Ecosystem Studies of Subarctic and Arctic Seas (ESSAS)

<https://essas.arc.hokudai.ac.jp/>

ESSAS objectives are to understand how climate variability and climate change affect the marine ecosystems of Subarctic and Arctic seas and their sustainability, and in turn, how changes in the marine ecosystems affect humans (<https://essas.arc.hokudai.ac.jp/>).

The Resilience and Adaptive Capacity of Marine Ecosystems in the Arctic (RACArctic) is an ESSAS initiative between Japan, the USA and Norway and is funded by the Belmont Forum. RACArctic held its 3rd stakeholder meeting in Tromsø, Norway, 19 March 2019.

ESSAS was very involved in the IMBeR *Future Oceans2* OSC (17-21 June 2019): ESSAS convened the Session ‘Arctic marine ecosystems in a changing climate’ (28 oral presentations and 15 posters) to better understand recent variability and changes in the Arctic. ESSAS workshops: (1) The Bioenergetics working group (WG) organised a workshop on ‘Bioenergetics and survival trajectories of Arctic fish in response to environmental stressors’, and (2) the AnalogueART WG (Natural Analogues of an Arctic in Rapid Transition) convened a workshop on ‘Using natural analogues to investigate the effects of climate change and ocean acidification on northern ecosystems’.

Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED)

www.iced.ac.uk/index.htm

The ICED regional programme aims to better understand climate interactions in the Southern Ocean, the implications for ecosystem dynamics, the impacts on biogeochemical cycles, and the development of sustainable management procedures. ICED is co-sponsored by SCAR (Scientific Committee on Antarctic Research).

ICED scientists in the USA (including Eileen Hofmann and Walker Smith) convened a Town Hall meeting at the fall AGU meeting in Washington, DC, USA in December 2018 with the aim of leveraging funding for a multidisciplinary, multinational effort in the Ross Sea to study the entire food web (end-to-end analyses), as well as a winter study involving novel technologies, and a study to investigate the initiation of the spring phytoplankton bloom. National Science Foundation and international representatives were present. An additional meeting was held in early 2019 in order to facilitate additional community input to address these critical scientific issues at circumpolar scales.

ICED contributed to the IMBeR *Future Oceans2* OSC, convening the session ‘Managing the effects of change on Southern Ocean ecosystems: Understanding, challenges, and solutions’. This was linked to ‘Southern Ocean ecosystems: a workshop on the Marine Ecosystem Assessment for the region (MEASO)’. The aim of the session was to reflect on the past decade of ICED science and apply insights to improve research on understanding and projecting changes in Southern Ocean ecosystems so that it is relevant to conservation and management decisions. The session focussed on: (i) Southern Ocean species and ecosystems; (ii) Modelling and projections of ecological change; (iii) Policy implications and decision-making (with a focus on integrated understanding of natural and human systems interactions). The workshop explored and discussed (i) the merits of different methods for assessing the status and trends of ecosystems, (ii) the respective utilities of the results for making management decisions on mitigating or adapting to prognoses of change, and (iii) how best to communicate the results to end-users. The workshop was attended by natural and social scientists.

CLimate Impacts on Oceanic TOP Predators (CLIOTOP)

<http://imber.info/science/regional-programmes/cliotop>

The CLIOTOP regional programme organises large-scale comparative studies to elucidate key processes involved in the interaction between climate variability and change and human use of the ocean on the structure of pelagic ecosystems and large marine species.

The very successful Fourth CLIOTOP Symposium was held in Keelung, Taiwan, 15-19 October 2018.

Karen Evans, co-chair of CLIOTOP, was nominated to the Executive Planning Group for the UN Decade of Ocean Science for Sustainable Development. In this role, Evans provides a direct link between IMBeR and planning for the Decade.

Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER)

<https://incois.gov.in/portal/siber/index.jsp>

The SIBER regional programme is co-sponsored by the Indian Ocean GOOS (IOGOOS) Programme with close ties to CLIVAR’s Indian Ocean Panel (IOP). It focuses on understanding climate change and anthropogenic forcing on biogeochemical cycles and ecosystems in the Indian Ocean, to predict the impacts of climate change, eutrophication and harvesting. The 2nd International Indian Ocean Expedition (IIOE-2) was motivated by SCOR, SIBER, IOGOOS and IOP and has become the main scientific focus of SIBER.

There have been multiple Indian Ocean research activities motivated by or directly associated with SIBER. Notable among these are activities of the *Eastern Indian Ocean Upwelling Research Initiative* (EIOURI), and the activities associated with the new SOLSTICE-WIO programme which most recently included the *Agulhas Bank Ecosystem Study* cruise with the South African RV *Ellen Khuzwayo* (March 2019), and the May-June 2019 cruise with Australia’s new RV *Investigator* (May/June 2019). The track repeats that of a cruise that was part of the original IIOE, almost 60 years ago. Other significant SIBER-associated research has been conducted through the *African Coelacanth Ecosystem Programme* (ACEP, with a cruise in May 2019).

SIBER convened a session at *Future Oceans2* ‘The Second International Indian Ocean Expedition (IIOE-2): Motivating New Exploration in a Poorly Understood Basin’. The session brought together observationalists and modellers to exchange information and understanding on the current ‘state-of-knowledge’, gaps, challenges, and future directions in observing and modelling the complex physical, biogeochemical and ecological processes in the Indian Ocean in the context of anthropogenic influences and climate change.

13. Working Groups

Brief descriptions of the Working Groups are presented below. Further details on their activities can be found in Section G. *Implementation of the IMBeR Science Plan*.

IMBeR-Future Earth Coasts Continental Margins Working Group (CMWG)

<http://www.imber.info/en/projects/imber/science/working-groups-1/cmwg>

The CMWG aims to compare a sparsely-populated northern Arctic shelf region with a shelf in a heavily-populated Southeast Asian region. The CMWG is a collaboration between IMBeR and Future Earth Coasts. The CMWG convened a session at *Future Oceans2* titled ‘Ecosystem-social interactions in marginal seas’. The session aimed to improve understanding of marginal social-ecological systems, guiding sustainable development of resources and advising governance regimes to facilitate sustainable governance, facilitating equitable sharing of margin resources, and evaluating alternative research approaches and partnerships that address major margin challenges.

Human Dimensions Working Group (HDWG) <http://www.imber.info/en/projects/imber/science/working-groups-1/human-dimensions-working-group-hdwg>

The HDWG has continued to develop systems understanding of the human dimensions of marine resource use and interactions with global oceans. In particular, work by members of the group is pivotal to guiding and informing IMBeR Grand Challenges II and III. Achieving sustainable ocean governance is a rapidly developing field of research potentially heightened by a global focus on blue growth/economy.

At the IMBeR *Future Oceans2*, the HDWG convened a workshop and three sessions. The workshop ‘Visioning Global Ocean Futures’ explored how the *Nature Futures Framework* of IPBES resonates for the Oceans, contributing to iterative cycles of visioning, stakeholder co-creation, and modelling at global, regional and local scales that are supported by the IPBES Scenarios and Models Expert Group. The sessions – (i) ‘Modelling social-ecological systems: methods and tools for scenario development and prediction’, (ii) ‘Designing the quilt of sustainable ocean governance’, and (iii) ‘But why won’t they use my science? Improving the impact of marine science on policy; advances in theory and practice’ – explored and promoted the integration of human dimensions and governance into IMBeR-related science.

IMBeR-CLIVAR Eastern Boundary Upwelling Systems Working Group (EBUS)

<http://www.imber.info/en/projects/imber/science/working-groups-1/eastern-boundary-upwelling-systems-ebus>

EBUS focuses on the potential effects of climate change on the intensity, seasonality and geography of upwelling systems and their ecological and socio-economical consequences. The WG promotes the understanding of biogeochemical, biological, fish and fisheries processes and trends on the four major coastal upwelling regions, i.e. California, Humboldt, Canary and Benguela, and their socio-economical impacts. In 2017 EBUS submitted a successful proposal to SCOR to form a SCOR working group co- chaired by IMBeR SSC member Ruben Escribano.

The EBUS SCOR WG met on 9 December 2018 in Washington DC. The group discussed issues relevant to modelling predictions and projections in EBUS and decided on the following actions: (1) Explore the opportunity to collaborate with the US CLIVAR Working Group “Changing Width of the Tropical Belt”, (2) Form a task team specifically focussed on this cross-shore wind stress comparison, (3) Planning for a summer school will continue via conference calls in winter and spring, and (4) Review and register comments on the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC; specifically the box on upwelling systems). R Escribano provides the link between this WG and IMBeR.

Integrated Ocean Carbon Research IOC-R

Collaboration between SOLAS, IMBeR, the Intergovernmental Oceanographic Commission - International Ocean Carbon Coordination Project (IOC-IOCCP), Global Carbon Project, World Climate Research Programme (WCRP) and CLIVAR

Following the disbandment of the SOLAS-IMBeR Carbon Working Group in 2017 (with the exception of SIOA), it was recognised that there was an important void to fill by the ocean carbon community. In July 2018, the IOC Secretariat agreed to the establishment of the Integrated Ocean Carbon Research working group (IOC-R). IOC-R is still in an early stage of development. The scientific committee includes IMBeR members Laurent Bopp, Niki Gruber and Carol Robinson and the first meeting will be held in October 2019.

SOLAS-IMBeR Ocean Acidification (SIOA)

<https://www.iaea.org/ocean-acidification>

The SOLAS-IMBeR Ocean Acidification Working Group continues to make advances, through the Ocean Acidification International Coordination Centre (OA-ICC), to its core activities of setting up a Global Observing Network, organising joint experiments and intercomparison exercises, providing advice on best practises and contributing to capacity building and outreach.

Selected highlights can be found in the quarterly releases from the OA-ICC available on their web page (above).

14. Endorsed projects

Atlantic Meridional Transect (AMT)

<https://www.amt-uk.org/>

AMT is a multidisciplinary programme which undertakes biological, chemical and physical oceanographic research during an annual voyage between the UK and destinations in the South Atlantic. The AMT provides a platform for scientists to capture and analyse data related to a range of oceanographic science areas. Over 256 scientists have participated in AMT cruises and many more have worked with the data which is accessible through the British Oceanographic Data Centre (BODC). Over 300 scientific papers have been published, and the long-term nature of the data (>20 years) continues to be useful in analysing trends and forecasting future outcomes.

Gulf of Trieste Time series (GoTTs)

http://nettuno.ogs.trieste.it/ilter/GoTTs/en_index.html

The Department of Biological Oceanography of the Italian National Institute of Oceanography and Experimental Geophysics is responsible for the Gulf of Trieste site as part of the Long Term Ecological Research network in the North Adriatic. The research activities, which have continued since 1970, range from marine biogeochemistry to ecology and are aimed at understanding the dynamics governing marine ecosystems and to evaluate the role of the oceans in the global energy balance.

Ocean acidification and Biogeochemistry: variability, trends and vulnerability (VOCAB)

<http://www.imber.info/en/projects/imber/science/endorsed-projects/vocab>

This project aims to address some of the gaps in our current knowledge of the vulnerability of selected marine ecosystems in Irish waters to ocean acidification (OA), by exploring some of the complex biogeochemical processes occurring at fine scales, and by studying the larger scale biogeochemistry of ocean waters impinging on those ecosystems. Fine scale sampling focuses on three areas, one of direct commercial interest (shellfish aquaculture) and two of wider importance (kelp beds and deep water coral ecosystems). NUI Galway and the Marine Institute led the GO-SHIP A02 survey in 2017 and the report has now been completed. Since then, several new systems have been installed on the RV *Celtic Voyager* that have enabled the collection of a variety of surface water and atmospheric samples. Surveys and fieldwork are continuing.

Processes and Approaches of Coastal Ecosystem Carbon Sequestration (PACECS)

<http://www.imber.info/en/projects/imber/science/endorsed-projects/pacecs>

The aim of PACECS is to investigate the key processes and mechanisms of carbon sequestration in coastal ecosystems in order to propose ways in which to increase the ocean carbon sink. Most of this 'Blue Carbon Sink' resides in the biomass of phytoplankton, bacteria, archaea, and protozoa, and so maximising the efficiency of this sink requires fundamental knowledge of the dynamics of marine microbes.

The Study of Kuroshio Ecosystem Dynamics for Sustainable Fisheries (SKED)

<http://snf.fra.affrc.go.jp/html/english/index.html>

This interdisciplinary study aims to investigate the paradox of high fisheries production in the low nutrient Kuroshio western boundary Current of the North Pacific Ocean, in order to ensure sustainable use of this ecosystem.

Mechanisms of Marine Carbon Storage and Coupled Carbon, Nitrogen and Sulphur cycles in response to global change (MCS-CNS) <http://www.imber.info/en/projects/imber/science/endorsed-projects/mcs-cns>

The sensitivity of marine biogeochemical cycles to climate change remains unclear, especially for key processes which influence the long-term health of marine ecosystems. By understanding the interactions between the microbial carbon pump and the biological carbon pump, this project aims to decipher the mechanisms of marine carbon storage, and the response of biogeochemical processes to climate change and anthropogenic activities.

Marine Ecosystem Modelling and Forecasting System in the China Seas and Northwestern Pacific (MEMFiS)

<http://imber.info/en/science/endorsed-projects/memfis>

Focusing on the ecology of the Bohai, Yellow, East and South China Seas, and the Northwestern Pacific, the MEMFiS project aims to develop an integrated modelling and forecasting framework, using high-resolution physical-ecosystem models and data from multiple sources. By investigating ecosystem variability at different temporal and spatial scales, several key scientific questions are being tackled. Marine ecosystem variability is addressed at the interface of different systems, parameterizations optimised for biogeochemical processes in different regions, data assimilation and ecosystem forecasting using multiple observations, not only from moorings, buoys and ships, but also from bio-Argo, gliders and high-resolution satellite imagery.

Integrated Arctic Observation System (INTAROS)

<http://www.intaros.eu/>

INTAROS is developing an integrated Arctic Observation System (iAOS) by extending, improving and unifying existing systems in the different regions of the Arctic. An integrated Arctic Observation System will enable better-informed decisions and better-documented processes within key sectors (e.g. local communities, shipping, tourism, fishing), to strengthen the societal and economic role of the Arctic region.

15. Implementation of the IMBeR Science Plan

The IMBeR regional programmes and working groups are working towards the research goal outlined in the SPIS (2016-2025). Progress towards achieving the objectives of the SPIS Challenges during the 2018-2019 period is outlined below:

Grand Challenge I: Understanding and quantifying the state and variability of marine ecosystems

The Challenge: To develop whole system level understanding of ecosystems, including complex biogeochemical cycles and human interactions, together with understanding of the scales of spatial and temporal variability of their structure and functioning.

SIBER - Grand Challenge I

SIBER was instrumental in fostering the development of both the 2nd International Indian Ocean Expedition (IIOE-2) and the Eastern Indian Ocean Upwelling Research Initiative (EIOURI), both of which are dedicated to understanding and quantifying the state and variability of marine ecosystems and also, importantly, the physical forcing that drives this variability. The IIOE-2 has become a major international research programme in the Indian Ocean with an active international steering committee and joint programme offices (located in Hyderabad, India and Perth, Australia). National IIOE-2 committees have also been established in India, Australia, Germany, France, South Africa, UK and USA. Current and former SIBER Scientific Steering Committee (SSC) members have been instrumental in establishing IIOE-2 National Committees in all of these countries. Most recently, SIBER SSC members Mike Roberts and Jenny Hugget launched the UK/South African SOLSTICE-WIO project (<https://www.solstice-wio.org/>). Francis Marsac initiated a French research programme in the Western Indian Ocean - an important new component of IIOE-2.

ICED - Grand Challenge I

ICED has continued to develop whole ecosystem level understanding of the structure and functioning of Southern Ocean ecosystems, their variability and response to change across a range of spatial and temporal scales. ICED conducted detailed work on key species from phytoplankton to higher predators (e.g. Costa et al. 2019; Cubaynes et al. 2018; Kaufman et al. 2018; Saunders et al. 2018; Thorpe et al. 2019; Young et al. 2018; Xavier et al. 2018), and the structure of food webs (e.g. Dimitrijević et al. 2018; Krüger et al. 2018; Sequeira et al. 2018). Work also continued on physical, chemical and biological interactions (e.g. Belcher et al. 2019; Manno et al., 2018; Peck et al. 2018) and the effects of past (e.g. Tarling et al. 2018) and recent variability and change, such as ocean acidification (e.g. Atkinson et al. 2018; Freer et al. 2018; Klein et al. 2018; Kruger et al. 2018b; Trathan et al. 2018). Work in these areas is pivotal to guiding and informing ICED's work under GC II and GC III.

ESSAS - Grand Challenge I

Understanding variability in high-latitude marine ecosystems in response to climate variability and change is a central goal of ESSAS. A major initiative by ESSAS to further this goal was the Resilience and Adaptive Capacity of Arctic marine ecosystems (RACArctic) project. The project is nearing its end and a 3rd stakeholder meeting was held in Tromsø, Norway, 19 March 2019 (following two earlier stakeholder meetings in Hakodate, Japan, and Juneau, Alaska, USA). Meeting participants included industry representatives and scientists. This project aims to synthesise expected effects of climate change on high-latitude marine ecosystems, including their consequences for fisheries and fisheries management.

A number of national programmes endorsed by ESSAS monitor marine ecosystems and conduct research in both the Pacific Arctic and Atlantic Arctic, in particular the northern Bering Sea / Chukchi Sea (Japan, USA, Korea), the Barents Sea / Fram Strait (Norway, Russia), the waters around Iceland, and the Northwest Atlantic (Canada, Greenland).

To foster a better understanding of high-latitude changes within the IMBeR community, ESSAS organised a scientific session on '*Arctic marine ecosystems in a changing climate*' (28 oral presentations and 15 posters) at the IMBeR Open Science Conference (OSC) to better understand recent variability and changes in the Arctic.

CLIOTOP - Grand Challenge I

CLIOTOP Task Team 2016-04 participated in the FAO led Fish Forum. This forum had the objective of "*Bringing together the wider community of scientists and experts working on fisheries and the marine environment in the Mediterranean and Black Sea in order to build a lasting network, discuss advancements in research, integrate scientific knowledge in support of decision-making and identify research priorities for the coming decade*". The task team participated in a workshop on operational fisheries oceanography where it was agreed that such a network should focus on 5 specific goals or challenges:

- a. Better identification and understanding of the environmental drivers affecting key species and ecological processes
- b. Adequate parameterisation of the environmental drivers identified (by definition of appropriate indicators)
- c. Development of best practices for integrating indicators into current assessment models
- d. Fostering capacity building
- e. Identifying successful case studies and promoting new ones

Task Team 2016-06 continued developing movement models for inferring behaviour- environment relationships in top predators, with a first case study of southern elephant seals.

A major focus has been the development of a model using Template Model Builder for the first time. This model is detailed in a publication in *Ecology* (Jonsen et al. 2018). The task team has also been developing movement models for the vertical dimension that enables inference at the scale of individual dives, as well as longer-term inference over many dives, at the scale of days and weeks. *In situ* and modelled oceanographic covariates are associated with seal dives to understand the relationship between environmental features and behavioural switches that manifest at biologically relevant time scales. An R package *foieGras* has also been developed by the team and has been published on CRAN (<https://cran.r-project.org/web/packages/foieGras/vignettes/foiegras-basics.html>). This focuses on Argos location filtering, a necessary step prior to analysis and simulation of movement behaviour in an environmental context.

Task Team 2017-01 attended a workshop on community-level metrics, mercury isotopes, and data-model linkages and has been wrapping up a number of publications that have either been published (Álvarez-Berastegui et al. 2018, Dhurmeea et al. 2018, Houssard et al. 2019, Pethybridge et al. 2018, and Regelo et al. 2018), are currently in review or in the final stages of preparation. These have focussed on improving understanding of the trophic pathways that underlie the production of tunas and other pelagic predators in the open ocean, the movements of these predators, and the natural variability forced by the environment.

Grand Challenge II: Improving scenarios, predictions and projections of future ocean-human systems at multiple scales.

The Challenge: To incorporate understanding of the drivers and consequences of global change on marine ecosystems and human societies at multiple scales into models to project and predict future states.

ESSAS - Grand Challenge II

As part of the RACArctic project (see above), ESSAS has focused on developing plausible scenarios for anticipated changes in high-latitude marine ecosystems, and in particular the consequences for fish populations and fisheries, based on a review of available literature, including qualitative predictions and available projections. Three manuscripts are in preparation, as well as an information sheet for stakeholders. ESSAS focuses on comparative analyses among Arctic marine ecosystems and works to initiate and facilitate such comparisons by bringing scientists from around the circumpolar North together at workshops and scientific sessions such as the IMBeR OSC.

ICED - Grand Challenge II

ICED has continued model development in support of creating a suite of models of physical dynamics (ocean circulation and climate), biogeochemical cycles, and biological dynamics (life histories, population dynamics, food web structure) within a hierarchical framework of models of different spatial, temporal and trophic resolution. The ultimate aim of these activities is to advance end-to-end ecosystem modelling approaches that integrate physical, chemical and biological processes and generate projections of Southern Ocean ecosystems. Recent work in this area includes Freer et al. 2018; Klein et al. 2018; Kruger et al. 2018b; and Murphy et al. 2018 -CCAMLR).

ICED has used its understanding of the drivers and impacts of climate change (under GC I in the Southern Ocean to further work on developing scenarios of key drivers and projections of ecological change. For example, an ICED Projections workshop was held in April 2018, in collaboration with the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), to further the scenarios and projections work (Murphy et al. 2018).

CLIOTOP - Grand Challenge II

CLIOTOP Task Team 2016-06 has been working on movement models for humpback whale populations and extracting and compiling CMIP5 output into environmental fields suitable for such models. Current models being tested relate movement to sea ice, ocean temperature and phytoplankton and carbon for the last decade of the historical run using the NorESM1-ME earth system model (selected as it performs well in representing the seasonal sea ice cycle) and setting up a simulation framework using the equivalent fields for the last decade (2091-2100) of the RCP8.5 run.

Grand Challenge III: Improving and achieving sustainable ocean governance

The Challenge: To improve communication and understanding between IMBeR science, policy and society to achieve better governance, adaptation to and mitigation of global change, and transition towards ocean sustainability.

SIBER - Grand Challenge III

The SIBER activities that are most relevant to this IMBeR Challenge are related to IIOE- 2 and the governance structure that has been created to guide it. The IIOE-2 is overseen by an international steering committee that has developed full operational details to guide the Expedition. This steering committee is chaired by high-level representatives from the Indian Ocean GOOS (IOGOOS) program, the Scientific Committee for Oceanic Research (SCOR) and UNESCO's Intergovernmental Oceanographic Commission (IOC). A key aspiration of this committee is to leave a lasting legacy throughout the Indian Ocean region, as did the original IIOE. This is being accomplished by establishing the basis for improved scientific knowledge transfer to wider segments of society and regional governments, and through the creation of educational and capacity development opportunities that target regional and early career scientists. These efforts all contribute directly to IMBeR's goal of improving and achieving sustainable ocean governance. As previously stated, SIBER has been instrumental in establishing IIOE-2 and its governance structure. Further, the Sustainable Oceans, Livelihoods and food Security Through Increased Capacity in Ecosystem research in the Western Indian Ocean (SOLSTICE- WIO) program (co-led by SIBER SCC member Mike Roberts), is focused on fisheries and food security in the western Indian Ocean, and combines environmental and socio- economic research with state-of-the art techniques and knowledge transfer, to develop policies for sustainable and resilient fisheries.

ICED - Grand Challenge III

ICED continues to work with the Antarctic Treaty Commission via the Scientific Committee for Antarctic Research (SCAR, within which ICED is a 'Co-Sponsored Programme'), and with a number of Antarctic Treaty agreements including the Committee for Environmental Protection (CEP) and the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). ICED also continues to work with other international environmental treaties and organisations, conservation groups, and international committees, including the International Whaling Committee.

Antarctic Treaty System: ICED provides input to the Antarctic Treaty System via SCAR and builds on collaborations with a number of treaty agreements, particularly the CEP and CCAMLR. The Antarctic Treaty System recognises the role that ICED can play in providing external and valuable input on climate change impacts on Southern Ocean ecosystems to their work, that otherwise would not be available.

SCAR: SCAR is tasked with providing scientific advice to the Antarctic Treaty via reports and representation at the annual Antarctic Treaty Consultative Meetings (ATCMs). ICED contributes to SCAR's annual scientific reports. This includes highlighting ICED science under GC's I, II and those that specifically address GC III. ICED provided input for SCAR's Annual Report to the Scientific Committee of CCAMLR (SC CCAMLR), summarising the 2018 work relating to fishery management and policy.

CEP: ICED scientists engage with CEP by providing information on climate change impacts on ecosystems to the Antarctic Treaty, e.g. ICED works with the CEP on their Climate Change Response Work Programme.

CCAMLR: ICED continues its work with CCAMLR to ensure that ICED science is relevant to CCAMLR and that scientific results are translated appropriately into messages that resonate with policy makers.

- A working group paper on the preliminary results of the ICED-CCAMLR Projections workshop (June 2018, Cambridge, UK) was submitted (Murphy et al. 2018a), followed by a background paper detailing the full results of the workshop, including recommendations to CCAMLR (Murphy et al. 2018b).
- ICED scientists attended the CCAMLR Workshop on Spatial Management in June 2018, Cambridge, UK (WS-SM-18). The potential for ICED and CCAMLR to work together on spatial management issues was noted. This includes, but is not limited to, joint ICED-CCAMLR activities on projections of change, together with ICED research focussed on understanding the structure and functioning of Southern Ocean ecosystems and their variability and response to change across a range of spatial and temporal scales. Currently, this has particular relevance to the future research and monitoring plan for the "Domain 1" MPA proposal for the Antarctic Peninsula region. ICED will continue to develop activities to support the work of CCAMLR and ensure this links with

CCAMLR's ongoing work on spatial management.

- A number of publications have been submitted by ICED scientists to CCAMLR in support of fisheries management and development of future MPA's.

Conservation Groups: ICED scientists continue to lead a science-policy initiative based in Cambridge, UK that relates to this objective (see IC 4 for details) and science-policy fora as part of the MEASO2018 Conference (see IC 4).

Other international organisations:

IPCC: ICED scientist, Jess Melbourne-Thomas (AAD and ACE CRC, Australia) was selected as lead author of the Polar Regions chapter of the IPCC Special Report on the *Ocean and Cryosphere in a Changing Climate*. This Report will build on the work of the IPCC's Fifth Assessment Report (AR5). It is scheduled to be finalised in September 2019. Other ICED scientists (including Dan Costa, ICED SSC) have been involved as contributing authors to the *Changing Ocean, Marine Ecosystems, and Dependent Communities* chapter.

IPBES: ICED scientists have expressed concern over the exclusion of the Southern Ocean in its remit both directly to IPBES and through the external reviewer process of the IPBES global assessment of biodiversity.

CLIOTOP - Grand Challenge III

Members of Task Team 2016-04 are now contributing to the European Union-funded PANDORA project. This project aims to:

1. Create more realistic assessments and projections of changes in fisheries resources by utilising new biological knowledge including, for the first time, proprietary data sampled by pelagic fishers.
2. Advice on how to secure long-term sustainability of EU fish stocks and elucidate trade-offs between profitability and number of jobs in their fisheries fleets. Provide recommendations on how to stabilise the long-term profitability of European fisheries.
3. Develop a public, internet-based resource tool box, including assessment modelling and stock projections code, economic models, and region- and species-specific decision support tools; increase ownership and contribution opportunities of the industry to the fish stock assessment process through involvement in data sampling and training in data collection, processing and ecosystem-based fisheries management.

CLIOTOP Co-chair Karen Evans, as well as being a member of the Group of Experts coordinating the second World Ocean Assessment is leading the writing of a chapter in the assessment on cumulative impacts and is contributing to chapters relating to management approaches. These chapters will provide an overview of current processes for the assessment of cumulative impacts and varying management approaches, including an assessment of pros and cons. She is also leading the writing of a manuscript for the special issue associated with OceanObs'19 discussing how the world ocean assessment provides links between ocean observations and policy across multiple scales.

Innovation Challenge 1 – To enhance understanding of the role of metabolic diversity and evolution in marine biogeochemical cycling and ocean ecosystem processes.

A recent publication in Trends in Ecology and Evolution by Baltar et al. (2019) entitled '*Towards Integrating Evolution, Metabolism, and Climate Change Studies of Marine Ecosystems*' is a product from the working group from '*Workshop 2: Metabolic diversity and evolution in marine biogeochemical cycling and ocean ecosystem processes*' of the IMBeR IMBIZO 5 meeting, Woods Hole Oceanographic Institution, October 2017.

Innovation Challenge 2 – To contribute to the development of a global ecosystem observational and modelling network that provides essential ocean variables (EOVs) and to improve marine data and information management.

SIBER – Innovation Challenge 2

This IMBeR Challenge represents one of the central goals of SIBER. SIBER emerged as a result of the potential opportunity to leverage the CLIVAR/GOOS Indian Ocean mooring array (RAMA/IndOOS) and associated measurements and cruises for doing biogeochemical and ecological research. SIBER provides the biogeochemical and ecosystem research focus and counterpart for IndOOS and the IORP. This opportunity is being realised through the deployment of biogeochemical sensors on the RAMA mooring array and the deployment of bio-Argo floats in the northern and southwestern Indian Ocean. An Australia/India 4-year BioArgo collaboration (Nick Hardmann-Mountford [CSIRO], and former SIBER SSC members Wajih Naqvi [NIO] and Ravichandran [INCOIS]) was launched in 2014 and recently completed, generating a large amount of unprecedented and valuable data; <http://biogeochemical-argo.org/key-areas-projects-io-bio-argo.php>. Plans are being developed for the deployment of many more biogeochemical sensors in the Indian Ocean as part of IIOE-2 and the second phase of IndOOS. These efforts are all focussed on measuring biogeochemical EOVs that contribute to the development of a global ecosystem observational and modelling network.

ICED – Innovation Challenge 2

The ICED community has made strong links with relevant SCAR groups, the SCAR- SCOR Southern Ocean Observing System (SOOS) and the CCAMLR Ecosystem Monitoring Program to progress integrated ecosystem observing. These, together with ICED's Marine Ecosystem Assessment of the Southern Ocean (MEASO) will (i) support assessments of current status and trends of Southern Ocean ecosystems and (ii) provide foundation data for assessing the likelihood of future states of the system. ICED scientists involved in SOOS have been involved in progressing its development of 5 regional working groups: West Antarctic Peninsula and Scotia Arc, the Weddell Sea and Dronning Maud Land, Southern Ocean Indian Sector, Ross Sea, and the Bellingshausen- Amundsen Sea working groups. It has also established a task team on ecosystem Essential Ocean Variables in support of the Marine Ecosystem Assessment for the Southern Ocean. These groups are directly aligned with activities in ICED and will contribute to sustained observations to support ICED modelling efforts. Also, there is consideration of circumpolar ecosystem field research activities that will support future activities of ICED in understanding key processes, such as in the sea ice zone. A further activity that will have synergies with ICED modelling activities is the Capability Working Group on designing the observing system.

ESSAS – Innovation Challenge 2

Many of the ESSAS-endorsed national projects provide observations of EOVs in high- latitude marine ecosystems. For example, the Arctic Marine Biological Observation Network (AMBON), an ESSAS endorsed project, is developing a long-term observing programme in the Chukchi Sea to monitor EOVs and biodiversity at all trophic levels, from microbes to whales. Several Japanese programmes routinely contribute to sampling standard transect lines in the northern Bering Sea and Chukchi Sea that together form the 'Distributed Biological Observatory'.

Former ESSAS co-chair and SSC member S.-I. Saitoh and current co-chair F. Mueter were involved in the development of an 'Integrated Ecosystem Assessments (IEA)' for the Central Arctic Ocean. F. Mueter is working with the PAME Ecosystem Approach to Management group to develop an IEA for the Chukchi Sea. Co-chair B. Planque is involved in IEAs for the Norwegian and Barents Seas.

ESSAS organised a workshop in 2018 on Integrated Ecosystem Assessments for the Subarctic and Arctic that helped inform the development of plans for a new Chukchi Sea IEA.

CLIOTOP – Innovation Challenge 2

Task Team 2016-04 participated in the 2018 conference of the Mediterranean Operational Network for the Global Ocean Observing System (MONGOOS) to further the development of the MONGOOS science and strategy plan. The plan can be accessed at [http://www.mongoos.eu/documents/11176/135008/MonGOOS+Science+and+Strategy+Plan+Document+\(Lower+Resolution\)](http://www.mongoos.eu/documents/11176/135008/MonGOOS+Science+and+Strategy+Plan+Document+(Lower+Resolution)).

Collaboration with GOOS – Innovation Challenge 2

IMBeR SSC members are involved in drafting the specification for an emerging GOOS EOv on microbial biomass and diversity.

Innovation Challenge 3 – To advance understanding of ecological feedbacks in the Earth System.

ICED – Innovation Challenge 3

An evaluation of regional ocean acidification from observations and CMIP5 models, species and functional group responses to OA and other stressors, ecological change and a review of marine biogeochemical feedbacks resulting from plankton community stoichiometry changes to ocean acidification and climate change has been undertaken as part of the SCAR Ocean Acidification review and led by ICED SSC member Richard Bellerby. In his IMBeR SSC role, Eugene Murphy, with Laurent Bopp, developed a session at *Future Oceans2* on ecological feedbacks.

Innovation Challenge 4 – To advance and improve the use of social science data for ocean management, decision making and policy development

SIBER – Innovation Challenge 4

An example of emerging SIBER-driven projects that address this IMBeR challenge is the SOLSTICE-WIO project (co-led by SIBER SCC member Mike Roberts). It involves case studies of threatened, emerging and collapsed fisheries, in Tanzania, Kenya and South Africa, respectively, including socio-economic as well as environmental research through to outreach and briefs to stakeholders and policy makers (<https://www.solstice-wio.org/>).

ESSAS – Innovation Challenge 4

Alan Haynie (NOAA, USA), chair of the ESSAS working group on Human Dimensions, is active at national and international levels to develop better approaches to using economic data for supporting decision making in fishery management.

ICED – Innovation Challenge 4

ICED scientists have been developing studies to expand analyses of ecosystems to consider human social and economic system interactions. Following a workshop convened by ICED scientists Eugene Murphy, Stuart Corney and Jess Melbourne-Thomas at IMBIZO IV, (which emphasised that ecological models are now sufficiently advanced that they are useful for decision-making) ICED continues to develop activities aimed at integrating human dimensions into marine ecosystem models. Eugene Murphy presented a talk on this topic at the MEASO2018 meeting held in Hobart, Australia in April 2018, considering how modelling can be developed to help robust decision making. ICED scientists have also been working on understanding stakeholder perspectives on ecosystem-based management of the Antarctic krill fishery. This has been well received within CCAMLR and discussions of follow-up work in this area are underway. Work has also continued on ecosystem services in the Southern Ocean. The use of social science data in decision-making is an area ICED is keen to develop with other relevant groups (e.g. IWC and Centre for Science and Policy, University of Cambridge, CSaP) and two workshops, held in Cambridge were led by ICED scientists Rachel Cavanagh and Susie Grant. The second of these was “Ocean Plastics: Challenges and Solutions” (Cambridge, Mar 2018). These form part of a series on Science-Policy Challenges in Polar Conservation and Management in collaboration with the Cambridge Conservation Initiative (a collaboration between the University of Cambridge and 9 leading international biodiversity conservation organisations).

16. Other IMBeR activities

Future Oceans2

<http://imber.info/en/events/osc/2019>

The 2nd IMBeR Open Science Conference – *Future Oceans2* – was held in Brest, France, 17-21 June 2019 (workshops held 15-16 June 2019)

553 Attendees • 27 Sessions • 10 Workshops • 549 Oral Presentations • 194 Posters • Early Career Researcher Day

4th CLIOTOP Symposium

<http://imber.info/events/imber-working-groups-program-events/4th-cliotop-symposium> The 4th CLIOTOP Symposium was held at the National Taiwan Ocean University, Keelung, Taiwan, 15-19 October 2019
>100 Attendees • 6 Sessions • 40 Oral Presentations • 15 Posters

Interdisciplinary Marine Early Career Network (IMECaN) <http://www.imber.info/science/imecan--interdisciplinary-marine-early-career-network> IMECaN was officially launched at *Future Oceans2* on 16 June 2019. Stephanie Brodie will take over as Chair of IMECaN from Chris Cvitanovic on 1 January 2020.

IMECaN Early Career Researcher Day

<http://imber.info/en/events/osc/2019/early-career-day>

IMECaN held an Early Career Day (16 June 2019) prior to *Future Oceans2*. The workshop focused on career development paths for marine researchers, and using infographics in research outputs. Attended by >200 Early Career Researchers and students.

ClimEco6 Summer School

<http://www.imber.info/en/events/climeco-imber-summer-schools/interdisciplinary-approaches-for-sustainable-oceans>

ClimEco6 was held at the Gadjadara University in Yogyakarta, Indonesia, 1-8 August 2018. The theme of the summer school was “Interdisciplinary approaches for sustainable oceans” and participants were provided with practical ways to deal with the challenges arising from working across social and natural science disciplines.

About 60 participants attended.

8th IMBeR China / Japan / Korea Symposium

<http://imber.info/en/events/china-japan-korea-imber-symposia/cik8>

The 8th IMBeR China / Japan / Korea Symposium was held at the East China Normal University, Shanghai, China, 17-19 September 2018

>100 Attendees • 3 Sessions • 1 Workshop • 47 Oral Presentations • 35 Posters

The next symposium in the series will be the first *IMBeR West Pacific Symposium* and will be held in Thailand in August 2020.

Inaugural Continental Margins Working Group Workshop

The inaugural Continental Margins Working Group workshop was hosted by the State Key Laboratory for Estuarine and Coastal Research (SKLEC), East China Normal University (ECNU), Shanghai, China, 20-21 September 2018.

I. IMBeR Project Offices

International Project Office (IPO, Norway)

The current IPO hosting arrangement with the Institute of Marine Research, Bergen, Norway, will come to an end in April 2020. The IPO is in the process of finalising its move to a new host institution and is in discussions with a consortium of institutions from Halifax, Canada, and with SKLEC, East China Normal University, Shanghai, China to grow the IMBeR Regional Project Office into an IPO. The possibility of having two IPOs is being discussed, with the current Bergen IPO Director and Deputy Director moving to Halifax.

Regional Project Office (RPO, China)

Xiaona Wang was recruited as Project Assistant.

Funding is available for the RPO from the State Key Laboratory for Estuarine and Coastal research (SKLEC) at the East China Normal University (ECNU) until 2020. SKLEC is in discussions for the RPO to become an IPO led by Deputy Director Fang Zuo (see above).

J. Scientific Steering Committee (SSC)

An open call for nominations for four new SSC members was advertised in 2017. From 36 applications, four new 2018 SSC members were proposed and accepted by SCOR and Future Earth – Oscar Iribane (M, Argentina), Alice Newton (F, Portugal), Suvaluck Satumanatpan (F, Thailand) and David VanderZwaag (M,

Canada). We also appointed *ex officio* members Olav Kjesbu (M, Norway; to act as an IMBeR liaison), Chris Cvitanovic (M, Australia; as the early career representative) and Frank Muller Karger (M, USA; as the liaison with GEO BON to contribute to Innovation Challenge 2). At the end of 2018, Daniel Costa (M, USA) and Cisco Werner (M, USA) rotated off the SSC as did *ex officio* member Ken Drinkwater (M, Norway), and Jeomshik Hwang (M, South Korea) was proposed and accepted as an SSC member in 2019.

Details of the current IMBeR SSC members are listed in the Appendix.

K. Collaborative partners

IMBeR science is strengthened and its impacts extended through on-going and new partnerships and collaborations with international and national organisations, including the International Council for Science (ICSU), the Scientific Committee on Oceanic Research (SCOR), Future Earth, the World Climate Research Programme (WCRP), and the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO) which sponsors the Global Ocean Observing System (GOOS) and the International Ocean Carbon Coordination Project (IOCCP).

IMBeR continues to have long standing collaborations with the SCOR and Future Earth global research projects SOLAS, Future Earth Coasts, PAGES, Earth System Governance and bioDiscovery.

1. Too Big To Ignore (TBTI)

IMBeR is a partner of the TBTI project which includes 15 partners, 62 scientists from 27 countries. TBTI is conducting a global analysis, based on information systems, to better understand small-scale fisheries and to develop research and governance capacity to address global fisheries challenges.

2. Ocean Carbon Biogeochemistry (OCB)

OCB continues to actively support IMBeR by advertising its activities and events, and by providing financial support for activities.

3. World Climate Research Project (WCRP)

CLIVAR, a core project of WCRP, and its Indian Ocean Panel works closely with SIBER. The IMBeR Eastern Boundary Upwelling working group is co-sponsored by CLIVAR. CLIVAR is also part of the newly established Integrated Ocean Carbon Research (IOC-R).

4. GOOS

SIBER has strong connections with the Global Ocean Observing System in the Indian Ocean – IOGOOS.

5. ICES

Collaboration with ICES continues through the membership of Mark Dickey-Collas (ICES) on the IMBeR Scientific Steering Committee.

6. PICES

IMBeR and PICES continue to collaborate, with representatives from both communities attending and funding each other's summer schools and science meetings. Carol Robinson was a member of the ICES/PICES working group on Climate Change and Biologically-driven Ocean Carbon Sequestration (WGCCBOCS) which ended in 2018 and represented IMBeR on the organising committee of the PICES International Symposium The Effects of Climate Change on the World's Oceans (ECCWO) to be held in Washington in June 2018. PICES co-sponsored ClimEco5 in August 2018 and *Future Oceans2* in June 2019.

L. Selected IMBeR Publications

IMBeR has produced more than 2,500 refereed research papers since 2005, with around 150 papers published in 2018-2019.

IMBeR General

Baltar F, Bayer, B, Bednarsek N, Deppeler S, Escibano R, Gonzalez CE, Hansman RL, Mishra RK, Moran MA, Repeta DJ, Robinson R, Sintes E, Tamburini C, Valentin LE, Herndl GJ (2019) Towards Integrating Evolution, Metabolism, and Climate Change Studies of Marine Ecosystems. *Trends in Ecology &*

ICED Publications

Management and Policy related reports and papers to CCAMLR, IWC, ACAP etc

- Atkinson, A., Hill, S.L., Pakhomov, E.A., Siegel, V., Reiss, C.S., Loeb, V., Steinberg, D.K., Schmidt, K., Tarling, G.A., Gerrish, L. & Sailley, S.F. 2019. Krill (*Euphausia superba*) distribution contracts southward during rapid regional warming. *Nature Climate Change*, 9:142-147 DOI: 10.1038/s41558-018-0370-z
- Cubaynes, Hannah C., Peter T. Fretwell, Connor Bamford, Laura Gerrish, Jennifer A. Jackson. 2018. Whales from space: four mysticete species described using new VHR satellite imagery. *Marine Mammal Science* 35 (466-491). <https://doi.org/10.1111/mms.12544>
- Dinniman, M.S., Klinck, J.M., Hofmann, E.E. & Smith, W.O. 2018 Effects of Projected Changes in Wind, Atmospheric Temperature, and Freshwater Inflow on the Ross Sea. *Journal of Climate*, 31, 1619-1635. doi:10.1175/jcli-d-17-0351.1
- Krüger, L., Ramos, J.A., Xavier, J.C., Grémillet, D., González-Solís, J., Petry, M.V., Phillips, R.A., Wanless, R.M. & Paiva, V.H. (2018). Projected distributions of Southern Ocean albatrosses, petrels and fisheries as a consequence of climatic change. *Ecography* 41: 195- 208 DOI: 10.1111/ecog.02590
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- Capurro A, Santos MM, Cavanagh RD, Grant SM. 2018. The identification of scientific reference areas in the wider context of Marine Protected Area planning. CCAMLR WS-SM-18/17
- Murphy, E.J., Johnston, N.M., Corney, S. P., and Reid, K. (2018). Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) programme: Preliminary report of the ICED-CCAMLR Projections Workshop, 5-7 Apr 2018. WG-EMM-18-09.
- Murphy, E, Johnston, N, Corney, S and Reid, K including workshop participants and contributors Atkinson, A, Belchier, M, Bellerby, R, Bindoff, N, Cavanagh, R, Constable, A, Costa, D, Eddy, T, Emmerson, L, Grant, S, Groeneveld, J, Hill, S, Hobbs, W, Hofmann, E, Jackson, J, Kawaguchi, S, Korczak-Abshire, M, Lenton, A, Meijers, A, Melbourne-Thomas, J, Newman, L, Nicol, S, Piñones, A, Reiss, C, Santos, M, Tarling, G, Trathan, P, Trebilco, R, Watters, G, Welsford, D, Zhu, G. (Submitted). Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) programme: Report of the ICED-CCAMLR Projections Workshop, 5-7 Apr 2018. SC-CAMLR XXXVII.

Other papers to CCAMLR Working Group on Ecosystem Monitoring and Management 2018 can be found at <https://www.ccamlr.org/en/wg-emm-18>

Scientific publications

- Atkinson, A., Hill, S.L., Pakhomov, E.A., Siegel, V., Reiss, C.S., Loeb, V., Steinberg, D.K., Schmidt, K., Tarling, G.A., Gerrish, L. & Sailley, S.F. 2019. Krill (*Euphausia superba*) distribution contracts southward during rapid regional warming. *Nature Climate Change*, 9:142-147 DOI: 10.1038/s41558-018-0370-z
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- Constable, A.J. & Kawaguchi, S. 2018 Modelling growth and reproduction of Antarctic krill, *Euphausia superba*, based on temperature, food and resource allocation amongst life history functions. *Ices Journal of Marine Science*, 75, 738-750. (doi:10.1093/icesjms/fsx190).
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- Goedegebuure, M., Melbourne-Thomas, J., Corney, S.P., McMahon, C.R. & Hindell, M.A. 2018 Modelling southern elephant seals *Mirounga leonina* using an individual-based model coupled with a dynamic energy budget. *Article, Plos One*, 13. (doi:10.1371/journal.pone.0194950).
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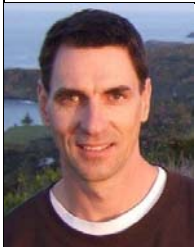
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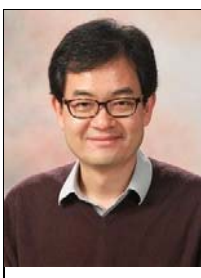





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Appendix: Current IMBeR SSC Members

	<p>Carol Robinson Chair since 2016 E-mail: Carol.Robinson@uea.ac.uk Web page: Link</p> <p>National contact, IMBER SSC (2007-2013) University of East Anglia, Norwich, UK Microbial biogeochemistry</p>
	<p>Marion Glaser Vice-Chair since 2017 E-mail: marion.glaser@leibniz-zmt.de Web page: Link</p> <p>Leibniz Center for Tropical Marine Research (ZMT) Bremen, Germany</p>
	<p>Multi-level social-ecological systems analysis, resilience and transformation, tropical coastal livelihoods, coastal and ocean governance and management, transdisciplinary research</p>
	<p>Eugene Murphy Vice-Chair since 2016 E-mail: e.murphy@bas.ac.uk Web page: Link</p> <p>ICED (Chair), National contact</p> <p>British Antarctic Survey, Cambridge, UK</p>
	<p>Biological oceanography, Southern Ocean food web modelling, ecosystems dynamics, biogeochemical cycles</p>
	<p>Alice Newton Vice-Chair since 2019 E-mail: anewton@ualg.pt Web page: Link</p> <p>Centre for Marine and Environmental Research, University of Algarve, Faro, Portugal</p>
	<p>Eutrophication, assessment frameworks of marine social - ecological systems, Regional Seas Conventions, marine environmental policy implementation, marine biodiversity assessments, science communication</p>
	<p>Laurent Bopp Member since 2014 E-mail: laurent.bopp@lsce.ipsl.fr Web page: Link</p> <p>National Centre for Scientific Research (CNRS), Paris, France</p> <p>Physical oceanography, climate-marine biogeochemistry interactions, marine ecology, computational modelling</p>

	<p>Chris Cvitanovic Early Career representative since 2018 E-mail: christopher.cvitanovic@anu.edu.au</p> <p>The Australian National Centre for the Public Awareness of Science, Australian National University, Canberra</p> <p>Marine governance, knowledge exchange, science-policy and stakeholder engagement</p>
	<p>Mark Dickey-Collas Member since 2017 E-mail: Mark.dickey-collas@ices.dk Web page: Link</p> <p>International Council for the Exploration of the Sea (ICES) and Danish Technical University National Institute of Aquatic Resources (DTU- AQUA), Copenhagen, Denmark.</p> <p>Population dynamics, ecosystem approach, science for policy, pelagic fish and fisheries</p>
	<p>Rubén Escribano Member since 2015 E-mail: rescribano@udec.cl Web page: Link</p> <p>IMBER-CLIVAR Upwelling WG (Chair)</p> <p>Department of Oceanography & Millennium Institute of Oceanography (IMO), University of Concepción, Concepción, Chile</p> <p>Marine zooplankton ecology, marine pelagic food webs, population biology</p>
	<p>Gerhard Herndl Member since 2014 E-mail: gerhard.herndl@univie.ac.at Web page: Link</p> <p>Department of Marine Biology, University of Vienna, Vienna, Austria</p> <p>Marine microbial ecology, microbial oceanography and biodiversity, marine biogeochemistry, dark ocean</p>
	<p>Alistair Hobday Member since 2017 E-mail: alistair.hobday@csiro.au Past co-Chair of CLIOTOP CSIRO Oceans and Atmosphere Hobart, Tasmania, Australia</p> <p>Climate variability and change, climate adaptation, fisheries management, ecological risk assessments, science-to-policy</p>

	<p>Jeomshik Hwang Member since 2019 E-mail: jeomshik@snu.ac.kr Web page: Link</p> <p>School of Earth and Environmental Sciences, Seoul National University, Seoul, South Korea</p> <p>Biological carbon pump, sediment resuspension, radiocarbon</p>
	<p>Oscar Iribarne Member since 2018 E-mail: osiriba@mdp.edu.ar Web page: Link</p> <p>National University of Mar del Plata (CONICET), Mar del Plata, Argentina</p> <p>Marine ecology, Determinants of community structure, Sustainable fisheries; Interface ecosystems</p>
	<p>Olav Sigurd Kjesbu Ex-officio Member since 2018 Tel.: +47 930 47 611 E-mail: olav.kjesbu@imr.no Web page: Link</p> <p>Institute of Marine Research, Bergen, Norway</p> <p>Reproductive ecology and recruitment dynamics, effect of environmental variability on fish stock productivity</p>
	<p>Frank Muller-Karger Member since 2018 E-mail: carib@usf.edu Web page: Link</p> <p>University of South Florida, Saint Petersburg, FL, USA</p> <p>Biological oceanography, ocean remote sensing, nutrient cycles, ecology/biodiversity</p>
	<p>Suvaluck Satumanatpan Member since 2018 E-mail: suvaluck.nat@mahidol.ac.th Web page: Link</p> <p>Mahidol University, Salaya, Thailand</p> <p>Marine and coastal management and fisheries governance</p>
	<p>David VanderZwaag Member since 2018 E-mail: David.VanderZwaag@Dal.Ca Web page: Link</p> <p>Marine & Environmental Law Institute, Dalhousie University, Halifax, NS, Canada</p> <p>Marine and environmental law and governance</p>



Ingrid van Putten Member since 2016

E-mail: Ingrid.Vanputten@csiro.au

Web page: [Link](#)

HDWG (2017-)

Commonwealth Scientific & Industrial Research Organisation (CSIRO) and
Centre for Marine Socioecology, Hobart, Australia

Modelling the interaction of social and economic behaviour with the
biophysical environment



Ying Wu Member since 2016

E-mail: wuying@sklec.ecnu.edu.cn

Web page: [Link](#)

State Key Laboratory of Estuarine and Coastal Research (SKLEC), East China
Normal University (ECNU), Shanghai, China

Marine organic geochemistry

Appendix 6

Surface Ocean – Lower Atmosphere Study (SOLAS)

SOLAS Annual Report to SCOR

Reporting period: May 2018 - May 2019 Version of 11
June 2019 by Jessica Gier

1. Progress on implementation of project science and implementation plans, and schedule for major project activities, including open science meetings, major data releases, synthesis activities, and project completion

I.a. SOLAS 2015-2025: Science Plan and Organisation

The SOLAS science mission is organised around five core themes:

- Core Theme 1: Greenhouse gases and the oceans
- Core Theme 2: Air-sea interface and fluxes of mass and energy
- Core Theme 3: Atmospheric deposition and ocean biogeochemistry
- Core Theme 4: Interconnections between aerosols, clouds, and marine ecosystems
- Core Theme 5: Ocean biogeochemical control on atmospheric chemistry

In addition, the study of these themes are integrated in efforts to understand key environments, e.g. upwelling systems, polar oceans, and the Indian Ocean, as well as to evaluate the environmental efficacy and impacts of climate intervention proposals, policy decisions, and societal developments.

The SOLAS 2015-2025: Science Plan and Organisation (SPO) is available to download from the SOLAS website (<http://www.solas-int.org/about/solas.html>) and hardcopies are available upon request from the IPO.

I.b. SOLAS 2015-2025: Implementation Strategy

SOLAS chose to use a pragmatic approach with a continually-evolving 2-year implementation strategy. This approach means that the document is a moving target that is regularly (i.e., annually) updated. The implementation strategy is intended to be a live web-based document only and is available for download from the SOLAS website at <http://www.solas-int.org/activities/implementation.html>.

The latest iteration of the Implementation Strategy was released online in April 2018 and the up-date for 2019 is in progress. Upcoming SOLAS activities include:

- iCACGP annual meeting, Montreal, Canada, 6-8 July, 2019
- BEPSII annual meeting at the IGS Sea Ice Symposium, Winnipeg, Canada, 16-18 August, 2019
- Global Ocean Oxygen Network (GO2NE) summer school, Xiamen, China, 2-7 September 2019
- Shipping & the Environment II, Gothenburg, Sweden, 4-6 September, 2019
- OceanObs'19, Hawai'i, USA, 16-20 September 2019
- SCOR annual meeting, Toyama, Japan, 23-25 September 2019
- IGAC SSC meeting, Mexico City, Mexico, 29-30 October 2019
- CATCH annual meeting at the AGU, San Francisco, USA, 9-13 December 2019
- CATCH Open Science workshop, Berkeley, USA, 7-8 December 2019
- Ocean Sciences Meeting, San Diego, USA, 16-20 February 2020
- Treatise on basic research needs in evaluating proposed climate intervention strategies
- 8th International Symposium on Gas Transfer at Water Surfaces, Plymouth, United Kingdom,

19-22 May, 2020

- Asian SOLAS-remote sensing workshop, 2020
- 8th international SOLAS Summer School, Cape Verde, 2021
- SOLAS Open Science Conference, 2022

L.c. Collaboration between CLIVAR, GCP, IMBeR, IOCCP, SOLAS, and WCRP on Ocean Carbon

Recognising the importance of improving holistic understanding of the role of the ocean in the global carbon cycle in the context of its societal and economic importance, the Working Group on Integrated Ocean Carbon Research has been created under the auspices of the Intergovernmental Oceanographic Commission (IOC). This think tank succeeds and expands on the mandate of the previous SOLAS-IMBER ocean carbon research group; it has a broader focus, and involvement of a larger expert community, including representatives of CLIVAR, GCP, IOCCP, and WCRP.

The major activity of 2018 has been the formation of the executive panel of the working group and adoption of terms of reference. Plans for 2019 include: (a) expanding membership of the working group to include specific carbon expertise currently not covered within the executive panel; (b) the first face to face meeting of the group, which is planned for 28-30 October, 2019, in Paris, France, to formulate the more detailed scope of the working group's activities; and (c) development of links to ongoing relevant initiatives (e.g., the Regional Carbon Cycle Assessment and Processes, RECCAP 2). Specific areas of interest are the interactions of the organic and inorganic ocean carbon cycles, and the impacts of the changing ocean carbon cycle on ocean health including higher tropic levels and sustainable fisheries.

L.d. SOLAS metadata portal

The SOLAS metadata portal was set up by the SOLAS project integration initiative (2007-2013) with the intention to help SOLAS scientists identify what data exist, where they are stored, and the data originators. The portal is hosted by NASA and the metadata files are stored on the international standard Global Change Master Directory (GCMD). The resource is freely available to the entire community at <http://www.solas-int.org/solas-metadata-portal.html>.

The SOLAS metadata portal is an ongoing effort. Scientists can help expanding the SOLAS metadata base by completing a simple template available at <http://tinyurl.com/328zjr5> and emailing it to solas@geomar.de.

L.e. Collaboration with Climate and Cryosphere (CliC) and the Scientific Committee on Antarctic Research (SCAR) on Biogeochemical Exchange Processes at Sea Ice Interfaces (BEPSII)
<http://www.bepsii.org>

Biogeochemical Exchange Processes at Sea-Ice Interfaces (BEPSII) started in 2011 with a focus on sea-ice biogeochemistry and was a SCOR working group from 2012 until September 2016, and has since been endorsed as a SOLAS-CliC Activity (from 2016) and as a SCAR Action Group (from 2017). Following a workshop in Switzerland in 2018, the BEPSII community is now preparing a Position Analysis on Arctic sea-ice biogeochemical responses to climate change for submission to *Nature Communications*. The BEPSII [Special feature](#) in *Elementa: Science of the Anthropocene* has been finalised (18 accepted contributions), the 5 year activity plan was completed and a new website and logo were launched. SOLAS will support the BEPSII annual meeting which is planned for 16-18 August in Winnipeg, Canada.

L.f. Collaboration with International Global Atmospheric Chemistry (IGAC) on Cryosphere and Atmospheric Chemistry (CATCH) <https://sites.google.com/view/catchscience/home>

The Cryosphere and Atmospheric Chemistry (CATCH) facilitates atmospheric chemistry research within the international community, with a focus on natural processes specific to cold regions of the Earth. The operational modus of CATCH was shaped in 2018 and CATCH now operates with a scientific steering committee (SSC), co-chairs, and liaisons with related activities elected by the community and rotated every four years. Katye Altieri (SOLAS SSC member) was named the SOLAS liaison to CATCH in Feb 2019. The CATCH SSC holds monthly teleconferences to discuss updates and planning of activities, and will hold their first annual physical meeting right after the CATCH December 2019 workshop.

L.g. Collaboration with Integrated Marine Biosphere Research project (IMBeR):

SOLAS/IMBER Ocean Acidification (SIOA)

The SIOA provides a key advisory role to the Ocean Acidification International Coordination Centre (OA-ICC) at the International Atomic Energy Agency in Monaco. In 2018, the SI- OA/IAEA OA-ICC continued to act as an international coordination platform for ocean acidification research and collaboration by

- Ensuring that scientists have access to recently updated, state-of-the-art software to calculate ocean acidification parameters, and that ocean acidification data collected across the globe is properly archived, accessible, and comparable. This is particularly relevant in the context of reporting of countries on the UN SDG 14.3.
- Acting as a hub for global stakeholders interested in ocean acidification, providing unique resources such as its comprehensive bibliographic database and a news stream updated daily with info on ocean acidification scientific articles, media coverage, jobs, and meetings.
- Providing increased awareness about ocean acidification with contributions to major reports and working groups, highly visible international events and meetings, training courses, the OA-ICC web site, news stream, and communication products.
- Providing enhanced capacity in ocean acidification research and networking opportunities in 2018 for 53 researchers from 32 IAEA Member States.
- Contributing to the development of international and regional coordination activities and networks, such as GOA-ON, LAOCA, and OA-AFRICA.
- Contributing to methodology development for UN SDG14.3 on Ocean Acidification and helping countries to get ready to report towards that target.
- [Improved software](#) used by the scientific community working on ocean acidification to calculate carbonate chemistry parameters, e.g. to offer new options to allow for uncertainty propagation and to use of new oceanographic standards (TEOS-10) for temperature and salinity. The most recent work on uncertainty propagation is described in [Orr et al. 2019](#).
- The largest OA community meeting, “The Ocean in a High CO₂ World”, will take place in Lima, Peru, 7-10 September 2020.

The 2019 SIOA and OA-ICC annual meeting took place in Monaco from 27-28 May.

L.h. Collaboration with Ocean Carbon & Biogeochemistry (OCB)

SOLAS participated and supported the **OCB Workshop** on Oceanic Methane and Nitrous Oxide: The present situation and future scenarios, Los Angeles, USA, 28-31 October 2018.

Ocean Carbon & Biogeochemistry (OCB) Ocean-Atmosphere Interaction Subcommittee.

<https://www.us-ocb.org/about/ocb-subcommittees/subcommittee-on-ocean-atmosphere-interactions/>

The scientific focus of this subcommittee is on ocean-atmosphere interactions and their role in marine biogeochemical cycles). The subcommittee secured funding for a workshop on “Ocean- Atmosphere Interactions: Scoping directions for U.S. research”, which will be held 1-3 October 2019 in Sterling, VA, USA (<https://web.whoi.edu/air-sea-workshop/>), and will gather U.S. scientists working at the air-sea interface to identify research priorities and facilitate the communication and collaboration required for future significant research advances. The workshop will serve as a critical next step in strengthening the U.S. air-sea interaction research community and encouraging synergistic activities across disciplines and nations. This 3-day scoping workshop will be open to interested members of the community, but attendance will be limited to ~60-65 scientists who are prepared to contribute to in-depth discussions about research priorities and engagement with international SOLAS. Participants will present and share cutting edge research and participate in discussions to identify key knowledge gaps and prioritise research needed to advance the field. From the discussions at the workshop, the OAIC will assemble a “grassroots” document to help assemble the U.S. air-sea interaction research community around a common set of science goals and research priorities. The workshop and its outcomes are expected to strengthen ties between the ocean and atmosphere research communities and foster a

more cohesive U.S. contribution to international SOLAS. We will send out another announcement when the workshop website and registration is open. .

II. Activities (including capacity building) and publications that resulted from the project's work since the previous year's report

IIa SOLAS Workshops on Core Themes 4 and 5

SOLAS Event Report Issue12

These consecutive workshops were held 27-29 November 2018 in Rome, Italy. They focused on the SOLAS core themes 4 and 5 and included experimentalists and modellers, representing the oceanographic and atmospheric science communities. Scientists from 17 different countries joined the workshops representing a wide range of career stages.

- I. Workshop I was about the “Influence of coastal pollution on marine atmospheric chemistry: effects on climate and human health”. This workshop focused on the importance of the coastal environment from the air-sea interaction point of view and on the different aspects of coastal pollution (air and water), with the main objectives to a) discuss how coastal pollution affects gas and particles emitted over the coasts, and b) understand the effects of coastal pollution on the air quality-climate system and human health.

Participants articulated a series of research needs for air-sea exchange investigations in the coastal environment. The necessity of linking different scientific communities (atmosphere, ocean, toxicology, and human society) through the development of a multidisciplinary investigation approach was deemed of paramount importance to significantly advance the science. The necessity of integrating laboratory and field observations, remote sensing and modelling was also highlighted, together with the importance of implementing integrated sea-atmosphere long-term observations in the coastal environment, which are almost non-existent at present.

This workshop was organised jointly by SOLAS and the ‘International Global Atmospheric Chemistry’ project.

- II. Workshop II was about the “Interconnections between aerosols, clouds, and marine ecosystems in contrasting environments”. The workshop was motivated by the existence of many large programs (highlighted in the annual reports from the SOLAS national networks) aimed at improving our understanding of the complex and highly dynamical interconnections between aerosols, clouds, and marine ecosystems. The goals of this workshop were to address the science of the ocean ecosystem-aerosol-cloud linkage (one of the key elements of the Surface Ocean - Lower Atmosphere Study (SOLAS) science plan), to make the participants aware of what other programs are doing, and to initiate cross-cutting studies. Participants in the different programs, as well as all interested researchers working on these topics, were invited to attend the workshop in order to share and compare their findings, to cross-fertilise their research, and to contribute to a community paper. The following programs were present: Antarctic Circumnavigation Expedition ([ACE](#)); Plankton-derived Emissions of trace Gases and Aerosols in the Southern Ocean ([PEGASO](#)); Process studies at the air-sea interface after dust deposition in the Mediterranean Sea ([PEACETIME](#)); Network on Climate and Aerosols: Addressing Key Uncertainties in Remote Canadian Environments ([NETCARE](#)); Marine biological production, organic aerosol particles and marine clouds: a Process Chain ([MarParCloud](#)); Surface Ocean Aerosol Production ([SOAP](#)); North Atlantic Aerosols and Marine Ecosystems Study ([NAAMES](#)); Reef to Rain Forest ([R2R](#)); Impact of Biogenic versus Anthropogenic emissions on Clouds and Climate: towards a Holistic Understanding ([BACCHUS](#)); and Variability of the American Monsoon Systems Ocean-Cloud-Atmosphere- Land Study ([VOCALS](#)).

IIb SOLAS Open Science Conference 2019

www.solas-int.org/osc2019.html

The 7th SOLAS Open Science Conference 2019 took place on 21-25 April 2019 in Sapporo, Hokkaido, Japan, and was organised by a committee of 31 people, hailing from 17 countries. We welcomed 190 attendees from 30

countries to share their research and knowledge of SOLAS science. The five core themes and three cross-cutting themes outlined in the current [SOLAS Science Plan 2015-2025](#) were covered by plenary lectures. These were complemented by poster session for each of the Themes in the afternoons, as well as nine discussion sessions (three in parallel on three days) which provided an opportunity for the community to identify new frontiers to explore. Details about the speakers, plenary/poster/discussion sessions can be found on the SOLAS OSC website, and a SOLAS Event Report will be published.

In addition to the main conference, a day-long **Climate Intervention Workshop**

(<https://www.confmanager.com/main.cfm?cid=2778&nid=16739>), led by Philip Boyd of the Institute of Marine and Antarctic Studies at the University of Tasmania, Australia, and Cliff Law of the National Institute of Water and Atmospheric Research, New Zealand, brought together observationalists, modellers, and legal experts working on the interactions between the ocean and the atmosphere. The workshop assessed how SOLAS science can contribute to the debate around negative CO₂ emission technologies (NETs) and geoengineering. In addition to considering different NET approaches and how SOLAS science can add rigour to their assessment, the workshop examined international governance frameworks and discussed how the air-sea research community can help inform the decision-making process in climate intervention. SOLAS recognises our responsibility in investigating the scientific basis of many carbon dioxide removal and solar radiation management techniques, such as iron fertilisation, alkalinity addition or increasing surface ocean reflectivity.

The day before the conference, an **Early-Career Scientists Day** (<https://www.confmanager.com/main.cfm?cid=2778&nid=16704>) brought together 25 doctoral students and postdoctoral researchers to network, discuss, and share their respective research. Lectures delved into the reasons why science needs to remain fun and accessible and into knowledge mobilisation of research activities within the public at large. Following the lectures, each participant presented their research during three-minute talks which were accompanied by two-minute Q&A, and Early-Career peer evaluations. The best three talks were given awards during the conference banquet. The Early-Career Scientists Day ended with a field trip to Lake Shikotsu.

II.c SOLAS Summer School

[SOLAS Event Report Issue 11](#)

<http://www.solas-int.org/summer-schools-archive-kopie-224.html>

The summer school gathered 64 students and 17 lecturers and practical demonstrators. The students came from 24 countries and were all either graduate students or recent post-docs in various fields of oceanography and atmospheric science. The lecturers were international experts on SOLAS science who also hailed from around the world. These people were brought together under the leadership of Christa Marandino, GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany, with the help of an organising committee consisting largely of past summer school alumni and lecturers.

II.d. Collaboration with ESA

Tom Bell represented SOLAS at the ESA Atlantic from Space workshop, Southampton, 23-25 January 2019. Potential collaborations between SOLAS and ESA were discussed and a summary of the workshop will be available soon. An ESA-SOLAS session on “[Remote Sensing of the Ocean Surface and Lower Atmosphere - a SOLAS Session](#)” was held at the ESA Living Planet Symposium at the ESA Living Planet Symposium, Milan, Italy, 12-16 May, 2019. Diego Fernández-Prieto, ESA ESRIN, mentioned ESA’s very high interest in continuing the collaboration with SOLAS, for example through joint activities on upwelling regions.

II.e. Collaboration with PICES

[SOLAS Event Report Issue 10](#)

SOLAS was engaged with the scientific planning of the 4th International Symposium on "The Effects of Climate Change on the World's Oceans", Washington D.C., USA, 4-8 June 2018. SOLAS organised a session on Eastern Boundary Upwelling Systems: Diversity, Coupled Dynamics and Sensitivity to Climate Change. This was a PICES, ICES, IOC, FAO event.

PICES jointly sponsored the Early-Career Scientist Day during the SOLAS Open Science Conference, 21 April 2019, in Sapporo, Japan. A report about the event will be published in the next PICES newsletter. The PICES-

2018 annual meeting took place in Yokohama, Japan, 25 October-4 November 2018. Lisa Miller attended the meeting and represented SOLAS. The next PICES annual meeting will take place 16-27 October 2019 in Victoria, BC, Canada. Lisa Miller will represent SOLAS at the meeting.

II.f. SOLAS Integrated Atmosphere-Ocean time-series station in Cape Verde The goal of this time series station is to better understand ocean-atmosphere interactions and the role of the sea surface microlayer. The aim of the Helmholtz International Ocean-Atmosphere Network (HI-OceAN) is to advance air-sea interaction science while providing a unique platform to the international community. The proposed air-sea platform will build upon existing time-series stations/infrastructure at Cape Verde. A development and funding (Helmholtz International Labs) meeting was held on 22-23 October, 2018, in Kiel, Germany. The proposal was submitted in March 2019 and the outcome will be announced in fall 2019.

Project partners:

- GEOMAR, Kiel, Germany: Christa Marandino, Anja Engel, Arne Körtzinger
- University of York, York, UK: Lucy Carpenter
- Weizmann Institute of Science, Rehovot, Israel: Ilan Koren
- Instituto Nacional de Desenvolvimento das Pescas, Cape Verde: Osvaldina Silva
- Instituto Nacional de Meteorologia e Geofísica, Cape Verde: Bruno Faria

II.g. Additional SOLAS events

Past events:

- Meeting with sister organisations, Victoria, BC, Canada, 1 May 2018, to facilitate joint activities in global environmental change research
- SOLAS SSC Meeting 2018, Victoria, BC, Canada, 2-4 May, 2018.
- POLAR2018, A SCAR & IASC Conference, Davos, Switzerland, 15-26 June 2018
- BEPSII & ECV-Ice annual meetings, Davos Switzerland, June 15-17, 2018.
- Future Earth Summit, Bonn, Germany, 28-29 August, 2018
- SFB 745 Ocean Deoxygenation conference, Kiel, Germany, September 2018
- SCOR annual meeting, Plymouth, United Kingdom, 10-13 September 2018
- IIOE-2 Working Group 1 Science & Research Meeting, Kiel, 28-30 November 2018
- SCOR China annual meeting, Zhoushan, China, 28-29 December 2018
- The 4th Xiamen Symposium on Marine Environmental Sciences, SOLAS session “Surface Ocean and Lower Atmosphere Study -Air-Sea inter-actions and their climatic and environmental impacts”, Xiamen, China, 6-9 January, 2019. A [SOLAS Event Report Issue 13](#)
- Royal Society Future Earth meeting, Wolfson suite, UK, 28 February 2019
- GESAMP/iCACGP/SOLAS session on “Air-sea Chemical Fluxes : Impacts on Biogeochemistry and Climate”, EGU, Vienna, 7-12 April 2019
- SOLAS SSC meeting, 26-28 April 2019, Sapporo, Japan
- Journée Future Earth, Paris, France, 9 May 2019
- First Global Planning Meeting of the Preparatory Phase of the UN Decade of Ocean Science for Sustainable Development, Copenhagen, Denmark, 13-15 May 2019
- Ocean KAN meeting, Copenhagen, Denmark, 16 May 2019

II.h. SOLAS publications

- Version 3 of the FluxEngine toolbox, which is an output from the joint ESA - SOLAS project, 'OceanFlux GHG' and is an open source toolbox for calculating air-sea CO₂ gas fluxes from in situ, model, and Earth observation data. The FluxEngine can be used through the web portal (<http://www.ifremer.fr/cersat1/exp/oceanflux/>).
- A discussion of new methods for inferring CO₂ fluxes at high resolution from satellite data: Hernández-Carrasco I, Garçon V, Sudre J, Garbe C, and Yahia H (2018) Increasing the Resolution of Ocean pCO₂ Maps in the South Eastern Atlantic Ocean Merging Multifractal Satellite-Derived Ocean Variables. *IEEE*

TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, 56(11): 6596 - 6610. DOI: 10.1109/TGRS.2018.2840526

- SOLAS remote sensing priorities identified at the ESA-SOLAS workshop in Frascati, Italy, 2016: Neukermans G, Harmel T, Galí M, Rudorff N, Chowdhary J, Dubovik O, Hostetler C, Hu Y, Jamet C, Knobelspiesse K, Lehahn Y, Litvinov P, Sayer AM, Ward B, Boss E, Koren I, and Miller LA (2018). Harnessing remote sensing to address critical science questions on ocean- atmosphere interactions. *Elementa: Science of the Anthropocene*, 6(1), p.71. DOI:<http://doi.org/10.1525/elementa.331>
- A new tool for assessing uncertainties in the ocean CO₂ system from the SOLAS-IMBeR Ocean Acidification working group: Orr JC, Epitalon J-M, Dickson AG, and Gattuso J-P (Nov 2018). Routine uncertainty propagation for the marine carbon dioxide system. *Marine Chemistry* 207: 84-107.
- A synthesis of the results from the SOLAS-sponsored NETCARE project: Abbatt JPD, Leaitch WR, Aliabadi AA, Bertram AK, Blanchet JP, et al. (2019) New insights into aerosol and climate in the Arctic. *Atmospheric Chemistry and Physics Discussions*, European Geosciences Union, 19, 2527–2560, 2019. <https://doi.org/10.5194/acp-19-2527-2019>
- A synthesis of the results from the SOLAS-sponsored NAAMES project: Behrenfeld MJ, Moore RH, Hostetler CA, Graff J, Gaube P, Russell LM, Chen G, Doney SC, Giovannoni S, Liu H, Proctor C, Bolaños LM, Baetge N, Davie-Martin C, Westberry TK, Bates TS, Bell TG, Bidle KD, Boss ES, Brooks SD, Cairns B, Carlson C, Halsey K, Harvey EL, Hu C, Karp-Boss L, Kleb M, Menden-Deuer S, Morison F, Quinn PK, Scarino AJ, Anderson B, Chowdhary J, Crosbie E, Ferrare R, Hair JW, Hu Y, Janz S, Redemann J, Saltzman E, Shook M, Siegel DA, Wisthaler A, Martin MY, and Ziemba L (2019) The North Atlantic Aerosol and Marine Ecosystem Study (NAAMES): Science Motive and Mission Overview. *Frontiers in Marine Science*. 6:122. doi: 10.3389/fmars.2019.00122
- SOLAS Event Report series:
 - [Issue 13, March 2019](#). SOLAS session at XMAS IV, Xiamen, China, 6-9 January 2019.
 - [Issue 12, January 2019](#). Two consecutive workshops on SOLAS Core Themes 4 and 5, Roma, Italy, 27-29 November 2018.
 - [Issue 11, December 2018](#). The 7th international SOLAS Summer School, Cargèse, Corsica, France, 23 July - 4 August 2018.
 - [Issue 10, August 2018](#). Session on: „Eastern Boundary upwelling systems: diversity, coupled dynamics and sensitivity to climate change” at ECCWO, Washington DC, USA, 2-8 June, 2018.
 - [Issue 09, May 2018](#). Workshop on: “Remote Sensing for Studying the Ocean Atmos- phere Interface”, Potomac, Maryland, USA, 13-15 March, 2018.
- SOLAS Position Statement on Climate Intervention
<http://solas-int.org/statement-on-geoengineering.html>
- SOLAS Code of Conduct
<http://solas-int.org/code-of-conduct.html>

ILI. SOLAS communications

Website, <http://www.solas-int.org/>

The IPO is currently redeveloping and updating the SOLAS website, with a new design and structure with the website support agency “Erdmann & Freunde” (<https://erdmann-freunde.de/en/>).

Monthly e-news: 13 SOLAS e-news have been sent to over 1000 SOLAS scientists since the last SCOR report in May 2017. The monthly e-news releases compile news from SOLAS, opportunities for meetings, abstract submission deadlines, recent publications, vacancies, and news from relevant partner projects and collaborators.

In May 2018, with implementation of the General Data Protection Regulation, the SOLAS mailing list was deleted and re-established. Before deletion, the mailing list included 2500 subscribers and is now back to 1060. Past issues of the e-news can be viewed on the SOLAS website: <http://solas-int.org/archive.html>.

Event Report series, reports on SOLAS sponsored or co-sponsored events. An event report is published after each SOLAS-sponsored event. These reports are sent to the SOLAS sponsors and other interested parties and are released in combination with the monthly e-news.

Poster: A poster presenting SOLAS and its new science plan is available to download on the SOLAS website. Anyone is welcome to freely use it for conferences/meetings/workshops or just to have a brief overview of SOLAS.

Presentation: A SOLAS presentation for workshop organisers is available upon request from the IPO.

Twitter account: Regular posts (currently 582) are being sent out and the number of followers is steadily increasing (currently 578). Twitter: [@SOLAS_IPO](#)

U.i. SOLAS national networks

<http://solas-int.org/community/national-networks.html>

SOLAS has National Representatives in 30 countries around the globe. The national representatives are asked to report annually on SOLAS activities in their countries. To facilitate the reporting effort, a template form is provided. In May 2019, 15 reports were received and are posted on the SOLAS website. The information contained in the reports has been a great source of information for the IPO to report to sponsors but also to facilitate coordination and dissemination of results and progress from national projects to the rest of the SOLAS community. Information provided through the reports is also used to update the implementation strategy.

All reports received during the reporting period are available in an Addendum to this document. Current national networks:

- Australia: Sarah Lawson and Andrew Bowie
- Belgium: Nathalie Gypens
- Brazil: Leticia Cotrim Da Cunha *
- Canada: Jon Abbatt
- Chile: Laura Farias *
- China (Beijing): Minhan Dai
- China (Taipei): Chonlin Lee
- Denmark: Lise Lotte Soerensen and Mikael Sejr *
- Finland: Lauri Laakso
- France: Rémi Losno *
- Germany: Christa Marandino and Hartmut Herrmann
- India: VVSS Sarma *
- Israel: Yoav Lehahn
- Ireland: Brian Ward *
- Italy: Chiara Santinelli *
- Japan: Yuzo Miyazaki
- Korea: Kitack Lee
- Mexico: Jose Martin Hernandez Ayon *
- Netherlands: Jan-Berend Stuut
- New Zealand: Cliff Law

- Norway: Siv Lauvset
- Peru: Michelle Graco *
- Poland: Timo Zielinski
- Russia: Sergey Gulev *
- South Africa: Sarah Fawcett *
- Spain: Alfonso Saiz-Lopez
- Sweden: Katarina Abrahamsson *
- Turkey: Baris Saglihoglu, Mustafa Koçak, Nazli Olgun
- UK: Tom Bell *
- USA: Rachel Stanley

* SOLAS has not yet received the 2018 report

II.k. Endorsed project since the previous year's report

- March 2019: Impact of atmospheric multi-stressors to coastal marine systems in a changing climate scenario (AMBIEnCE). Website: <https://projectambience.wordpress.com/>
- Information on all endorsed projects is available on the SOLAS website: <http://www.solas-int.org/activities/project-endorsement.html>.

III. Update on the Scientific Steering Committee and International Project Office status since the last report

SOLAS Scientific Steering Committee

Lisa Miller (F, Canada) is the 5th SOLAS SSC Chair, acting for 3 years, from January 2018 until December 2020.

SOLAS has an Executive Committee composed of the Chair Lisa Miller, Katye Altieri, Cristina Faccini, and Maurice Levasseur.

The following SSC members rotated off at the end of 2018:

- Veronique Garçon (finished her ex-officio term)
- Ilan Koren
- Alfonso Saiz-Lopez

Phil Boyd, Peter Minnett, and Parvatha Suntharalingam finished their first terms at the end of 2018 and were renewed for second terms.

In January 2019, two new SSC members were appointed: Anoop Mahajan (M, India), Jurgita Ovadnevaite (F, Ireland)

Phil Boyd will be completing his second term at the end of 2019, and we are currently searching for a replacement with expertise in climate intervention science.

Guiling Zhang, Anna Rutgeresson, Erik van Doorn, and Jun Nishioka will finish their first terms at the end of 2019 and were renewed for second terms

The current membership of the SOLAS SSC is 17 members including the chair:

Name	Country	Gender	Scientific expertise	SOLAS expertise	Term	End
Parvatha Suntharalingam	UK	F	Numerical modelling / C, N, S bgc cycles	Theme 1 and 3	2	2021
Arne Körtzinger	Germany	M	Carbon cycle, Ocean observation	Theme 1, Upwelling	1	2020
Guiling Zhang	China	F	Bgc of trace gases	Theme 1, Coastal ocean	1	2019
Peter Minnett	USA	M	Remote sensing, physical air-sea exchange	Theme 2	2	2021
Anna Rutgersson	Sweden	F	Air-sea physical inter- action	Theme 2, Coastal ocean, Science & society, WCRP rep	1	2019
Mohd Talib Latif	Malaysia	M	Microlayer, atmosph. aerosols	Theme 2 and 5	1	2020
Katie Altieri	South Africa	F	Atmospheric molecules, climate policy	Theme 3 and 5, Polar oceans, Science & society	1	2020
Phil Boyd	Australia	M	Marine bgc	Theme 3, geoengineering	2	2019
Santiago Gasso	USA	M	Remote sensing, aerosols, dust transport	Theme 3 and 4, NASA connection	1	2020
Maurice Levasseur	Canada	M	Ocean bgc, dimethylsulfide, Arctic, ice algae	Theme 3 and 4, Polar oceans	2	2020
Laura Gallardo	Chile	F	Atmospheric modeling, pollutants	Theme 4 and 5, Upwelling, Coastal ocean, Science & society, IGAC	1	2020
Cristina Facchini	Italy	F	Physical and chemical processes in multi-phase atm. systems	Themes 4 and 5, Coastal ocean	2	2020
Jurgita Ovadnevaite	Ireland	F	Aerosol chem, physics and cloud processes	Themes 4 and 5	1	2021
Anoop Mahajan	India	M	Atm. chemistry, halogens, climate modelling	Theme 5, Indian Ocean	1	2021
Lisa Miller	Canada	F	Sea-ice bgc and marine inorganic bgc	Theme 2, Polar oceans, PICES connection	2	2020
Jun Nishioka	Japan	M	Oc. trace metal bgc cycle, Polar oceanography and sea-ice bgc	Theme 3, Polar oceans , Coastal ocean	1	2019

Erik Van Doorn	Germany	M	Law of the Sea	Science and Society	1	2019
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The current gender and country balance of the SSC is as follows, for a total of 17 members including the chair:

- 8 female, 9 male
- 4 members from developing countries and 13 from developed countries

SOLAS International Project Office

The SOLAS IPO is hosted at the GEOMAR Helmholtz Centre for Ocean Research Kiel in Kiel, Germany. In April 2018, Jessica Gier was appointed the SOLAS Executive Director. The salary of the Executive Director and office space for the IPO, are supported by GEOMAR until December 2020.

A proposal to NSF to maintain a Project Officer position at GEOMAR was approved in September 2018, and Esther Rickert was appointed on a half-time basis. Every three months, GEOMAR sends an invoice to SCOR, and Esther submits a job description to SCOR.

Minhan Dai and MEL, Xiamen University supports a SOLAS regional hub and an additional project officer, Li Li, until September 2020.

Appendix 7 GEOTRACES

GEOTRACES SCIENTIFIC STEERING COMMITTEE ANNUAL REPORT TO SCOR 2018/2019

1 April 2018 to 31 March 2019

1. SCOR Scientific Steering Committee (SSC) for GEOTRACES

Co-Chairs

Andrew Bowie, Australia
Phoebe Lam, USA

Members

Eric Achterberg, Germany
Adrian Burd, USA
Zanna Chase, Australia
Jay T. Cullen, Canada
Susanne Fietz, South Africa
Tina van de Flierdt, UK
Vanessa Hatje, Brazil
Marina Kravishina, Russia

Rob Middag, Netherlands
Hajime Obata, Japan
Haojia (Abby) Ren, China-Taipei
Yeala Shaked, Israel
Kazuyo Tachikawa, France
Antonio Tovar-Sanchez, Spain
Liping Zhou, China-Beijing

The SSC membership (listed above) contains representatives of 15 different countries, with diverse expertise, including marine biogeochemistry of carbon and nutrients; trace elements and isotopes as proxies for past climate conditions; land-sea fluxes of trace elements/sediment-water interactions; trace element effects on organisms; internal cycles of the elements in the oceans; hydrothermal fluxes of trace elements; tracers of ocean circulation; tracers of contaminant transport; controls on distribution and speciation of trace elements; and ocean modelling.

2. Progress on implementation of the project

With 2 GEOTRACES Intermediate Data Products released, 111 cruises completed, 1,230 publications published (45 in high impact journals), 3 international synthesis workshops conducted and more than 40 scientific or training workshops undertaken, the GEOTRACES programme is enjoying a very successful implementation.

2.1 Status of GEOTRACES field programme

The GEOTRACES field programme continues to progress successfully. Overall 111 cruises have been completed, corresponding to 30 GEOTRACES sections (with 40 cruises), 32 process studies (with 51 cruises) and 9 compliant data sets, as well as, 11 cruises completed as a GEOTRACES contribution to the International Polar Year (IPY).

During the past year (1 April 2018 to 31 March 2019), 5 cruises have been completed. This includes 1 new section cruise from USA (with 2 cruises, see map below, section in orange) and 3 process studies from Australia, Germany and The Netherlands (see data management section below for further details).

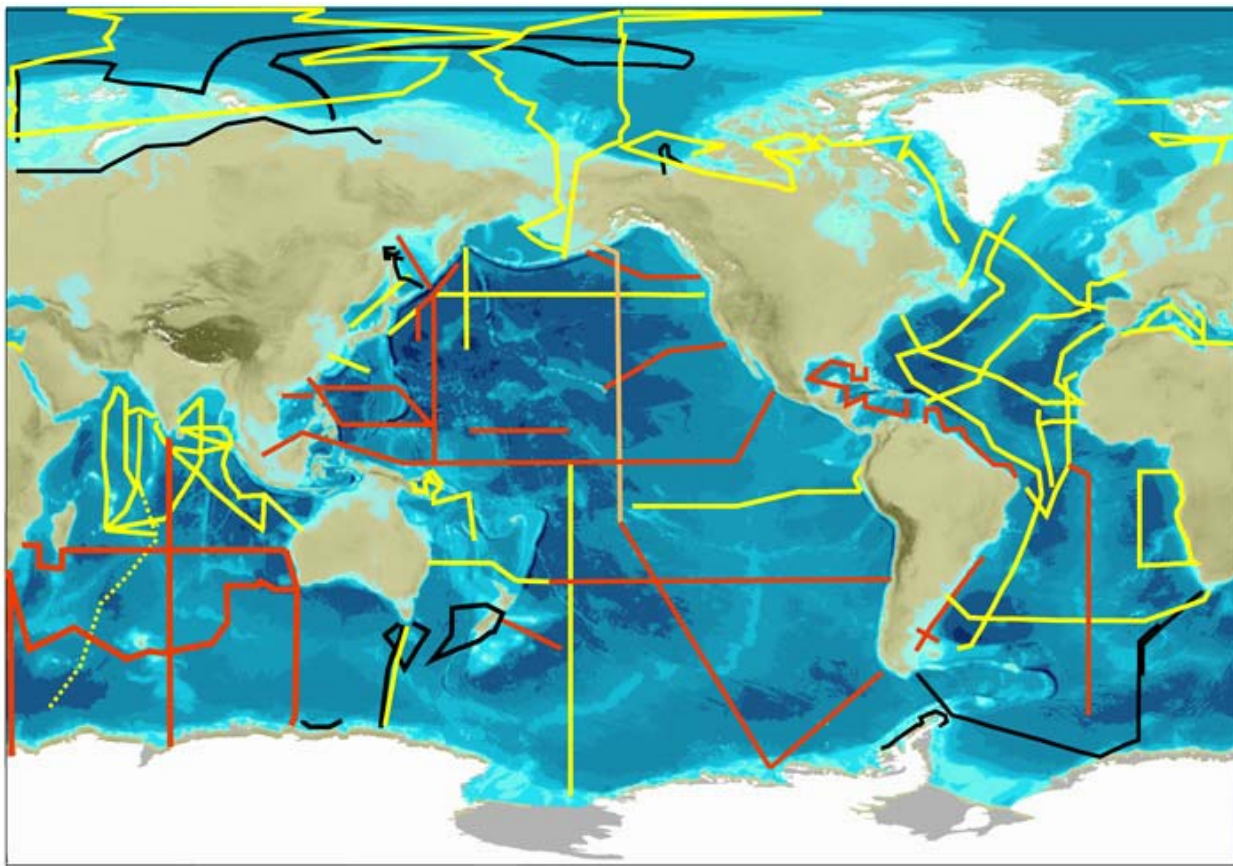


Figure 1. Status of GEOTRACES global survey of trace elements and their isotopes. In black: Sections completed as the GEOTRACES contribution to the International Polar Year. In yellow: Sections completed as part of the primary GEOTRACES global survey. In orange: Sections completed during the past year. In red: Planned Sections. An updated version of this map can be found on the GEOTRACES home page <<http://www.geotraces.org>>.

2.2 GEOTRACES Intermediate Data Products

Towards Intermediate Data Product 2021: Development of an on-line metadata portal

GEOTRACES has successfully released two Intermediate Data Products (IDP, in 2014 and in 2017, <https://www.bodc.ac.uk/geotraces/data/dp/>) with a new release planned in 2021. The number of parameters and samples compiled into the second IDP released in 2017 compared to the first was about double. This was a clear demonstration of the success of the programme, but also a sobering lesson on the resources required to accomplish this task. For this reason, GEOTRACES has decided to move to a more automated data management process to reduce the amount of work required to build the IDP. The development of an on-line metadata portal has been a major activity of the IPO, S&I, PDC and DMC committees during the reporting period. It is currently (April 2019) undergoing initial testing, and the goal is for it to be functional for data contributors to use for IDP2021. See the GEOTRACES International Project Office report for more details.

Intermediate Data Product download statistics

Overall the GEOTRACES Intermediate Data Products have been downloaded more than 2,655 times (as per March 2019). That is, the IDP2017 has been downloaded more than 1,168 times since its release in August 2017, while the IDP2014 has been downloaded 1,487 times since its release in February 2014.

2.3 **GEOTRACES Publications**

During the reporting period, 295 new peer-reviewed papers have been published. In total the GEOTRACES peer-reviewed papers database includes 1,230 publications (45 in high impact journals). This includes peer-reviewed papers that have “GEOTRACES” in either its keywords, abstract or summary, as well as publications that have been reported by the GEOTRACES national representatives in their annual activity reports and which are relevant for GEOTRACES research. PhD and Masters dissertations from GEOTRACES research are also included in the publication database.

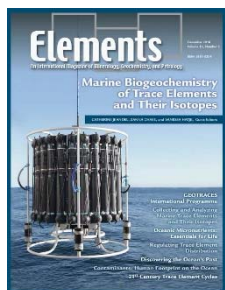
Synthesis papers

Following the GEOTRACES Synthesis of Results Strategy (<http://www.geotraces.org/science/synthesis-of-results>) launched in 2015 in partnership with other institutions and international programmes, GEOTRACES has started to produce important synthesis papers that benefit both GEOTRACES but also the broader oceanographic community. Two recent examples of synthesis papers resulting from the workshop organised jointly with the Ocean Carbon and Biogeochemistry (OCB) programme are:

- Hayes, C. T., et al. (2018), Replacement times of a spectrum of elements in the North Atlantic based on thorium supply, *Global Biogeochemical Cycles*, 32(9), 1294-1311, DOI: <https://doi.org/10.1029/2017GB005839>
- Hayes, C. T., et al. (2018), Flux of particulate elements in the North Atlantic Ocean constrained by multiple radionuclides, *Global Biogeochemical Cycles*, 32(12), 1738-1758, DOI: <https://doi.org/10.1029/2018GB005994>

Publicity documents

It is important to mention that in addition to the peer-reviewed publications, publicity articles to promote GEOTRACES are continuously published nationally and internationally. These publications are not included in the GEOTRACES publication database, but have a dedicated web page on the GEOTRACES site. An example is the volume that was published in December 2018 in *Elements Magazine* devoted to GEOTRACES research and showcasing the diverse roles that trace elements and isotopes (TEIs) play in marine biogeochemistry:



Marine Biogeochemistry of Trace Elements and Their Isotopes
Catherine Jeandel, Zanna Chase, and Vanessa Hatje - Guest Editors

<http://www.geotraces.org/news-50/news/116-news/1636-elements-magazine-geotraces>

For complete information about GEOTRACES publications please check the following web pages:

- GEOTRACES peer-reviewed papers database: <http://www.geotraces.org/library-88/scientific-publications/peer-reviewed-papers>
- GEOTRACES special issues: <http://www.geotraces.org/library-88/scientific-publications/geotraces-special-issues>
- List of GEOTRACES promotional articles: <http://www.geotraces.org/outreach/publicity-documents>

2.4 **GEOTRACES Science highlights**

The GEOTRACES International Project Office regularly generates science highlights of notable published articles, which are posted on the website (<http://www.geotraces.org/science/science-highlight>) and in the electronic eNewsletter (<http://www.geotraces.org/outreach/geotraces-enewsletter>). So far, about 200 highlights have been published. Among the numerous highlights published since last year's report, we selected the following six:

The circulation loop in the North Atlantic and Arctic oceans depicted by the artificial radionuclides

Atlantic waters have been recently recognised to play an increasing role in reducing sea-ice extent in the Arctic Ocean at a rate now comparable to losses from atmospheric thermodynamic forcing. Beyond the Arctic Ocean, the water mass transport and transformation processes in the North Atlantic Ocean substantially contribute to the Atlantic meridional overturning circulation (AMOC). Artificial radionuclides can be used as transient tracers that provide crucial information on pathways, timescales and processes of key water masses that cannot be obtained from hydrographic properties alone. In particular, radionuclides released from the two European Nuclear Reprocessing Plants, have proven to be specifically useful to trace the circulation of Atlantic waters into the Arctic and sub-Arctic oceans. Within this context, the three recent articles by Castrillejo et al. (2018), Wefing et al. (2019) and Casacuberta et al. (2018, see references below) describe the journey of the two long-lived anthropogenic radionuclides iodine-129 (^{129}I ; $T_{1/2}=15.7 \cdot 10^6\text{y}$) and uranium-236 (^{236}U ; $T_{1/2}=23.4 \cdot 10^6\text{y}$) from their sources up through the Arctic Ocean and back into the North Atlantic Ocean. Each paper corresponds to one GEOTRACES expedition that took place between 2014 and 2016 in the North Atlantic Ocean ([GA01 section](#)), Arctic Ocean ([GN04 section](#)) and Fram Strait ([GN05 section](#)). Main results show that the combination of ^{129}I and ^{236}U serves very well to identify the different Atlantic branches entering the Arctic Ocean: Barents Sea Branch Water (BSBW) and Fram Strait Branch Water (FSBW). Due to the uneven mixing of ^{129}I and ^{236}U from the two European Reprocessing Plants of Sellafield and La Hague in the North Sea, each branch brings a different $^{129}\text{I}/^{236}\text{U}$ ratio. Furthermore, this ratio allowed identifying a third Atlantic branch evolving from the Norwegian Coastal Current (NCC), which stays within the upper Polar Mixed Layer and carries a significantly larger proportion of ^{129}I and ^{236}U releases from the European reprocessing plants compared to the FSBW and the BSBW. The evolution of the NCC with a strong ^{129}I and ^{236}U signal is further observed when it returns to the Atlantic Ocean as Polar Surface Water (PSW) in the Fram Strait. This allowed estimating a transit time of 15-22 years for the PSW flowing through the Arctic Ocean. In the subpolar North Atlantic Ocean (SPNA), an increase of ^{129}I was observed in the deep overflow waters in the Labrador and Irminger Seas, confirming the major pathways of Atlantic Waters in the SPNA that were previously suggested by other authors: a short loop through the Nordic seas into the SPNA (8-10 years) and a longer one, which includes transport all the way through the Arctic Ocean (>16 years). The output of these works proves the potential of using ^{129}I and ^{236}U as a tool for investigations on the circulation within and exchanges between the Arctic and sub-Arctic Seas.

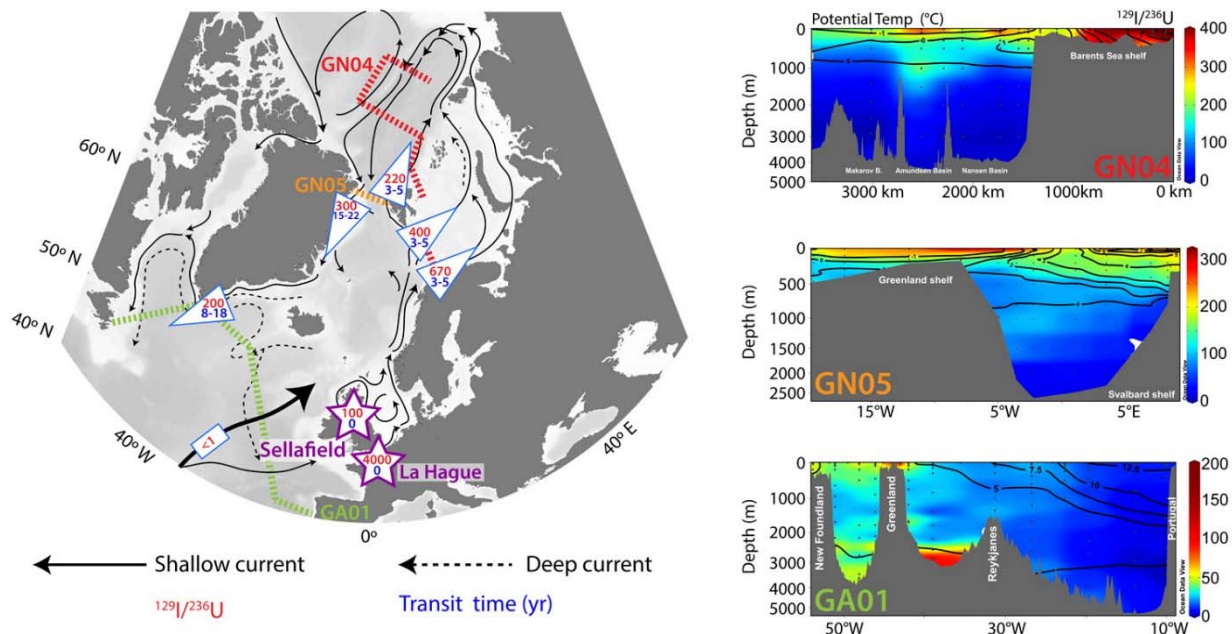


Figure 2. (Left) Map showing the main Atlantic water circulation in the North Atlantic and Arctic oceans (black arrows). Dashed lines represent the three GEOTRACES sections sampled between 2014 and 2016: North Atlantic Ocean (GA01), Arctic Ocean (GN04) and Fram Strait (GN05). Both ^{129}I and ^{236}U are released from the two European Reprocessing Plants of Sellafield and La Hague (purple stars). Blue triangles represent the $^{129}\text{I}/^{236}\text{U}$ atom ratios (in red) at sampling time and the transit time of Atlantic waters (in blue) from their source in the North Sea, to the sampling location. (Right) Section plots of $^{129}\text{I}/^{236}\text{U}$ atom ratio in the three GEOTRACES sections, with black contour lines representing potential temperature.

References:

- Casacuberta, N., Christl, M., Vockenhuber, C., Wefing, A.-M., Wacker, L., Masqué, P., Synal, H.-A., Rutgers van der Loeff, M. (2018). Tracing the Three Atlantic Branches Entering the Arctic Ocean With ^{129}I and ^{236}U . *Journal of Geophysical Research: Oceans*, 123(9), 6909–6921. DOI: <http://doi.org/10.1029/2018JC014168>
- Castrillejo, M., Casacuberta, N., Christl, M., Vockenhuber, C., Synal, H.-A., García-Ibáñez, M. I., Lherminier, P., Sarthou, G., Garcia-Orellana, J., Masqué, P. (2018). Tracing water masses with ^{129}I and ^{236}U in the subpolar North Atlantic along the GEOTRACES GA01 section. *Biogeosciences*, 15(18), 5545–5564. DOI: <http://doi.org/10.5194/bg-15-5545-2018>
- Wefing, A.-M., Christl, M., Vockenhuber, C., van der Loeff, M. R., & Casacuberta, N. (2019). Tracing Atlantic waters using ^{129}I and ^{236}U in the Fram Strait in 2016. *Journal of Geophysical Research: Oceans*. DOI: <http://doi.org/10.1029/2018JC014399>

Gulf stream eddies are fertilizing the Western Atlantic Ocean

Tim Conway and co-authors (2018, see reference below) show that Gulf Stream eddies can provide an extra supply of iron, and nutrients such as phosphate and nitrate to the iron-starved Western Atlantic Ocean. Gulf stream eddies form when the northward fast-flowing Gulf Stream meanders and pinches off coastal water, spinning these 'rings' out into the ocean. This coastal water is rich in iron. The authors used satellite and ocean datasets to show that these eddies may be just as important as dust in supplying iron to this area of the ocean!

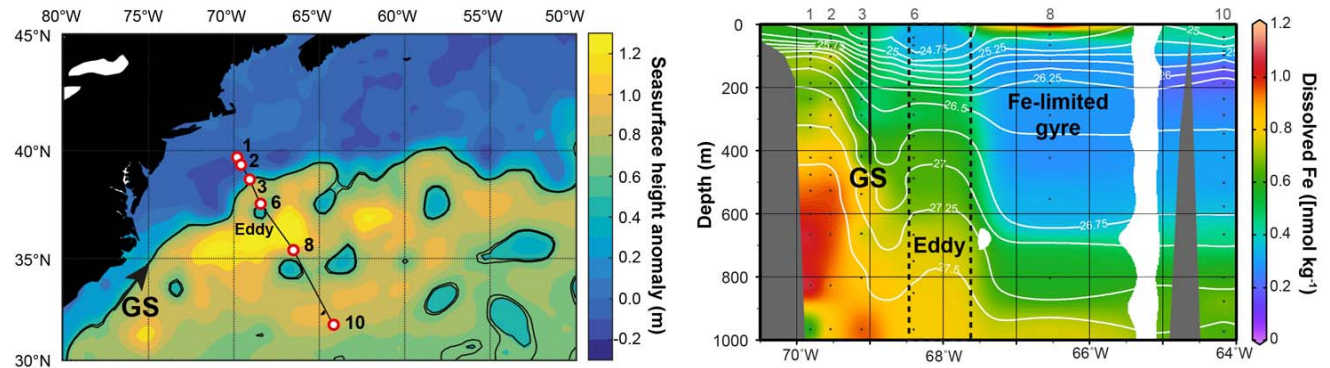


Figure 3. Cruise track (left) and dissolved iron (Fe) concentrations (right) from a North Atlantic GEOTRACES dataset (GA03). The northward flowing Gulf Stream (labelled GS) can be clearly picked out as the boundary between the coastal Slope Water which is enriched in Fe, and the open gyre which is Fe-depleted. A gulf stream eddy (labelled) was serendipitously sampled on the cruise, and can be seen as carrying a column of water enriched in Fe across the Gulf Stream and out into the gyre. The authors used this chemical dataset, together with satellite data to calculate how much iron eddies carry into the gyre each year.

Reference:

Conway, T. M., Palter, J. B., & de Souza, G. F. (2018). Gulf Stream rings as a source of iron to the North Atlantic subtropical gyre. *Nature Geoscience*, 1. DOI: <http://doi.org/10.1038/s41561-018-0162-0>

Artificial intelligence helps investigate the oceanic zinc cycle

What explains the hitherto mysterious correlation between zinc (Zn) and silicon, an element not involved in the Zn cycle?

Roshan and co-workers (2018, see reference below) used an artificial neural network (ANN, a machine learning technique inspired by biological neural systems) to produce a global climatology of dissolved Zn concentration, the first such global climatology of a trace metal. They first used an ensemble of ANNs to produce climatological maps of dissolved Zn with the same spatial resolution as the World Ocean Atlas 2013 (WOA13) and then coupled these dissolved Zn maps, and those of phosphate (PO_4^{3-}) and silicate (SiO_4^{4-}) from WOA13, to a data-constrained ocean circulation model. They then employed a restoring model to compute the biogeochemical sources and sinks of dissolved Zn, PO_4^{3-} and SiO_4^{4-} .

The main results are:

- The Zn: PO_4^{3-} uptake ratio varies by approximately tenfold across latitude and is modulated by Fe availability;
- Zn remineralizes like PO_4^{3-} in the upper ocean, but its accumulation in deep waters exceeds that of PO_4^{3-} ;
- The strong Zn- SiO_4^{4-} correlation is caused by a combination of surface uptake, desorption from particles, and hydrothermal input, and is therefore completely fortuitous.

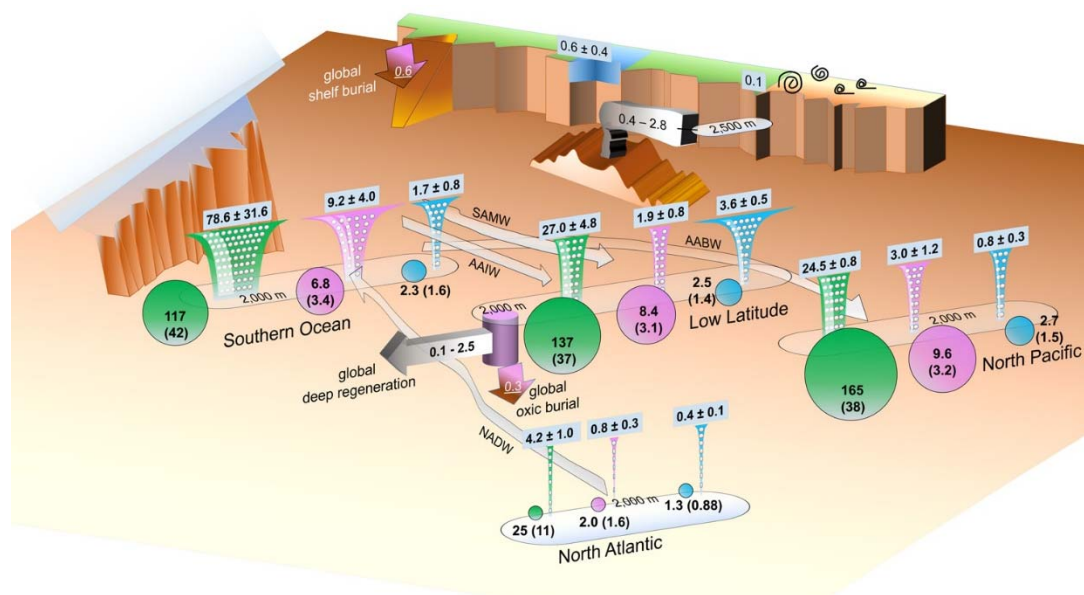


Figure 4. This schematic shows the reconstructed internal particle-associated cycling of zinc (Zn) in the ocean, as well as some recent estimates of the external sources and sinks of Zn. Funnels represent fluxes of particulate zinc (pink; in giga mol/yr), silicon (green; in tera mol/yr) and phosphorous (cyan; in tera mol/yr), which are biologically-produced in the sunlit surface ocean and exported to the subsurface. In the subsurface, the fluxes gradually attenuate due to degradation/dissolution. Particulate zinc flux attenuates quickly like particulate phosphorus, meaning that these two compounds are associated with labile soft tissues of plankton and re-enter water column at shallower depths than silicon, which is a hard-tissue compound. However, a significant amount of dissolved zinc is supplied to the deep ocean (below 2,000 m; 0.1-2.5 giga mol/yr), which is most likely resulted from a combination of seafloor hydrothermal input and desorption of the zinc ions that are passively adsorbed on the particles at shallower depths. Circles represent the mean dissolved concentrations of the above three compounds at depths below 2,000 m of different regions, which indicate that the mentioned excess input of zinc makes its deep ocean increasing trend (according to water flow arrows) more similar to silicon than phosphorous, and eventually leads to a coincidental zinc-silicon correlation in the ocean. Also annotated are some estimates of the zinc input from rivers and dust, and those of removal to deep and shelf sediments.

Reference:

Roshan, S., DeVries, T., Wu, J., & Chen, G. (2018). The Internal Cycling of Zinc in the Ocean. *Global Biogeochemical Cycles*, 32(12), 1833-1849. DOI: <http://doi.org/10.1029/2018GB006045>

Ever wonder how long your favourite element remains in the ocean before it's gone again?

This timeframe, sometimes called a residence time, ranges from decades for the most reactive trace elements to millions of years for the most unreactive elements such as the major components of sea salt. The residence time is often difficult to constrain and involves estimating how much of an element is presently in the ocean (i.e., the inventory) as well as the magnitude of the total supply rate or removal rate of the element. In the study published by Hayes and co-authors in *Global Biogeochemical Cycles* (2018, see reference below), a replacement time (or residence time with respect to supply) can be quantified using large synthesised GEOTRACES datasets from the North Atlantic which can precisely define the inventory of trace elements as well as their supply rate using radioactive tracers. In particular, their method suggests an ocean replacement for iron that is only 6 years, meaning this micronutrient element may be cycling much more quickly than previous estimates have suggested and will provide a target for ocean models to understand how this element is removed from the ocean in terms of biological uptake or abiotic scavenging.

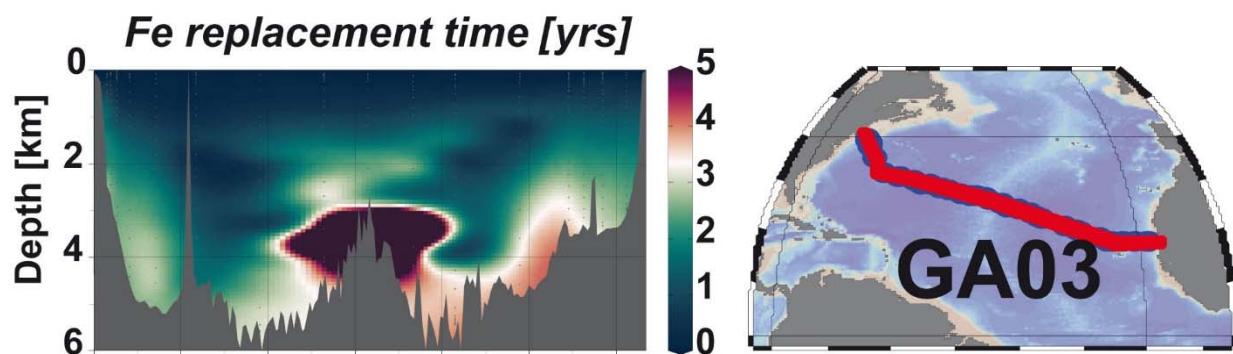


Figure 5. (Left) Replacement time of dissolved Fe across the GEOTRACES cruise section [GA03](#). This replacement time is how long it would take to replace all of the iron in the North Atlantic Ocean with a source of iron derived from the quantifiable delivery of the crustal isotope thorium-232 to the ocean. (Right) Map showing the GEOTRACES section [GA03](#) in the Atlantic Ocean.

Reference:

Hayes, C. T., Anderson, R. F., Cheng, H., Conway, T. M., Edwards, R. L., Fleisher, M. Q., Ho, P., Huang, K.-F., John, S., Landing, W.M., Little, S. H. Lu, Y., Morton, P. L., Moran, S. B., Robinson, L. F., Shelley, R. U., Shiller, A. M., Zheng, X.-Y. (2018). Replacement Times of a Spectrum of Elements in the North Atlantic Based on Thorium Supply. *Global Biogeochemical Cycles*, 32(9), 1294–1311. DOI: <http://doi.org/10.1029/2017GB005839>

[The role of melting-ice in driving the slowdown of circulation in the western Atlantic Ocean revealed by protactinium-thorium ratio](#)

Abrupt climate changes in the past have been attributed to variations in Atlantic Meridional Overturning Circulation (AMOC) strength. Knowing the exact timing and magnitude of the AMOC shift is important to understand the driving mechanism of such climate variability. After a thorough selection of 13 sediment cores, the authors show that the proxy Protactinium-231-Thorium-230 ($^{231}\text{Pa}/^{230}\text{Th}$) exhibits remarkably consistent changes both in timing and amplitude over the last 25 thousand years (kyr) in the West and deep high-latitude North Atlantic. This consistent signal reveals a spatially coherent picture of western Atlantic circulation changes over the last deglaciation, during abrupt millennial-scale climate transitions. At the onset of deglaciation, an early slowdown of circulation in the western Atlantic is observed consistent with the timing of accelerated Eurasian ice melting, followed by a persistence of this weak AMOC for another millennium, corresponding to the substantial ice rafting from the Laurentide ice sheet. This timing indicates a role for melting ice in driving a two-step AMOC slowdown. This work also emphasises that $^{231}\text{Pa}/^{230}\text{Th}$, under thorough criteria, could hold as pertinent proxy of ocean circulation.

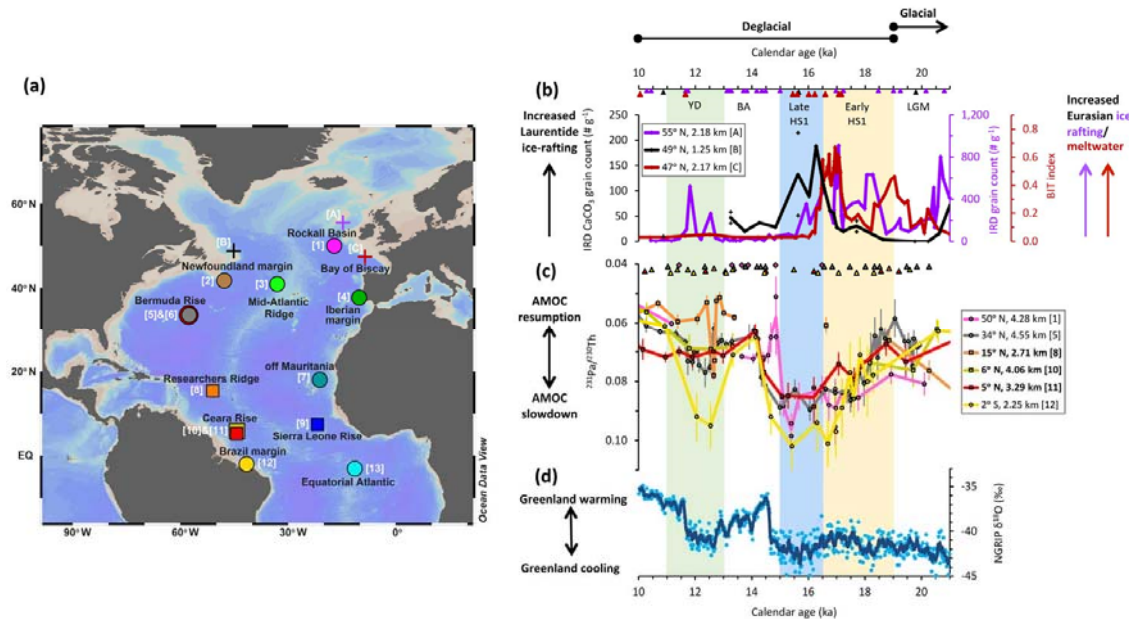


Figure 6. Use of sedimentary $^{231}\text{Pa}/^{230}\text{Th}$ to interpret changes in Atlantic Meridional Overturning Circulation (AMOC) strength and its link to climate variations over the past 25 thousand years. (a) Location map of $^{231}\text{Pa}/^{230}\text{Th}$ records [1]–[13] and ice melting proxy records [A]–[C] presented in this study, (b) North Atlantic ice rafting records (IRD) and a proxy record of Eurasian meltwater discharge (BIT index), (c) selected West and high-latitude North Atlantic $^{231}\text{Pa}/^{230}\text{Th}$ records, (d) Northern Greenland temperature proxy record. The AMOC slowdown observed (c) is consistent with the timing of an increased Eurasian ice melting (b).

Reference:

Ng, H. C., Robinson, L. F., McManus, J. F., Mohamed, K. J., Jacobel, A. W., Ivanovic, R. F., Gregoire, L. J., Chen, T. (2018). Coherent deglacial changes in western Atlantic Ocean circulation. *Nature Communications*, 9(1), 2947. DOI: <http://doi.org/10.1038/s41467-018-05312->

52 years of benthic nepheloid layer data!

A data base of 2412 profiles collected using the Lamont Thorndike nephelometer from 1964 to 1984 is used to globally map turbid nepheloid layers by Gardner and co-workers (2018, see reference below). The authors compare maps from that period with maps based on data from 6392 profiles measured using transmissometers from 1979 to 2016. Beyond this comparison, the final goal is to gain insight about the factors creating/sustaining Benthic Nepheloid Layers (BNLs). Eleven maps, including mean surface Kinetic Energy (KE), are discussed here. The similarity between general locations of high and low particle concentration BNLs during the two time periods indicates that the driving forces of erosion and resuspension of bottom sediments are spatially persistent during recent decadal time spans, though in areas of strong BNLs, intensity is highly episodic. This work confirms that topography, well-developed current systems, and surface KE and EKE play a role in generating and maintaining BNLs.

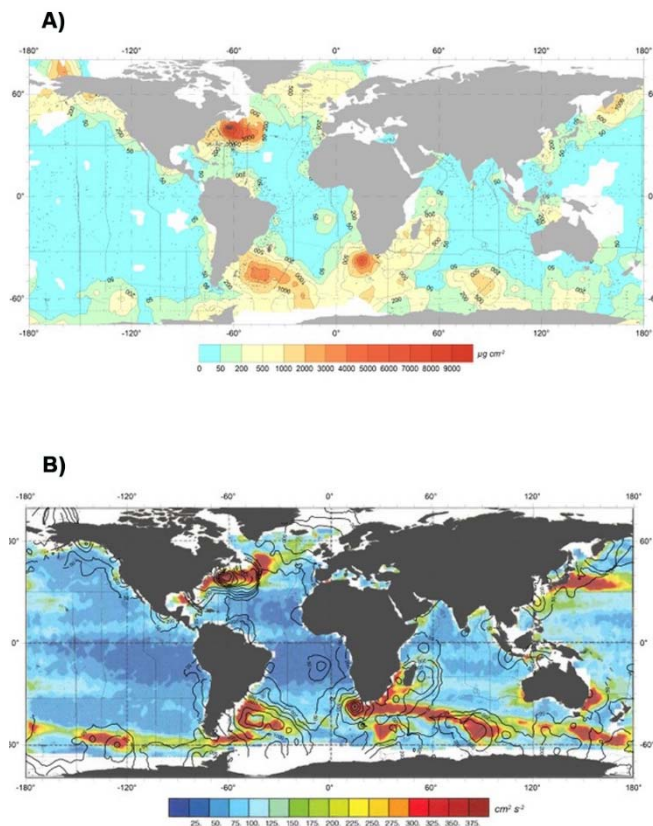


Figure 7. A) Excess particulate matter in “strong” nepheloid layers ($> 20 \mu\text{g l}^{-1}$) based on transmissometer (cp) and nephelometer (E/ED) profiles. B) Mean Kinetic Energy per unit mass, $\text{cm}^2 \text{s}^{-2}$, in surface waters, derived from four years of satellite altimetric data and using the geostrophic relationship (adapted from Wunsch, 2015). Black contours superimposed are Excess particulate matter in “strong” nepheloid layers ($> 20 \mu\text{g l}^{-1}$ from Figure A).

Reference:

Gardner, W. D., Richardson, M. J., Mishonov, A. V., & Biscaye, P. E. (2018). Global comparison of benthic nepheloid layers based on 52 years of nephelometer and transmissometer measurements. *Progress in Oceanography*, 168(May), 100–111. DOI: <http://doi.org/10.1016/j.poccean.2018.09.008>

3. Activities

3.1 GEOTRACES intercalibration activities

The Standards & Intercalibration (S&I) Committee has welcomed four new members: Ana Aguilar-Islas from the University of Alaska Fairbanks, Yoshiko Kondo from Technology Nagasaki University, Peter Sedwick from Old Dominion University, and Alyson Santoro from University of Santa Barbara.

The complete S&I Committee is currently composed of Ana Aguilar-Islas, Karen Casciotti, Tina van de Flierdt, Walter Geibert, Lars-Eric Heimbürger-Boavida, Yoshiko Kondo, Maeve Lohan, Hélène Planquette, Peter Sedwick and Alyson Santoro. Maeve Lohan and Walter Geibert serve as co-chairs. The committee met in person on 6th and 7th December 2018 in Marseille, hosted by Lars-Eric Heimbürger-Boavida.

The focus for the past reporting period was almost completely shifted away from the intercalibration of datasets towards the preparation of our procedures for the upcoming intermediate data product, implementing improvements

of the S&I report submission procedure together with the data management committee and the International Project Office. The main focus has been on the development of an on-line portal system for analysts to submit their data to be calibrated. This system will track all the data and the permissions for future IDP's. This involved the participation of the S&I co-chairs at a DMC meeting in Liverpool (17-18 April 2018) and in Toulouse on 24-26 September for the IDP data portal meeting.

During the S&I-meeting in December 2019, a key task was the introduction of the new committee members to the existing intercalibration procedures for labs, cruise data sets and materials. The existing procedures for the submission of intercalibration reports to S&I and the subsequent review and approval were discussed in detail, before agreeing on suggestions how these procedures should be reflected in the data submission portal. The S&I committee produced a template for the portal whereby an analyst will download a form with a series of questions to be answered that will act as the intercalibration report. The analyst will then upload this back through the portal.

S&I has already received a significant number of intercalibration reports in the previous report-style IDP2017 format and approved 4 datasets for IDP 2021.

Laboratory Intercomparisons & Consensus Materials:

The status and progress on several initiatives to produce consensus materials and lab intercomparisons is reported below:

Sea ice:

Ana Aguilar-Islas and Peter Sedwick led a successful exercise on trace metals in sea-ice, comparing sampling equipment and processing intercalibration and exploring ways to produce consensus materials, including artificial sea-ice. They are still awaiting results from one other group but the results look promising.

Seawater Consensus materials:

For the seawater consensus materials GSC and GSP, material has been sent out to a number of labs, 18 of which have reported back for GSP and 16 for GSC. Consensus values for this material are under development, and a request for reporting data to Jim Moffett is published on the GEOTRACES web page. Overall the data look good for most laboratories and we have enough data for consensus values for Cd, Cu, Fe, Mn, Ni and Pb but awaiting more data for Co and Al. The S&I committee are working with Jim Moffett on establishing the best way to assign errors on the data and we hope the consensus values will be on the GEOTRACES web page soon.

An additional consensus material for seawater (CAP) has been collected by E. Achterberg and C. Schlosser during GA08 in the Cape Basin. To date only 4 laboratories have reported back with their results, so S&I are encouraging more laboratories to report results for this material before consensus values can be published. The GEOTRACES web page will be updated to encourage more people to submit data and to analyse this material.

Leachable Particulate data:

Hélène Planquette led an exercise for comparing results for the Berger marine particle leach protocol for which five of seven labs had reported results by 7th December 2018.

Next Meeting:

The next meeting for the following reporting period is scheduled for 12/13 June 2019 in Norfolk, Virginia, hosted by Peter Sedwick. It is hoped that a test run of the portal submission process can be undertaken and assessed by the S&I.

3.2 Data management for GEOTRACES

The GEOTRACES Data Assembly Centre (GDAC) is hosted by the British Oceanography Data Centre (BODC), with the head office located in Liverpool; Dr Mohamed Adjou, the GEOTRACES Data Manager, is based at Liverpool BODC office. He is assisted by Donna Cockwell from the Southampton BODC office. GDAC benefits from additional BODC expertise when work cases require it.

GDAC is responsible for the entirety of the GEOTRACES data activities from reception to completion. This takes into account the following components:

- Interaction between PIs and national data centres in order to encourage regular and timely data/ metadata submissions;
- Maintaining and modifying GDAC web pages to include updated ocean basin maps (http://www.bodc.ac.uk/geotraces/cruises/section_maps/) and upcoming cruises on the programme page (<http://www.bodc.ac.uk/geotraces/cruises/programme/>);
- Liaising with the Data Management Committee and Standards and Intercalibration Committee to ensure issues/questions relating to GEOTRACES and its progress can be discussed, and deadlines can be met accordingly;
- Input of metadata and data into the BODC database and compilation of documentation to include analysis methodologies;
- Preparing for future data reception at GDAC under the recommendation of the Data Management Committee;
- Collation of data and metadata for the future IDP; and
- Answering requests from GEOTRACES community and assisting on IDP download and use for all kind of users.

This year, GDAC would like to highlight and report on the following tasks:

Cooperation with the IPO

The IPO is in permanent contact with GDAC in order to have an up-to-date cruise inventory as displayed on the GDAC website. IPO is also assisting GDAC by sending reminders to respect time-scheduled tasks.

GDAC website updates

All basin maps have been updated. The update of the GDAC website maps was not considered as a priority task during the IDP publication year, under intense data processing work at GDAC.

DMC and SSC meetings

The DMC meeting (Liverpool, April 2018) and SSC meeting (Taipei, July 2018) were occasions for Mohamed to meet most of the key GEOTRACES participants and country representatives.

The DMC meeting was one month after Mohamed took on the post of GEOTRACES data manager. Discussions focused on data quality control of IDP2017 and future IDP, as well as the control of datasets submission workflow and how to track the data sets approved by S&I and author permission. During the SSC, the following points, among others, were addressed under GDAC perspectives:

1. Information and highlights on version 2 of the IDP2017
2. A comparison/ interpretation of version 1 and version 2 IDP2017 download statistics.
3. A GDAC website report
4. Proposing a new methodology to improve data quality checking and reporting.
5. Suggesting SeaDataNet flags to have a broader range of data quality flagging possibilities.
6. Proposing a proofreading step by the scientists to enable them to check the final version of their data in the IDP.

Contribution to GEOTRACES metadata portal effort

Although GDAC is not in charge of the development and the future deployment of GEOTRACES metadata portal, GDAC contributed in defining the functional requirement of such web portal (GEOTRACES Metadata Portal

meeting, 25-26 September in Toulouse, France). One of the major tasks assigned to GDAC from Toulouse meeting was to review the list of cruise identifiers, GEOTRACES cruise names and aliases, and find a way to standardise these different labels in order to avoid using free-text for cruise names in the metadata portal. This list was established and circulated in a spreadsheet, as a first step, to the Toulouse meeting participants. GDAC is working on providing this standardised cruise list through a webservice enabling “real-time” updates to be distributed instantly.

Liaison with national data centres

National marine data centres (BCO-DMO, CYBER-LEFE and NIOZ) in charge of supplying GDAC with GEOTRACES data were contacted and short work visits are scheduled for the upcoming months of this year. GDAC also hosted Yanping Xu from Xiamen University (China) in November 2018 for a week-long training session on GEOTRACES data management prior to China’s first GEOTRACES section cruise (GP09).

Data and cruise metadata overview

This year is a post IDP publication year and only a few datasets were submitted to GDAC. The next DMC and SSC meetings, expected in September 2019, will communicate on the future IDP2021 and this will encourage people to submit their data to GDAC.

Summary of GEOTRACES cruises, which have taken place in the period April 2018-April 2019:

Cruise	Chief scientist	GEOTRACES scientist	Type	Period	Location
PS117 (GApr12)	Boebel Olaf	Middag Rob	Process Study	2018-12-15 — 2019-02-07	Zero meridian towards continent (Lazarev Sea) & Weddell Sea
RR1815 (GP15 Leg2, PMT)	Cutter G, Casciotti K & Lam P	Cutter Gregory, Casciotti Karen & Lam Phoebe	Section Cruise	2018-10-24 — 2018-11-24	Pacific Ocean
RR1814 (GP15 Leg1, PMT)	Cutter G, Casciotti K & Lam P	Cutter Gregory, Casciotti Karen & Lam Phoebe	Section Cruise	2018-09-18 — 2018-10-22	Pacific Ocean
IN2018_V04 (GIpr13)	Michael Ellwood	Michael Ellwood	Process Study	2018-09-11 — 2018-10-08	East Australian Current
M147 (AMAZON-GEOTRACES, GApr11)	Frank Martin	Frank Martin	Process Study	2018-04-19 — 2018-05-21	Amazon estuary & the associated plume

Summary of GEOTRACES cruises to take place in May 2019-April 2020:

Cruise	Chief scientist	GEOTRACES scientist	Type	Period	Location
TONGA (GPpr14)	Guieu Cecile & Bonnet Sophie	Géraldine Sarthou, Matthieu Bressac & Hélène Planquette	Process Study	2019-10-31 — 2019-12-06	Western Tropical South Pacific
KK1902 (GP09)	Cai Yihua & Zhou Kuanbo	Zhimian Cao, Minhan Dai & Liping Zhou	Section Cruise	2019-04-25 — 2019-06-10	North West Pacific

IN2019_V02 (GIpr08 bis)	Trull Tom	Boyd Phillip	Process Study	2019-03-12 — 2019-04-05	Southern Ocean (East Indian sector)
BAIT* (GApr13)	Rod Johnson	Peter Sedwick	Process Study	2019-03* — 2020-03*	Sargasso Sea (BATS site)

(*) BAIT project will cover several cruises on-board of the RVs Endeavor or Atlantic Explorer. The first cruise 'EN631' will take place during the period 2019-03-10 —2019-03-15. During the period 2019-05-01 —2020-04-30 four other cruises are planned (cruise IDs and dates not yet known).

In summary

This year, during the calm data submission period, the main task at GDAC was to review and improve data processing, with a special attention to data QC. The collection and processing of data to be included in the IDP2021 will be the focal point of GDAC's data activities over the coming year, as DMC and SCC are expected to communicate on IDP2021 at the Hobart meeting (September 2019).

The workflow of data processing and tracking will benefit from the on-going developments of the GEOTRACES IDP portal. Meanwhile at GDAC, a new controlled data processing workflow will be launched in close consultation with S&I and DMC.

We continue to provide useful information on GDAC web pages for scientists and answer questions related to data and metadata submission through our GDAC email (geotraces.dac@bodc.ac.uk). We encourage the GEOTRACES community to contact GDAC for any question about their data or metadata submission.

3.3 GEOTRACES International Project Office

The GEOTRACES International Project Office (IPO) is based at the Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS) in Toulouse, France. The IPO is staffed by a single person, the IPO Executive Officer, Elena Masferrer Dodas. She works under the scientific supervision of Catherine Jeandel (CNRS, LEGOS, France).

The IPO is responsible for:

- assisting the Scientific Steering Committee (SSC) in implementing the GEOTRACES Science Plan and implementation plans of the programme;
- organising and staffing meetings of the SSC, working groups and task teams;
- liaising with the sponsors and other relevant organisations;
- seeking and managing programme finances;
- representing the project at international meetings;
- maintaining the project website and Facebook and Twitter pages;
- maintaining the project mailing lists;
- preparing GEOTRACES science highlights and the bimonthly GEOTRACES eNewsletter;
- maintaining the GEOTRACES publications database and the GEOTRACES Scientists Analytical Expertise Database;
- assisting the GDAC in securing information about upcoming cruises; and
- interacting with GEOTRACES national committees and groups, as well as other international projects.

This year, we want to highlight the following activities:

- On-line GEOTRACES metadata portal

An important activity conducted this year by the IPO is supporting the development of an on-line GEOTRACES metadata portal. Following the success of the GEOTRACES Intermediate Data Products, the amount of data to be reviewed, managed and processed has increased considerably. In order to facilitate

the tasks of the core group of persons working on the construction of the product (co-chairs of S&I, DMC, PNC, GDAC, IPO and Reiner Schlitzer), this group met in Liverpool in April 2018 on a joint DMC and GEOTRACES Executive meeting to review the lessons learned from the IDP2017 and to propose to the SSC the creation of an on-line GEOTRACES metadata portal that should allow: (1) a major participation of the data contributors in directly filling in the information necessary for the evaluation and management of their data into the portal, (2) a quick and easy access to this information for all people involved in the construction of the product, (3) a more automatic management of these data to allow easier updating and evaluation. The SCC approved the development of this portal to be charged to Guillaume Brissebrat (head) and Arnaud Mière (IT) from the Observatory Midi-Pyrénées Data Center (SEDOO, Toulouse, where the IPO is hosted), particularly as they have already successfully worked with the IPO in developing the GEOTRACES publication database. In September 2018, the IPO organised a working meeting with Guillaume and the IDP core group in order to define the structure and functional requirements of the portal (GEOTRACES Data Portal meeting, 25-26 September 2018, Toulouse, France). The IPO contributed to this meeting by proposing a working document defining a possible structure for the portal. Following the meeting, the IPO is assisting the developers (Guillaume and Arnaud) in providing input when needed, chasing the information from GEOTRACES senior scientists and pushing developers to get the portal done in time. Regular meetings between the IPO and the SEDOO (every two weeks) are held.

- GEOTRACES Publications Database (<<http://www.geotraces.org/library-88/scientific-publications/peer-reviewed-papers>>)
New search functionalities have been added to the database. For instance, it is now possible to make more complex searches equivalent to using operators such as “AND”, “OR” and “NOT”.
- Guide for cruise PI (<<http://www.geotraces.org/cruises/cruise-summary/cruise-guide>>)
The IPO has developed an interactive flow chart to guide cruise leaders on the overall process from getting their cruise designated as a GEOTRACES cruise or compliant data until the data resulting from the cruise is included in the IDP. A derived guide (short version) is also available for cruise leaders to distribute to cruise participants to guide them on the process to get their data in the IDP (<<http://www.geotraces.org/dp/submit-data/flow-chart>>).
- GEOTRACES Best Practices (<<http://www.geotraces.org/about-us/geotraces-policies/geotraces-best-practices>>)
The IPO has published a list of best practices for GEOTRACES researchers with the objective of (1) informing scientists on the actions needed in order that the IPO can properly broadcast their GEOTRACES scientific results and activities and (2) reinforce the information on the process to get the cruise data included in the IDP. The best practice list covers the following topics: data: cruise information; scientific publications; special sessions and issues; outreach and educational materials and activities; national events and activities; and networking.
- New GEOTRACES Programme Brochure
A new GEOTRACES brochure presenting the GEOTRACES programme along as the Intermediate Data Product is being developed.
- GEOTRACES website (<<http://www.geotraces.org>>)
The main menu bar of the GEOTRACES website has been improved in order to simplify the access to the intermediate data product and GDAC web site resources. During the 2018 SSC, the IPO distributed a survey to SSC members asking for feedback and suggestions for improvement. Ninety per cent of the respondents found the web site well organised and have no suggestions for improvement. The main proposal for amelioration is to enhance the search engine. In the coming reporting period, the IPO plans to undertake a major overhaul of the web site that will imply moving the web site from Joomla! to WordPress. All the suggestions received will be taken into account during this process.

We want to thank Olivier Boebion (IT system administrator at Observatoire Océanologique de Villefranche sur Mer, France) for all his technical assistance with the GEOTRACES web site.

- GEOTRACES Science Highlight keyword search cloud
The IPO has now published almost 200 science highlights on the GEOTRACES web site. In order to improve the search functionality, the IPO is currently working on setting up a GEOTRACES Science Highlight keyword cloud that will allow for users to click on a keyword and get a list of science highlights corresponding to the keyword selected. This functionality will be available on the new GEOTRACES web site.
- Logistics for meetings
The IPO has hosted the GEOTRACES Data Portal Meeting (25-27 September 2018) and has provided assistance in the organization of the GEOTRACES Data Management Meeting (April 2018, Liverpool, UK), the GEOTRACES SSC Meeting (July 2018, Taiwan), the GEOTRACES-PAGES Workshop (November 2018, Aix-Marseille, France) and the GEOTRACES S&I meeting (November 2018, Marseille, France).
- Some statistics
36 new highlights published (191 in total)
6 eNewsletters published, including one special issue (bimonthly 33 in total)
295 new peer-reviewed papers included in the GEOTRACES Publication Database (1230 in total)
108 new articles published on the GEOTRACES website
72 new announcements sent through the GEOTRACES mailing list
546 likes in Facebook (top post reached 1.6K)
780 likes and 1,007 followers (top tweet reached 3.1K)
157 new subscribers on the GEOTRACES mailing list

Featured outreach activity: Float Your Boat Project



The 2015 US Arctic GEOTRACES initiative participated in a novel outreach project coordinated with Dave Forcucci (US Coast Guard Marine Science Coordinator) to involve students and the public with an Arctic research cruise on the *US Coast Guard ice-breaker Healy*. GEOTRACES was a perfect match for the inaugural kick off of "Float your Boat" <

<https://www.facebook.com/explorethearctic/> >. Over one thousand 8-inch (20-cm) long cedar boats were commissioned (funded by the National Science Foundation) from the Center for Wooden Boats (CWB.org) in Seattle, WA and distributed to school groups, scout troops, and science open-house events around the country. Students personalized their boats with bright colours and after returning to Seattle the boats were branded with floatboat.org and packed into the hold of the Healy for the journey to the North Pole. During the GEOTRACES cruise, four groups of boats were deployed on ice floes between 87.5 N and 80 N on the 150 W meridian, each with a small satellite buoy

(deployed by the University of Washington Applied Physics Laboratory to study ice movement). The iridium satellite-linked buoys provided an opportunistic chance for high resolution, real-time tracking of the boats for about a year and a half. After drifting with the Arctic ice, it was hoped that the boats would eventually be freed from its grasp and float to a distant shore to be discovered and reported. This project is described by our teacher-at-sea, Bill Schmoker, at <https://www.polartrec.com/expeditions/us-arctic-geotraces/journals/2015-09-16> and by Prof. Timothy Kenna, the scientist who was in charge of deploying the boats: <https://blogs.ei.columbia.edu/2015/09/21/arctic-magic-one-research-vessel-multiplies-to-hundreds/>.

In October 2018, three years after deployment, one of these small wooden boats was found by a gentleman in Iceland, Bolli Thor (in the picture). He wrote: "These are the coordinates 63.962285, -22.734055 where I found one of your little wooden boats, near small town called Sandgerði in Iceland where I live. I found it at my favorite spot, where I usually walk with my dog called Tyra." Remarkably, we identified the pre-deployment picture, the student and school (Upper Nyack Elementary School).

The drift track data stopped in February, 2017. Two groups of boats ran aground in northern Canada, while two groups, deployed near the N. Pole, were entrained in the Trans Polar drift and travelled south, through Fram Strait, into the E. Greenland Current. A boat from these groups made it to Iceland.

3.4 GEOTRACES Workshops

A list of completed or planned GEOTRACES Workshops is available below:

GEOTRACES Taiwan Training Workshop, 26 July 2018, Taipei, China-Taipei

A GEOTRACES-Taiwan training workshop was organised the day immediately after the SSC meeting in Taipei. The workshop was organised by Tung-Yuan Ho (Academia Sinica) and attended by 62 participants from Taiwan. GEOTRACES lectures were given by 8 SSC members (Phoebe Lam, Andy Bowie, Maeve Lohan, Hajime Obata, Reiner Schlitzer, William Landing and Tung-Yuan Ho) included topics such as GEOTRACES and IDP2017 introduction; Seawater trace metal clean sampling and pre-treatment; particle sampling and analysis; TEIs on-board sampling and FIA&CSV analysis; Ocean Data View and marine biogeochemistry. The workshop was followed by a fruitful debate between GEOTRACES international scientists and local scientists.

For further information please visit the GEOTRACES web page:

<http://www.geotraces.org/images/stories/documents/workshops/2018-GEOTRACES-Workshop-Info.pdf>

Introduction to the Awesome OCIM, 12 August 2018, Boston, USA

A workshop to introduce Awesome OCIM (OA), a new modeling toolbox designed to bring cutting-edge transport matrix models to a wide community of users, was held in August in Boston in the vicinity of the Goldschmidt 2018 meeting. The AO uses Ocean Circulation Inverse Model (OCIM) transport for realistic global 3D circulation. Within this circulation, broad features of the distribution of many marine TEIs can be achieved by combining just a few processes. For example, iron might be modeled as a combination of atmospheric and sedimentary sources, biological uptake, and remineralization. Thorium might be modeled with radioactive production and decay, plus scavenging. A clickable interface allows the user to include processes such as these, and tune their magnitude to match observed GEOTRACES data. Further adjustments to biogeochemical cycling can be achieved with changes to the underlying Matlab code.

For further information please visit the GEOTRACES web page: <http://www.geotraces.org/meetings/meetings-by-year/eventdetail/331/-/introduction-to-the-awesome-ocim>

GEOTRACES-PAGES Synthesis workshop: Trace Element and Isotope Proxies in Paleoceanography, 3 - 5 December 2018, Aix-Marseille, France

60 researchers from the PAGES and GEOTRACES communities participated to an intensive 2.5 day workshop from the 3rd to the 5th of December in Aix en Provence, France. The aim of the workshop was to conduct open discussions on the applicability and scientific gaps regarding the use of some proxies exploited to infer past circulation, surface productivity and particle fluxes. Indeed, thanks to the GEOTRACES programme, these tracers are more and more documented in the modern ocean, raising important caveats in the understanding of their present behaviour and distributions. Fruitful confrontations and discussions conducted the two communities to identify common exciting perspectives and workshop products.

Further information is available at the workshop web page: <https://geotracespages.sciencesconf.org/>



Figure 8. Participants at the Joint GEOTRACES PAGES Workshop.

Biogeosciences Workshop, 8-10 November 2018, Johnsson Center, Woods Hole, USA

In November 2018, approximately 28 international scientists from the fields of chemical oceanography, omics, physiology and modeling met to explore the need and scope of a new international programme loosely aimed around coupling the potential insight onto ocean ecosystems from new advances from different fields (primarily arising from the Tara Oceans and GEOTRACES efforts). The meeting was sponsored by the Scientific Commission on Ocean Research, the Ocean Carbon and Biogeochemistry programme and the Moore Foundation. Four invited speakers highlighted the insight and added value gained from integrating observations of micronutrients and omics. Reflection on previous programmes identified the importance of intercalibration and data management, and the need for omics intercalibration efforts and investment in novel data management and open access, user-friendly platforms. Equally, the need for new ecosystem modelling approaches, capable of integrating the mechanisms and feedbacks emerging from omics datasets was noted. Time was spent discussing the potential extent and impact of a new program, as well as choosing Biogeosciences as the name. The role of different types of contributions from different nations, including the routes to funding Biogeosciences activities were discussed, and the overall outcome of the meeting is summarised in the broad mission statement above. This preliminary broad mission of Biogeosciences will be improved by further input and feedback from the international community. It is anticipated that feedback from the wider community will occur first via national meetings during 2019 and then in a larger international forum, which would shape the preliminary science plan in much more detail.

For further information please visit: www.biogeosciences.org

BioGEOTRACES-Japan begins, 19-21 September 2018, Nagasaki, Japan

A workshop, entitled "BioGEOTRACES-Japan begins" was held on 19-21 September 2018 in Nagasaki, Japan to evaluate the potentials of biological studies related to trace elements and their isotopes (TEI) in the ocean, and to find the future directions of these studies in Japan. For three days, 15 registered Japanese scientists took part in the workshop. Drs. Maria Maldonado (University of British Columbia, Vancouver) and Tung-Yuan Ho (Academia Sinica, Taipei) were invited as guest speakers. The workshop consisted of 3 invited talks, 3 keynote talks and 11 research topics related to GEOTRACES & BioGEOTRACES. During the workshop, recent scientific findings, and possible future collaborations among TEI chemists, biologists and modellers were discussed. It was decided to organise the BioGEOTRACES-Japan in order to promote these comprehensive studies and cooperate with the international community.

7th Kaplan Symposium: Tracers in the Sea: Trace Elements and their Isotopes in the Oceans, Future Directions and Instrumental Frontiers, 11-13 February 2019, Eilat, Israel

The 7th Kaplan Symposium was dedicated to GEOTRACES research with the title “Tracers in the Sea: Trace Elements and their Isotopes in the Oceans, Future Directions and Instrumental Frontiers”. The workshop counted with the participation of 72 scientists and it was organised by Adi Torfstein and Yeala Shaked at the Institute of Earth Sciences of the Hebrew University of Jerusalem. The symposium had 4 scientific themes: trace element cycling in seawater and marine particulates; the role of atmospheric dust in marine biogeochemistry; novel isotope systems in the oceans; and instrumental developments in marine geochemistry. It counted with several GEOTRACES senior scientists as invited speakers including: Eric Achterberg, GEOMAR, Germany; Mark Altabet, U Massachusetts Dartmouth, USA; Bob Anderson, Lamont-Doherty Earth Observatory, Columbia University, USA; Gideon Henderson, Oxford University, UK; Catherine Jeandel, LEGOS, University of Toulouse, France; William Landing, Florida State University, USA; Claire Rollion-Bard, Institut de Physique du Globe de Paris, France; and Derek Vance, ETH, Switzerland.

For further information please visit the symposium web site: <https://sites.google.com/view/7th-kaplan-symposium/home>

3.5 GEOTRACES Summer School

The second GEOTRACES Summer School will be held from 23 to 28 September 2019 in Cadiz, Spain. It aims at teaching the skills and knowledge necessary for a good understanding of the biogeochemical cycles of trace metals. It will bring together 36 students and 10 world-leading international scientists.

Particular objectives of the summer school are:

- Gaining knowledge and experience on oceanographic sampling campaigns for collection of samples for the analysis of trace metals.
- Students should be capable to properly select and conduct analytical strategies for the study of trace metals in marine samples.
- Gaining knowledge on bio-geochemical cycles of metals in the ocean and their speciation.
- Data management to analyse the role of trace metals in the ocean.

The summer school is organised by the International GEOTRACES programme, the University of Cádiz (UCA), the Andalusian Institute of Marine Sciences of the Spanish National Research Council (ICMAN-CSIC), and the International Campus of Excellence of the Sea (CEI-MAR); with funding from the Scientific Committee on Oceanic Research (SCOR)/GEOTRACES, the General CSIC Foundation, the International Doctorate School of Marine Studies (EIDEMAR), and CEI-MAR.

For further information please visit the Summer School web site: <https://geotraces.uca.es/>

3.6 Special sessions at international conferences featuring GEOTRACES findings

Several GEOTRACES special sessions were held or are planned in major international conferences including:

Association for the Sciences of Limnology and Oceanography (ASLO) 2018 Summer Meeting, 10 -15 June 2018, Victoria, BC, Canada

For further information: <https://aslo.org/victoria2018/main>

GEOTRACES-related session: □

*SS82: Emerging Models of Trace Metal Bioavailability to Aquatic Organisms

Conveners: David Semeniuk, Randelle Bundy and Anne Cremazy

Goldschmidt 2018, 12- 17 August 2018, Boston, USA

For further information: <https://goldschmidt.info/2018/index>

GEOTRACES session:

*Session 07i: New Insights in Marine Trace Element Biogeochemistry

Conveners: Christian Schlosser, Florian Scholz, Rene Boiteau, Tim Conway, Daniel Ohnemus, Jennifer McKay, William Homoky and Jessica Fitzsimmons

Fourth Xiamen Symposium on Marine Environmental Sciences (XMAS), 6-9 January 2019, Xiamen China

For further information: <http://mel.xmu.edu.cn/conference/4xmas>

GEOTRACES session:

*The role of trace metals in controlling structure and function of microbial communities in contemporary oceans

Conveners: Punyasloke Bhadury, Yeala Shaked, Maria Maldonado, Yihua Cai and Chris Bowler

ASLO 2019, Aquatic Sciences Meeting, 23 February - 2 March 2019, San Juan, Puerto Rico

For further information: <https://aslo.org/sanjuan2019/main>

GEOTRACES session:

*SS51. New views on the biological transformation of metals in the marine environment

Conveners: Randelle Bundy, Shane Hogle, Katherine Heal, Kristen Buck and P. Dreux Chappell

Forthcoming:

SOLAS Open Science Conference, 21-25 April 2019, Sapporo, Japan

For further information: <https://www.confmanager.com/main.cfm?cid=2778>

GEOTRACES session:

*Atmospheric deposition of iron, ocean biogeochemistry and marine emission of biological aerosols

Conveners: Akinori Ito (JAMSTEC), William M. Landing (Florida State University) and Douglas S. Hamilton (Cornell University)

27th IUGG General Assembly, 8-18 July, 2019, Palais des Congrès in Montréal, Québec, Canada

GEOTRACES relevant sessions:

*P02 Physics and biogeochemistry of semi-enclosed, shelf seas and coastal zones

Conveners: Peter Zavialov, Jianping Gan, Osmar Moller Jr, Katrin Schroeder

*P09 Marine biogeochemistry through time: nutrient, trace metal, oxygen, and carbon cycling in the past, present and future

Conveners: Kate Hendry, Zanna Chase, Katja Fennel and Patrick Rafter

Goldschmidt 2019, 18-23 August 2019, Barcelona

For further information: <https://goldschmidt.info/2019/>

GEOTRACES or GEOTRACES-related sessions:

*10c: Arctic and sub-Arctic Large Scale Ocean Processes: What can We Learn from Tracers?

Conveners: Núria Casacuberta, Michael Karcher

*10j: Biogeochemical Cycles of Low Oxygen Zones and their Response to Ocean Deoxygenation

Conveners: Nicole Bale, Darci Rush, Ruifang Xie, Tim Conway, Insa Rapp, Laura Bristow

*10k: Trace Metal Cycling and Radioisotope Tracers of Ocean Biogeochemistry (GEOTRACES)

Conveners: Aridane G. González, Hannah Whitby, Amber Annett, Emilie Le Roy

*08j: Dynamics and Fluxes of the Exogenic Carbon Cycle and Interactions with Biogeochemical Cycling

Conveners: Gerhard Kuhn, Norbert Frank, Thomas Chalk, William Gray

Keynote: Robert Anderson

*10a: Linking Marine Silicate Alteration to Carbon Cycle and Trace Elements Budgets in the Ocean and Sediment

Conveners: Wei-Li Hong, Jianghui Du, Antoine Crémière

Keynote: Catherine Jeandel

*10h: The Oceanic Particle Flux and its Cycling within the Deep Water Column

Conveners: Maureen Conte, Rut Pedrosa Pamies, Phoebe Lam, Henry Ruhl

*12a: Hydrobiogeochemical Processes at the Sediment-Water Interface: Wetlands, River Corridors and Coastal Zones

Conveners: Dipankar Dwivedi, Xingyuan Chen, Joseph Tamborski, Valentí Rodellas, Edward O'Loughlin, Yamin Deng, Virginie Sanial

Keynote: Christof Meile

*13e: Radionuclides in the Environment: Modeling, Experimental, Scaling, Controlling Chemical/Microbial/Hydrological Processes

Conveners: Peter H. Santschi, Daniel Kaplan

*13f: Trace Elements Speciation: Novel Methodologies and Insights into Transformations Influencing their Global Biogeochemical Cycle

Conveners: Sylvain Bouchet, Adrien Mestrot

3.7 Capacity building

Activities It is a GEOTRACES strategy to organise training workshops the day or the two-days immediately after a SSC meeting in order to increase the local impact of these meetings (e.g. the GEOTRACES-Taiwan training workshop held in July 2019, see GEOTRACES Workshops above for further details). In this sense the capacity building benefits are considered at the time of selecting the host of the meeting. During the training workshops selected SSC members give lectures, along with local scientists, to national scientist and students. Note that SSC meetings are also an occasion for a fruitful exchange with local scientists and often-parallel scientific meetings are organised during the breaks all along the SSC meeting.

Travel Grants GEOTRACES has requested support from SCOR to enable scientists from developing countries and countries with economies in transition to participate in the second GEOTRACES Summer School.

Sampling Systems It is a goal of GEOTRACES that every nation carrying out oceanographic research should have access to a trace metal-clean sampling system. GEOTRACES offers guidance based on past experience in the design and construction of sampling systems, as well as advice in operating these systems as shared facilities. At the time of writing this review, a document “Recommendations for nations developing a trace metal-clean sampling system” is being prepared by Greg Cutter (Old Dominion University, past S&I co-chair). This document will

summarise the lessons learned during past guidance experiences and it will be of great resource for other countries wishing to develop trace metal-clean sampling. This document will be available on the GEOTRACES Capacity Building web page <http://www.geotraces.org/science/geotraces-activities>.

An updated status of trace metal-clean sampling systems to support GEOTRACES research is provided in the table below. Scientists interested in developing one of these systems for their own use are encouraged to contact the GEOTRACES IPO or any member of the SSC, who will arrange for contact with an appropriate person to provide technical information about the design, construction and cost of a system.

Nation	Status	System/ Carousel	Bottles	Depth
Australia (Australia National University)	Complete	Powder coated aluminium, autonomous 1018 intelligent rosette system (General Oceanics)	12 x 10-L Teflon-lined Niskin-1010X (General Oceanics)	6000 m; 6 mm Dynex rope
Australia (Marine National Facility)	Complete	Polyurethane powder-coated aluminium autonomous Seabird rosette with CTD and other sensors, auto-fire module, and all titanium housings and fittings	12 x 12-L Teflon-lined OTE external-spring Niskin-style bottles	1750 m 9mm Dyneema rope or 200 m 6 mm Dyneema rope wth coupling to 6000 m CTD wire
Australia (Marine National Facility)	Complete (backup system)	Polyurethane powder-coated aluminium autonomous Seabird rosette with CTD and other sensors, auto-fire module, and all titanium housings and fittings	12 x 12-L Teflon-lined OTE external-spring Niskin-style bottles	1750 m 9mm Dyneema rope or 200 m 6 mm Dyneema rope wth coupling to 6000 m CTD wire
Brazil	Complete	GEOTRACES WATER SAMPLER - 24-bottle sampler for use with modem equipped 911plus CTD	24 X 12-L GO-Flo	3000 m; Kevlar cable
Canada	Complete	Powder coated aluminium with titanium CTD housing, Seabird Rosette	24 X 12-L GO-Flo	5000 m conducting Vectran
China - Beijing	Complete	Seabird Rosette. Powder coated aluminium with titanium pressure housings and fittings	24 x 12-L OTE GO-Flo; 24 X 12-L Teflon-lined Niskin-X	8000 m; conducting Kevlar
China - Taipei	Complete	Teflon coated rosette	Multi- size GO-Flo	3000 m; Kevlar line
France	Complete	Powder coated aluminium with titanium pressure housing for CTD	24 X 12-L GO-Flo	8000 m; conducting Kevlar
Germany	Complete	Powder coated aluminium with titanium pressure housings and fittings	27 x 12-L OTE GO-Flo	8000 m; conducting Kevlar
India	Complete	Powder coated aluminum with titanium pressure housings and fittings	24 X 12-L Niskin-X	8000 m; conducting Kevlar
Israel	Complete	Powder coated aluminium, SeaBird Rosette	12 X 12-L Niskin; 8 X 12-L GO-Flo (Teflon coated)	2000 m, steel conducting cable
Italy	Complete	Go-Flo bottles on Kevlar line	5 x 20-L Go-Flos	Kevlar
Japan	Complete	Powder coated aluminium	12-L Niskin-X	7000 m; Vectran conducting Cable
Netherlands	Complete	Titanium frame	24 X 24-liter ultraclean polypropylene	10000 m; conducting Kevlar* <i>*There is only one cable</i>

				<i>for the two systems</i>
Netherlands	Complete	Titanium frame	24 X 24-liter ultraclean PVDF	10000 m; conducting Kevlar* <i>*There is only one cable for the two systems</i>
New Zealand	Complete	Powder coated aluminium	13 X 5-L Teflon-lined Niskin-X; 13 X 5GO-Flo	4000 m; 8 mm Kevlar line
Norway	In development	Standard 12 positions CTD Rosette GO	5-L Niskin-X	
Poland	Complete * (although the steel cable)	Powder coated aluminum, SeaBird Rosette	8x 10L GoFlo	3000m, steel conducting cable
Poland	Complete	Single bottle	10l G-FLO X Teflon coated	300m Kevlar
Poland	Complete	Teflon pump on-line	Surface water pump	1.5m fixed
Poland	In development	Pump CTD	Teflon hose 10mm	Up to 200m
Russia	Complete * (although the steel cable)	Powder coated aluminium, SeaBird Rosette SBE9p occupied CTD SBE 9+	24 × 12-L Niskin bottles	4000 m, steel conducting cable
Russia	In development (by 2021–2024)	Powder coated aluminium, SeaBird Rosette and all titanium housings and fittings	GO-FLO, Niskin-X, 24 × 12-L	10000 m, conducting Kevlar
South Africa	Complete	Powder coated aluminium, titanium housing/fittings	24 X 12-liter GO-Flo	6500 m; Kevlar cable
South Korea	Complete	Titanium frame	24 × 12L PVDF	10,000 m; conducting Kevlar
UK	Complete	2 x Titanium frame, Ti pressure housings	24 10-L OTE 24 10-L OTE	2 x 8000m conducting Kevlar
USA - CLIVAR	Complete	Powder coated aluminium	12 X 12-L GO-Flo	1500 m; conducting Kevlar
USA - GEOTRACES	Complete	Powder coated aluminium with titanium pressure housings and fittings	24 X 12-L GO-Flo	8000 m; conducting Kevlar
USA- University of Alaska Fairbanks	Complete	Seabird Rosette. Powder coated aluminium with Ti parts and pressure housing. Fires at pre-programmable depths	12 X 5-L Teflon-lined Niskin-X	No Kevlar line available yet.
USA- Old Dominion University	Complete	Seabird Rosette. SBE-19plusV2 CTD unit. Powder coated aluminium with Ti parts and pressure housing. Fires at pre-programmable depths	12 X 5-L Teflon-lined Niskin-X	2000 m 0.5-inch Kevlar wire
USA – Polar	Complete	Powder coated aluminium with	12 X12-L	3000 m; conducting

Programs		titanium pressure housings and fittings	Niskin-X	Kevlar
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4. Plans for the coming year

Towards Intermediate Data Product 2021

The development of the web based metadata portal will continue over the next reporting period with the goal for it to be functional for data contributors to use for the IDP2021. GEOTRACES hopes that this data portal will not only smooth the production of the remaining intermediate and final data products for the GEOTRACES programme, but will provide a data management framework for future programmes.

Also, having completed over half of the global survey (Figure 1) GEOTRACES plans to continue to advance the GEOTRACES field programme through section cruises (with one section cruise from China scheduled so far for next reporting period), supplemented by process studies (3 already planned for next year) that have investigated particular physical, chemical, and biological processes regulating the distributions of these TEIs.

Capacity building through GEOTRACES Summer Schools

Following the successful GEOTRACES Summer School organised in August 2017 in Brest, France, GEOTRACES has decided to organise GEOTRACES summer schools every two years. GEOTRACES is currently preparing the second summer school to be held in September 2019 in Cadiz, Spain as reported previously. The third GEOTRACES summer school is already planned to be held in 2021 in Germany.

In addition, a workshop “Southern Ocean Biogeochemistry in a Changing World” will be held in Hobart, Australia, on 12-13 September 2019, immediately after the 2019 SSC meeting. The workshop will bring together national and international GEOTRACES scientists as well as local students and researchers in biogeochemical oceanography, modelling and paleoceanography focused on the Southern Ocean’s response to climate change.

Scientific workshops

The following scientific meetings will be organised:

Regional and Basin Workshops:

A fourth East Asia GEOTRACES Workshop will be organised in Xiamen in fall 2019 (initially planned for early 2019). This workshop will continue collaboration advanced by the third East Asia Workshop (16-18 January 2017, Sapporo, Hokkaido, Japan) where a first picture of the current status of the studies in the Northwestern Pacific Ocean (NWPO) was completed and important scientific questions and directions for regional collaborative studies defined.

Future synthesis of results workshops:

GEOTRACES plans to continue its synthesis efforts initiated by the suite of three synthesis workshops (in 2015, 2016 and 2018, <http://www.geotraces.org/science/synthesis-of-results>) by organising a synthesis workshop on sensitivity to trace elements and isotopes cycles to global change to be held in 2021 (tentatively) in Germany. This workshop will combine new knowledge gained from GEOTRACES with the latest models of TEIs. The workshop should also continue the efforts in bringing together the observational and modelling communities fostered by the three Data-Model Synergy Workshops that GEOTRACES organised in 2007, 2009 and 2011. In any case, the synthesis will continue to respond to the expectation that GEOTRACES results benefit other oceanographic disciplines.

Biogeosciences effort

GEOTRACES investigators and the IPO will provide advice and recommendations, as appropriate, to help launch this new programme as needed.

Acknowledgements

Once more, we wish to express our gratitude to SCOR and Ed Urban for the continuous support and valuable advice generously given to help with the implementation of the GEOTRACES programme.

Written and compiled by:

Elena Masferrer Dodas (GEOTRACES IPO Executive Officer)

Catherine Jeandel (GEOTRACES IPO Science Director)

Andrew Bowie and Phoebe Lam (Co-Chairs GEOTRACES SSC)

Bob Anderson, Gideon Henderson and Reiner Schlitzer (Past GEOTRACES SSC Co-chairs)

Maeve Lohan and Walter Geibert (Co-Chairs of the GEOTRACES S&I Committee)

Alessandro Tagliabue and Bill Landing (Co-Chairs of the GEOTRACES DMC Committee)

Mohamed Adjou (GEOTRACES Data Manager)

May 2019

Appendix 8
International Quiet Ocean Experiment (IQOE)



IQOE News #3
August 2019

Endorsed projects (7): ADEON, JOMOPANS, JONAS, PHYSIC, QUIETMED2, SanctSound, TANGO

Publications in Aquatic Acoustic Archive: 4,689

IQOE Email List: 209

IQOE Co-founder Knighted

IQOE co-founder Ian Boyd was knighted at the 2019 Queen's Birthday Honors in June 2019 "for services to Science and Economics on Food and the Environment" and for his "visionary leadership in his role as Chief Scientific Advisor at DEFRA", the UK Department for Environment, Food and Rural Affairs. Congratulations, Sir Ian!

ECO Magazine Special Issue on Underwater Sound

IQOE sponsored development of a [special issue](#) of *ECO Magazine* focused on ocean sound. This issue is a well-balanced presentation of the issues related to sound in the ocean, with excellent articles on science, technology, management, and the environment. This publication will be helpful for public outreach related to IQOE. The embedded sounds from the ocean from DOSITS (<https://dosits.org/>) should be especially helpful to attract public interest to the issue of sound in the ocean.

IQOE Data Office

The Alfred Wegener Institute in Bremerhaven, Germany has recently announced that it is seeking one data scientist and one data engineer to develop a data system for ocean acoustics data. These individuals will work with the IQOE Working Group on Data Management and Access and Working Group on Standardization to implement their terms of reference. Advertisements for these positions are available at [Data Scientist](#) and [Data Engineer](#). The deadline for applications is 31 August 2019. Please contact [Olaf Boebel](#) if you have questions.

OceanObs'19

IQOE Science Committee members Jennifer Miksis-Olds and Hanne Sagen teamed with Bruce Howe, Eric Rehm, Peter F. Worcester, and Georgios Haralabus to produce a community white paper for OceanObs'19 entitled "[Observing the Oceans Acoustically](#)". This paper combines information about the use of both passive and active acoustics to study the global ocean. The paper has been published in *Frontiers in Marine Science*.

IQOE and the IQOE WG on Arctic Acoustic Ecosystems have submitted abstracts for posters to be presented at the meeting.

Please let [Ed Urban](#) know if you will be attending OceanObs'19. We are hoping for a good showing of people interested in observations of acoustics and bioacoustics in the ocean, and may plan some acoustics-focused event.

Ocean Sound Essential Ocean Variable (EOV)

The Biology and Ecosystems Panel of the Global Ocean Observing System (GOOS) has adopted an [Ocean Sound EOV](#), under the responsibility of IQOE. An IQOE Panel supported by the Partnership for Observation of the Global Ocean (POGO) proposed this EOV and created the specification sheet. IQOE and GOOS are discussing next steps to progress this EOV, including the potential for an implementation meeting in the coming year.

News from Endorsed Projects

JOMOPANS: Joint Monitoring Programme for Ambient Noise North Sea

Contributed by Niels Kinneging: “Jomopans implements a monitoring strategy for continuous sound in the North Sea. The project responds to requirements of the European Marine Strategy Framework Directive, but the resulting data will also be available for the wider community of underwater sound specialists.

The second year of Jomopans is crucial for the project. All activities are now in full swing and Jomopans scientists are enthusiastically working on the results. Most of the 14 measurement stations around the North Sea are now operational and data will be gathered for all seasons in 2019. In addition, the first soundscape maps are being produced through propagation modelling.

In the first half of 2019, the development of the GES Tool resulted in great progress. Michael Carder Ltd. was contracted to build the tool and in a very animated workshop the functionality of the tool was further detailed. After a short delay in 2018, the tool is now on track again.

Apart from the technical developments, the future use of Jomopans results is being discussed with the marine managers of all participating countries. In this way, the results can be adapted to the needs of the marine managers and the system can be made operational shortly after the project's end.

Jomopans participated in the Aquatic Noise conference in The Hague from 7 to 12 July and organized (in co-operation with IQOE) two workshops on monitoring underwater sound on 13 July, also in The Hague.

On 8 October, the Jomopans Midterm event will be held in London. This will be an opportunity to meet the Jomopans team, discuss the progress of Jomopans, the connection with other projects and learn more about sound in the sea. More information can be found shortly in our [newsletter](#) and on the Jomopans website (www.northsearegion.eu/jomopans).”

PHYSIC: Ports, Humpbacks, Y Soundscapes In Colombia

Contributed by Kerri Seger: “During the month of May, two students at Javeriana University in Bogota continued data analysis to assemble time series of sound sources at the Morro Mico site. These students also submitted an abstract to the Senalmar conference in Barranquilla, Colombia, in October to practice their presentation skills and take ownership over processing cyclical sound comparisons in the dataset. Also during the month of May, Dr. Kerri Seger (PHYSiC PI) processed the Ecological Acoustic Recorder (EAR) sound samples as power spectral density percentiles. A diel cycle in humpback whale singing activity, with nighttime peaks, was easily discernible. Boat passes were only detectable in the 99th percentile, confirming expectations that this environment is relatively pristine compared with many other passive acoustic monitoring sites in more disturbed areas of the world, where boat engine noise occurs in lower percentiles more often. These results have been requested by numerous local councils and university groups writing a manifesto to petition the Colombian government not to proceed with port construction. These results were also disseminated at the Acoustical Society of America conference in Louisville, Kentucky, with Dr. Chris Verlinden presenting on the behalf of Dr. Seger, who was unable to attend. Journalists and filming agencies from the UK and Colombia have asked for statements about the soundscape of the Gulf of Tribugá during the last few weeks. Planning for the 2019 season began in May 2019.”

quietMED2

QUIETMED2: Joint programme for GES assessment on Descriptor 11-noise in the Mediterranean Marine Region (2019-2021)

The IQOE Science Committee approved endorsement of QUIETMED2 in May 2019. This project will support implementation of the second cycle of the European Union's Marine Strategy Framework Directive (MSFD). QUIETMED2 will assess the extent to which Good Environmental Status (GES) on underwater noise has been achieved in the Mediterranean Region. "The project will help implement this GES standard through

- i) a joint proposal of a candidate for an impulsive noise indicator in the Mediterranean Region;
- ii) a common methodology for Competent Authorities to establish threshold values on impulsive noise in the Mediterranean region;
- iii) a data and information tool to support the implementation of the monitoring programs of impact of impulsive noise based on the current joint impulsive noise register developed under QUIETMED project, which will be demonstrated on
- iv) an operational pilot of the tool; and
- v) several activities to boost regional cooperation efforts of the Barcelona Convention." (from endorsement proposal)"

The QUIETMED2 consortium is made up of 11 entities from 8 EU Member States (Spain, Italy, Malta, Greece, Cyprus, Croatia, Slovenia and Denmark) and is linked to the Barcelona Convention (UNEP/MAP) and to other Conventions as OSPAR and HELCOM. This project will help all EU Member States cooperate in the Mediterranean Marine Region to implement the next 6-year cycle of MSFD requirements. See <http://quietmed2.eu/>.

SanctSound: NOAA Navy Sanctuary Soundscape Monitoring Project

IQOE approved endorsement of SanctSound in June 2019. From the SanctSound endorsement application: "The U.S. National Oceanic and Atmospheric Administration (NOAA) and the U.S. Navy are engaged in a multi-year effort to monitor underwater sound within the U.S. National Marine Sanctuary System. The agencies are working with numerous scientific partners to study sound within 7 national marine sanctuaries and one marine national monument, in waters off the east coast region of the United States (Stellwagen Bank, Gray's Reef and Florida Keys National Marine Sanctuaries), the west coast region (Olympic Coast, Monterey Bay and Channel Islands National Marine Sanctuaries) and the Pacific region (Hawaiian Islands Humpback Whale National Marine Sanctuary and Papahānaumokuākea Marine National Monument). The project is designed to provide standardized baseline information as a context to understand both how much sound is introduced within these protected areas by specific sources and potential impacts to the areas' marine taxa and habitats."

Get your project endorsed

IQOE would like to endorse any research project or observation activities that are relevant to IQOE. Information about the endorsement process and endorsed projects can be found at <http://www.iqoe.org/projects>. The benefits of endorsement include increased international visibility of endorsed projects, which are usually national or regional, and the potential for joint activities with other endorsed projects and with other IQOE-involved scientists

Changes in the IQOE Website

- A link was added to the passive acoustic data from the MBARI MARS Cabled Observatory (see <https://iqoe.org/acoustic-data-portal>). The system provides access to hourly spectrograms from the Monterey Bay area collected since August 2015. More information about the system and its purpose can be found at <https://www.mbari.org/technology/solving-challenges/persistent-presence/mars-hydrophone/>.
- Information has been added to the Endorsed Projects page for the two newly endorsed projects, [QUIETMED2](#) and [SanctSound](#).
- The terms of reference and membership of the Working Group on Marine Bioacoustical Standardization were approved by the IQOE Science Committee and this information was added to the IQOE Web site (see <https://www.iqoe.org/groups/marine-bioacoustical-standardization>).

We still need help from the community to do the following (send update information to Ed Urban at ed.urban@scor-int.org):

- update the database of passive acoustic observatories (<https://iqoe.org/systems>),
- submit IQOE-relevant papers for the IQOE literature database (<https://iqoe.org/library>)
- submit entries for the portal to acoustic data (<https://iqoe.org/acoustic-data-portal>)
- submit entries for the portal to marine animal sounds (<https://iqoe.org/marine-animal-sounds>), and
- submit projects for endorsement.

WG Progress

IQOE established four working groups in 2016 and one in 2019:

- [*WG on Acoustic Measurement of Ocean Biodiversity Hotspots*](#) (chaired by Aran Mooney, USA): A subset of the group (Lucia Di Iorio, Mark Lammers, Aran Mooney, Miles Parsons, Craig Radford, and Jenni Stanley) met in The Netherlands on 13 June to finalize a review paper and discuss other aspects of the group's future work. The paper will summarize the advantages and challenges of measuring biodiversity using passive acoustic methods and will provide a framework for future research. This is one of the primary tasks of the working group. The group also discussed membership changes and affirmed its terms of reference. Participants discussed and outlined future projects that the team can work on together, including a multi-site experiment measuring the same parameters in different parts of the world with comparable methods, maybe even with the same equipment. Finally, the group discussed multiple funding options for future projects and working group meetings, and several white papers, which will be the group's goal after the framework manuscript is submitted.



Meeting of Acoustic Measurement of Ocean Biodiversity Hotspots WG in The Hague

- [*WG on Arctic Acoustic Environment*](#) (co-chaired by Hanne Sagen, Norway and Philippe Blondel, UK): The group met for the first time in Paris, France on 29-30 January 2019 and identified actions to implement the

group's terms of reference. The group was represented at the [UACE2019 Conference](#) by Philippe Blondel and will be represented at [OceanObs'19](#) by Hanne Sagen.

- IQOE and the IQOE-endorsed Jomopans project (see earlier) co-sponsored concurrent workshops on “Guidelines for observation of ocean sound” and on “Monitoring continuous underwater sound – beyond acquisition” on 13 June 2019 in The Hague, Netherlands. These workshops were held on the day after Aquatic Noise 2019 and contributed to the work of the IQOE [WG on Data Management and Access](#) (chaired by Rob McCauley, Australia) and [WG on Standardization](#) (co-chaired by Christ de Jong and Michael Ainslie, Netherlands).

For the workshop on “Guidelines for observation of ocean sound”, the organizers collected, analyzed, and summarized information about existing guidelines for measuring, processing, reporting, and managing ocean sound data from various national and international projects. The organizers presented results of the collated information at the workshop, including suggestions for standardized guidelines, for discussion with the participants. Organizers will report on the discussions of the workshop in a document that will provide guidelines where consensus could be achieved and describing the obstacles to reaching further consensus. After review by workshop participants and the IQOE WG on Standardization, the final report will be published on the IQOE website.

The purpose of the workshop on “Monitoring continuous underwater sound – beyond acquisition” was to discuss the requirements for data management, sharing and to find solutions for best possible harmonisation. Workshop participants developed the following declaration.

Declaration from the workshop

The participants of the workshop “Monitoring continuous underwater sound: beyond acquisition” state that the sharing of knowledge and data in the field of underwater acoustics is essential to progress in the scientific field as well as on the management of underwater sound. Measured and modelled data, and corresponding metadata, including the processing pathways, should be stored with the highest resolution possible in an easy-to-find repository.

Long-term international co-operation needs to be established and supported in order to realize an operational framework for sharing and disseminating acoustical raw and/or processed data from monitoring programmes.



Meeting of IQOE WGs on WG on Data Management and Access and WG on Standardization in The Hague

- The IQOE [WG on Marine Bioacoustical Standardization](#) was approved in June 2019 and held its kick-off meeting at the Park Hotel in The Hague on 13 July 2019. Chaired by Michele Halvorsen (USA) and Michael Ainslie (Netherlands), its present membership comprises Tomonari Akamatsu (Japan), Rebecca Dunlop (Australia), Dorian Houser (USA), Robert McCauley (Australia), Sander von Benda-Beckmann (Netherlands), and Paul Wensveen (Iceland). The purpose of this group is to increase comparability of results from different locations and institutions by promoting standardization in the field of marine bioacoustics. After the terms of reference are in place, the group's first task will be to develop an inventory of existing standards.



Meeting of Marine Bioacoustical Standardization WG in The Hague

National/Regional Activities

Canada

The MERIDIAN Underwater Acoustic Data Discovery Portal

Contributed by Ines Hessler: “Have you ever thought about how convenient it would be if a platform existed that enables you to find available and well-described underwater acoustic data that you may want to assess for its suitability to support your research, advance the project you are currently working on, or simply get an overview of other acoustic datasets available in your region of interest?”

If you quietly answered yes to the above question, be assured that such platform will be available soon! We at [MERIDIAN](#) (Marine Environmental Research Infrastructure for Data Integration and Application Network), a Canada Foundation for Innovation funded national CyberInfrastructure project, are currently in the process of building a data discovery portal that will provide you with the opportunity to discover available underwater acoustic resources and contribute rich descriptions of your own datasets. The interface of the discovery layer will allow for web-based searching by keywords, geographical extent and other attributes. To contribute descriptions of your individual datasets (aka metadata) we are developing a web-based and user-friendly metadata submission form. For larger collections we offer direct harvesting of information using common information exchange protocols such as CSW (Catalog Service for the Web) and OAI-PMH (Open Archives Initiative Protocol for Metadata Harvesting). We are currently in the process of testing the discovery portal and its workflows, initially internally but soon with a selected number of community members. We are aiming at completing testing and feedback implementation in the course of the coming few months and will, hopefully, be able to make the discovery service's prototype available

later in the year. For further information and inquiries don't hesitate to send an email to meridian@dal.ca.”

United Kingdom

The [Underwater Sound Forum](#) held a [Bioacoustics Conference](#) on 17-18 April 2019.

USA

- The [U.S. Quiet Ocean Project](#) held a data “standards” workshop on 6-7 August 2018 in Washington, D.C. and has released a report from the workshop on [Recommendations Related to Passive Ocean Acoustic Data Standards](#).
- The U.S. SanctSound project was endorsed by IQOE.
- The U.S. Office of Naval Research issued a Broad Agency Announcement in 2018 to respond to research areas of interest to Task Force Ocean. White papers were due on 31 January 2019. The funded research that will result is likely to stimulate ocean acoustics research and support for graduate students and post-doctoral fellows in the United States in the next several years.
- As a direct result of IQOE discussions, passive acoustic monitoring was added to the [Stones Mooring in the Gulf of Mexico](#), funded by the funded by U.S. Gulf Research Program and Shell. The first results are being analyzed.

IQOE Email List: IQOE maintains an email list containing your first name, surname, and email address. We do not collect or store any additional information or share our email list with other organizations. If you wish to unsubscribe from the IQOE email list at any time, please click the “Unsubscribe” link at the bottom of this page.

Upcoming Meetings—New meetings have been added to the [calendar of IQOE-relevant events](#).

Appendix 9

Second International Indian Ocean Expedition (IIOE-2)

IIOE-2 Annual Report 2019 for SCOR

Executive Reporter: Peter Burkill²²

Our understanding of the complex processes in the Indian Ocean is improving year-on-year but still remains rudimentary in many respects. This is largely because modern research capabilities are only now being applied to the Indian Ocean, which still remains relatively under-sampled in both space and time. The Indian Ocean is a dynamically complex and highly variable system under monsoonal influence and, we now realise, is fundamental in oceanic and coupled climatic Earth system inter-connections with all the other major oceans. The recent Indian Ocean Observing System (IndOOS) Decadal Review re-affirmed this with for example: recent studies suggesting that the Indian Ocean has stored in the order of 60% of the global oceanic heat uptake from the atmosphere over the last two decades while it is also home to 30% of the world's coral reefs and 13% of global wild-catch fisheries.

Recent impacts of IIOE-2

GLOBAL CLIMATE: Through the integrated IIOE-2 programme, we now realise how central the Indian Ocean is to the control of our global climate. The southern Indian Ocean is warming faster than any other part of the global ocean: twice the rate of the Pacific and some 50% faster than the Atlantic. Marine Heat Waves, having profound biophysical impacts, have been identified in the past few years. The focus is now shifting to understanding the mechanisms involved in the Indian Ocean's warming. There are at least two hypotheses that need to be investigated. First, the Indonesian throughflow from the Pacific has increased, bringing more warm Pacific water into the Indian Ocean. Second, the westerly winds over the equatorial Indian Ocean are becoming stronger, strengthening the downwelling conditions, leading to the warming of the upper ocean. The latter is linked to Madden-Julian Oscillations (see below) and the Indian Ocean Dipole, which itself has 'teleconnections' with Pacific Ocean met-ocean processes. With more than 40% of the world's population living in countries prone to cyclones, floods and droughts bordering the Indian Ocean, it is a study with far reaching consequences. It is vital to understand how the climate affects people and their livelihoods.

BUILDING RESEARCH CAPACITY IN THE INDIAN OCEAN REGION: This is central to all the sponsors missions and is addressed through a variety of means. The first IIOE-2 cruise set the scene by offering 50% of berths to scientists of other nations. Following IIOE-2 cruises have offered berths to other nations. SCOR has also responded by given preference in choosing scientists from nations around the Indian Ocean for some of its capacity building activities.

SUPPORTING SUSTAINABLE DEVELOPMENT: IIOE-2 endorsed initiatives link science and socio-economic analysis to inform policy-making across the Indian Ocean region. For instance, the new £8M UK/SA collaborative project Sustainable Oceans, Livelihoods and food Security Through Increased Capacity in Ecosystem research in The Western Indian Ocean (SOLSTICE–WIO) is just one example.

IMPROVING MONSOON PREDICTION: The IIOE-2-endorsed Bay of Bengal Boundary Layer Experiment (BoBBLE) has revealed new knowledge on factors regulating monsoonal variability and its implications for ocean ecosystems and the billions of people affected by the monsoons. This knowledge is critical for securing water sources and sustaining agricultural economies.

MADDEN-JULIAN OSCILLATION (MJO): The MJO is a little understood tropical weather phenomenon involving intense winds that blow over a small area of the eastern Indian Ocean. As a result, during the

²²With thanks to Raleigh Hood, Hermann Bange and Nick d'Adamo for input.

months of December to April, the Indian Ocean routinely gains or loses ~three trillion tons of water from the Pacific

Ocean every ~30 to 80 days accompanied by a sea level rise or fall of ~4cm. This accounts for ~ 30% of the total sea-level change during the period. Not only does this influence the heat budget but it also influences the polar motion of the Earth and the length of the day, the variability of which is of utmost importance to the accuracy of the Global Positioning System (GPS). This research was published in Nature Communications in a paper entitled: Basin-wide Sea Level Coherency in the Tropical Indian Ocean Driven by Madden-Julian Oscillation. (Rohith et al. <https://www.nature.com/articles/s41467-019-09243-5>)

Peer-reviewed Publications (this does not include the JMS and AOS publication list which is not yet available).

- Al-Yamani, F, and S.W.A. Naqvi. Chemical oceanography of the Arabian Gulf. 2019. *Deep-Sea Research Part II* 161: 72-80.
- Al-Yamani, F., Madhusoodhanan, R., Skryabin, V., Al-Said, T., 2018. The response of microzooplankton (tintinnid) community to salinity related environmental changes in a hypersaline marine system, northwestern Arabian Gulf. *Deep Sea Res. II* 166, 151-170.
- Baer, S.E., S. Rauschenberg, Garcia, N.S., A.C. Martiny, B.S. Twining and M.W. Lomas. 2019. Carbon and nitrogen productivity during spring in the oligotrophic Indian Ocean along the GOSHIP IO9N transect. 2019. *Deep-Sea Research Part II* 161: 81-91.
- Bange, H.W., Kock, A., Pelz, N., Schmidt, M., Schutte, F., Walter, S., Post, A.F., Jones, B.H., Kurten, B., 2018. 'Nitrous oxide in the northern Gulf of Aqaba and the central Red Sea. *Deep Sea Res. II* 166, 90-103.
- Beckley, L.E., D. Holliday, A.L. Sutton, E. Weller, M.P. Olivar and P.A. Thompson. 2019. Structuring of larval fish assemblages along a coastal-oceanic gradient in the macro-tidal, tropical Eastern Indian Ocean. *Deep-Sea Research Part II* 161: 105-119.
- Beckmann, A., Hense, I., 2018. 'Modelling nitrogen-oxygen dynamics in the central Arabian Sea: large-scale meridional structure and seasonal variations. *Deep Sea Res. II* 166, 114-124.
- Burdanowitz, N., Gaye, B., Hilbig, L., Lahajnar, N., Luckge, A., Rixen, T., Emeis, K.-C., 2018. Holocene monsoon and sea level-related changes of sedimentation in the northeastern Arabian Sea. *Deep Sea Res. II* 166: 6-18.
- Dréo R., L. Bouffaut, E. Leroy, G. Barruol and F. Samaran. 2019. Baleen whale distribution and seasonal occurrence revealed by an ocean bottom seismometer network in the Western Indian Ocean. *Deep-Sea Research Part II* 161: 132 - 144
- Forke, S., Rixen, T., Burdanowitz, N., Luckge, A., Ramaswamy, V., Munz, P., Wilhelms-Dick, D., Vogt, C., Kasten, S., Gaye, B., 2019. Sources of laminated sediments in the north eastern Arabian Sea off Pakistan and implications for sediment transport mechanisms during the late Holocene. *Holocene* 29, 130-144.
- Harms, N.C., Lahajnar, N., Gaye, B., Rixen, T., Dähnke, K., Ankele, M., Schwarz-Schampera, U., Emeis, K.C., 2019.
- Nutrient distribution and nitrogen and oxygen isotopic composition of nitrate in water masses of the subtropical southern Indian Ocean. *Biogeosciences* 16, 2715-2732.
- Hood, R. R., L. E. Beckley, B. Gaye, S K. Singh, J. Vialard & J. D. Wiggert. 2019a. The Second International Indian Ocean Expedition (IIOE-2): Motivating New Exploration in a Poorly Understood Ocean Basin (Volume 1). *Deep- Sea Research Part II* 161: 1 – 144.
- Hood, R.R., L. E. Beckley, B. Gaye, S K Singh, J Vialard, J D. Wiggert 2019b. The 2nd International Indian Ocean Expedition (IIOE-2): Motivating New Exploration in a Poorly Understood Ocean Basin (Volume 2). *Deep-Sea Research Part II*: 166, 1-186
- Huot, Y., Antoine, D., Daudon, C., 2018. 'Partitioning the Indian Ocean based on surface fields of physical and biological properties. *Deep Sea Res. II* 166, 74-79.
- Kämpf, J., Kavi, A., 2019. 'SST variability in the Eastern Intertropical Indian Ocean: on the search for trigger mechanisms of IOD events. *Deep Sea Res. II* 166, 64-74.
- Krishnamohan, K.S., Vialard, J., Lengaigne, M., Masson, S., Samson, G., Pous, S., Neetu, S., Durand, F., Shenoi, S.S.C., Madec, G., 2018. 'Is there an effect of Bay of Bengal salinity on the northern Indian Ocean climatological rainfall? *Deep Sea Res. II* 166, 19-33.
- Mao, H. M. Feng, H.E. Phillips and S. Lian Mesoscale eddy characteristics in the interior subtropical southeast Indian Ocean, tracked from the Leeuwin Current system. *Deep-Sea Research Part II* 161: 52-62.
- Menezes, V.V., Vianna, M.L., 2019. 'Quasi-biennial Rossby and Kelvin waves in the south Indian ocean: tropical

- and subtropical modes and the Indian Ocean Dipole. *Deep Sea Res. II* 166, 43-63.
- Miller, M.J., S. Wouthuyzen, E. Feunteun, Aoyama, J., S. Watanabe, A. Syahailatua, M. Kuroki, T. Robinet, S. Hagihara, T. Otake and K. Tsukamoto. 2019. Contrasting biodiversity of eel larvae across the central Indian Ocean subtropical gyre. *Deep-Sea Research Part II* 161: 120-131.
- Noyon, M., Morris, T., Walker, D., Huggett, J., 2018. 'Plankton distribution within a young cyclonic eddy off south-western Madagascar. *Deep Sea Res. II* 166, 141-150
- Pearce, A., Jackson, G., Cresswell, G.R., 2018. Marine debris pathways across the southern Indian Ocean. *Deep Sea Res. II* 166, 34-42.
- Prend, C.J., H. Seo, R.A. Weller and John.T. Farrar. 2019. Impact of freshwater plumes on intra-seasonal upper ocean variability in the Bay of Bengal. *Deep-Sea Research Part II* 161: 63-71
- Rigual-Hernández, A.S., C.H. Pilskaln, Cortina, F. Abrantes and L.K. Armand. 2019. Diatom species fluxes in the seasonally icecovered Antarctic Zone: New data from offshore Prydz Bay and comparison with other regions from the eastern Antarctic and western Pacific sectors of the Southern Ocean. *Deep-Sea Research Part II* 161: 92-104.
- Rohith et al 2019. Basin-wide Sea Level Coherency in the Tropical Indian Ocean Driven by Madden-Julian Oscillation. *Nature Communications* (www.nature.com/articles/s41467-019-09243-5)
- Saalin, S.M., R. Saraswat, T. Suokhrie and R. Nigam. Assessing the ecological preferences of agglutinated benthic foraminiferal morphogroups from the western Bay of Bengal. *Deep-Sea Research Part II* 161: 38-51.
- Singh, R. S. Sautya and B.S. Ingole. 2019. The community structure of the deep-sea nematode community associated with polymetallic nodules in the Central Indian Ocean Basin. *Deep-Sea Research Part II* 161: 16-28.
- Suntharalingam, P., Zamora, L.M., Bange, H.W., Bikkina, S., Buitenhuis, E., Kanakidou, M., Lamarque, J.-F., Landolfi, A., Resplandy, L., Sarin, M.M., Seitzinger, S., Singh, A., 2019. Anthropogenic nitrogen inputs and impacts on oceanic N₂O fluxes in the northern Indian Ocean: the need for an integrated observation and modelling approach. *Deep Sea Res. II* 166, 104 -113.
- Sutton, A.J., Jenner, K.C.S., Jenner, M.-M.M., 2018. 'Habitat associations of cetaceans and seabirds in the tropical eastern Indian Ocean. *Deep Sea Res. II* 166, 171-186.
- Twining, B.S., Rauschenberg, S., Baer, S.E., Lomas, M.W., Martiny, A.C., Antipova, O., 2019. A nutrient limitation mosaic in the eastern tropical Indian Ocean. *Deep Sea Res. II* 166, 124-140.
- White, C.M., C. Woulds, G.L. Cowie, A. Stott and H. Kitazato 2019. Resilience of benthic ecosystem C-cycling to future changes in dissolved oxygen availability. *Deep-Sea Research Part II* 161: 29-37.
- Wiles, E. A. Green, M. Watkeys, R. Botes and W. Jokar. 2019. Submarine canyons of NW Madagascar: A first geomorphological insight. *Deep-Sea Research Part II* 161: 5-15

2019 Annual Meeting

Our 2019 IIOE-2 meeting formed part of the 3rd International Indian Ocean Science Conference held over 11–15 March and hosted by Nelson Mandela University, South Africa in conjunction with the Joint Project Office of IIOE-2. The conference was attended by >100 delegates from 21 countries. An aim of this conference was to bring the Second International Indian Ocean Expedition (IIOE-2) community into the WIO region so as to promote exposure and the research being undertaken by Western Indian Ocean (WIO) institutions and to promote and facilitate the building of new relationships through the vehicle of ocean science.

The main highlights of the 2019 SSC meeting were:

- a. a 4-page colour brochure on IIOE-2 (see <https://iioe-2.incois.gov.in/documents/IIOE-2/IIOESC2019/IIOE-2-HighlightsBrochure.pdf>)
- b. a review of why IIOE-2 is essential to the community and the impact it has had;
- c. involvement of 28 countries in IIOE-2;
- d. ratification of 34 projects;
- e. review of 16 research cruises that have sailed;
- f. endorsement of the IIOE-2 Early Career Scientists Network;
- g. confirmation of a slimmed down administration to oversee IIOE-2 (see below); and
- h. a very strong affirmation by the community that IIOE-2 should continue beyond 2020.

The Conference focussed on many science areas that are being researched by the IIOE-2, including:

- Evolution of heat uptake and its impact on the global ocean and climate.
- Physical-biological coupling and biogeochemistry in the western Equatorial Indian Ocean.
- Ecosystem impacts of meteorological and oceanographic conditions in upwellings of the East African Coastal Current system.
- Indian Ocean variability and monsoon prediction through the Indian Ocean Observing System including the Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction.
- Building the Indian Ocean Observing System.
- Major boundary currents around the Indian Ocean rim and their biogeochemistry.
- Biogeochemistry-Atmosphere processes in the Bay of Bengal.
- Physical and biogeochemical aspects of upwelling systems in the Indian Ocean.
- Nitrogen fixation rates, primary production and oxygen minimum zones of the Arabian Sea, comparative to the Bay of Bengal.
- Mesoscale vortices, currents and dynamical features in the Northwest Indian Ocean.
- Phytoplankton blooms in the north-western Arafura Sea during the southeast monsoon.
- Sustained ocean observations along the east coast of Africa
- Ecosystem function on seamounts and the effects of environmental stressors.

Administration

IIOE-2 continues to be well supported by the Administrative Offices of SCOR in USA, IOC in Australia and India and IOGOOS in India. This is very much appreciated by the IIOE-2 community.

The IOC, through its IOC Perth Programme Office in Western Australia provides one node of the IIOE-2 Joint Project Office (JPO) and India the other node through the Indian National Centre for Ocean Information Services (INCOIS) in Hyderabad, which also administers IOGOOS. The cash funding to IIOE-2 via IOC and IOGOOS combined will continue at ~\$30K per year, as will the significant human and supporting underpinning resourcing for these two nodes (with each node engaging at least the equivalent of two full time FTEs each). The JPO hosting (personnel and office/administrative underpinning) through their respective IOC and national government agency sponsors, combines in value to be several hundreds of thousands of dollars per year at FEC. IOC and IOGOOS have re-committed to this full framework (cash and complementary personnel/hosting) out to 2025 and request SCOR to continue its funding for research coordination as a collegiate partnership.

In 2018, the sponsors agreed to reduce the administration of IIOE-2 by forming the “Core Group”. This comprised the co-chairs, the executive officers and the chairs of Science and of Operations. We have continued to stream-line the administration further. This has been accepted by the 2019 IIOE-2 Steering Committee and reducing the number of Working Groups to three:

WG1: Science and Research (Chairs: Raleigh Hood, USA & Hermann Bange, Germany)
WG2: Data and Information Management (Chair: Cyndy Chandler, USA)
WG3: Operational Coordination (Chair: Shailesh Nayak, India)

Website (www.iioe-2.incois.gov.in):

This is the front window of IIOE-2, including details of past and future events. It is hosted by INCOIS and paid for by India.

Indian Ocean Bubble & IIOE-2 Newsletter

These informal publications help to maintain the IIOE-2 Community, keeping it in touch. The Bubble appears ~ quarterly while the Newsletter appears monthly. They are both produced by INCOIS. Items in recent copies are shown below.

<i>Date</i>	<i>Output</i>	<i>Topics</i>
2019 February	Bubble 10	<ol style="list-style-type: none"> 1) Proposed new structure for delivering IIOE-2 2) IIOE-2 Working Group 1 'Science & Research' Meeting, Kiel, 28-30 November 2018 3) First comprehensive book on the nature of Timor-Leste, underwater and on land 4) A Shout-out for Better Estimates of Ocean Mixed Layer Depths from Observations 5) Biogeochemistry of the Indian Ocean 6) Argo reaches 2 million profiles globally! But what of the Indian Ocean? 7) Ponman: A method for exploratory analysis of ocean depths using Bio-Argo 8) The improved COARE 3.5 Algorithm for ocean heat flux estimations 9) Investigating the shelf dynamics and sedimentary records of South Eastern Arabian Sea 10) multidisciplinary approach 11) New insights into the Indian Ocean
2019 March	News V 3 Issue 3	<ol style="list-style-type: none"> 1) The third meeting of the IIOE-2 Steering Committee, Nelson Mandela University, Port Elizabeth, South Africa, 11-15 March 2019 2) Deep Madagascar Basin (DMB) Experiment: A Quest to Find the Abyssal Water pathways in the Southwest Indian Ocean 3) Join the Marine Research Information Network on Biodiversity (MARINE-B) 4) Early announcement: International Indian Ocean Science Conference-2020 5) Some Upcoming Events
2019 April	News V 3 Issue 4	<ol style="list-style-type: none"> 1) The origin of 85°E Ridge and its role in the plate tectonic history of the Bay of Bengal (85ERBB) 2) Handing over the International Indian Ocean Expedition (IIOE-2) Flag 3) Early announcement: International Indian Ocean Science Conference-2020 4) Some upcoming events
2019 May	News V 3 Issue 5	<ol style="list-style-type: none"> 1) Exploring the marine biodiversity of the submarine Cape Range Canyon, north western Australia 2) Recommendations for an integrated modelling-observational approach for estimating N₂O fluxes under the IIOE-2 3) Early announcement: International Indian Ocean Science Conference-2020 4) Some upcoming events
2019 June	News V 3 Issue 6	<ol style="list-style-type: none"> 1) In the wake of HMAS Diamantina 2) Does Somali current upwell during the summer monsoon? 3) Call for papers - Special IIOE-2 Issue. Volume 3 DEEP SEA RESEARCH- PART II 4) Call for papers - Special Issue in Acta Oceanologica Sinica on "Environment and Ocean-Atmosphere Interaction in the Indian Ocean" 5) Early announcement: International Indian Ocean Science Conference-2020 6) Some upcoming events
2019 August	News V 3 Issue 8	<ol style="list-style-type: none"> 1) Exciting collaboration for IIOE-2: Deep Argo deployments from RV Investigator 2) The need for a dedicated observing system for cyclone prediction 3) International Indian Ocean Science Conference-2020 (IIOSC-2020)- Call for Abstracts 4) Some upcoming events

2019 August	Bubble 11	1) Conference and integrated meetings 2) Intergovernmental Oceanographic Commission Assembly 3) Plankton Identification Workshop held in Zanzibar 4) Walter Munk- A Founding Father of Modern Oceanography (1917-2019) 5) R/V INVESTIGATOR Voyage- 110°E 6) Is Carbon-to-Chlorophyll Ratio getting its due in the Indian Ocean? 7) Boreal MJO induced coherent rise and fall of the tropical Indian Ocean 8) Dynamics of the Arabian Sea High Salinity Water Mass and Hypoxic Zones along the South West Coast of India - A Modelling Approach 9) Approach field trials of gillnets and fishing lines with alternate materials in the Arabian Sea
2019 November	12	Next Bubble

Media

IIOE-2 has informal outputs intended for the public. Science journalist Heather Dugmore attended the 2019 IIOE-2 meeting in Port Elizabeth, and masterminded the following media clips in the Mail & Guardian 31 May-6 June 2019:

- a. *“Collective Ocean Action”* by Vice Chancellor Nelson Mandela University
- b. *No single nation has the capacity* by Heather Dugmore
- c. *International Indian Ocean Expedition* by Lynnath Beckley
- d. *Big thinking, big science* by Heather Dugmore
- e. *Combatting fisheries organised crime* by Heather Dugmore
- f. *Indian Ocean Africa* by Rose Boswell
- g. *World’s most advanced ocean research vessel* by Heather Dugmore
- h. *New marine robotics unit* by Akshay Lakhani
- i. *Democratising marine robotics* by Terry Sloane
- j. *Fish species overexploited or collapsed* by Tor Næsje and Paul Cowley
- k. *Sewage and contaminants in Cape Town sea* by Leslie Petrik
- l. *Maritime engineering and naval architecture* by Howard Theunissen,
- m. *Vehicle tyre particles a major marine polluter* by Andy Booth
- n. *Coastal link in the origins of human awareness* by African Centre for Coastal Palaeoscience (ACCP)
- o. *Life below water from Zanzibar* by Julius Francis
- p. *Era of marine spatial planning* by Mandy Lombard
- q. *“Tackling the ocean plastics problem now”* by Andy Cundy
- r. *One Ocean Hub* by Elisa Morgera
- s. *“The marine plastic pollution crisis”* by Peter Manyara
- t. *“IUCN Marine Mammal Task Force includes SA”* by Stephanie Plön
- u. *“Why the Indian Ocean?”* by Heather Dugmore and Peter Burkill
- v. *“India rapidly gearing up”* by Sateesh Shenoi. see https://iioe-2.incois.gov.in/documents/IIOE-2/ocean_science.pdf

A clip was published in The Herald 12 March 2019. *“Experts share Indian ocean findings”* (see https://iioe-2.incois.gov.in/documents/IIOE-2/IIOSC2019/newsclipping_sc3.jpg).

Another clip was published 32 days on the Indian Ocean exploring climate change. Raleigh Hood (USA) 13 May 2019 (see <https://www.umces.edu/news/32-days-indian-ocean-exploring-climate-change>).

Planning the International Conference 2020

The next major event on the IIOE-2 calendar is The International Indian Ocean Science Conference (IIOSC-2020). This will be held in Goa, March 16-20 2020, to celebrate recent research in the Indian Ocean and to plan the next phase of IIOE-2. It aims at assessing the scientific understanding of the IO gained during the period of

IIOE-2 from 2016 to 2020. It will focus on, but not be limited by, all six themes of IIOE-2 Science plan (i.e., human impacts and benefits; boundary current dynamics and ecosystem impacts; monsoon variability and ecosystem response; circulation, climate variability and change; extreme events; and discovery of unique physical, geological, biogeochemical and ecological features of the Indian Ocean). It will provide an opportunity for the scientists working on different facets of the Indian Ocean to present their ideas and discuss the outstanding issues, identify the knowledge gaps and plan a way forward to address such issues, including as context for a continuing IIOE-2. Presentations highlighting innovative ideas on "Translating benefits of Science to Society" or with societal implications are encouraged. IIOSC-2020 is sponsored by the Ministry of Earth Sciences (MoES), Govt. of India, and will be co-hosted by the National Institute of Oceanography (NIO) Goa, National Centre for Polar Ocean Research (NCPOR) Goa, Goa University and Indian National Centre for Ocean Information Services (INCOIS) Hyderabad.

The conference is being planned by scientists from Australia, China, France, Germany, India, Indonesia, Japan, Kuwait, Russia, South Africa, South Korea, Tanzania, UK, USA as well as SCOR, IOC and IOGOOS.

There are two 'early career' scientists on the International Planning Committee. The development of IIOE-2 beyond 2020 is likely to be a regional contribution to the UN Decade of Sustainable Ocean Development. The 4th full Steering Committee meeting of IIOE-2 will take place immediately after the conference to pick up research issues arising at IIOSC-2020 and to develop future international collaboration in IIOE-2.

Other Future Events - Cruises

Some 16 cruises have contributed to IIOE-2 in the past 4 years. These are shown in <https://iioe-2.incois.gov.in/IIOE-2/Expedition.jsp>. For the future, the following cruises are at various stages of planning. While many of these are confirmed and funded, there are several countries (China, Japan, Korea, Russia) which are active in IIOE-2 but for which plans are not known.

AUSTRALIA: Australia has had one RV Investigator voyage. There are two RV Falkor cruises in 2020 covering canyons along the south west Australian shelf edge (largely UWA) and another one to the shelf edge canyons (largely WA Museum).

FRANCE: Their involvement includes a) Durban Cyclone and Secondary Production, in June/July 2021; b) A Mahe Plateau ecosystem Survey in October/December 2021; c) Resources and coastal vulnerability in a changing Southern Ocean in Dec 2020/ Jan2021. All involve multiple nations.

GERMANY: Has already led expeditions. Germany's effort will also include an Indian Ocean cruise in September 2020, and then 9 cruises planned (and funded) through until March/April 2021 in the Indian Ocean including the Bay of Bengal.

There are other large prospective exploratory programs being planned for the Indian Ocean, such as the 'Global Seamounts Project' through the not-for-profit Global Oceans (GO) group. For example, GO is seeking significant philanthropic funds to implement 18 deep-sea expeditions over the next four years, including the Indian Ocean. This is an exemplar of an IIOE-2 related prospect that would benefit greatly from the high-level imprimatur that SCOR can provide (in concert with IOC and IOGOOS) by virtue of ongoing support for IIOE-2.

Extending IIOE-2 beyond 2020

At the 2019 IIOE-2 Steering Committee meeting, there was unanimous agreement that IIOE-2 should continue into the next decade. This was underscored by the following statement: *"Resolution of IIOE-2 Steering Committee, Meeting No 3, 12-13 March 2018: The IIOE-2 International Steering Committee, chaired by representatives of IOC, SCOR and IOGOOS, and comprising a diverse multi-national constituency, agreed to continue the mission of the IIOE-2 out to at least 2025, in order to build on the significant scientific achievements of IIOE-2 to date, the extension that will occur of many current and imminent major IIOE-2 research initiatives into the next decade, the expected emergence of many new major scientific initiatives well into the next decade strongly aligning with the IIOE-2 Science Plan, and in light of IIOE-2's clear alignment, relevancy and potential to make an important and substantive contribution to the UN Decade of Ocean Science for Sustainable Development 2021-30."*

IOC and IOGOOS have already agreed to extend IIOE-2 beyond 2020. IOGOOS did so in response to the IIOE-2 Steering Committee's unanimous agreement in March 2019 to continue as an IIOE-2 focussed alliance (see above). Then, in June 2019, the 32nd Session of the 150 Member State IOC Assembly agreed to the same. This now means that IOGOOS and IOC will continue to support IIOE-2, seamlessly and as they have done since 2015. The cash funding to IIOE-2 via IOC and IOGOOS combined will continue at ~\$30K per year, with significant human and supporting to underpin IIOE-2 with these two nodes valued at several hundreds of thousands of dollars per year (FEC values). IOC and IOGOOS have re-committed to this fullframework out to 2025 and they have requested SCOR to continue its research coordination of IIOE-2 as a collegiate partnership.

Request

That SCOR provides \$15k towards the 2020 IIOE-2 SSC providing T&S for key participants with the funds administered by SCOR's Executive Director.

Appendix 10
2018 Audited SCOR Statement of Activities

SCIENTIFIC COMMITTEE ON OCEANIC RESEARCH, INC.
STATEMENT OF
ACTIVITIES YEAR ENDED
DECEMBER 31, 2018

	Without Donor Restrictions	With Donor Restrictions	Total
SUPPORT AND REVENUE			
Grant and contract revenue	\$822,524	-	\$822,524
Contribution revenue		\$84,459	\$84,459
Membership dues	\$379,196	-	\$379,196
Meeting registration fees and miscellaneous income	\$61,146	-	\$61,146
Interest income	\$3,062	-	\$3,062
NET ASSETS RELEASED FROM RESTRICTIONS			
Satisfaction of program restrictions	\$126,337	(\$126,337)	-
Total support and revenue	\$1,392,265	(\$41,878)	\$1,350,387
EXPENSES			
Program services			
Scientific programs	\$1,021,883	-	\$1,021,883
Travel and subsistence programs	\$77,494	-	\$77,494
Other conferences and meetings	\$20,401	-	\$20,401
Total program services	\$1,119,778	-	\$1,119,778
Supporting services			
Management and general	\$308,535	-	\$308,535
Total expenses	\$1,428,313	-	\$1,428,313
CHANGE IN NET ASSETS	(\$36,048)	(\$41,878)	(\$77,926)
NET ASSETS			
BEGINNING OF YEAR	\$209,223	\$88,969	\$298,192
END OF YEAR	\$173,175	\$47,091	\$220,266

Appendix 11
SCOR-Related Meetings (2019-2021)

2019		
29-30 January	IQOE WG on Arctic Acoustic Environments	Paris, France
11-15 March	IIOE-2 Steering Committee and Related Events	Cape Elizabeth, South Africa
21-25 April	SOLAS Open Science Conference 2019	Sapporo, Japan
26-28 April	SOLAS Scientific Steering Committee	Sapporo, Japan
7-9 May	WG 153 on Floating Litter and its Oceanic Transport Analysis and Modelling (FLOTSAM)	Utrecht, The Netherlands
15-18 May	SOOS Scientific Steering Committee	Incheon, Korea
3-7 June	WG 156 on Active Chlorophyll fluorescence for autonomous measurements of global marine primary productivity	Vancouver, B.C., Canada
12-13 June	GEOTRACES Standards and Intercalibration Committee	Norfolk, Virginia, USA
14-15 June	WG 149: Changing Ocean Biological Systems (COBS)	Brest, France
17-21 June	IMBeR Open Science Conference 2019	Brest, France
22-23 June	IMBeR Scientific Steering Committee	Brest, France
7-10 July	WG 147: Towards comparability of global oceanic nutrient data (COMPONUT) Writing Meeting	La Jolla, California, USA
16-18 August	WG 152 on Measuring Essential Climate Variables in Sea Ice (ECV-Ice)	Winnipeg, Canada
7-8 September	GEOTRACES Data Management Committee	Hobart, Tasmania, Australia
9-11 September	GEOTRACES Scientific Steering Committee	Hobart, Tasmania, Australia
13-14 September	WG 157: Toward a new global view of marine zooplankton biodiversity based on DNA metabarcoding and reference DNA sequence databases (MetaZooGene)	Gothenburg, Sweden
14 September	WG 154 on Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (P-OBS)	Honolulu, Hawaii, USA
23-25 September	SCOR Annual Meeting	Toyama, Japan
28 October - 1 November	WG 148: International Quality Controlled Ocean Database: Subsurface temperature profiles (IQuOD)	Brest, France
2020		
20-24 January	WG 159: Roadmap for a Standardised Global Approach to Deep-Sea Biology for the Decade of Ocean Science for Sustainable Development (DeepSeaDecade)	Aveiro, Portugal
15-16 February	WG 156 on Active Chlorophyll fluorescence for autonomous measurements of global marine primary productivity	San Diego, Calif., USA
February 16	WG 145 on Chemical Speciation Modelling in Seawater to Meet 21st Century Needs (MARCHEMSPEC)	San Diego, Calif., USA

16 February	WG 151: Iron Model intercomparison project (FeMIP)	San Diego, Calif., USA
16 February	WG 157: Toward a new global view of marine zooplankton biodiversity based on DNA metabarcoding and reference DNA sequence databases (MetaZooGene)	San Diego, Calif., USA
16-20 March	International Indian Ocean Science Conference 2020	Goa, India
22-23 March	IIOE-2 Steering Committee	Goa, India
1-3 April	SOLAS Scientific Steering Committee	Santiago, Chile
2-3 May	SCOR Working Group 155 Eastern boundary upwelling systems (EBUS): diversity, coupled dynamics and sensitivity to climate change	Dakar, Senegal
4-15 May	SCOR WG 155 Summer School	Dakar, Senegal
22-24 May	IMBeR Scientific Steering Committee Meeting	
17-18 July	Changing Ocean Biological Systems (COBS)	Waterville, New Hampshire
19-23 October	2020 SCOR Annual Meeting	Guayaquil, Ecuador
2021		
5-10 September	EBUS Open Science Conference	Lima, Peru