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OF THE
SCIENTIFIC COMMITTEE ON OCEANIC RESEARCH**

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SCOR Proceedings, Volume 54
REPORT OF THE 2018 ANNUAL SCOR MEETING

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2018 SCOR ANNUAL MEETING

Plymouth, UK
4-7 September 2018

1.0 OPENING

1.1 Opening Remarks and Administrative Arrangements

Richard Thompson, Director of the University of Plymouth's Marine Institute, welcomed participants and gave a short introduction to the work of the Institute. Marie-Alexandrine Sicre, SCOR President, welcomed participants and asked each person to introduce themselves. Sicre gave tributes for three scientists who were involved in SCOR activities and died since the 2017 SCOR Annual Meeting: John Bullister, Fred Grassle, and Temel Oguz.

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 primary changes were to move the SOOS and SCAR presentations to Wednesday because the SCAR Executive Director would only be available that day.

1.3 Report of the President of SCOR

The President briefly reviewed her activities for SCOR since the SCOR Annual Meeting in September 2017 in Cape Town, South Africa. She noted that she had represented SCOR in meetings on many occasions and has been in contact with scientists and government officials in Kenya about joining SCOR.

1.4 Report of SCOR Executive Director

The SCOR Executive Director, Ed Urban, reported on his activities for SCOR since the 2017 SCOR Annual meeting, and on the current condition of SCOR. SCOR finances are in good condition and there should be adequate funding to approve two new working groups this year, depending on recommendations from the SCOR Finance Committee. Working groups are making good progress. For example, WG 139 on Organic Ligands – A Key Control on Trace Metal Biogeochemistry in the Ocean has a Research Topic open in [*Frontiers in Marine Science*](#) and has 22 articles in the section so far. All three working groups approved at the 2017 SCOR Annual Meeting met for the first time in the past year. In terms of outreach, SCOR had a booth at Ocean Sciences 2018, which had very good visibility. The new SCOR website was just launched and it was generally appreciated by the participants at the meeting. The number of Twitter followers and email contacts both significantly increased in the past year. Urban asked that national SCOR representatives encourage scientists in their countries to sign up for SCOR emails. Ireland joined SCOR in 2017 and Namibia in 2018. A new model for payment of SCOR dues seems to be arising in several countries, in which national academies are reducing support and delegating dues payment and management of national SCOR committees to national institutions. An early-career scientist, Nuria Casacuberta Arola (Switzerland) was added to the SCOR Executive Committee. There were a good number of strong applicants. The percentage of

female participants in SCOR activities continues to increase and is at about 41%. The percentage of developing country members has fluctuated between 20% and 24% for the past 14 years and is currently at 24%.

1.5 Appointment of an *ad hoc* Finance Committee

The SCOR Constitution requires that a Finance Committee be appointed at every SCOR Annual Meeting. It must consist of at least three Nominated Members 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 2019 activities and dues for 2020. Members of the 2018 Finance Committee approved by the Executive Committee are Isabelle Ansorge (South Africa), Annalisa Griffa (Italy), and Paul Myers (Canada). The Committee will report to the meeting under agenda item **8.3**.

1.6 2018 Elections for SCOR Officers and Approval of Proposed Changes to SCOR Constitution

Peter Burkill, Past President, chaired the Nominations Committee, which also included Annalisa Griffa (Italy), Jorma Kuperinen (Finland), and Maria Van Leeuwe (Netherlands). The SCOR Secretary and all three Vice-President positions were open for nominations for the 2018 elections. The new Secretary is Paul Myers (Canada) and the Vice-Presidents are David Halpern (USA, re-appointed), Sinjae Yoo (Korea), and Jing Zhang (Japan). The terms of all SCOR officers began at the end of the SCOR meeting.

Proposed changes to the SCOR Constitution were disseminated to national SCOR Committees. Burkill explained the proposed changes to the SCOR Constitution, which were emailed to national representatives and affiliated organization representatives present at the meeting. At the end of the meeting, it was agreed to adopt an Appendix 2 to the SCOR Constitution, which would allow national committees not attending SCOR Annual Meetings to vote on future proposed changes to the SCOR Constitution.

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. Corina Brussaard suggested asking disbanded groups for a legacy statement in the thank-you letter to the groups, telling them that this statement will be placed online. All meeting participants agreed with this suggestion.

2.1.1 SCOR/InterRidge WG 135 on Hydrothermal energy transfer and its impact on the ocean carbon cycles

Denise Smythe-Wright reported that WG 135 has submitted its final report. The primary activity of the group for the last several years has been the preparation of a second peer-reviewed paper,

which has now been published in *Frontiers in Marine Sciences*. It was agreed to disband the group.

The group had three terms of reference:

- 1. synthesizing current knowledge of chemical substrates, mechanisms and rates of chemosynthetic carbon fixation at hydrothermal systems, as well as the transfer of phytoplankton-limiting micronutrients from these systems to the open ocean.**

This goal has been partly achieved with the second review paper, in which the drivers and controls of carbon fixation at hydrothermal systems has been considered.¹ Inventories of different geochemical drivers of the transfer of phytoplankton-limiting micronutrients from these systems to the open ocean were already considered by WG members within the GEOTRACES program² and included in specific reviews led by WG 135 members.³

- 2. integrating these findings into conceptual models of energy transfer and carbon cycling through hydrothermal systems which would lead to quantification of primary production and assessment of the contribution of these systems to the global carbon cycles.**

The first WG paper provided an attempt to model plume processes related to the export of iron in plumes. It addressed an overlooked aspect of this cycling related to the deep-sea carbon pool, by considering the deposition of organics adsorbed on precipitating iron oxides.⁴

- 3. identifying critical gaps in current knowledge and proposing a strategy for future field, laboratory, experimental and/or theoretical studies to bridge these gaps and better constrain the impact of deep-sea hydrothermal systems on ocean carbon cycles.**

The papers produced from the WG have identified critical gaps in the current understanding of geochemical, metabolic, and ecological processes that drive the efficiency of energy and micronutrient transfer from the geothermal source to ecosystems, and emphasized the need for a globally coordinated research effort in the deep ocean. In particular, important knowledge gaps in the assessment of stabilized iron forms that can undergo long-range transport, as confirmed by GEOTRACES, are likely linked with the variability of iron and organic ligands at vents, in space and in time. This emphasizes the need to better understand the geochemistry and

¹Le Bris, N., M. Yücel, A. Das, S.M. Sievert, L.B. PonnaPakkam, and P.R. Girguis. In review. Hydrothermal energy transfer and organic carbon production at the deep seafloor. *Frontiers in Marine Sciences*

²German, C.R., K.A. Casciotti, J.-C. Dutay, L.E. Heimbürger, W.J. Jenkins, C.I. Measures, R.A. Mills, H. Obata, R. Schlitzer, A. Tagliabue, D.R. Turner, and H. Whitby. 2016. Hydrothermal impacts on trace element and isotope ocean biogeochemistry. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 374(2081) <https://doi.org/10.1098/rsta.2016.0035>.

³Gartman, A., M. Yücel, and G.W. Luther. 2014. An Introduction to the Major Chemical Components Released from Hydrothermal Vents, in: Reference Module in Earth Systems and Environmental Sciences. Elsevier.

⁴German, C.R., L.L. Legendre, S.G. Sander, N. Niquil, G.W. Luther, L. Bharati, X. Han, and N. Le Bris. 2015. Hydrothermal Fe cycling and deep ocean organic carbon scavenging: Model-based evidence for significant POC supply to seafloor sediments. *Earth and Planetary Science Letters* 419:143–153.

biogeochemistry of elements in distal plumes accounting for the different iron sources at vent fields.

2.1.2 SCOR/IGBP WG 138: Modern Planktic Foraminifera and Ocean Changes

Corina Brussaard reported that no annual report was received from WG 138 by the time the background papers were printed, but was submitted before the meeting (see http://scor-int.org/Annual%20Meetings/2018_SCOR_Meeting/WG138_final_report_2018.pdf). The products of the group include the following:

- Ten peer-reviewed publications mentioning SCOR
- Workshop and Shortcourse on Culturing Planktonic Foraminifera: 30 August-4 Sept. 2015 on Catalina Island, California, USA
- Videos: A Foram's Tale http://youtu.be/xfZ_9UWcAB8 and <http://youtu.be/6MakjP6MkdE>
- Website: http://www.eforams.org/index.php/WG138_Startpage

The group's terms of reference were the following:

1. **Synthesize the state of the science of modern planktonic foraminifera, from pioneering to ongoing research including as a peer-reviewed publication in an open-access journal (deliverable 1).**

WG 138 efforts allowed the community working on genetic studies of planktonic foraminifera to produce a comprehensive synthesis of existing genetic resources,⁵ devise a scheme to implement stable nomenclature to genetically delimit taxa⁶ and provide a comprehensive synthesis and analysis of methods used to obtain genetic information from single-cell extractions.⁷ In addition, WG 138 efforts facilitated the development of a comprehensive new database on the distribution of species identified by their shells in surface sediments.⁸

⁵Morard, R., K. Darling, F. Mahé, S. Audic, Y. Ujiie, A. Weiner, A. André, H. Seeers, C. Wade, F. Quillévéré, C. Douady, G. Escarguel, T. de Garidel-Thoron, M. Siccha, M. Kucera, and C. de Vargas, 2015. PFR²: a curated database of planktonic Foraminifera 18S ribosomal DNA as a resource for studies of plankton ecology, biogeography, and evolution. *Molecular Ecology Resources* 15:1472–1485. doi:10.1111/1755-0998.12410.

⁶Morard, R., G. Escarguel, A. Weiner, A. André, C.J. Douady, C.M. Wade, K.F. Darling, Y. Ujiie, H.A. Seeers, F. Quillévéré, T. de Garidel-Thoron, C. de Vargas, and M. Kucera. 2016. Nomenclature for the nameless: a proposal for an integrative molecular taxonomy of cryptic diversity exemplified by planktonic foraminifera. *Systematic Biology* 65(5):925-940. doi: 10.1093/sysbio/syw031.

⁷Weiner, A.K.M., R. Morard, M.F.G. Weinkauf, K.F. Darling, A. André, F. Quillévéré, Y. Ujiie, C.J. Douady, C. de Vargas, and M. Kucera. 2016. Methodology for single-cell genetic analysis of planktonic foraminifera for studies of protist diversity and evolution. *Frontiers in Marine Science* 3:255. doi: 10.3389/fmars.2016.00255.

⁸Siccha, M., and M. Kucera. 2017. ForCenS, a curated database of planktonic foraminifera census counts in marine surface sediment samples. *Scientific Data* 4:170109. doi:10.1038/sdata.2017.109.

- 2. Provide guidelines (cookbooks) in terms of species identification, experimental setup for culture studies, laboratory treatment prior to geochemical analysis (deliverable 2).**

An advanced draft version of a revised taxonomy, including essential formal taxonomic amendments⁹, now exists and includes an identification key that has passed several rounds of review (including during the Catalina meeting) and is already starting to be used.¹⁰

- 3. Establish an active Web-based network in cooperation with ongoing (inter)national research programs and projects to guarantee an open-access worldwide dissemination of results, data and research plans (deliverable 3).**

An online resource has been developed associated with the synthesis of data on single-cell DNA extraction and sequencing of planktonic foraminifera: <http://pfr2.sb-roscoff.fr/>.

- 4. Document the work of the group in a special issue of an open-access journal (deliverable 5) in connection with a specialized symposium with special emphasis on modern ocean change i.e. thermohaline circulation and ocean acidification, during one of the AGU or EGU conferences, ideally held at the joint EGU/AGU meeting (envisaged for 2013 or 2014) and/or at the FORAMS 2014 meeting in Chile (deliverable 4).**

The envisaged eBook project with Copernicus is not progressing and whilst not yet abandoned, its fate must be considered as uncertain. An updated review on recent advances in the research on planktonic foraminifera is underway as a journal article.¹¹

It was agreed to disband the group.

2.1.3 WG 139: Organic Ligands – A Key Control on Trace Metal Biogeochemistry in the Ocean

Colin Devey noted that no annual report was received from WG 139 by the time the background papers were printed, but that a report was submitted before the meeting (see http://scor-int.org/Annual%20Meetings/2018_SCOR_Meeting/WG139.pdf). It was agreed to disband the group, as it has completed its terms of reference:

⁹Spezzaferri, S., M. Kucera, P.N. Pearson, B. Wade, S. Rappo, C. Poole, R. Morard, and Stalder, C. 2015. Fossil and genetic evidence for the polyphyletic nature of the planktonic foraminifera "Globigerinoides", and description of the new genus *Trilobatus*. *PLoS ONE* 10(5): e0128108. doi:10.1371/journal.pone.0128108.

¹⁰Meilland J., S. Fabri-Ruiz, P. Koubbi, C. Lo Monaco C. Cotte, G.W. Hosie, S. Sanchez, and H. Howa. 2016. Planktonic foraminiferal biogeography in the Indian sector of the Southern Ocean: Contribution from CPR data. *Deep-Sea Research I* 110:75–89.

¹¹Schiebel, R., S.M. Smart, A. Jentzen, L. Jonkers, R. Morard, J. Meilland, E. Michel, H.K. Coxall, P.M. Hull, T. Garidel-Thoron, T. Aze, F. Quillévéré, H. Ren, D.M. Sigman, H.B. Vonhof, A. Martínez-García, M. Kučera, J. Bijma, H.J. Spero, and G.H. Haugan. 2018. Advances in planktonic foraminifer research: New perspectives for paleoceanography. *Revue de Micropaléontologie* 61(3–4):113–138, <https://doi.org/10.1016/j.revmic.2018.10.001>.

- 1. To inform the Ocean Sciences community of this WG and related objectives via a widely distributed publication in EOS or analogous journal.**

The initiation of this SCOR Working Group, including the terms of reference and overall objectives of this working group, was announced in two publications in 2012:

- S.G. Sander, K.N. Buck, and M.C. Lohan. 26 June 2012. Improving understanding of organic metal-binding ligands in the ocean. *Eos*, 93(26): 244.
 - K.N. Buck, M.C. Lohan, and S.G. Sander. July 2012. Metal-binding organic ligands. *IUPAC Chemistry International*, 34(4): 23.
- 2. To summarize published results on all aspects of metal-binding ligands in the oceans (e.g., distributions, chemical structure, sources, sinks, stability constants), and to contribute to the organic ligand database for use in biogeochemical models and for those working in the field (including results from ongoing GEOTRACES, SOLAS and CLIVAR efforts).**

Databases for metal-binding ligand measurements have been compiled by members of the working group for Co, Cu, Fe, and Zn. The iron-binding ligand database is the most developed and an additional database for the raw titration data used to calculate iron-binding ligands has also been initiated. A compilation review of iron-binding ligands based on these databases was published in the *Frontiers in Marine Science* special issue for this working group (<http://journal.frontiersin.org/article/10.3389/fmars.2016.00221/full>).

- 3. To expand upon the ligand intercalibration programme, initiated by GEOTRACES, to evaluate key analytical issues with currently employed methodologies and determine how to best link ongoing efforts in trace metal and organic geochemistry to assess natural metal-binding ligands.**

A large intercalibration of the interpretation techniques routinely used for determining ligand concentrations and conditional stability constants from titration data was conducted, and results were published in the first WG 139 special issue.¹² Powerful new interpretation tools developed by participants in this working group were also presented in the special issue and evaluated in the intercalibration, all of which are now freely available to download from the SCOR WG 139 website <http://www.marine.usf.edu/scor139/>.

For field-based intercalibration efforts, large volumes of filtered seawater were collected for this purpose from the Gulf of Mexico and from the Southern Ocean. Initial analyses of these samples for dissolved metals have been done in the host lab and samples for ligand analyses and intercomparison samples will be sent to selected laboratories with known expertise in the

¹²Pižeta, I., S.G. Sander, R.J.M. Hudson, D. Omanović, O. Baars, K.A. Barbeau, K.N. Buck, R.M. Bundy, G. Carrasco, P.L. Croot, C. Garnier, L.J.A. Gerringa, M. Gledhill, K. Hirose, Y. Kondo, L.M. Laglera, J. Nuester, M.J.A. Rijkenberg, S. Takeda, B.S. Twining, and M. Wells. 2015. Interpretation of complexometric titration data: An intercomparison of methods for estimating models of trace metal complexation by natural organic ligands. *Marine Chemistry* 173:3–24.

analysis of Cu and Fe-ligands analysis by the end of 2018. The results of this intercomparison will be published in a peer-reviewed article. This article will include a recommendation on best practices for measurements. The best practices need to be seen as a living document that will be updated and disseminated including on the SCOR WG 139 website.

4. To identify how best to incorporate published and future data into biogeochemical models.

The working group discussed several aspects of incorporating ligands into models, including how analysts can provide ligand concentrations, their sources and sinks and complexation kinetics such as the variability in conditional stability constants of iron, how to distinguish between different iron-binding ligand classes, and if trace metals compete for the same class of ligands. A paper published in the first special issue examined how organic iron-binding ligands could be represented in biogeochemical ocean models.¹³ This effort is ongoing and will be part of a new SCOR Working Group, WG151: Iron Model Intercomparison Project (see <https://scor-int.org/group/151/>).

5. To debate the nature of sampling strategies and experimental approaches employed in laboratory and field efforts from different communities in workshops and meeting discussions to foster cross-fertilization of ideas across groups, capitalize on joint expertise between specialties and ultimately enhance our understanding of the links between the provenance, fate, distribution, and chemistry and biological functions of these organic metal-binding ligands in the oceans.

This working group met annually from 2012 to 2014, coinciding with the February Ocean Sciences Meetings. Notes from each of these meetings are posted on the WG 139 Website. The co-chairs of this Working Group also chaired a special session related to the working group at each of the conferences in 2012, 2014, and 2016. A Town Hall Meeting during the 2014 Ocean Sciences meeting was attended by 47 people and served to highlight accomplishments of the working group to date and engage broader community participation in working group activities. These meetings fostered discussions on the need for improved modeling of trace metal speciation in seawater and led to a new SCOR Working Group, WG 145: Modeling Chemical Speciation in Seawater to Meet 21st Century Needs. Several members of SCOR WG 139 are also members of WG 145 and the new model will incorporate trace metal-organic ligand interactions across marine environments.

6. To recommend future approaches to ligand biogeochemistry in a designated symposium, including ongoing GEOTRACES field efforts (i.e., regional surveys and process studies), integration of CLE-ACSV and organic geochemistry techniques, and the need for rapid incorporation of this research in biogeochemical models. Such future recommendations will also be included in the aforementioned downloadable manual. It will also include a series of recommended downloadable digital products on multiple platforms for interpreting ACSV data.

¹³Völker, C., and A. Tagliabue. 2015. Modeling organic iron-binding ligands in a three-dimensional biogeochemical ocean model. *Marine Chemistry* 173:67-77.

A final two-day symposium was held for SCOR WG 139 in Sibenik, Croatia. This symposium was open to the broader scientific community and was used as a platform to recommend future approaches to ligand measurements and highlight results from intercalibration and field activities. Fifty-one people attended the symposium, including 24 students and postdocs, who were each allotted time to present their research results in the field of ligand biogeochemistry. Twenty of the 51 symposium attendees also participated in a training workshop held the day before the symposium. This workshop was held at the Martinska Marine Station in Sibenik, and consisted of hands-on training in analyzing samples for metal-binding ligands and in using the state-of-the-art interpretation techniques developed in part through the activities of the working group.

- 7. To establish a webpage for this SCOR working group, to promote a forum for discussion of ideas and results in form of a blog, soliciting input from the trace metal biogeochemistry, organic geochemistry and modelling communities and provide a platform to propose special sessions on trace metal-binding ligands at international meetings such as Ocean Sciences, AGU and/or EGU.**

A webpage was created for this SCOR working group hosted by the University of Otago. However, since co-chair Sander relocated to the Marine Environment Laboratories of the IAEA in Monaco the webpage was moved to co-chair Buck's institution, the University of South Florida <http://www.marine.usf.edu/scor139/>. An email list for the WG members and another for those interested in following the working group's activities is hosted at the University of South Florida (scorwg139members@marine.usf.edu and scorwg139all@marine.usf.edu). The 'all' email list for this SCOR WG currently has 188 followers and will remain active for continued use in discussing accomplishments and activities of the working group.

- 8. To produce conclusions resulting from the outcome of the above objectives in the form of a Website, a journal special issue or book, and a report to SCOR.**

Information regarding the webpage is given above. The first special issue resulting from this WG's activities was published in July 2015 in *Marine Chemistry*, and included 28 research articles plus an editorial (<http://www.sciencedirect.com/science/journal/03044203/173>). The second special issue was published in *Frontiers in Marine Biogeochemistry* in June 2017 with a total of 21 research articles and an additional editorial (<http://journal.frontiersin.org/researchtopic/3981/organic-ligands---a-key-control-on-trace-metal-biogeochemistry-in-the-ocean#articles>). This second special issue was published as an open access e-book in summer 2017 and has been made available from the SCOR WG 139 website.

2.1.4 WG 141 on Sea-Surface Microlayers

Peter Burkill reported that no annual report was received from WG 141 by the time the background papers were printed, but that all the group's terms of reference have been completed. The group accomplished a [cruise on the R/V Falkor](#). Several papers were published from the group's work.

The terms of reference were the following:

- 1. Review sampling techniques and provide best practice sampling protocols. Such protocols will support new scientists entering the field of SML research to produce reliable and comparable data among different research groups/oceanic regions. The best practice sampling document will be made freely available online.**

COMPLETED. The 'Guide to best practices to study the ocean's surface' was published online in September 2014. To ensure that the document will be accessible beyond the lifetime of the SCOR SML WG, the document will be held by the Plymouth Marine Science Electronic Repository (managed by the Marine Biological Association), ensuring a permanent and free download link. <http://plymsea.ac.uk/6523/>.

- 2. Create a consensus definition of the SML in terms of physical, chemical and biological perspectives for a better understanding within the ocean science community, and discuss the SML's role in a changing ocean. This will be delivered as opinion/position paper in a peer-reviewed journal and will support future international projects concerning the SML and ocean change.**

COMPLETED. The recent publication including members of the SCOR SML WG in *Elementa* fulfills TOR 2 by providing SML's role in a changing ocean as well reiterate the definition proposed earlier by Hunter (2005).

- 3. Initiate sessions on SML research during major meetings (e.g., Ocean Sciences Meetings), to increase the awareness of the importance of the SML within the general ocean science community.**

COMPLETED. The working group has been engaged in several major meetings:

- Special session at Ocean Sciences Meeting 2016 in New Orleans 'Linking the Ocean with the Atmosphere - Exploring the Importance of the Ocean-Atmosphere Interface and Near Surface Waters in Global Scale Processes' (February 2016).
 - Special session at Ocean Sciences Meeting 2018 in Portland 'Ocean Biogeochemistry and Air-Sea Interactions' (February 2018).
- 4. Summarize and publish the latest advances in microlayer research in a special issue of a peer-reviewed journal, including consolidation of existing sea surface microlayer datasets among different disciplines (chemistry, biology, atmospheric, physics). The publication will promote new research ideas and projects at an interdisciplinary level.**

COMPLETED. The working group has published a special issue in the journal *Elementa: Science of the Anthropocene*. A total of 11 papers have been published in the special issue 'The Sea Surface Microlayer - Linking the Ocean and Atmosphere' (<https://collections.elementascience.org/sea-surface-microlayer>). The special issue is interdisciplinary, with a wide range of topics, including new technology, soot and aerosol

particles, biogeochemistry, role of bubbles, trace elements, microbiology and rheology.

It was agreed to disband the group.

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

Peter Burkill reported that no annual report was received from WG 142 by the time the background papers were printed. The group has published three papers so far:

- Bittig, H., A. Kortzinger, K. Johnson, H. Claustre, S. Emerson, K. Fennel, H. Garcia, D. Gilbert, N. Gruber, D.-J. Kang, W. Naqvi, S. Prakash, S. Riser, V. Thierry, B. Tilbrook, H. Uchida, O. Ulloa, and X. Xing. 2015. SCOR WG 142: Quality Control Procedures for Oxygen and Other Biogeochemical Sensors on Floats and Gliders. Recommendation for oxygen measurements from Argo floats, implementation of in-air-measurement routine to assure highest long-term accuracy. <http://doi.org/10.13155/45917>
- Bittig, H., A. Kortzinger, K. Johnson, H. Claustre, S. Emerson, K. Fennel, H. Garcia, D. Gilbert, N. Gruber, D.-J. Kang, W. Naqvi, S. Prakash, S. Riser, V. Thierry, B. Tilbrook, H. Uchida, O. Ulloa, and X. Xing. 2016. SCOR WG 142: Quality Control Procedures for Oxygen and Other Biogeochemical Sensors on Floats and Gliders. Recommendations on the conversion between oxygen quantities for Bio-Argo floats and other autonomous sensor platforms.
- Johnson, K.S., and H. Claustre. 2016, Bringing biogeochemistry into the Argo age. *Eos*, 97, <https://doi.org/10.1029/2016EO062427>. Published on 8 November 2016

One additional publication is in progress. It was agreed that the group should be extended until the 2019 SCOR meeting and that they should be requested to submit a final report.

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

John Turner reported that this group held its final meeting in conjunction with the Ocean Sciences meeting in Portland, Oregon, USA in Feb. 2018. They submitted an article on “A global inter-comparison of oceanic methane and nitrous oxide measurements” to the journal *Biogeosciences* in June 2018 (see <https://www.biogeosciences-discuss.net/bg-2018-274/>). Group members are leading a workshop on methane and nitrous in October 2018 at Lake Arrowhead, California, USA, funded by the U.S. Ocean Carbon and Biogeochemistry (OCB) program. The group is participating in preparation of a white paper for OceanObs’19.¹⁴ The group has requested to extend its term until the 2019 SCOR annual meeting to complete activities underway. This extension was agreed, but it was also noted that it would be good to increase the visibility of the group.

¹⁴Bange, H.W., D.L. Arévalo-Martínez, M. de la Paz, L. Farías, J. Kaiser, A. Kock, C.S. Law, A.P. Rees, G. Rehder, P.D. Tortell, R.C. Upstill-Goddard, and S. T. Wilson. 2019. A Harmonized Nitrous Oxide (N₂O) Ocean Observation Network for the 21st Century. *Front. Mar. Sci.*, 02 April 2019, <https://doi.org/10.3389/fmars.2019.00157>.

The group's terms of reference include the following:

1. Conduct an intercalibration exercise between the time series programs (for methane and nitrous oxide)

This is completed, with data analysis and publication pending. The group has conducted three intercomparison exercises of discrete seawater samples and one intercomparison of underway equilibrator systems. The inter-comparison of discrete seawater samples is the basis for the manuscript 'A global inter-comparison of oceanic methane and nitrous oxide measurements' which will be completed by June 2018.¹⁵

2. Establish the appropriate standards to be used by the scientific community

This is completed and the Technical Report has been published on the SCOR website.¹⁶ Gas standards were manufactured by John Bullister at NOAA PMEL and distributed to twelve groups around the globe. Every recipient is working with other scientists in their own respective countries to cross-calibrate their own standards where necessary.

3. Recommend the analytical reporting procedures to be used for N₂O and CH₄

The manuscript 'A global inter-comparison of oceanic methane and nitrous oxide measurements' will include some good practice recommendations for sample collection and analysis as well as data reporting. This will be completed by June 2018.

4. Establish framework for an N₂O/CH₄ ocean time series network and write a global oceanic N₂O/CH₄ summary paper for publication in an open-access journal.

There are different components to this Term of Reference:

- The production and distribution of common gas standards will benefit the framework for methane and nitrous oxide measurements. This has been completed.
- The intercomparison work identified several key steps to methane and nitrous oxide analyses that need to be taken into consideration when conducting the measurements. This forms part of the forthcoming *Biogeosciences* manuscript.
- There will be an OCB workshop at Lake Arrowhead Conference Center in October 2018. This workshop specifically asks the question 'Where are the critical locations in the global oceans to measure dissolved methane and nitrous oxide in order to document long-term changes to the ocean as a source of these greenhouse gases?' Therefore, in addition to existing measurements, where should new or increased measurements be located? This

¹⁵Wilson, S.T., H.W. Bange, D.L. Arévalo-Martínez, J. Barnes, A.V. Borges, I. Brown, J.L. Bullister, M. Burgos, D.W. Capelle, M. Casso, M. de la Paz, L. Fariás, L. Fenwick, S. Ferrón, G. Garcia, M. Glockzin, D.M. Karl, A. Kock, S. Laperriere, C.S. Law, C.C. Manning, A. Marriner, J.-P. Myllykangas, J.W. Pohlman, A.P. Rees, A.E. Santoro, M. Torres, P.D. Tortell, R.C. Upstill-Goddard, D.P. Wisegarver, G.L. Zhang, and G. Rehder. 2018. An intercomparison of oceanic methane and nitrous oxide measurements. *Biogeosciences* 15:5891–5907.

<https://doi.org/10.5194/bg-15-5891-2018>.

¹⁶<http://dspace.udel.edu/handle/19716/23288>

information will comprise the workshop report and will become part of any open-access peer-reviewed publication that is produced following the event.

- The GEOMAR group (H. Bange, A. Kock, D. Arevalo) will take the lead in writing a manuscript about the MEMENTO database for submission to *Earth System Science Data*. The MEMENTO database is the current data portal for the methane and nitrous oxide measurements.

2.1.7 WG 144 on Microbial Community Responses to Ocean Deoxygenation

Patricia Miloslavich reported that the group's major product, a special issue of the journal *Deep-Sea Research II*, is nearing completion and the group has asked to be disbanded. It was agreed to disband the group after publication of the special issue. It was also suggested that the group should be encouraged to complete the white paper related to its Warnemünde, Germany meeting.

- 1. Convene a practical workshop in Saanich Inlet, a seasonally anoxic fjord off the coast of Vancouver Island, British Columbia, Canada, to ground truth common standards for process rate and molecular measurements and identify model ecosystems for future cross-scale comparative analyses.**

The Saanich Inlet workshop was completed as planned during the first year of the program.

- 2. Convene a meeting at the Leibniz Institute for Baltic Sea Research in Warnemünde, Germany to codify standards of best practice, and compose a white paper describing said standards and opportunities.**

The Warnemünde meeting was held as planned during the second year of the program and a white paper was drafted. Although a final version was expected at the Goa workshop, that did not occur and the leader of that effort has let it be known that he will not be pursuing the project to publication.

- 3. Sponsor a workshop at the marine lab of the University of Concepcion, Chile, to disseminate the best practices described in the white paper, and to provide hands-on experience to international participants, and local students and scientists, with those practices.**

The workshop in Chile was an ambitious addition to the original plan, but it did not occur, due to funding and time limitations.

- 4. Convene a meeting at the National Institute of Oceanography in Goa, India, engaging local students and scientists in the project. The goal of this meeting is to compile a peer-reviewed monograph, which will be published as an electronic book in an open-access journal such as Frontiers or PLoS to ensure both visibility and long-term access.**
- 5. The Goa workshop, originally planned for the fourth year of the program, was moved to the third year and was successfully completed in December 2016. In addition to SCOR funds, the U.S. Ocean Carbon and Biogeochemistry (OCB) and**

Indian National Institution of Oceanography (NIO) also contributed substantially to the cost of the workshop and enabled the participation of many international scientists. The special journal issue planned for the output of the Goa workshop is in progress at DSR II and will be completed this year.¹⁷

2.1.8 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 also enlisted the help of several national laboratories in its work. The status of achievement of the groups terms of reference follow.

- 1. To document the current status, and basis in laboratory measurements, of Pitzer models of seawater and estuarine water focusing on the chemistry of ocean acidification and micronutrient trace metals (including, but not limited to, Fe, Cu, Cd, Co, Mn, and Zn).**

Documentation of the Pitzer model is completed (internal document). The first set of measurements for the model development is done and the database established.

- 2. To publish the results of the first term of reference in the refereed scientific literature, and to introduce the conclusions and recommendations to the oceanographic community at a “town hall” event or special session at an international ocean sciences meeting.**

The Website document is in progress and will be made available through internal reports. It was publicized at the 2018 Ocean Sciences meeting.

- 3. To specify the functions and capability for a web-based modelling tool that will make chemical speciation calculations easily accessible for a wide range of applications in oceanography research and teaching, and thus improve understanding and spread best practice in modelling.**

The SurveyMonkey web questionnaires on user requirements has been summarized on the WG web site.

- 4. To implement the web-based tool for chemical speciation calculations, based upon the specification developed in the third term of reference which will also be used to obtain external funding to develop the programs, documentation, and site.**

The coding is underway.

The group would like to postpone its next meeting until after the research is completed; they will have a special session, Town Hall, and/or tutorial at the 2020 Ocean Sciences Meeting. This

¹⁷Ward, B., N. Ramaiah, V. Edgcomb, and S. Crowe (eds.). 2018. Ecosystem Response to Ocean Deoxygenation. *Deep Sea Research Part II: Topical Studies in Oceanography* 156:1-168.

request was approved.

2.1.9 WG 146 on Radioactivity in the Ocean, 5 decades later (RiO5)

Denise Smythe-Wright reported that the group has completed its work in three areas related to its terms of reference. It has (1) published a major review article,¹⁸ (2) held several training workshops and created a series of four *Limnology and Oceanography* eLectures,¹⁹ and (3) has created a [cookbook of methods](#).

SCOR WG 146 has fulfilled all the Term of References. Some actions being taken are summarized below along the Terms of Reference:

- 1. Combine and build upon existing global and individual databases of natural and artificial radionuclide distributions to make a user friendly and easily accessible on-line product which will be useful to both the scientific community and the public.**

The WG has updated the database via the IAEA's MARiS portal (<https://maris.iaea.org>).

- 2 and 3: Summarize and publish review papers in peer-reviewed journals on these global radionuclide datasets and provide examples of how these can help improve our understanding of ocean processes and contaminant fate and transport. Identify gaps in scientific knowledge in relation to radioactivity in the marine environment and publish the results in a perspectives paper in Eos or elsewhere.**

A review paper was published:

Buesseler, K., M.H. Dai, M. Aoyama, C. Benitez-Nelson, S. Charmasson, K. Higley, V. Maderich, P. Masqué, D. Oughton and J. N. Smith. 2016. Fukushima Daiichi-Derived Radionuclides in the Ocean: Transport, Fate, and Impacts. *Annual Review of Marine Science* 9:1-31.

- 4. Bring together academic, nuclear industry and national laboratory expertise for an international symposium on radionuclides in the ocean.**

Due to financial difficulties in organising an international symposium, the WG decided to disassemble this ToR into multiple events with lower costs to serve similar purposes, which included special sessions organised in international conferences and designated public engagement and lectures. At the Goldschmidt 2017 conference in Paris, France, Paul Morris, along with other colleagues, organised a session entitled "Insights into Ocean Processes Through the Application of Radioactive Tracers". Ken Buesseler and Pere Masque co-chaired a session on "Radionuclides in the Ocean" at the Goldschmidt 2015 conference in Prague, Czech Republic on 16-21 August 2015. Michio Aoyama co-organized a session "Geoscience processes related to Fukushima and Chernobyl nuclear accidents" at the EGU General Assembly 2015 in Vienna,

¹⁸Buesseler, K., M.H. Dai, M. Aoyama, C. Benitez-Nelson, S. Charmasson, K. Higley, V. Maderich, P. Masqué, D. Oughton and J. N. Smith. 2016. Fukushima Daiichi-Derived Radionuclides in the Ocean: Transport, Fate, and Impacts. *Annual Review of Marine Science* 9:1-31.

¹⁹<https://aslopubs.onlinelibrary.wiley.com/toc/21640254/2018/8/1>

Austria on 12–17 April 2015. A series of public educational events was delivered in Xiamen on 8-10 June 2016, including demonstrations and hands on activities about radioactivity and radiation with the students in three local middle schools and one science museum, as well as a panel discussion (with 4 talks) for public audience and the media.

5. Provide a warehouse of education materials to assist in the education and training of the next generation of marine radiochemists and radioecologists.

A series of e-lectures on 1) Introduction to radiochemistry; 2) U–Th Series Radionuclides in Marine Systems; 3) Cosmogenic and Artificial Radionuclides in marine Systems; and 4) Marine Radioecology have been submitted for publication to *Limnology and Oceanography* e-lectures. All of the lectures have been accepted with some minor revisions. The WG held the first training course in Xiamen, China on 8-10 June 2016 and the second training workshop on 13 August 2017, in conjunction with the Goldschmidt conference in Paris, France. A training course building on RiO5 has been scheduled to be held in Puerto Rico on 21-23 February 2019 as a post-RiO5 event.

6. Develop web-based tools to enhance public understanding of radioactivity, in particular in the ocean.

The on-line methods “Cookbook” for radionuclides was developed (<https://cmer.who.edu/>). This is a resource for all where we could readily share past and current step-by step methods used for measuring radionuclides in largely (but not exclusively) marine samples.

It was agreed to disband the group.

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

Marie-Alexandrine Sicre reported that the group held its third meeting in February 2018 in conjunction with the 2018 Ocean Sciences Meeting in Portland, Oregon. Their work continues on the nutrient analysis portion of the GO-SHIP manual, work on the OceanObs’19 white paper, and on international nutrient intercalibration exercises. These activities will continue in the coming year and it was agreed to extend the group for another year and to provide funding for small writing meetings.

The group’s progress in fulfilling its terms of reference is as follows:

1. To establish mechanisms to ensure comparability of oceanic nutrient data in collaboration with International organisations such as ICES and PICES.

WG 147 has collaborated with JAMSTEC, and has now been providing SI-traceable Nutrient CRMs for the global community since November 2016, and the final Atlantic water high and medium concentration CRMs have just recently become available. At the 3rd WG 147 meeting, we discussed how to continue the distribution and sale of the SCOR-JAMSTEC CRMs, and considering the possibility of JAMSTEC stopping supporting the current distribution system. The group discussed a new system that would be supported by international bodies such as IOCCP and others. WG 147 has already been in close collaboration with IOCCP and JAMSTEC

to conduct the IOCCP-JAMSTEC inter-laboratory calibration exercise of CRM/RMNS in 2017/2018.

- 2. To assess the homogeneity and stability of currently available RMs/CRMs: The group needs to determine whether the current producers are achieving a level of precision within and between laboratories which is comparable to or better than 1%.**

In the IOCCP-JAMSTEC Inter-laboratory calibration exercise of CRM/RMNS in 2017/2018, NMIJ CRM, KANSO CRM and KIOST RM were used. The results of this exercise have not yet been finalized and will be published once complete.

- 3. To develop standardized data-handling procedures with common data vocabularies and formats, across producers and users, and will include the future linking of national and international data archives. The group will seek to involve international data center representatives to contribute to and lead this task.**

A part of this ToR #3 will be included in the updated GO-SHIP nutrients manual, discussed in ToR #6.

- 4. To promote the wider global use of RMs by arranging workshops to actively encourage their use, and to provide training in analytical protocols and best practices, including sample preservation protocols, particularly targeted towards developing countries.**

WG 147 organized the ‘International training workshop on Nutrient analysis’, which was held at the NIOZ laboratory in November 2017. This was co-organized by NIOZ and PML. Details of this very successful workshop are outlined above in Section 2.

- 5. To continue regular global inter-comparison studies, following on from the previous exercises in 2003, 2006, 2008, 2012 and 2015/16, with collaboration of IOCCP-SSG and RCGC-JAMSTEC.**

WG 147 collaborated with IOCCP and JAMSTEC and helped to conduct the IOCCP-JAMSTEC inter-laboratory calibration exercise of CRM/RMNS in 2017/2018. The 8 scientists from developing countries who attended the training workshop were also invited to participate in the international intercalibration exercise.

- 6. To update the GO-SHIP nutrient measurement manual, which was originally a product of the IOC-ICES SGONS, (Study Group on Nutrient Standards).**

WG 147 has a near final draft of the updated GO-SHIP nutrient manual, and this draft is out for comment to the authors. WG 147 are continuing this work to finalize this update.

7. To publish reports on this WG's activities and workshops.

Updates have been communicated to the other WG members and for the Intercalibration exercise and GO-SHIP manual will be published when completed.

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

Sergey Shapovalov reported that no annual report was received from WG 148 by the time the background papers were printed, but was submitted before the meeting (see https://scor-int.org/Annual%20Meetings/2018_SCOR_Meeting/WG_148_Report.pdf). There have been some membership changes in the group. Funding was approved for a 2019 meeting of the group.

The status of the group's terms of reference are as follows:

- 1. To develop, implement and document algorithms for assignment of “intelligent” metadata –i.e. an informed guess as to likely values for missing information – for temperature profiles where crucial metadata is missing.**

A Palmer et al. (2018) paper describing the IQuOD v0.1 intelligent metadata algorithm has been published in *Journal of Atmospheric and Oceanic Technology*.²⁰ These metadata assignments have been included in the v0.1 IQuOD database (published March 2018).

- 2. To evaluate and document the most effective combination of automated quality control (AutoQC) procedures for temperature profile observations.**

Fifty AutoQC tests from six different institutions have been implemented and are freely available from the GitHub repository: <https://github.com/IQuOD/AutoQC>. Progress has been made improving the software infrastructure and code to assess the performance of AutoQC combinations to yield best combination of tests for a given false positive rate. A first assessment of best combinations has been carried out on the QuOTA dataset.

- 3. To establish and implement a set of optimal automated quality control procedures, by reaching international community consensus and using the knowledge gained in the benchmarking tests from ToR-2 (above); to produce and publish a reference guide for best practices in automated quality control of ocean temperature profiles; and to develop and freely distribute an open-source quality control software toolkit to promote wide and rapid adoption of best practices by the oceanographic community.**

All code continues to be made available in real-time via the GitHub repository. Analysis of AutoQC tests has begun and will form the basis of a scientific paper.

²⁰Palmer, M.D. T. Boyer, R. Cowley, S. Kizu, F. Reseghetti, T. Suzuki and A. Thresher. 2018. An Algorithm for Classifying Unknown Expendable Bathythermograph (XBT) Instruments Based on Existing Metadata. *Journal of Atmospheric and Oceanic Technology* 35:429-440, <https://journals.ametsoc.org/doi/abs/10.1175/JTECH-D-17-0129.1>.

- 4. To examine and document the feasibility of machine learning and other novel computational methods for enhanced quality control, to potentially minimize labor costs associated with human expert quality control procedures.**

Machine learning approaches are being used as part of the AutoQC benchmarking exercise (e.g. the CoTeDe “fuzzy logic” test). Machine learning approaches are also being investigated for future assignment of XBT intelligent metadata (iMeta). A paper on applying a neural network approach to iMeta is currently under revision at *Journal of Atmospheric and Oceanic Technology* with a more comprehensive intercomparison of various Machine Learning approaches underway at the UK Met Office.

- 5. To develop, implement and document internationally agreed best practice methods for assignment of uncertainty estimates to each temperature observation.**

A first approach to assignment of uncertainty to each temperature observation has been devised and is incorporated into the IQuOD v0.1 dataset. Details are available here:

https://www.nodc.noaa.gov/archive/arc0118/0170893/1.1/data/0-data/IQuOD_v0.1_information.pdf.

- 6. To freely disseminate (interim) versions of the IQuOD global temperature profile database (and added value-products) as it evolves over the next 3 years, in user-friendly file formats.**

A first v0.1 IQuOD dataset has been released, using the World Ocean Database file format, which is widely used by the international community. There are ongoing discussions on the file format for the first complete IQuOD release (including AutoQC flags), which will be based upon the widely used Argo NetCDF format. More details are available here:

<https://github.com/IQuOD/Formats>.

- 7. To share knowledge and transfer skills in instrumentation, regional oceanography, quality control procedures and data stewardship with international scientists in both developed and developing nations.**

Knowledge transfer activities are reflected in the strong representation of WG members at the AGU Ocean Sciences meeting in February 2018 and the EGU general assembly meeting in April 2018. The 2018 IQuOD workshop was well attended with participants from a range of different countries. More details are available here:

https://iode.org/index.php?option=com_oe&task=viewEventParticipants&eventID=2100.

2.1.12 WG 149 on Changing Ocean Biological Systems (COBS): how will biota respond to a changing ocean

Patricia Miloslavich reported that no annual report was received from WG 149 by the time the background papers were printed, but a report was submitted before the meeting (see http://scor-int.org/Annual%20Meetings/2018_SCOR_Meeting/WG149.pdf). The group has been active, but has not yet finished its terms of reference. They raised \$30-40k of additional funds to support the group’s work and NSF has approved \$20,000 per year for 2019-2021. SCOR will transition WG

149 to a SCOR “infrastructural project” funded by NSF, continuing SCOR branding.

Progress of WG 149 on its terms of reference are as follows:

- 1. Assess the current status of emerging research themes 1-3 by reviewing the literature to assess the dominant research foci, their relative coverage, and identify any major gaps and/or limitations. Publish this review in an open-access peer-reviewed journal.**

The following open-access review was published:

Boyd, P.W., S. Collins, S. Dupont, K. Fabricius, J.-P. Gattuso, J. Havenhand, D.A. Hutchins, U. Riebesell, M.S. Rintoul, M. Vichi, H. Biswas, A. Ciotti, K. Gao, M. Gehlen, C.L. Hurd, H. Kurihara, C.M. McGraw, J.M. Navarro, G.E. Nilsson, U. Passow, and H.-O. Pörtner. 2018. Experimental strategies to assess the biological ramifications of multiple drivers of global ocean change—A review. *Global Change Biology* DOI: 10.1111/gcb.14102

- 2. Raise awareness across different scientific communities (evolutionary experimental biologists, ecologists, physiologists, chemists, modelers) to initiate better alignment and integration of research efforts.**

The group has been better aligning and cross-referencing research efforts by making contact with other groups engaged in multiple driver research. In particular, the group has swapped details and posted them reciprocally on partner websites (see Group Website: <http://scor149-ocean.com/partners/>). The group is also trying to grow stronger international linkages, and during its 3rd annual WG meeting in July 2018, skyped with Denise Breitburg (chair of the GO2NE IOC-based hypoxia program) and Salvatore Arico of IOC. The group has also been engaging with IMBeR, and plans to jointly host a 1-day workshop at IMBeR’s 2019 Open Science Conference in Brest, France.

- 3. Co-ordinate thematic transdisciplinary sessions to attract and assemble experts from other fields such as paleoceanography and marine ecotoxicology to learn from the successful approaches their fields have developed to address multiple drivers.**

WG 149 was part of a joint session on multiple stressors along with IMBER and NOAA as part of the ECCWO Climate Change conference in Washington, DC in May 2018 <https://meetings.pices.int/meetings/international/2018/climate-change/scope>. The group also ran a special session on multiple drivers and microbes at the AGU Ocean Sciences meeting in Portland, Oregon in February 2018.

- 4. Develop a multi-driver Best-Practice Guide (BPG, or other tools) as one potentially valuable way to help this research field move forward in a cohesive manner.**

The main topic of discussion at the WG 149 annual meeting was the advances of the Web-based BPG. In summary, the decision support strand is complete, the ‘story-board’ and 4D look-up

data table for the virtual laboratory strand is also complete, and the first video tutorial is ready to be released. The 40-page ‘course-book’ pdf is written with a cover design. We have had some delays with the software/graphical interface company, such that we are now seeking another company to carry out this part of the Web-based guide. Christina McGraw continued to shoot video footage at the SCOR WG and at the GRC (Kristy Kroeker on meta-analyses and Gretchen Hoffman on Evolution and Ecology). The forthcoming Web-based BPG has been publicized at a range of venues: Ocean Sciences (Feb. 18 in Portland, Oregon; posters at SCOR and OCB booths); U.S. Ocean Acidification PI meeting (March 18, Poster); Ocean GBC GRC (July 18, Hong Kong, poster); IMBeR SSC (Hobart, April 18, oral) Ocean Carbon Biogeochemistry workshop (Woods Hole, June 18, poster and oral presentation); and oral presentations at both the Ocean Global Change Biology GRS and GRC (July 18, New Hampshire). The group’s plans for the remainder of 2018 are to finish and launch the Web-based BPG, calling on members to help with publicity within their countries/institutions about the launch.

5. Mentor early career scientists in the design process for complex multiple driver manipulation experiments, familiarize them with BPG, and teach them practical methodologies for the analysis of their experimental findings.

COBS will run a training workshop (sponsored by IAEA) at IAEA Monaco lab on 24-28 June 2019. The group is in discussions to arrange other training workshops/summer schools, potentially in the United States and Europe in 2020.

6. Publish a series of short articles in both the scientific media and with scientific journalists to disseminate the challenges and opportunities surrounding multiple drivers and ecosystems.

7. Engage with policy-makers and science communication experts to produce a glossary of terms and an implementation guide for policy-makers to better understand the role of multiple drivers in altering marine living resources and ecosystem services.

TOR 6&7. These will be worked on via intersessional work, for which we already have had some input on from various COBS members.

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

Sari Giering, the chair of WG 150, made a presentation about the group’s work. WG 150 met in conjunction with the 2018 Ocean Sciences Meeting. They opened a Research Focus topic in *Frontiers in Marine Science* (see <https://www.frontiersin.org/research-topics/7817/we-shed-light-optical-insights-into-the-biological-carbon-pump#overview>); the anticipated submission deadline is 19 April 2019. Members of TOMCAT are actively involved in shaping a Community White Paper on Observational Needs as part of OceanObs’19. Peter Burkill noted the good progress of the group. The next meeting of the group is planned for early 2019. SCOR approved funding for the 2019 meeting.

2.1.14 WG 151: Iron Model Intercomparison Project (FeMIP)

Colin Devey reported that WG 151 held its first meeting in February 2018, in conjunction with the Ocean Sciences Meeting in Portland, Oregon. The WG has formed three subgroups, on (1) external input, (2) biological cycling (incl. uptake and regeneration), and (3) speciation/scavenging (including ligand aspects). A review article is being planned to recommend how to include these factors for iron in ocean models. The group is compiling information on created software routines to assess skill metrics. Term of Reference #4 may be particularly difficult to achieve, but SCOR will emphasize that this item needs to be addressed during the lifetime of the group.

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

John Turner reported that the group held an intercalibration exercise in March 2018. It has submitted one article, to *Polar Biology*, on the intercalibration, and has two additional publications in preparation. The group has created a Website in the past year: <https://sites.google.com/view/ecv-ice/>. The group met in conjunction with the June 2018 POLAR2018 meeting in Davos, Switzerland. WG 152 is active and funding was approved for a 2019 meeting of the group.

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

Denise Smythe-Wright reported that this group met for the first time in April 2018 in conjunction with another meeting on marine litter, where they were involved in one plenary session and four break-out sessions. They have established a Website for the group (<http://scor-flotsam.it>). WG 153 is preparing several publications, including participating in a white paper on marine litter for OceanObs'19, to be published in *Frontiers in Marine Science*. The group is planning to meet next in Utrecht, The Netherlands in spring 2019. Funding was approved for a 2019 meeting of the group.

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

Patricia Miloslavich reported that the group met for the first time in conjunction with the Ocean Sciences Meeting in Portland, Oregon in February 2018. It published an article about the group in the *Limnology and Oceanography Bulletin*.²¹ A subgroup of the group will meet 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, possibly in conjunction with Ocean Obs'19. The group is working well. Funding was approved for the group's 2019 meeting.

²¹Boss, E., A. Waite, F. Muller-Karger, H. Yamazaki, R. Wannikof, J. Uitz, S. Thomalla, H. Sosik, B. Sloyan, A. Richardson, P. Miloslavich, J. Karstensen, G. Gregori, K. Fennel, H. Claustre, M. Cornejo, I. Berman-Frank, S. Batten, S. Acinas, 2018. Beyond Chlorophyll Fluorescence: The Time is Right to Expand Biological Measurements in Ocean Observing Programs. Community news, *Limnology and Oceanography Bulletin*, <https://doi.org/10.1002/lob.10243>

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

David Halpern reported that the group met for the first time in June 2018, in conjunction with the 4th International Symposium on the Effects of Climate Change on the World's Oceans (ECCWO) in Washington, D.C. As a result of the June 2018 meeting, the group is working on a review paper about Knowledge of EBUS systems, a second paper on EBUS models, ideas for a summer school and open science meeting, a data portal, and a data and monitoring needs report. Funding was approved for a 2019 meeting of the group.

2.2 Working Group Proposals

2.2.1 Active Chlorophyll fluorescence for autonomous measurements of global marine primary productivity

Denise Smythe-Wright presented the proposal. There were very few negative comments. Most national SCOR committees thought the proposal focused on a timely and priority topic; there is an urgent need for standardization of primary productivity measurements, since this underpins so many important ocean processes. No countries ranked the proposal as “do not fund”. Some countries found the terms of reference to be ambitious, although they well reflected what is needed. The membership includes key scientists, but few women and too many Northern Hemisphere members. The capacity building is primarily through developing protocols.

In terms of national comments, the German SCOR Committee rated the proposal as “may fund”. If the group is approved, it may be necessary to get manufacturers involved in some way. The group's capacity building activities should be improved. The Italian SCOR Committee rated the proposal as “must fund”. It is ambitious, but timely. In terms of membership, developing countries are missing and the gender balance is poor. The Korean SCOR Committee ranked the proposal as its top “must fund”. They did not think the manufacturer problem is significant, as each machine is calibrated individually. The key issue is the development of protocols and this will be a focus of the group. The terms of reference are too ambitious. The Japanese SCOR Committee was very positive about the proposal, although ranked it as a “may fund”. The remote sensing aspects of the proposal seem very scattered. The South African SCOR Committee noted that the South African community is not involved in the proposal; this is something that needs to be addressed by the national committee. The Dutch SCOR Committee stated that the terms of reference are too ambitious and should be addressed to check for feasibility when funded. The U.S. SCOR Committee found the proposal to be visionary, timely, and explained very well. If half of the terms of reference are accomplished, that would still be a very good outcome. An effort should be made to fix the gender imbalance. The UK SCOR Committee ranked the proposal as “may fund”. If funded, the group should ensure to transfer the resulting knowledge to the community. The Canadian SCOR Committee ranked the proposal as a high “may fund”; having a SCOR working group may be helpful to get the extra funds to conduct some of the proposed work. There was a question about whether the group could fulfill its terms of reference without raising more funds. The Swedish SCOR Committee had the same ranking and similar concerns. The China-Beijing SCOR Committee also ranked the proposal as a high “may fund”. The Russian SCOR Committee ranked the proposal somewhat lower, considering it not so

timely, moderately interesting scientifically, but not a high priority for SCOR. The terms of reference are clear and the membership is OK, but the gender balance could be improved.

Fauzi Mantoura (chair of former SCOR WG 78) noted that partnerships are essential and co-funding could come from a consortium of manufacturers. Missy Feeley, a representative of the SCOR Committee on Capacity Building stated that the capacity-building plans need to be clearer and more specific. Peter Burkill noted that if the group wants to do experimental work (and it seems essential), extra funding will need to be secured.

After discussions, this proposal was approved.

2.2.2 The Surface Ocean CO₂ Mapping intercomparison initiative: Phase 2 (SOCOMv2)

Denise Smythe-Wright presented a summary of the proposal and of comments received from national SCOR committees. Most committees considered the proposal to be timely and of high priority for the ocean science community. The topic is appropriately global in scope. The terms of reference are generally good. The membership includes some young scientists, although most Full Members are from the Northern Hemisphere and the chair and co-chair are both from Germany. The activities proposed may be too broad and long term for a SCOR working group. The terms of reference are ambitious. It wasn't clear why they would estimate uncertainty using models instead of using data. The capacity building plan is not convincing. This is the second stage of the project; does it need SCOR to move forward or can it succeed in the same manner as the first phase, with no SCOR involvement? There was no mention about data quality in the proposal.

The Netherlands SCOR Committee ranked the proposal as “may fund”, as these issues need to be addressed. The German SCOR Committee ranked the proposal as “must fund”, but recognized that one of the German co-chairs would have to be changed. They also noted that the proposal should have explained better the relation of the proposed work with SOCAT and SOLAS. This is a very pressing topic, so they ranked this proposal first among the 9 proposals. The UK SCOR Committee was mixed in its assessment of the proposal. The most negative comment was about the narrowness of the membership. The Finnish SCOR Committee rated the proposal as “may fund”; they had some doubts about this proposal because uncertainties in CO₂ fluxes are still not addressed. The South African SCOR Committee rated the proposal as “may fund” and noted that it has the ability to contribute to the CO₂ flux database. The Italian SCOR Committee rated the proposal as “may fund”. They recognized the importance of the problem, but the terms of reference were not entirely clear. What would be the advantage of having a SCOR working group rather than continuing as SOCOM did? The gender balance is acceptable. The Japanese SCOR Committee rated the proposal as “may fund”. The topic is important and a SCOR working group would be a good mechanism to address it. However, the terms of reference would still be difficult to achieve. The Korean SCOR Committee rated the proposal as high in the “may fund” category. The Canadian National Committee for SCOR considered this proposal to be in the “must fund” category because the topic is so timely because of the need to understand CO₂ fluxes to create more accurate climate forecasts. The Swedish SCOR Committee rated the proposal as a “do not fund”. The CO₂ flux problem is important, but there are many other groups working on this topic, so it is not clear what a SCOR working group would add. The terms of reference are not clear enough for a SCOR working group. The Polish SCOR Committee rated

the proposal as “must fund”, although agreed with other committees that there should not be two chairs from the same country. The Russian SCOR Committee rated the proposal as “may fund” because the topic is timely and important. The U.S. SCOR Committee rated the proposal as “may fund”.

The SOLAS representative stated that it is not clear that the approach described will answer the problems noted. PICES rated the proposal as “may fund”, but it was not clear how the working group would be more than a phase II of the SOCOM project. SCOR should focus on Phase 1 projects and not the continuation of existing projects. IAPSO rated the proposal as “must fund” because it is an important problem. IABO rated the proposal as “may fund” because it is a continuation of a previous project, there is a lack in disciplinary collaboration, and the membership is limited. The group should include experts to link biology to the carbon sink.

After discussion of all the proposals, this one was not approved for funding.

2.2.3 Ocean Governance and Policy Analysis for Ocean Deoxygenation (WG-OGOD)

Sergey Shapovalov summarized the proposal and comments from national SCOR committees. Ocean deoxygenation is a timely issue, but there were mixed comments about whether a working group on governance is timely, and most national SCOR committees thought that SCOR is not the right organization to pursue governance and policy analysis activities. SCOR has already had three working groups on ocean oxygen topics in the past 10 years (WGs 128, 142, 144). The terms of reference are too general, broad, long term, and ambitious for a SCOR working group. The gender balance of the proposed membership is good, but the geographic balance needs to be improved. The work plan and deliverables are too vague. There is duplication with the IOC program GO₂NE.

The German SCOR Committee rated the proposal “do not fund”; it is much more applicable for the Ocean Knowledge Action Network than for a SCOR working group. The terms of reference were too vague for a working group and the deliverables were not clear. The Italian SCOR Committee also rated the proposal as “do not fund” because it is very weak. This is not a traditional topic for SCOR, but actually interesting and might be encouraged in the SCOR realm in other ways. The South African SCOR Committee noted that a good number of developing country scientists are proposed as members. The UK SCOR Committee did not think this would be a good proposal to get more social science aspects into SCOR. There is a policy issue about whether SCOR should fund proposals that are strictly outside the scientific approach, but the proposal is very weak and thus was rated “do not fund”. The SCOR Executive Committee will discuss this. IAPSO wondered whether SCOR we needs to reach out to social scientists.

After discussion of all the proposals, this one was not approved.

2.2.4 Carbonate system intercomparison forum (CSIF)

Peter Burkill presented a summary of the proposal and the written comments received from national SCOR committees. Many committees thought the concept of the proposal is important because of the importance of consistent CO₂ measurements. However, issues were noted in related to the membership (all proposed Associate Members are from developed countries) and

the capacity building plan (completely missing). The number of rankings from national committees were similar between the “must fund”, “may fund” and “do not fund” categories.

National committee representatives present at the meeting presented their comments. The Swedish SCOR Committee thought that there were too many similarities between this proposal and SCOR WG 145 (Modelling Chemical Speciation in Seawater to Meet 21st Century Needs), but these similarities were not addressed. The Swedish Committee rated the proposal as “do not fund”. The UK SCOR Committee thought the terms of reference were not clear. The German SCOR Committee ranked the proposal low because the activities seem to be mostly about convening discussion, and not producing ground-breaking products. There is a Northern Hemisphere bias, although the gender balance is good. This proposal is complementary to the other carbonate proposal (SOCOMv2). The Italian SCOR Committee rated the proposal as “must fund”. The scientific question is clear, important, and needs to be addressed, although the terms of reference and deliverables are a bit vague. The South African SCOR Committee rated the proposal as “do not fund” because it is too Northern Hemisphere biased and does not have much scientific merit. The Canadian National Committee for SCOR rated the proposal as “may fund”. The topic is very important and the proposal is timely, but it discusses the problems without much clear action proposed. The Korean SCOR Committee agreed with the views of the Canadian Committee. The China-Beijing SCOR Committee rated the proposal as “may fund”. The Finnish SCOR Committee rated the proposal as “must fund”, but there were doubts in terms of low salinity and good buffer environments (e.g., Baltic Sea) not being acknowledged. Despite their rating, the Finnish Committee thought that the SCOR working group approach is not needed to do the suggested work. The Finnish representative lowered their rating to “may fund” after the discussion. They also raised the question about who would arrange the intercomparison discussed in the proposal. The Japanese SCOR Committee rated the proposal as “must fund” because of the importance of this issue, although their proposal was not well written. The U.S. SCOR Committee, Dutch SCOR Committee, and Russian SCOR Committee rated the proposal as “must fund” because of the importance of better understanding the carbonate system. The Polish SCOR Committee rated the proposal as “may fund”.

IAPSO rated the proposal as “must fund” because of the importance of the carbonate issue. The SOLAS representative stated that the proposed work is important, but it is not clear that a SCOR working group is best way to do it. The membership should be changed if it is important to raise visibility, adding developing country and early-career scientists who are facing the standards issue. The proposal now only includes senior scientists. PICES rated the proposal as “may fund”.

After discussion of all the proposals, this proposal was not approved.

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

The proposal was presented by Patricia Miloslavich. The group has a strictly zooplankton focus in its terms of reference and membership, with an emphasis on molecular taxonomy, with almost no traditional taxonomists involved. The group was generally considered to be timely and a priority for SCOR and the field of ocean science. The work of the group will be important for developing and applying indicators to assess the state of the ocean. There was mixed opinion on the ability of the group to develop and maintain the DNA reference database. International

collaboration is essential to have standardization of methods and comparability of results. The gender and geographic balances, and inclusion of four members from developing countries, is good. National committees and meeting participants noted that the new working group should find ways to collaborate with SCOR WG 154 on Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (P-OBS), the Continuous Plankton Recorder, and the Best Practices platform of the International Oceanographic Data and Information Exchange (IODE).

The German SCOR Committee ranked the proposal as “may fund”. The most problematic issue for the committee was that the proposed group did not link to morphological taxonomists and to other actions ongoing on the topic globally, for example, funded by the Moore Foundation. The Canadian SCOR Committee ranked the proposal as “must fund” and found it to be strong and well-organized. The proposed members are the key scientists in zooplankton molecular biology. The Dutch SCOR Committee ranked the proposal as “may fund”, although they thought the terms of reference looked too much like deliverables. The Italian SCOR Committee ranked the proposal as “must fund”. They found that the proposed members are good experts in this area and the composition of the group is appropriate. The topic is important and they had no significant negative comments. The UK SCOR Committee rated the proposal as their highest “must fund” and found that the proposed membership is good for this topic. The proposal did a good job of justifying why a SCOR working group is needed. This is a good topic for SCOR because it is a future-looking topic. The Korean SCOR Committee thought that the theme is very important, but it may take longer to synthesize the morphological and molecular database than the typical life of a SCOR working group. The China-Beijing SCOR Committee ranked the proposal as “must fund” and found that the proposal provided good background for this topic that is relevant to SCOR. The South African SCOR Committee was undecided about how to rank the proposal. Barcoding will be important for the future, but perhaps the focus on zooplankton is too narrow. The U.S. SCOR Committee ranked the proposal as “may fund” because they were unsure whether SCOR is a good mechanism for this kind of activity in a rapidly moving field. The terms of reference were not compelling. The Japanese SCOR Committee rated the proposal as “must fund”, as did the Russian SCOR Committee. The latter committee stated that this is a very interesting approach for a topic that is important at the global level. The North Pacific Marine Sciences Organization (PICES) rated the proposal as “must fund”, whereas IAPSO reviewers were split between “must fund” and “do not fund”.

Peter Burkill noted that there is a huge problem for measuring zooplankton and the only way to analyze species composition rapidly is through barcoding. A SCOR working group would provide the opportunity to bring together information from many nations working on this issue and SCOR would provide the best mechanisms. However, it is unclear whether they will focus on all zooplankton or will focus on copepods.

The final decision of the representatives of national SCOR committees and Affiliated Organizations present was that this should be one of the two proposals funded this year.

2.2.6 The Caribbean Upwelling Research Network (CURNet)

David Halpern presented a summary of the proposal and of comments from national SCOR committees. The upwelling zone in the Caribbean is not well studied. The proponents want to

promote exchange between local science groups. This is perhaps more of a capacity building opportunity that might be addressed by IOC. The proposed deliverables would potentially duplicate those of the SCOR WG on Eastern Boundary Upwelling Systems (WG 155). National committees rated the proposal as timely, but low priority. Most committees did not think the terms of reference were compelling. The proposed membership did not include enough female members or enough members from the Caribbean.

The Swedish SCOR Committee noted that this region needs strengthening of its research, but the impact of this group on ocean sciences would not be very high. The U.S. SCOR Committee commented that the only positive attribute of the proposed activity would be capacity building, so it should not be funded as a working group. They rated the proposal in the lower “may fund” range. Perhaps IOC would like to take on such a project. The U.K. SCOR Committee rated the proposal as “do not fund” because the proposal is undeveloped and there is a lack of Caribbean representation. The Italian SCOR Committee rated the proposal as “do not fund” as the science is too general and is limited to the Caribbean. The German SCOR Committee was worried that this community has the potential to become isolated; they need to connect to the global community. Nations with upwelling systems should suggest the membership. The Finnish SCOR Committee rated the proposal “do not fund” in the form in which it was submitted. The China-Beijing SCOR Committee rated the proposal “do not fund”. The Korea SCOR Committee also rated the proposal “do not fund”; the Caribbean is too regional a topic for SCOR. There is not good enough science proposed.

IABO noted that their main concern is that the proposal did not include the largest database in the Caribbean, for the Cariaco Basin. Data collection stopped two years ago, but this is a unique database, with data for 20 years, 2 cruise per year. There is a lack of background information in the proposal. They rated it “do not fund.” PICES ranked the proposal very low. It looks like a rushed application. However, this regional does need capacity building and the topic is valid.

After discussion of all the proposals, this proposal was not approved for funding.

2.2.7 A Framework for Ocean Observation for the Next Generation - expanding quantifiable methods and Best Practices (FOO-BP)

Peter Burkill presented a summary of the proposal and of comments from national SCOR committees. The rankings were mixed, with a predominance of “do not fund” rankings.

The German SCOR Committee rated the proposal as “do not fund” because the group is not suited for SCOR. There are other ways to pursue these activities, such as through the OceanObs’19 conference. The South African SCOR Committee thought the proposal was not clear enough. The U.S. SCOR Committee stated that the proposal is not timely and there is no indication that the group will advance ocean science. The Italian SCOR Committee rated the proposal as a lower “may fund”; it is potentially important activity, with many disciplines going in this direction, but perhaps is not timely now. The proposal should be written better. The China-Beijing and Korean SCOR Committees rated the proposal as “do not fund”. It would use existing mechanisms and the proposal is very vague. The Russian SCOR Committee also rated the proposal as “do not fund”, since there are other similar international activities. The Dutch SCOR Committee also rated it as “do not fund” because this does not fit SCOR well and is not a

good proposal. The Finnish Committee rated the proposal as “may fund” because compiling best practices is an important activity. Peter Burkill commented that the ocean science community should embrace this kind of activity, but it is not suitable for SCOR; GOOS and OceanObs’19 would be more appropriate.

After discussion of all the proposals, this one was not approved.

2.2.8 Coordinated Global Research Assessment of Seagrass Systems (C-GRASS)

Sun Song presented a summary of the proposal and written comments from national SCOR committees. Seven national committees rated the proposal as “must fund”, 10 rated it as “may fund” and 1 rated it as “do not fund”. The consensus was that it is an important topic globally and urgent. But it would be hard for the working group to achieve the proposed goals.

The UK SCOR Committee rated the proposal as “must fund” because the well-written proposal focuses on an important subject. The Canadian National Committee for SCOR rated the project as “may fund” because it is an important topic and they thought the approach described is achievable. The Korean SCOR Committee rated the proposal as “must fund” because the subject is important and the global distribution of seagrasses has not been assessed. The proposal is well written. The Swedish SCOR Committee rated the proposal as a high “may fund”. The proposal is well written and it would be good to have a standardized monitoring approach for seagrass. The Finnish SCOR Committee rated the proposal as “may fund”, although there are already excellent networks for seagrass and it is difficult to find the added value of a SCOR working group on this topic. The German SCOR Committee had similar comments to the Finnish Committee, and rated the proposal as “may fund”. The capacity building plan should be clearer. The Italian SCOR Committee rated the proposal at the high end of “may fund”. They liked the proposal, but the three measurement approaches were not well described. The South African SCOR Committee rated the proposal as “must fund” because seagrass observations is an important topic and the proposal was well written. The Polish SCOR Committee thought the proposed work is achievable and rated the proposal as “must fund”. The Japanese and U.S. SCOR Committees rated the proposal as “may fund” and the China-Beijing SCOR Committee rated it as “must fund”. The Russian SCOR Committee rated the proposal as “do not fund” because they believe that other proposals were more important for ocean science and for SCOR. They thought that terms of reference #1 and #4 will be difficult to finish in three years.

PICES liked the proposal, rating it “may fund”. The effort to synthesize is important, and the proposal recognizes social and economic relevance of seagrass observations. IAPSO also rated the proposal as “may fund”.

After discussion of all the proposals, this one was not funded.

2.2.9 Co-ordinated approach for Aerosol Trace element Solubility and Bioavailability Research in Oceanography (CoATS-BRO)

Núria Casacuberta Arola presented a summary of the proposal and of written comments from national SCOR committees. There was general agreement that the activity would be timely because it had been 10 years since the previous intercalibration, and that the activity is high priority for SCOR and SCOR would be a good mechanism to conduct some of the terms of

reference. However, there was some disagreement about whether all the terms of reference would be suitable for a SCOR working group. There were some comments that these activities might be better suited for SOLAS or GEOTRACES, there should be more focus (e.g., on iron), and that activities of the group do not tackle bioavailability, as stated in title. There is only one modeler involved, as an Associate Member, yet one term of reference focuses on modeling. It is unclear how they plan to interact with GEOTRACES and other projects. The proposed membership has good gender and geographical balance.

The UK SCOR Committee rated the proposal as “may fund”. It is good science, but not high priority compared with the other proposals. There is a potential overlap with other SCOR working groups and projects. The German SCOR Committee rated the proposal as “must fund”, mainly because the atmospheric scientists who reviewed the proposal were strongly in favor of it. The Finnish SCOR Committee rated the proposal as “do not fund”. There is a strong aerosol group in Finland and they do not think the funds for a SCOR working group will cover the work proposed. And the aerosol activity as mentioned in the title is not addressed because iron is the only element that seems to be in mind. They considered the proposal premature for funding. The Italian SCOR Committee also rated the proposal as “do not fund” because the terms of reference are not convincing. The Korean SCOR Committee recognized that this is an important topic, but there are weaknesses in the proposal, such as not recognizing related activities that could be complementary. The China-Beijing SCOR Committee rated the proposal as “may fund”. The South African SCOR Committee rated the proposal as “may fund” as the long list of deliverables looked too ambitious. The Canadian National Committee for SCOR also rated the proposal as “may fund” for similar reasons mentioned by other national committees. The U.S. SCOR Committee rated the proposal as “must fund” because it is timely and high priority, and a SCOR working group would be a good mechanism to accomplish the proposed activities. The terms of reference and membership are appropriate. The Russian SCOR Committee rated the proposal as “may fund”. The Japanese SCOR Committee rated the proposal as “do not fund” because they thought more East Asian members should be included in the proposed membership and there was no mention of other related SCOR working groups.

PICES rated the proposal as “may fund”. They thought there were not enough Asians involved, given the expertise on Asian dust effects on the ocean and not enough modelers. SOLAS also rated the proposal as “may fund”. They were excited about topic, but disappointed by the proposal itself, although a SCOR working group would be a good mechanism for an intercalibration experiment. They were concerned that only one reference material would be considered.

After discussion of all the proposals, this one was not approved.

Discussions about working group proposals continued during the second day of the SCOR meeting. National SCOR committees were asked to consider whether the fourth ranked proposal (SOCOMv2) should be moved into the top three. The SCOR Finance Committee advised that it was likely that SCOR could only fund two groups to start in 2019. It was decided after consideration by National Committees that only the original top three proposals should be discussed on the second day: Fluoro, MZG and C-Grass. There was discussion about whether Fluoro should be considered a guaranteed fund and then decide on the second group to fund, or

consider all three proposals to be equal and to discuss them all. The Fluoro proposal had no rankings of “do not fund”, but its total points were equal to the MZG proposal, and there were more “must fund” rankings for the MZG proposal. The total points for the Fluoro and MZG proposals were equal (i.e., 12.5) and the C-Grass proposal had 12 total points.

The Finnish SCOR Committee noted that it had no vote for MZG originally, but that subsequent comments from committee suggest that it should be ranked “may fund”, which raises MZG to a total of 13 points. Finland prefers MZG to the other proposals because it is a new research initiative and C-GRASS already is well established.

It was decided to re-vote for the top two proposals among the top three. All national SCOR committees and affiliated organizations were given 10 min. to decide their votes. The result was MZG 16 votes, Fluoro 12 votes, and C-GRASS 8 votes. Therefore, MZG and Fluoro will be funded for start in 2019.

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 SCOR/Future Earth Integrated Marine Biosphere Research (IMBeR) project (see Appendix 5)

John Claydon, the IMBeR Executive Officer who began his service in June 2018, gave a presentation about IMBeR achievements and plans. IMBeR is organized around three Grand Challenges and four Innovation Challenges.

Grand Challenges (with some example IMBeR-related publications)

- Grand Challenge I: Understanding and quantifying the state and variability of marine ecosystems
 - Cavanagh, R.D., E.J. Murphy, T.J. Bracegirdle, J. Turner, C.A. Knowland, S.P. Corney, W.O. Smith, Jr., C.M. Waluda, N.M. Johnston, R.G.J. Bellerby, A.J. Constable, D.P. Costa, E.E. Hofmann, J.A. Jackson, I.J. Staniland, D. Wolf-Gladrow, and J.C. Xavier. 2017. A synergistic approach for evaluating climate model output for ecological applications. *Frontiers in Marine Science*, 26 September 2017, <https://doi.org/10.3389/fmars.2017.00308>.

- Hood, R.R., L.E. Beckley, and J.D. Wiggert. 2017. Biogeochemical and ecological impacts of boundary currents in the Indian Ocean. *Progress in Oceanography* 156:290-325, <https://doi.org/10.1016/j.pocean.2017.04.011>.
- Murphy, E.J., S.E. Thorpe, G.A. Tarling, J.L. Watkins, S. Fielding, and P. Underwood. 2017. Restricted regions of enhanced growth of Antarctic krill in the circumpolar Southern Ocean. *Scientific Reports* 7, Article number 6963, <https://www.nature.com/articles/s41598-017-07205-9>.
- Grand Challenge II: Improving scenarios, predictions and projections of future ocean-human systems at multiple scales
 - Hobday, A., H. Arrizabalaga, K. Evans, K.L. Scales, I. Senina, and K.C. Weng (eds.). 2017. Future of oceanic animals in a changing ocean. *Deep Sea Research Part II: Topical Studies in Oceanography* 140:1-298.
 - Kwiatkowski, L., and J.C. Orr. 2018. Diverging seasonal extremes for ocean acidification during the twenty-first century. *Nature Climate Change* 8(2):141-145, <https://www-nature-com.udel.idm.oclc.org/articles/s41558-017-0054-0>.
- Grand Challenge III: Improving and achieving sustainable ocean governance
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Innovation Challenges

- Innovation Challenge 1: Understanding the role of metabolic diversity and evolution in marine biogeochemical cycling and ocean ecosystem processes
- Innovation Challenge 2: To contribute to the development of a global ocean ecosystem observational and modelling network that provides ecosystem essential ocean variables (eEOVs) and to improve marine data and information management
- Innovation Challenge 3: To advance understanding of ecological feedbacks in the earth system
- Innovation Challenge 4: To advance and improve the use of social science data for ocean management, decision making and policy development

IMBeR is implemented through regional programs and working groups. The regional programs include Ecosystem Studies of Subarctic & Arctic Seas (ESSAS), Integrated Climate and Ecosystem Dynamics (ICED, focused on the Southern Ocean), Climate Impacts on Oceanic Top Predators (CLIOTOP, a global program focused on the tropics), and Sustained Indian Ocean Biogeochemical and Ecological Research (SIBER). The working groups include Eastern Boundary Upwelling Systems (EBUS, which is now equivalent to SCOR WG 155), the Human Dimensions Working Group, the Continental Margins Working Group (with Future Coasts), and the SOLAS-IMBeR Ocean Acidification working group.

Approximately 150 IMBeR-related publications were produced in 2017-2018.

The 5th IMBeR Imbizo Open Science Conference was held on 2-5 October 2017. The aim of IMBIZO 5 was to progress the implementation of the new IMBeR Science Plan (2016-2025). The overall theme of the meeting was “Marine biosphere research for a sustainable ocean: Linking ecosystems, future states and resource management.” This is the basis of the Science Plan, where the research goal is to understand, quantify and compare the 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. The conference consisted of three concurrent, with joint plenary and poster sessions:

1. Critical constraints on future projections of marine systems (co-Chairs: Laurent Bopp and Eric Galbraith)
2. Metabolic diversity and evolution in marine biogeochemical cycling and ocean ecosystem processes (co-Chairs: Gerhard Herndl and Tatiana Rynearson)
3. Management Strategy Evaluation: Achieving transparency in natural resource management by quantitatively bridging social and natural science uncertainties (co-Chairs: Ingrid van Putten and Cisco Werner)

This format has previously been successful in promoting discussion between disciplinary experts, in developing interaction between biogeochemical, ecological, and social science research, and in producing synthesis papers and journal special issues. The themes of the workshops highlight the direction of IMBeR science over the next ten years, and the scales and interactions that will be explored.

IMBeR scientists have been participating in a Belmont Forum-funded GlobalResilience and Adaptive Capacity of Arctic Marine Systems under a Changing Climate (RACArctic) related to a Belmont Forum call several years ago related to the Arctic. In the past year, stakeholder workshops were held in Japan, Alaska, and Norway.

The 6th IMBeR ClimeCO summer school took place on 1-8 August 2018 in Yogyakarta, Indonesia. Sixty students (1 of 5 applicants selected) participated. The focus of the summer school was interdisciplinary approaches for sustainable oceans. IMBeR early-career scientists have self-organized an Interdisciplinary Marine Early Career Network (IMECaN). Its first activity was a workshop on “Building the capacity of EU early career marine researchers to

operate effectively at the science-policy-society interface” on 17-20 June 2018 in Lošinj, Croatia.

The IMBeR Scientific Steering Committee met most recently in Hobart, Tasmania, Australia in April 2018 and the 2nd IMBeR Open Science Conference will take place on 23-27 June 2019 in Brest, France. IMBeR has issued a request for bids for moving its International Project Office in March 2020.

3.2 Surface Ocean – Lower Atmosphere Study (SOLAS; see Appendix 6)

Lisa Miller, the current SSC chair, gave a presentation about the achievements and plans of SOLAS. 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 is organized around five themes:

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 also investigates integrated topics (e.g., upwelling systems, polar oceans, coastal waters, Indian Ocean) that cross the five themes. SOLAS has interests in themes related to science and society, such as evaluating the environmental efficacy and impacts of geoengineering, the impacts of ship-plume emissions on ocean biogeochemistry, blue carbon, and open-ocean stewardship.

Miller presented the SOLAS SSC list and discussed the staffing of the International Project Office (IPO). The host of the IPO, the GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany, is providing office space and the Executive Director’s salary until 2020. Jessica Gier was appointed Executive Director in April 2018. Esther Rickert also works in the IPO and is paid by funds from the U.S. National Science Foundation. Xiamen University is providing a Project Officer, based at Xiamen University. In Sept. 2017, Li Li was hired for three years for this position.

SOLAS activities since the 2017 SCOR meeting have included the SOLAS SSC Meeting, held in May 2018 in Victoria, BC, Canada and the SOLAS Summer School, held on 23 July-4 August 2018 in Corsica, France. In the coming year, SOLAS is planning workshops on [SOLAS Core Themes 4 and 5](#) in November 2018 in Rome, Italy; and the [2019 SOLAS Open Science Conference](#) in April 2019 in Sapporo, Japan.

An important achievement in the past year was the formation by the U.S. Ocean Carbon and Biogeochemistry program of a Subcommittee on Ocean-Atmosphere Interactions, which is essentially a U.S. SOLAS committee. This group will help advance SOLAS science in the United States.

SOLAS is maintaining a Web-based SOLAS Implementation Strategy for 2015-2025 (see <http://www.solas-int.org/activities/implementation.html>). This document will be revised on a regular basis and is currently in Version 2. This document provides detailed descriptions of activities and events that directly address SOLAS science, and provides information about established working groups and planned developments.

SOLAS has continued to make progress on the remote sensing topic. It held a workshop in June 2016 in Frascati, Italy, on “Harnessing remote sensing to address critical science questions on ocean-atmosphere interactions”, which was co-sponsored by the European Space Agency. The outcomes of the workshop were published in a paper in the journal *Elementa: Science of the Anthropocene*.²² SOLAS sponsored a workshop in Potomac, Maryland, USA in March 2018 on Remote Sensing for Studying the Ocean Atmosphere Interface (see [SOLAS Event Report #9](#)). A SOLAS workshop is planned in Korea in spring 2020 to better entrain Asian space agencies in SOLAS activities.

SOLAS has been working to forge new collaborations among global environmental change (GEC) programs and sponsored a workshop at the University of Victoria, B.C., Canada in May 2018 to help achieve this goal. The workshop explored possible approaches to develop new activities, such as hosting an annual workshop series to foster collaborations among GEC programs and managing a capacity-building facility to host summer/winter schools to train early-career scientists in global change research.

The 7th SOLAS Summer School was held on July 23-August 4, in Cargèse, Corsica, France, attracting 64 students and 22 lecturers. It featured practical exercises, lectures, and career development activities.

SOLAS is planning several meetings over the next year:

- Consecutive Workshops on SOLAS Core Themes 4 and 5: 27-29 November 2018, in Rome, Italy
- [SOLAS Open Science Conference](#): 21-25 April 2019 in Sapporo, Japan
- SOLAS Scientific Steering Committee: 26-28 April 2019 in Sapporo, Japan
- Kick-off meeting for integrated atmosphere-ocean time-series station Cape Verde: Fall 2018 in Kiel, Germany. The goal of this station is to better understand ocean-atmosphere interactions and the role of the sea-surface microlayer. It would build on the existing time-series stations/infrastructure at Cape Verde.
- Workshop on Geoengineering: Winter/Spring 2020. This will be a collaboration with Future Earth and the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP).

²²Neukermans, G., T. Harmel, M. Galí, N. Rudorff, J. Chowdhary, O. Dubovik, C. Hostetler, Y. Hu, C. Jamet, K. Knobelspiesse, Y. Lehahn, P. Litvinov, A.M. Sayer, B. Ward, E. Boss, I. Koren, and L.A. Miller. 2018. Harnessing remote sensing to address critical science questions on ocean-atmosphere interactions. *Elem Sci Anth* 6(1):71. DOI: <http://doi.org/10.1525/elementa.331>

SOLAS is also sponsoring several other meetings and/or planning special sessions:

- Oct 2018: SOLAS-supported OCB Workshop on Oceanic Methane and Nitrous Oxide: The Present Situation and Future Scenarios in Lake Arrowhead, California, USA. This workshop was planned and executed by SCOR WG 143.
- Jan 2019: SOLAS-sponsored session at XMAS-IV meeting, Xiamen, China.
- Spring 2019: IMBER-SOLAS-IOCCP-GCP-CLIVAR-WCRP-IOC meeting on Ocean Carbon (and related topics), Paris, France.
- April 2019: SOLAS-sponsored session(s) at the annual European Geophysical Union meeting, Vienna, Austria.
- May 2019: SOLAS session at the Living Planet Symposium, Mailand, Italy.

SOLAS has moved away from publishing newsletters and instead switched to SOLAS Event Reports, which are issued after major SOLAS events.

3.3 GEOTRACES (see Appendix 7)

Gideon Henderson, former SSC chair, gave a presentation about the achievements and plans of the GEOTRACES project. He noted that the GEOTRACES Scientific Steering Committee has excellent geographic and gender balance. The GEOTRACES SSC met in Taipei on 23-25 July 2018 and will meet next on 9-11 September 2019 in Hobart, Tasmania, Australia.

GEOTRACES scientists have completed 106 cruises, including 38 GEOTRACES Section cruises. Three section cruises were completed since last year's report by Australia, Japan, and the UK. GEOTRACES also endorses studies that focus on particular regions or processes, rather than occupying a GEOTRACES Section. Thirty-one GEOTRACES Process Studies have been completed, accomplished by 48 cruises. Three Process Studies were completed since last year's report, by scientists from Australia, Germany, and Korea.

GEOTRACES released its 2017 Intermediate Data Product (IDP) just before the 2017 SCOR Annual Meeting and its next IDP is planned for 2021. IDP2017 was described in a peer-reviewed paper in the journal *Chemical Geology* (see <http://doi.org/10.1016/J.CHEMGEO.2018.05.040>). IDP2017 includes data from 39 cruises, 458 parameters, 1,810 stations, and 46,794 samples. New data types in IDP2017 include aerosols and BioGEOTRACES data.

So far, 957 publications have resulted from GEOTRACES, an increase of 139 since last year's report. GEOTRACES provides an on-line searchable publications database: <http://www.geotraces.org/library-88/scientific-publications/peer-reviewed-papers>.

Henderson presented three science highlights from GEOTRACES research published in the past year:

1. Climate change-induced spectacular increase of the land-ocean inputs in the Arctic Ocean²³—Measurements of ²²⁸Ra in 2015 U.S. Arctic cruise (GN01), revealed that

²³Kipp, L. E., M.A. Charette, W.S. Moore, P.B. Henderson, and I.G. Rigor. 2018. Increased fluxes of shelf-derived

surface water content of this tracer has almost doubled over the last decade. A mass balance model for ^{228}Ra suggests that the increase is due to an intensification of shelf-derived material inputs to the central basin. Coastal changes, in turn, could also be delivering more nutrients, carbon, and other chemicals into the Arctic Ocean and lead to dramatic impacts on Arctic food webs and animal populations.

2. Why did the concentration of atmospheric carbon dioxide rise so much and so quickly during the last deglaciation?²⁴—During the Last Glacial Maximum, the deep southern Pacific waters were stratified, efficiently accumulating old, CO₂-rich waters. Neodymium isotopes measured in sediment cores clearly show that when these deep waters became less stratified as the climate warmed, they released their carbon, which could escape to the atmosphere.
3. Widespread nutrient co-limitation discovered on GEOTRACES cruise²⁵—Multiple nutrients must be supplied to stimulate phytoplankton growth. Experiments were conducted with seawater samples amended with nitrogen, iron, and cobalt, alone and in all possible combinations. Adding both nitrogen and iron in combination was needed to stimulate any significant phytoplankton growth over 1000s of kilometers of ocean. Addition of cobalt in combination with nitrogen and iron further enhanced phytoplankton growth in several experiments.

GEOTRACES is already conducting synthesis activities, oriented along its three major themes:

1. Supply and removal of TEI at ocean interfaces—Two synthesis meetings were held at the U.K. Royal Society, on 7-10 December 2015.
2. Internal cycling of TEIs within the ocean—A Joint GEOTRACES/Ocean Carbon and Biogeochemistry (OCB) program Workshop was held on 1-4 August 2016.
3. Geochemical tracers as paleoceanographic proxies—A joint workshop will be convened with PAGES on 3-5 December 2018 on the implications of GEOTRACES observations for paleoceanography. The scientific themes of the workshop include biological productivity, oceanic circulation, particle flux and sedimentation rate, and physical and/or biogeochemical modelling. The objective of the workshop is to establish the strength, limits, and conditions of application for specific proxies.

GEOTRACES is planning its second Summer School, to be held in September 2019 in Cadiz, Spain. The Summer School will accept 20-25 students and will last 6 days. The course will include lectures, student presentations, practical sessions, and field sampling on board of R/V *UCadiz*.

materials to the central Arctic Ocean. *Science Advances* 4(1), eaao1302, DOI: <http://doi.org/10.1126/sciadv.aao1302>.

²⁴Basak, C., H. Fröllje, F. Lamy, R. Gersonde, V. Benz, R.F. Anderson, M. Molina-Kescher, and K. Pahnke. 2018. Breakup of last glacial deep stratification in the South Pacific. *Science* 359(6378):900–904. DOI: <http://doi.org/10.1126/science.aao2473>.

²⁵Browning, T.J., E.P. Achterberg, I. Rapp, A. Engel, E.M. Bertrand, A. Tagliabue, A. and C.M. Moore. 2017. Nutrient co-limitation at the boundary of an oceanic gyre. *Nature* 551:242–246 doi:10.1038/nature24063.

GEOTRACES has conducted several capacity-development activities in the past year:

1. Robert Anderson (U.S. GEOTRACES project office director) participated in two meetings in the Republic of South Korea in late 2017. Korea recently acquired the NIOZ-TITAN clean sampling system for use aboard their new global-class research vessel *Isabu*. Following a successful test of their system in summer 2017, Korean scientists are keen to begin developing an ambitious GEOTRACES program with a focus on the Indian Ocean. Anderson offered advice about the design and scientific goals of Korean GEOTRACES research.
2. Catherine Jeandel (GEOTRACES IPO director) gave a 3-week course on “Tracers in the Oceans: applications of isotopes to unveil processes controlling trace element distributions” at CIEnAm, Universidade Federal da Bahia, Brazil, thanks to the SCOR Visiting Scholars Program. The course was attended by 16 graduate students from various universities of Brazil.

SCOR has begun the mid-term review process for GEOTRACES.

There was a question about whether GEOTRACES envisions constructing time series of elements. Henderson responded that GEOTRACES plans a one-time survey of trace elements and isotopes in the ocean to provide a baseline to compare future measurements by other programs. Patricia Miloslavich suggested archiving any videos from GEOTRACES Summer Schools in the OceanTeacher Global Academy, to make them widely available.

3.4 SCOR/POGO International Quiet Ocean Experiment (IQOE; see Appendix 8)

Ed Urban gave a presentation about IQOE achievements and plans. IQOE can be described as involving two fundamental areas of activity:

1. documenting ambient sound levels in the ocean at frequencies important for marine organisms, including variability over time and space; and
2. bringing together existing information and developing new information on the 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. An example of an opportunistic approach is the acoustic monitoring before, during, and after Nyepi, a “day of silence” observed each year on the Indonesian island of Bali.²⁶ Another example is the IQOE-endorsed TANGO project, in which sounds from shipping and organisms will be monitored before and after rerouting of shipping lanes in the Kattegat.

²⁶Williams, R., C. Erbe, I.M.I. Dewantama, and I.G. Hendrawan. 2018. Effect on ocean noise: Nyepi, a Balinese day of silence. *Oceanography* 31(2):16–18, <https://doi.org/10.5670/oceanog.2018.207>.

IQOE science 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?

Urban described the organizational structure of the IQOE and its working groups. IQOE is still ramping up its activities and laying a foundation for its research, through its working groups:

- IQOE WG on Acoustic Measurement of Ocean Biodiversity Hotspots met in May and is working on a review paper. The group is also planning to develop a catalog of sounds as a step to develop metrics to understand bioacoustic diversity.
- IQOE WG on Arctic Acoustic Environment will meet in January 2019.
- IQOE WG on Standardization has created an inventory of existing ocean acoustic standards

Endorsed projects, five so far, can be considered as pilot projects of IQOE.

IQOE Progress in the Past Year

In addition to the activities of the IQOE Working Groups, the project has made progress in several other areas:

- **Acoustic Essential Ocean Variable**—The Framework for Ocean Observations (FOO) of the Global Ocean Observing System (GOOS) developed the idea of Essential Ocean Variables (EOVs) that would be measured by GOOS worldwide. The initial set of EOVs did not include acoustics. IQOE proposed an acoustic EOV, through the work of the IQOE Working Group of the Partnership for Observation of the Global Oceans (POGO). The GOOS Steering Committee approved the Ocean Acoustic EOV at its June 2018 meeting. The Ocean Acoustic EOV is under the responsibility of the GOOS Biology and Ecosystems Panel, but “outsourced through the IQOE”. Co-chair Peter Tyack will attend BioEco Panel meeting in November 2018 to learn more about what GOOS needs from IQOE.
- **IQOE Abstract for OceanObs’19**—IQOE submitted an abstract for OceanObs’19, focused on passive acoustics. The abstract was combined with three other abstracts to create a white paper on Ocean Acoustics (Passive and Active), including authors from IQOE Science Committee. The white papers from OceanObs’19 will be published in *Frontiers in Marine Science*.

Activities for 2018-2019

- Promote the Gulf of Mexico as IQOE research area and deployment of more hydrophones there for passive acoustic monitoring.

- Follow-up on declassification of U.S. ambient noise data from decades ago and find recent data for time series comparisons.
- Seek other sources of historic acoustic data that could be used to construct time series
- Commission paper on eDNA-acoustics co-measurements
- Investigate developing Gordon Research Conference proposal for ocean acoustics and/or bioacoustics
- Follow up with the GOOS Biology and Ecosystems Panel on Panel expectations of IQOE role in the EOVS.
- Find out about the opportunities for IQOE at OceanObs'19, including a side event about the EOVS
- Draft articles for *Eos* and/or *Oceanography* regarding IQOE achievements
- Gather information about before-after (BACI) studies as background for endorsed projects and potential WG or workshop at some point in future

The IQOE Science Committee will meet in conjunction with OceanObs'19 in September 2019. IQOE is supported primarily by the Urban Coast Institute (Monmouth University, New Jersey USA) and the Program for the Human Environment (The Rockefeller University, New York USA), with supplemental support from SCOR.

3.5 SCOR/IOC/IOGOOS Second International Indian Ocean Expedition (IIOE-2; see Appendix 9)

Peter Burkill, one of the IIOE-2 Steering Group Co-chairs, gave a presentation about IIOE-2 achievements and plans. The mission 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. The guiding documents for the project are a [Science Plan](#), primarily produced by SCOR, and an [Implementation Plan](#), primarily produced by IOC.

IIOE-2 is governed by a Steering Committee. SCOR has helped support the first two annual meetings of this committee, which met for the second time in March 2018 in Jakarta, Indonesia, and will meet next in March 2019 in Port Elizabeth, South Africa. A major focus of the March 2019 meeting will be to discuss how to update and simplify the project, and how to move it forward. The project will not be completed in 2020 within the original five-year time frame, due to a slow start, many countries involved, and a large number of cruises planned. It will be important to consider what IIOE-2 will be after 2020.

SCOR will support a meeting of the IIOE-2 WG on Science and Research, to be held in Kiel, Germany at the end of November 2018. This meeting will discuss coordination of research activities, documenting existing research in review publications, stimulating new research, and planning the Goa 2020 symposium. It will be important for SCOR to know if science themes and working groups are working optimally. The project may need to be simplified a bit more to be effective.

Assisting the IIOE-2 Steering Committee is a Joint Project Office consisting of two sites, one in Perth, Australia and the other in Hyderabad, India.

IIOE-2 has endorsed 31 projects so far, including 6 since last year's SCOR meeting. One of the tasks for the IIOE-2 Steering Committee is to consider how to streamline the endorsement process. Cruises to the Indian Ocean have been carried out by South Africa and the United States in the past year.

The first two special issues put together by IIOE-2 scientists to help synthesize Indian Ocean research will be published in the journal *Deep-Sea Research II*. For Volume 1, 22 manuscripts were submitted and are under review. Volume 2 is still in progress. The *Indian Ocean Bubble-2* is a newsletter-type publication that helps members of the IIOE-2 community keep updated about scientific activities going on in the region. Three issues of the *Indian Ocean Bubble-2* were published in the past year.

The capacity building potential of IIOE-2 is large. Early-career scientists have self-assembled, starting with the initial Goa Symposium in December 2015. An IIOE-2 Young Scientist Forum has been developed, currently led by Arvin Singh (India). The IIOE-2 Steering Committee has requested that each IIOE-2 Science Theme team include at least one early-career scientist.

In summary, Burkill noted that IIOE-2 is now in mid-term and activities are increasing widely. Publications are now flowing well. The Joint Project Office is active and the Website is the focal point of IIOE-2. The Steering Committee in March 2018 in Jakarta allowed those driving IIOE-2 forward to exchange ideas and ensure integration of a very wide range of scientists active in the Indian Ocean. The IIOE-2 Core Group continues to meet electronically at 3-monthly intervals to discuss and agree strategy and high-level developments. Nine new projects involving 14 countries were endorsed by IIOE-2 in 2018. Four major cruises took place in the last year with ~70 in various stages of planning. The *Indian Ocean Bubble-2* was published three times in 2018.

SCOR approved \$15,000 for IIOE-2 for 2019, primarily for the 3rd Steering Committee meeting in Port Elizabeth for 2019.

4.0 INFRASTRUCTURAL ACTIVITIES

4.1 IOC/SCOR International Ocean Carbon Coordination Project

Maciej Telszewski, IOCCP Project Director, reported on IOCCP's achievements and plans. IOCCP is leading an effort to re-evaluate international coordination for ocean observations and research, which will involve SOLAS, IMBeR, and other projects.

Major activities in past 12 months

IOCCP serves as the GOOS Biogeochemistry Panel and has been expanding its membership to include expertise related to the GOOS Biogeochemistry Essential Ocean Variables (EOVs). Most recently, IOCCP added a member to its Scientific Steering Group to cover the oxygen EOv. IOCCP is developing an oxygen page for its Website (www.ioccp.org/oxygen) and is involved in several international activities related to oxygen. IOCCP is cooperating with the IOC Global Ocean Oxygen Network (GO₂NE); an IOCCP Scientific Steering Group (SSG) member and staff

member were co-authors of a major peer-reviewed publication on the topic.²⁷ IOCCP is also cooperating with the Variability in the Oxycline and its ImpaCts on the Ecosystem (VOICE) project, which is answering the question: “How do changing OMZs affect the spatio-temporal distribution, productivity and trophic structure of the benthic and pelagic communities?” VOICE has submitted a community white paper for OceanObs’19.

IOCCP cooperated with the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) in 2018 to conduct the next Inter-laboratory Comparison Exercise of a Certified Reference Material for Nutrients in Seawater. A report from the exercise is available as IOCCP Report No 1/2018 at <http://www.ioccp.org/index.php/nutrients>.

IOCCP is contributing to the addressing Target 14.3 of SDG 14: “Minimize Impacts of Ocean Acidification”, starting with a review of existing methodologies in relation to definitions, sampling approaches, guidelines for measurements, data collection processes, data quality controls, data analysis, data visualization, and reporting. A resulting document has been approved by the UN.

Curation of the Ocean Colour EOVS is overseen by the GOOS Biogeochemistry Panel (i.e., IOCCP), but a multidisciplinary approach is ensured by involvement of representatives of all ocean disciplines. A final draft is being reviewed by the International Ocean Colour Coordinating Group (IOCCG) and the final document will be published on GOOS Website by mid-September 2019.

IOCCP is participating in developing new marine carbon research directions through the IOC Ocean Carbon Research Working Group, along with SOLAS, IMBeR, the Global Carbon Project (GCP), US-OCB, CLIVAR, and WCRP. Two meetings have taken place so far, in 2017 in Interlaken, Switzerland and in 2018 in Portland, Oregon, USA to develop the way forward. IOC approved the working group in June 2018 and agreed to host an initial scoping meeting.

IOCCP continues to develop and promote the use of standards, reference materials, manuals, best practices, etc. among the marine biogeochemistry observers through www.oceanbestpractices.net.

Major plans for the next 12 months

IOCCP will participate in OceanObs’19 in Honolulu, Hawaii, USA in September 2019.

IOCCP plans to clarify and assemble a set of societal and scientific requirements, and develop and implement observing and data management strategies for three biogeochemical EOVS:

- **Oxygen**—This is the most feasible and impactful EOVS. It is measured on most observing networks. As described earlier, the IOCCP SSG now includes a member with expertise on oxygen and IOCCP is involved in several activities on this topic.

²⁷Breitburg, D., L.A. Levin, A. Oschlies, M. Grégoire⁴, F.P. Chavez, D.J. Conley, V. Garçon, D. Gilbert, D. Gutiérrez, K. Isensee, G.S. Jacinto, K.E. Limburg, I. Montes, S.W.A. Naqvi, G.C. Pitcher, N.N. Rabalais, M.R. Roman, K.A. Rose, B.A. Seibel, M. Telszewski²¹, M. Yasuhara, and J. Zhang. 2018. Declining oxygen in the global ocean and coastal waters. *Science* 359(6371), DOI: 10.1126/science.aam7240

- Nitrous Oxide—There is global interest in improved information on this parameter because of its role as a greenhouse gas and because of the ocean's role in the global cycle of nitrous oxide. A self-organized community exists around the creation of a data product for nitrous oxide and SCOR WG 153 helped push this field forward.
- Dissolved Organic Carbon—This is a new topic for IOCCP, which will take the opportunity to increase the readiness of GOOS to measure this parameter.

IOCCP agreed to help develop and implement a strategy for ship-based measurements of atmospheric CO₂ to meet the rigorous accuracy requirements set by the atmospheric science community required to constrain the global carbon cycle estimates in Earth system models. Many ocean regions are still severely under-sampled in relation to atmospheric CO₂. Such measurements are needed to better constrain the global carbon cycle in Earth System models and to constrain atmosphere-land CO₂ fluxes. Ocean community CO₂ observing systems do not typically meet the rigorous accuracy standards of the atmospheric community.

IOCCP will convene the Second International Summer Course on Best Practices for Selected Biogeochemical Sensors (oxygen, pH, pCO₂, nitrate) at the Sven Lovén Center for Marine Sciences in Kristineberg, Sweden on 9-19 June 2019. IOCCP will also be involved in the GO₂NE Summer School: Xiamen, China, on 2-7 September 2019.

Internal Project issues

In 2018, Kim Currie (New Zealand) replaced Toste Tanhua (Germany) as one of the two SSG IOCCP Co-Chairs.

IOCCP is submitting several proposals for support of the IOCCP Project Officer position.

4.2 GlobalHAB

Elisa Berdalet, GlobalHAB chair, gave a presentation about GlobalHAB achievements and plans. She started by acknowledging the financial and logistic support provided by SCOR to GlobalHAB during the 2015-2018 period. These funds have made possible meetings of the GlobalHAB SSC to develop the *GlobalHAB Science Plan*, representation of the program at international meetings, publications completing the work of the GEOHAB program, and initial implementation of the *GlobalHAB Science Plan* (2016-2020).

Berdalet showed photos of recent harmful algal bloom (HAB) events in the Baltic Sea, Gulf of Mexico, Mediterranean Sea, and New Zealand, demonstrating that there is a continuing need to develop new knowledge of the causes and consequences of HABs through a project like GlobalHAB. The overall goal of GlobalHAB is to improve understanding and prediction of HABs in aquatic ecosystems, and the management and mitigation of their impacts. The mission of GlobalHAB includes the following elements:

- 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 is continuing to take responsibility for completion of products from the predecessor GEOHAB project. One major product was a book entitled *Global Ecology and Oceanography of Harmful Algal Blooms*,²⁸ which was published in 2018. This book summarizes the advances in understanding of HABs during the GEOHAB era, as well as providing an introduction to GlobalHAB.

GlobalHAB is relevant to addressing some of the Sustainable Development Goals (SDGs) of the UN's Agenda 2030.

The GlobalHAB Website went online in January 2018. The GlobalHAB SSC met in Villefranch-sur-Mer, France on 10-11 April 2018 to continue implementing its science plan. Funding for GlobalHAB from NSF has been terminated, so the project is seeking new sources of funding.

Berdalet activities are focused in the following themes. Different members of the GlobalHAB SSC are leading on each topic.

- **Biodiversity and Biogeography**—GlobalHAB representatives will participate in a workshop focused on dinoflagellates (5-9 Nov. 2018) aimed to integrate the HAB community to taxonomists developing a framework for the knowledge of diversity and evolution of protist eukaryotes. Other activities related to this theme are the Harmful Algae Event Database (HAEDAT), which will be used to produce a Global Harmful Algae Bloom Status Report by early 2019, and the IOC-UNESCO Taxonomic Reference List of Harmful Microalgae.
- **Toxins**—A GlobalHAB SSC member was involved in the training workshop “Applying analytical method for detecting ciguatoxin in fish”, which was organized by IOC WESTPAC Toxic Marine Organisms (WESTPAC-TMO) at Institute of Oceanography, Nha Trang on 5-9 April 2018.
- **Nutrients and Eutrophication**—GlobalHAB SSC members are participating in the development of the second World Ocean Assessment, particularly Chapter 10 on changes in inputs of nutrients to the marine environment. In addition, GlobalHAB and GO₂NE are sponsoring a joint workshop in mid-2019 to discuss the linkages between high-biomass HABs
- **Freshwater HABs and Cyanobacterial HABs (cyanoHABs) from Marine to Freshwater Systems**—Several activities are being conducted as part of this theme. A manual for water managers on mitigation of cyanobacterial HABs is being created. A Webinar series on cyanoHABs will be developed for water managers. These will be informative one-hour presentations on cyanoHABs, with a focus on management implications. Finally, the theme leaders are producing global maps of cyanoHABs.
- **Benthic HABs (BHABs)**—Participants in this theme are helping to implement the Global Ciguatera Strategy, a multi-agency, international initiative (IPHAB-IOC, FAO,

²⁸Glibert, P.M., E. Berdalet, M.A. Burford, G.C. Pitcher, and M. Zhou (eds.). 2018. *Global Ecology and Oceanography of Harmful Algal Blooms*, Springer.

WHO, IAEA), and are involved in an international exercise for standard sampling methods for BHAB organisms. Finally, GlobalHAB SSC members contributed to the Regional Workshop on Monitoring and Management Strategies for Benthic HABs being led by the International Atomic Energy Agency (IAEA), and held in April 2018.

- **HABs and Aquaculture**—A GlobalHAB SSC member is participating in developing a workshop on "International Collaborative Study for the Validation of a HILIC-MS/MS Method for Analysis of Paralytic Shellfish Toxins and Tetrodotoxin in Live Bivalve Molluscs", involving 24 laboratories.
- **Observation, Modelling and Prediction**—GlobalHAB is addressing this theme by the involvement of a GlobalHAB SSC member in the GOOS Biology and Ecosystems Panel, which is developing the Phytoplankton EOV.
- **HABs and Human and Animal Health**—GlobalHAB served as an external advisor for the European Food Safety Agency's "Emerging threats on human health in Europe due to climate change" activity and the Coordination and Support Action (CSA) of the European Commission aimed to develop a program on Oceans and Human Health in Europe.
- **Economy**—GlobalHAB, PICES, and NOAA are developing a workshop on the economic impacts of HABs, to be held at the October 2018 PICES annual meeting.
- **Climate Change and HABs**—Activities under this theme are focused on developing Best Practice Guidelines for the Study of HABs and Climate Change, being produced by GlobalHAB with the support of SCOR, IOC, PICES, ICES and the International Society for the Study of Harmful Algae (ISSHA). The Editorial Board for the document met on 26 February–1 March 2018 in Naples, Italy. The document will include a discussion about how to conduct long-term observations of HABs, understanding the responses of HAB species to climate change through experimentation (including studying adaptation and acclimation), databases, and HAB modelling and forecasting. Another activity under this theme is a special issue on "Harmful Algae and Climate Change", in the journal *Harmful Algae* in 2019. GlobalHAB representatives participated in two sessions at the 4th International Symposium on Climate Change and the Ocean in June 2018 in Washington, D.C., USA and will participate in the International Symposium on Marine Environmental Science (XMAS IV) to be held on 6-9 Jan. 2019 in Xiamen, China.

Lisa Miller, chair of SOLAS, noted that she attended a Future Earth planning meeting at which there was discussion of a future focus of marine and freshwater algal blooms. Miller suggested that GlobalHAB contact Future Earth. A major issue for GlobalHAB is how to move forward in the context of their funding from NSF ending. This will be discussed in an opportunistic meeting of most GlobalHAB SSC members at the September 2019 International Conference on Harmful Algae. Ed Urban noted that GlobalHAB has some funding from NSF through 31 August 2019 and also some non-NSF funds held by SCOR, as well as support from IOC. There may be possibilities to find funding from the EU and/or foundations.

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

Denise Smythe-Wright provided an update about the JCS. This group was formed to continue the work of SCOR/IAPSO WG 127 on Thermodynamics and Equation of State of Seawater. Normally, SCOR support is used for opportunistic meetings of group members, but SCOR and IAPSO provided funding in 2018 for the entire group to meet during the same week as the

annual SCOR meeting in September 2018, in the Czech Republic. The group is very active and doing well. SCOR gets a good return for a small contribution. Funding was approved for JCS activities in 2019.

4.4 Workshop on Seafloor Ecosystem Functions and their Role in Global Processes

Ed Urban reported that this activity has been completed, by publication of an article from the workshop in the journal *Trends in Ecology and Evolution*.²⁹

4.5 SCAR/SCOR Southern Ocean Observing System (SOOS)

Louise Newman reported remotely on the progress and plans of SOOS. Although SOOS is not officially part of the Global Ocean Observing System (GOOS) Regional Alliance, it cooperates with GOOS. Data from GOOS observing assets deployed in the Southern Ocean contribute to SOOS data streams. SOOS also cooperates with nationally funded observing systems in the Southern Ocean.

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.”

The SOOS SSC met in Hangzhou, China in May 2018 and held a variety of opportunistic meetings at POLAR2018 in June 2018 in Davos, Switzerland.

Newman described the 2017 project milestones:

Regional Working Groups—Five Regional Working Groups have been formed to coordinate and integrate observational activities, for the Indian Ocean sector of the Southern Ocean, the West Antarctic Peninsula region, the Ross Sea, the Amundsen Sea/Bellingshausen Sea area, and the Weddell Sea/Dronning Maud Land. The first three of these groups held their first workshops in 2017. The Western Antarctic Peninsula’s workshop involved 80 participants from 13 nations and an *Eos* report and special issue resulted. The Indian Sector Working Group workshop involved 20 participants from 5 nations and produced a workshop report and observational heat maps, available on the SOOS Website. The Ross Sea Working Group workshop involved 40 participants from 7 nations and produced a workshop report.

The purpose of these groups is to

- determine key gaps in observational coverage
- standardize methods
- ensure data discoverability and delivery
- design a regional observing system

²⁹Snelgrove, P.V.R., K. Soetaert, M. Solan, S. Thrush, C.-L. Wei, R. Danovaro, R.W. Fulweiler, H. Kitazato, B. Ingole, A. Norkko, R.J. Parkes, and N. Volkenborn. 2018. Global Carbon Cycling on a Heterogeneous Seafloor. *Trends in Ecology and Evolution* 33(2):96-105. DOI: <http://dx.doi.org/10.1016/j.tree.2017.11.004>.

- coordinate field activities, share resources, align projects
- **Capability Working Groups (CWGs)**—These groups are important to develop capacity, identify gaps in observations and technical developments needed, and build networks. An observing system design CWG was formed. A CWG on Enhancing Observations of the ACC is in development.
- Develop important capabilities for SOOS and include the following groups:
 - SOFLUX (Southern Ocean Fluxes)
 - CAPS (Censusing Animal Populations from Space)
 - ATWG (Acoustic Trends WG)
 - OASIIS (Observing the ocean beneath Antarctic Sea Ice and Ice Shelves)
 - OSD (Observing System Design) in development
 - ACC (Enhancing observations of the ACC) in development
- SOOSmap—Newman gave a demonstration of SOOSmap, which provides direct links to data, where possible. It has progressed well in the past year.
- DueSouth—This is a database of upcoming expeditions to the Southern Ocean. It is a planning and coordination tool. Currently, metadata are entered manually, but there is a plan to develop automatic metadata transfer.

SOOS is fortunate to have a variety of financial sponsors of its various activities and was working to secure its Partnership Agreement for sustained funding of IPO.³⁰ In the next year, SOOS will continue to make progress against the 5-Year Implementation Plan (2016-2020) including consolidation of key products and building working group networks. SOOS plans to deliver a Southern Ocean community paper for the OceanObs'19.

Finally, Newman provided details about plans for the near future:

- Sponsorship/Partnership
- Implementation plan and Science Plan review
- SSC meeting

SCOR has committed funding for 2019 and 2020, as has SCAR. The 2019 SOOS SSC meeting will be held in Korea.

5.0 CAPACITY-BUILDING ACTIVITIES

5.1 SCOR Committee on Capacity Building

Missy Feeley reported that the Committee worked by email this year, evaluating two sets of requests for travel support for ocean science meetings and applications for the SCOR Visiting Scholars Program. SCOR support made it possible for representatives of the Committee to attend the launch of the Namibian SCOR Committee in March 2018 and the annual SCOR meeting.

Feeley noted that the total SCOR capacity-building budget is about \$130,000 per year, including flow-through money. Of this SCOR contributed \$6,500 for the SCOR Visiting Scholars program and \$10,000 for the SCOR Committee on Capacity Building. A question was raised about what is the limited factor to SCOR's capacity-building activities. Feeley answered that more funding is needed to expand activities, for which it will be necessary to advertise achievements of SCOR activities. Another question was raised about whether SCOR should reach out for collaborative actions with other organizations. Ed Urban added that SCOR does work cooperatively with other organizations, but that they do not contribute financially to SCOR capacity building. Ed Urban and Sophie Seeyave (POGO Executive Director) are working on a publication describing the SCOR Scholars program and POGO Visiting Professors program, which may draw attention from new funding sources. A question was raised about what percentage of dues goes to SCOR capacity-building activities. Perhaps we can ask national SCOR committees to raise dues specifically for capacity building? Ed Urban replied that countries have been asked to contribute for specific actions, but not as part of dues to SCOR. There is some danger in getting countries into the habit of contributing funds for specific SCOR activities, as this decreases the budgeting flexibility.

5.2 SCOR Visiting Scholars

Missy Feeley reported that seven SCOR Visiting Scholars were approved this year, to work in Bangladesh, Brazil, Croatia, Ecuador, Indonesia, Morocco, and Mozambique. The amount of crowdfunding increased from last year and the number of qualified applicants approved is still below the number that could have been approved if more funding were available. This year, 30 applications were received and funding was available for 7 of them. The service time is at least two weeks to as long as the host institution is willing to provide lodging. SCOR provides US\$2,500 per participant. Commitment from the host country is important in the review process.

5.3 POGO-SCOR Visiting Fellowships for Oceanographic Observations

Feeley reported that four POGO-SCOR Visiting Fellows were funded in 2018, selected by reviewers from SCOR and POGO. SCOR and POGO have been cooperatively funding this program since 2001.

5.4 NSF Travel Support for Developing Country Scientists

Feeley reported that funding from the U.S. National Science Foundation made it possible to provide support in the amount of \$61,462 since the 2017 SCOR meeting for participation of students and early-career scientists in ocean science meetings. The second year of funding in the current grant was awarded by NSF on 31 July 2018.

5.5 Research Discovery Camps at the University of Namibia

Feeley reported that the 5th Research Discovery Camp was held at the University of Namibia and National Marine Information and Research Centre (NatMIRC). Some of the funding this year was devoted to training activities for local teachers in Swakopmund, Namibia. Funding is

available for at least three additional annual Research Discovery Camps, from two U.S. foundations, the Agouron Institute and the Simons Foundation.

Future new focus areas for the SCOR Committee on Capacity Building will be to stimulate IIOE-2 capacity building and to create a document for working groups of examples of past working group capacity-building activities (see <https://scor-int.org/work/groups/capacity-dev-examples/>).

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 July to represent SCOR. At that meeting, SCOR expressed support for 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). IOC also provided full support for one SCOR Visiting Scholar in 2017.

Vladimir Ryabinin, IOC Executive Secretary, made a presentation early in the meeting about the UN Decade of Ocean Science for Sustainable Development. Salvatore Arico presented remotely later in the meeting. He identified the following scientific interests of IOC:

- Documenting the status of global ocean science through the Global Ocean Science Reports.
- Ocean acidification
- “Blue Carbon”
- De-oxygenation of the ocean
- Nutrients, particularly related to SDG 14.1.1.
- Microplastics, in relation to which IOC has helped support GESAMP WG 40 (see <http://www.gesamp.org/work/groups/40>)
- Eastern Boundary Upwelling Systems
- Ocean time series through the IGMETS project (see URL)

Arico noted that IOC had interests in the Fluoro, CSIF, C-GRASS and MZG proposals.

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

GESAMP WG 38 convened two concurrent workshops in Norwich, UK on 27 February to 2 March 2017. Workshop participants are still working on publications from the workshop, although one peer-reviewed paper has already been published.³¹ The goal of WG 38 for the next year is to complete the submission and publication of all papers resulting from the 2017

³¹Kim, J.-M., K. Lee, Y.-S. Suh, and I.-S. Han. 2018. Phytoplankton do not produce carbon-rich organic matter in high CO₂ oceans. *Geophysical Research Letters* 45:4189-4197.

workshop at the University of East Anglia. There is a small amount of funding left in the NSF grant for this activity for presentation of results at scientific meetings.

6.3 North Pacific Marine Science Organization (PICES)

Hal Batchelder reported on PICES activities and interactions between PICES and SCOR. The two organizations 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.

PICES is an intergovernmental scientific organization, established in 1992 to promote and coordinate marine scientific research in the North Pacific Ocean and adjacent seas in order to advance scientific knowledge of the area concerned and its living resources. Its six member countries include Canada, Japan, People's Republic of China, Republic of Korea, the Russian Federation, and the United States of America. The PICES areas of scientific focus include climate science, lower trophic levels, fish, marine mammals and birds, contaminants and, recently, the human dimension component. PICES groups produce special issues of peer-reviewed journals, as well as reports in a PICES report series.

The major organizing program of PICES at the current time is the Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems (FUTURE), which has three research questions:

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 uses a variety of collaboration approaches, including joint symposia, workshops, working groups, publications, summer schools, and monitoring programs.

7.0 RELATIONS WITH NON-GOVERNMENTAL ORGANIZATIONS

7.1 International Council for Science

The International Council for Science and International Social Science Council were merged this year to form the International Science Council (ISC). Marie-Alexandrine Sicre and Ed Urban attended the launch of the ISC in Paris in July 2018.

The SCOR Executive Committee and Executive Director continue to work on actions to respond to the ICSU review of SCOR. Potential changes to the SCOR Constitution will be voted on at this meeting. A new SCOR Website will be launched at the SCOR meeting. A survey to SCOR partners is being prepared to clarify SCOR's "partnership landscape". Two new national SCOR

committees—in Ireland and Namibia—have been established since the time of the ICSU region. Reviews of IOCCP and GEOTRACES have been initiated. SCOR added an early-career scientist to the SCOR Executive Committee in 2018.

7.1.1 World Climate Research Programme (WCRP)

Mike Sparrow presented remotely about WCRP and CLIVAR activities relevant to SCOR. WCRP focuses its activities on seasonal-to-century time scales, including interactions among the ocean, atmosphere, land, and cryosphere, particularly related to carbon, heat, and water transfers.

WCRP is finalizing the draft of its new Strategic Plan 2019-2029, which has been made available to the community (including SCOR) for comment until 31 August 2018 (<https://www.wcrp-climate.org/wcrp-sp-pc>). A five-year Implementation plan is also being developed. WCRP has identified overarching Grand Challenges, of which the one on Regional Sea-Level Change and Coastal Impacts is most relevant to SCOR.

Of WCRP's Core Projects, the Climate Variability (CLIVAR) project is particularly relevant to SCOR. CLIVAR has identified three scientific priorities (see <http://www.clivar.org/documents/>):

1. Mechanisms of climate variability and change that require further investigation with the ultimate goal of better constraining the fluxes of energy and carbon in the climate system
2. Ocean processes that modulate climate variability and change for which open questions remain
3. Climate predictability challenges that exist over a broad range of space and time scales

A CLIVAR project that has been active since 2013 is a project called CONCEPT-HEAT: Consistency between planetary energy balance and ocean heat storage.

In addition to its own work, CLIVAR cooperates with other organizations on a variety of topics:

- CLIVAR cooperates with the CLiC (Climate & Cryosphere) project on An International Panel to Coordinate and Facilitate Activities on the Role of the Northern Oceans in the context of the Global Climate System from a Coupled Ocean-Air-Ice Perspective (NORP)
- CLIVAR is cooperating with PRIMAVERA on a “big data” project.
- CLIVAR is supporting a new working group with PICES whose goal is to “identify, diagnose and quantify predictable response in North Pacific marine ecosystems that arise from regional- and large-scale climate processes.”

CLIVAR is reviewing its role in defining observing system requirements for ocean and climate with ongoing reviews in various basins, including the Pacific Ocean (TPOS2020), Atlantic Ocean (Tropical Atlantic Observing System), and Indian Ocean (Indian Ocean Observing System).

SCOR WG 155 on Eastern Boundary Upwelling Systems (EBUS) and the CLIVAR EBUS Research Focus have determined how to conduct non-overlapping, complementary activities. David Halpern commented that there is an internal review of CLIVAR activities related to Eastern Boundary Upwelling Systems. Given that SCOR has WG 155, it may be good idea to include a member of WG 155 in the review committee. Marie-Alexandrine asked how long CLIVAR will run. Mike Sparrow was unsure. The CLIVAR EBUS meeting will be held in Washington, D.C. at the end of November.

7.1.2 Scientific Committee on Antarctic Research (SCAR)

Chandrika Nath, the SCAR Executive Director, reported on SCAR's activities relevant to SCOR. SCAR was created in 1958 following (and as a result of) the International Geophysical Year of 1957-1958. Like SCOR, it is part of the International Science Council. SCAR focuses on developing and coordinating research in Antarctica and the Southern Ocean, and how these affect the Earth System. SCAR activities relate to the ocean, land, atmosphere, and cryosphere. SCAR also provides scientific advice to the Antarctic Treaty Consultative Meetings (ATCMs) and other intergovernmental organizations. SCAR has an obligation to the ATCM's Committee for Environmental Protection (CEP), which it does (in part) through the SCAR Antarctic Environments Portal (www.environments.aq). In relation to the UN Decade of Ocean Science for Sustainable Development, SCAR would like to identify the key scientific questions for the Southern Ocean that will best inform priorities for this region (in collaboration with partners), perhaps host a Southern Ocean regional consultation workshop, and nominate members of SCAR community to participate in stakeholder forum and executive planning group.

SCAR's work is carried out through a variety of different subsidiary groups:

- **Action groups**, which are similar to SCOR working groups. These action groups are relevant to SCOR: Plastics in Polar Environments, Krill, and Input Pathways of persistent organic pollutants to AntarCTica (ImPACT), Biogeochemical Exchange Processes at the Sea-Ice Interfaces (BEPsII), Integrated Science for the Sub-Antarctic (ISSA), Remote Sensing of Birds and Animals, and Southern Ocean Acidification
- **Expert Groups**: Antarctic near-shore and terrestrial observing system (ANTOS), Antarctic Biodiversity Informatics (EG-ABI), Birds and Marine Mammals (EGBAMM), Joint Expert Group on Human Biology and Medicine (JEGHBM), Southern Ocean Continuous Plankton Recorder Database (SO-CPR), and Antarctic History.
- **Scientific Research Programs (SRPs)**: State of the Antarctic Ecosystem, Antarctic Thresholds - Ecosystem Resilience and Adaptation, Past Antarctic Ice Sheet Dynamics (PAIS), Solid Earth Responses and influences on Cryospheric Evolution (SERCE), Antarctic Climate Change in the 21st Century (AntClim21), and Astronomy and Astrophysics from Antarctica (AAA). These groups have a maximum term of 8 years and a new batch will be developed in the next two years.
- **Science Groups**
- **Standing Committees**: Capacity Building, new group on Humanities and Social Sciences. These groups are permanent.
- **Program Planning Groups**: Antarctic Ice Sheet Dynamics and Global Sea Level, Near-term Variability and Prediction of the Antarctic Climate System (AntClim^{now}), Integrated Conservation Planning for Antarctica and the Southern Ocean (Ant-ICON)

- **Groups co-sponsored with other organizations.**

Each of these has a different mode of formation and lifetime.

SCAR delegates meet once every two years for the biennial SCAR Open Science Conference. At the 2018 Ocean Science Conference, SCAR celebrated its 60th anniversary. Forty-three countries and 9 union members participated in the 2018 Open Science Conference, which was held in conjunction with a meeting of the International Arctic Science Committee. SCAR also organizes an Antarctic Biology Symposium every 4 years, an International Symposium on Antarctic Earth Sciences (ISAES) every 4 years, and Humanities and Social Sciences symposia.

SCAR operates several capacity-development activities, including early career fellowships, Visiting Professor Awards, and a joint fellowship scheme with the World Meteorological Organization (WMO) to be launched in 2019. SCAR's Capacity Building activities are coordinated by the SCAR Capacity Building, Education and Training Committee (CBET). SCAR is interested in advice from SCOR on capacity building.

SCOR and SCAR currently co-sponsor the Southern Ocean Observing System (SOOS).

7.2 Affiliated Organizations

7.2.1 International Association for Biological Oceanography (IABO)

Patricia Miloslavich, President of IABO, reported on IABO activities. IABO was established in 1964 by the International Union of Biological Sciences (IUBS) of the International Council of Scientific Unions (now the International Science Council, ISC). IABO adopted a new set of terms of reference in 2018:

- 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 held its General Assembly at the 4th World Conference on Marine Biodiversity in Montreal, Canada on 13-16 May 2018. The conference included more than 600 participants, including policymakers. 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 World Conference on Marine Biodiversity is 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 1st Carlo Heip Award Recipient was Prof. Carlos M. Duarte, Director of the Red Sea Research Center and Tarek Ahmed Juffali Chair in Red Sea Ecology of King Abdullah University of Science Technology of the Kingdom of Saudi Arabia. The 5th WCMB will be held on the 13-16 December 2020 in

Auckland, New Zealand and will be hosted by the University of Auckland under the auspices of IABO.

IABO uses several different forms of communication. It maintains the Marine Research Information Network on Biodiversity (MARINE-B), which has more than 1,000 subscribers. IABO is seeking new subscribers, particularly from countries with low subscriber counts so far. The IABO Facebook account has about 180 followers. The IABO Website, hosted by SAMS, is being redesigned.

Miloslavich went on to present the latest developments related to the Biology and Ecosystems Panel of the Global Ocean Observing System (GOOS), of which she is the staff person. She described the process to identify Essential Ocean Variables (EOVs), which consider impact and feasibility of a type of observation. The impact factors considered are (1) whether the observation is relevant to help solve science questions and address societal needs and (2) whether the observation would contribute to improve management of marine resources. The feasibility factors considered are whether the available observation methods are scientifically credible, technically practical, cost effective, and within human capabilities. Following development of specification sheets for an EOVS, it is necessary to convene a meeting to develop an implementation plan describing how to produce observations that are globally coordinated with global coverage, intercomparable, with open-access data, to support international reporting needs. Implementation plan workshops discuss vision and mission, needs and requirements, capabilities, impact in terms of capacity development, funding, and governance. The GOOS Biology and Ecosystems Panel is working the Marine Biodiversity Observation Network (MBON) on the relationship between EOVS and Essential Biodiversity Variables (EBVs) and with the Southern Ocean Observing System (SOOS) on how its Ecosystem Essential Ocean Variables relate to EOVS. An Ocean Sound EOVS proposed by the International Quiet Ocean Experiment was approved by the GOOS Biology and Ecosystems Panel in June 2018.

7.2.2 International Association for Meteorology and Atmospheric Sciences (IAMAS)

John Turner, President of IAMAS, reported on the organization's activities. IAMAS was formed in 1919 and is one of eight associations that comprises the International Union of Geodesy and Geophysics. IAMAS has no permanent secretariat, so must rely on the voluntary efforts of scientists to do the work normally done by a secretariat. IAMAS science is carried out by 10 commissions:

1. International Commission on Atmospheric Chemistry and Global Pollution (ICACGP)
2. International Commission on Atmospheric Electricity (ICAE)
3. International Commission on Climate (ICCL)
4. International Commission on Clouds and Precipitation (ICCP), including the Committee on Nucleation and Atmospheric Aerosols (CNAA)
5. International Commission on Dynamic Meteorology (ICDM)
6. International Commission on Meteorology of the Middle Atmosphere (ICMA)
7. International Commission on Planetary Atmospheres and their Evolution (ICPAE)
8. International Commission on Polar Meteorology (ICPM)
9. International Ozone Commission (IOC)
10. International Radiation Commission (IRC)

Turner mentioned some recent and future meetings sponsored by IAMAS:

- IAMAS, IAPSO, and IAGA held a successful joint assembly in Cape Town, South Africa on 27 August–1 September 2017, just prior to the SCOR annual meeting in Cape Town. This assembly attracted around 1,000 attendees, who participated in 11 joint symposia among the sponsoring symposia, 20 sessions IAMAS, 7 IAPSO sessions, and 20 IAGA sessions.
- Since the Cape Town assembly, the IAMAS Bureau, commissions, and Executive have been heavily involved in planning of the IUGG assembly, which will be held in Montreal, Canada on 8–18 July 2019. In 2019, both IUGG and IAMAS will be 100 years old and several special events are being planned. The conference web site can be found at <http://iugg2019montreal.com/>.
- The next IAMAS-IAPSO-IACS assembly will be held on 18-23 July 2021 in Busan, South Korea.

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

Denise Smythe-Wright, reported on IAPSO activities. IAPSO is one of the other eight IUGG associations, like IAMAS. Its goal is to “promote the study of the oceans and the interactions that take places at its boundaries with the sea floor, coastal environment and atmosphere, through the use of physics, chemistry, mathematics and biogeochemistry.” IAPSO works mainly through biennial scientific assemblies, working groups, committees, commissions and services, and by providing information through its Website.

Special importance is given to involving scientists and students from developing countries in oceanographic activities.

The Joint IAPSO-IAMAS-IAGA Scientific Assembly entitled ‘Good Hope for Earth Sciences’ was held in Cape Town, South Africa, during the week of 27 August-1 September 2017. IAPSO presented the Prince Albert I Medal 2017 to Professor Lynne Talley (USA) and the Eugene LaFond Medal 2017 to Dr Jonathan Durgadoo (Mauritius). The IAPSO plenary lecture given by Dr Essam Yassin Mohammed, who emphasized the importance of investing in the blue economy. There was a large joint symposia with IIOE-2 which provided the infrastructure for the IIOE-2 conference and opened up IAPSO funding to IIOE-2 scientists from developing countries.

Like IAMAS, IAPSO is preparing for the IUGG Centenary meeting in Montreal in 2019. IAPSO’s 2021 Assembly will be held in Busan, Korea. IAPSO is working on a centenary book to celebrate its 100 years.

7.3 Affiliated Program

7.3.1 InterRidge - International, Interdisciplinary Ridge Studies

Kamil Szafranski, Executive Officer of InterRidge, reported on the project. InterRidge scientific activities are currently being conducted within the framework of the 3rd Decadal Plan 2014-2023 'From Ridge Crest to Deep-Ocean Trench: Formation and Evolution of the Oceanic Crust and Its Interaction with the Ocean, Biosphere, Climate and Human Society', launched in 2012. The InterRidge Office will remain in France through the end of 2019. SCOR and InterRidge are co-sponsoring a meeting on "Mid-Ocean Ridges and Other Geological Features of the Indian Ocean" on 14-16 November 2018, in Goa, India. This meeting aims to encourage involvement of the scientists involved in marine geology and geophysics in the second International Indian Ocean Expedition (IIOE-2). InterRidge has approved a new working group on mid-ocean ridge islands and seamounts and one on seafloor massive sulfides along mid-ocean ridges. InterRidge is in the process of updating its code of conduct for conducting research in the deep sea. The InterRidge Vents database is well used; it includes many kinds of data from deep-sea vents.

7.3.2 International Ocean Colour Coordinating Group (IOCCG)

Sun Song, liaison to IOCCG, reported on IOCCG's activities. IOCCG has a system of working groups that produce scientific monographs to advance the field of ocean color observations from satellites. IOCCG and the SCOR/IOC GlobalHAB project co-sponsor a working group on WG on Harmful Algal Blooms. 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 will take place in Busan, South Korea in April 2019. SCOR manages NASA grants for IOCCG.

7.3.3 Global Alliance of CPR Surveys (GACS)

Willie Wilson reported on GACS, which is a global alliance of CPR surveys to understand changes in plankton at ocean scales through collecting, observing, and storing plankton samples; analyzing and sharing the results, and connecting among the different surveys. GACS involves about 50 plankton experts (technicians and scientists, working in 12 different laboratories conducting regional CPR surveys, using about 50 ships of opportunity, owned by nearly 40 shipping companies and government agencies.

As part of its work, GACS has three major objectives:

1. Creating common standards among the participating labs for data collection and observations, after comparing existing methods used. GACS has also encouraged the establishment of new surveys. The standardized methods have been promoted through a library of protocols and methods, on which several training courses have been run.
2. Develop a global database. The focus of GACS is now on creating improved products and integration of available data to improve research results. Models are being applied to better extrapolate across time and space.
3. Production of a Global Marine Ecological Status Report

So far, more than 500,000 samples have been analyzed from the different CPR surveys. GACS aims to understand changes in plankton biodiversity; 800 taxonomic units can currently be differentiated. Understanding changes in plankton biodiversity requires obtaining consistent data on species diversity among GACS members and then to connect diversity data with other data, such as organisms on other trophic levels that are higher up in food webs (e.g., fish and jellies), environmental conditions (e.g., temperature and wind), and data from other spatio-temporal scales (e.g., satellite observations and molecular analyses). GACS uses the GBIF (Global Biodiversity Information Facility) Integrated Publishing Toolkit (IPT) to develop this global database. The IPT facilitates the integration of distributed data sources, in a range of formats. All surveys will be soon able to upload their datasets using the Darwin Core Archive as a metadata standard.

7.4 Other Organizations

7.4.1 Partnership for Observation of the Global Ocean (POGO)

Sophie Seeyave, POGO Executive Director, presented on the organization's activities. POGO is a consortium of major oceanographic institutes around the world, represented by their Directors. POGO's mission is to do the following:

1. "Lead innovation and development of the crucial components of the ocean observing system.
2. Identify and contribute to the development of key skills, capabilities and capacities.
3. Work with governments, foundations and industry, to articulate the benefits to society and required funding to build and sustain the system."

The "three pillars" of POGO are ocean observations, professional training, and outreach and advocacy. POGO promotes innovation in development of ocean observing systems by workshops held at annual POGO meetings (e.g., on long-term data visualization, deep-ocean observations, marine protected areas, estuaries, Arctic observations, and innovative biological sampling). POGO Working Groups also promote innovations, such as related to ocean sound (IQOE), South Atlantic observations (SAMOC), observations under ice/ice shelves, industry liaison council, biological observations, observations of macroalgae, and observations for water-related diseases. POGO has formed partnerships with other organizations with complementary missions, such as GOOS/IOC, Argo, OceanSITES, GEO Blue Planet, SCOR, WOA, IASC/SAON, etc.

SCOR and POGO co-sponsor the POGO-SCOR Operational Oceanography Fellowships, as well as the International Quiet Ocean Experiment (IQOE). POGO has provided support to the Southern Ocean Observing System (SOOS) and the POGO Biological Observations WG interacts with SCOR WG 154 on Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (P-OBS).

An important focus of POGO in terms of innovation in observations are the design of Open Access Marine Observation Devices (OpenMODs). These are intended to be open-access, cost-effective, multipurpose, user-friendly equipment for observation of Essential Ocean Variables in developing countries. An important step is to identify user requirements (parameters, cost,

complexity). The development uses an “open science” approach and low-cost technologies (e.g., “off the rack” cheap sensors, OpenCTD, smart phones).

POGO promotes capacity development through the following programs:

- POGO-SCOR Visiting Fellowships (2001-present): Scientists from developing countries spend up to 3 months receiving one-to-one training and supervision in ocean observations at a major oceanographic institution.
- Nippon Foundation-POGO Centre of Excellence (CofE) (2008-present): Each year, ten young scientists from ten different, mostly developing, countries, study for ten months in an intensive program on ocean observations.

Seeyave described the Ocean Training Partnership (see <http://www.oceantrainingpartnership.org/>), which is a Web portal launched in December 2017, linked to MarineTraining.eu portal. The Partnership has an open call for partners and collaborators to join the initiative and to host fellowships and training cruises. Shipboard training fellowships are currently conducted on UK, German, and Spanish ships.

An innovative POGO capacity-building activity, funded by the Nippon Foundation, are the NANO regional projects (2012-2017). NANO (or NF-POGO Alumni Network for Oceans) is a global network of past and present NF-POGO scholars with common interests in ocean science, and an interest in communicating the results of their work to the general public, so that they can be applied for the benefit of society at large. NANO regional projects were intended to help stimulate cooperation among NF-POGO alumni in planning and conducting cooperative research projects.

POGO and SCOR have cooperated on several different capacity development activities, including the POGO-SCOR fellowship program mentioned earlier, capacity building workshops, the Ocean Summer Schools portal, a joint side event at the UN Oceans Conference (2017), evaluation of capacity building program, and joint publication about POGO and SCOR visiting scholar/professor programs.

In terms of outreach and advocacy, POGO issues letters and statements aimed at governments and intergovernmental organizations (e.g., the G7, UN, IPCC), policy makers and the general public. POGO representatives contributed to several Community White Papers for OceanObs’19.

8.0 ORGANIZATION AND FINANCE

8.1 Membership

Urban

Ireland joined SCOR in 2017 and appointed Peter Croot, Eleanor O'Rourke, and Brian Ward as Nominated Members. Namibia joined SCOR in March 2018 and we are awaiting their list of Nominated Members. Spain was removed from membership for non-payment of dues for 5 years

8.2 Publications Arising from SCOR Activities

A list of publications from SCOR working groups and other activities were listed in the SCOR background book. 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.

8.3 Finances

The SCOR Executive Committee approved a Finance Committee consisting of Isabelle Ansorge (South Africa), Annalisa Griffa (Italy), and Paul Myers (Canada). This committee conducted its work during the SCOR meeting and reported on (1) the 2017 Audit report, (2) recommendations related for revisions to the 2018 SCOR budget, (3) recommendations for the 2019 SCOR budget, and (4) recommendations for dues levels in 2020.

The Finance Committee reviewed the final 2017 financial statement and the auditor's report based on this statement. They noted that membership dues amounted to US\$366,000, with an additional \$44,000 from NSF and other sources to yield a total discretionary income of \$410,000. Expenses for SCOR working groups were \$52,000, \$61,000 was spent for other science activities, and \$303,000 for administrative expenses, yielding a total discretionary expense of \$416,000. The \$6,000 net loss in 2017 decreased the cash balance from \$253,000 at the end of 2016 to \$246,000 at the end of 2017. SCOR requires an ending cash balance of at least \$100,000, so the 2017 year-end figure met this requirement. The Finance Committee reviewed the auditor's report of 2017 finances. The Finance Committee found the Auditor's report in accordance with SCOR financial report, and there were no special remarks in the Audit to consider. The auditor found no accounting discrepancies and found SCOR a low-risk auditee. The Finance Committee recommended meeting participants to accept the 2017 financial report, which they did.

The Finance Committee considered the revised budget suggested by the SCOR Executive Director. The 2018 budget approved at the 2017 SCOR Annual Meeting in Cape Town had a discretionary income of \$459,317. The suggested revision has a discretionary income of \$491,450. The committee noted that SCOR is on target to receive the budgeted amount of dues by the end of the 2018. The revised budget includes discretionary expenses of \$560,639, for a net decrease in cash balance of \$69,189. The revised budget would decrease the ending cash balance to \$229,000, greater than the \$100,000 balance that must be maintained. The Finance Committee recommended accepting the revised 2018 budget, which meeting participants did.

The 2019 SCOR budget proposes income of \$467,000, which assumes 90% payment of dues, and discretionary expenses of \$589,000, for a budgeted decrease of the cash balance of \$122,000, to \$102,000. The Finance Committee recommended acceptance of the proposed SCOR budget for 2019, including the funding of two new SCOR working groups. (It is likely to expect to be able to fund two new working groups in 2019, with a possibility of a third.) Meeting participants approved this recommendation.

Regarding dues for 2020, the Finance Committee found that the working group underspending has returned to historical and sustainable levels, and that SCOR should increase its dues by 3%, from 2019 to 2020, as practiced in recent years. A large portion of the dues income is spent on costs that are increasing by 2.5-3.0 percent per year, such as salaries and benefits for the SCOR Executive Director.

9.0 SCOR-RELATED MEETINGS

9.1 SCOR Annual Meetings

9.1.1 2018 General Meeting: Plymouth, UK

Marie-Alexandrine Sicre thanked the local hosts and UK SCOR Committee for hosting the meeting. Ed Urban presented engraved plaques to Corina Brussaard, Sergey Shapovalov, and Sun Song in thanks for their years of service as members of the SCOR Executive Committee.

9.1.2 2019 Executive Committee Meeting: Toyama, Japan

Jing Zhang reported on preparations for the 2019 SCOR Annual Meeting in Toyama, Japan, which will be the first SCOR Annual Meeting held in Japan since 2002. The meeting will include a joint symposium with the Japanese Oceanography Society and Zhang has raised some local support. The Japanese SCOR Committee suggested the dates of 23-25 September, which is in the week following the OceanObs'19 meeting in Hawaii. A public event will be held on 22 September, with the theme of living with global climate change (natural disasters, microplastics; sea surface temperature increase). The Japanese SCOR Committee has planned several social events that will highlight the cultural aspects of the Toyama area.

9.1.3 Future SCOR Annual Meetings

Discussions are underway with potential hosts for the 2020 and 2021 annual SCOR meetings.

9.2 Locations of Past SCOR Annual Meetings

The locations of past SCOR Annual Meetings were listed in the background book for the meeting.

9.3 SCOR-Related Meetings Since the 2017 SCOR Annual Meeting and Planned for the Future

The locations of meetings since the 2017 SCOR Annual Meeting and into the future were listed in the background book for the meeting

Appendix 1
Participants

2018 SCOR ANNUAL MEETING
Plymouth, UK
4-7 September 2018

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NM = Nominated Member

Appendix 2
Agenda

2018 SCOR ANNUAL MEETING

Plymouth, UK
4-7 September 2018

ANNOTATED AGENDA

1.0 OPENING

- | | |
|---|-------------------------------|
| 1.1 Opening Remarks and Administrative Arrangements | <i>Thompson, 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 2018 Elections for SCOR Officers and Approval of Proposed Changes to SCOR Constitution | <i>Burkill</i> |

2.0 WORKING GROUPS

- | | |
|---|----------------------|
| 2.1 Current Working Groups | |
| 2.1.1 SCOR/InterRidge WG 135 on Hydrothermal energy transfer and its impact on the ocean carbon cycles | <i>Smythe-Wright</i> |
| 2.1.2 SCOR/IGBP WG 138: Modern Planktic Foraminifera and Ocean Changes | <i>Brussaard</i> |
| 2.1.3 WG 139: Organic Ligands – A Key Control on Trace Metal Biogeochemistry in the Ocean | <i>Devey</i> |
| 2.1.4 WG 141 on Sea-Surface Microlayers | <i>Burkill</i> |
| 2.1.5 WG 142 on Quality Control Procedures for Oxygen and Other Biogeochemical Sensors on Floats and Gliders | <i>Burkill</i> |
| 2.1.6 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>Turner</i> |
| 2.1.7 WG 144 on Microbial Community Responses to Ocean Deoxygenation | <i>Miloslavich</i> |
| 2.1.8 WG 145 on Chemical Speciation Modelling in Seawater to Meet 21st Century Needs (MARCHEMSPEC) | <i>Sicre</i> |
| 2.1.9 WG 146 on Radioactivity in the Ocean, 5 decades later (RiO5) | <i>Smythe-Wright</i> |
| 2.1.10 WG 147: Towards comparability of global oceanic nutrient data (COMPONUT) | <i>Sicre</i> |
| 2.1.11 WG 148 on International Quality Controlled Ocean Database: Subsurface temperature profiles (IQuOD) | <i>Shapovalov</i> |
| 2.1.12 WG 149 on Changing Ocean Biological Systems (COBS): how will biota respond to a changing ocean? | <i>Miloslavich</i> |
| 2.1.13 WG 150 on Translation of Optical Measurements into particle Content, Aggregation & Transfer (TOMCAT) | <i>Burkill</i> |
| 2.1.14 WG 151: Iron Model Intercomparison Project (FeMIP) | <i>Devey</i> |
| 2.1.15 WG 152 on Measuring Essential Climate Variables in Sea Ice (ECV-Ice) | <i>Turner</i> |
| 2.1.16 WG 153 on Floating Litter and its Oceanic TranSport Analysis and Modelling (FLOTSAM) | <i>Smythe-Wright</i> |

- 2.1.17 WG 154 on Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (P-OBS) *Miloslavich*
- 2.1.18 WG 155 on Eastern boundary upwelling systems (EBUS): diversity, coupled dynamics and sensitivity to climate change *Halpern*
- 2.2 Working Group Proposals
- 2.2.1 Active Chlorophyll fluorescence for autonomous measurements of global marine primary productivity *Smythe-Wright*
- 2.2.2 The Surface Ocean CO₂ Mapping intercomparison initiative: Phase 2 (SOCOMv2) *Smythe-Wright*
- 2.2.3 Ocean Governance and Policy Analysis for Ocean Deoxygenation (WG-OGOD) *Shapovalov*
- 2.2.4 Carbonate system intercomparison forum (CSIF) *Burkill*
- 2.2.5 Toward a new global view of marine zooplankton biodiversity based on DNA Metabarcoding and reference DNA sequence databases (MetaZooGene) *Miloslavich*
- 2.2.6 The Caribbean Upwelling Research Network (CURNet) *Halpern*
- 2.2.7 A Framework for Ocean Observation for the Next Generation - expanding quantifiable methods and Best Practices (FOO-BP) *Burkill*
- 2.2.8 Coordinated Global Research Assessment of Seagrass Systems (C-GRASS) *Sun*
- 2.2.9 Co-ordinated approach for Aerosol Trace element Solubility and Bioavailability Research in Oceanography (CoATS-BRO) *Casacuberta Arola*

3.0 LARGE-SCALE SCIENTIFIC PROGRAMS

- 3.1 GEOTRACES *Henderson, Devey*
- 3.2 Surface Ocean – Lower Atmosphere Study (SOLAS) *Miller, Turner*
- 3.3 SCOR/POGO International Quiet Ocean Experiment (IQOE) *Urban, Shapovalov*
- 3.4 SCOR/IOC/IOGOOS Second International Indian Ocean Expedition (IIOE-2) *Burkill*
- 3.5 SCOR/Future Earth Integrated Marine Biosphere Research *Claydon, Burkill*

4.0 INFRASTRUCTURAL ACTIVITIES

- 4.1 IOC/SCOR International Ocean Carbon Coordination Project *Telszewski, Halpern*
- 4.2 GlobalHAB *Berdalet, Sun*
- 4.3 IAPWS/SCOR/IAPSO Joint Committee on Seawater (JCS) *Smythe-Wright*
- 4.4 Workshop on Seafloor Ecosystem Functions and their Role in Global Processes *Urban*
- 4.5 SCAR/SCOR Southern Ocean Observing System (SOOS) *Newman, Miloslavich*

5.0 CAPACITY-BUILDING ACTIVITIES

- 5.1 SCOR Committee on Capacity Building *Feeley*
- 5.2 SCOR Visiting Scholars *Feeley*
- 5.3 POGO-SCOR Visiting Fellowships for Oceanographic Observations *Feeley*
- 5.4 NSF Travel Support for Developing Country Scientists *Feeley*

5.5 Research Discovery Camps at the University of Namibia

Feeley

6.0 RELATIONS WITH INTERGOVERNMENTAL ORGANIZATIONS

6.1 Intergovernmental Oceanographic Commission (IOC)

Sicre, Arico

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

Urban

6.3 North Pacific Marine Science Organization (PICES)

Batchelder, Sun

7.0 RELATIONS WITH NON-GOVERNMENTAL ORGANIZATIONS

7.1 International Council for Science

Sicre

7.1.1 World Climate Research Programme (WCRP)

Sparrow, Halpern

7.1.2 Scientific Committee on Antarctic Research (SCAR)

Nath, Brussaard

7.1.3 Future Earth Initiative

Sicre

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)

Turner

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

Smythe-Wright

7.3 Affiliated Program

7.3.1 InterRidge - International, Interdisciplinary Ridge Studies

Szafrański, Devey

7.3.2 International Ocean Colour Coordinating Group (IOCCG)

Sun

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)

Seeyave, Shapovalov

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 2018 General Meeting: Plymouth, UK

Sicre

9.1.2 2019 Executive Committee Meeting: Toyama, Japan

Zhang

9.1.3 Future SCOR Annual Meetings

Urban

9.2 Locations of Past SCOR Annual Meetings

9.3 SCOR-Related Meetings Since the 2017 SCOR Annual Meeting and Planned for the Future

Appendix 3

Proposal for a Working Group on Active Chlorophyll fluorescence for autonomous measurements of global marine primary productivity

1. Summary

Marine primary productivity controls ocean food webs and biogeochemical cycles, exerting a strong influence on CO₂ uptake from the atmosphere and global climate. Unprecedented anthropogenic pressure has created an urgent need to understand environmental controls on primary productivity. This, in turn, relies on consistent and coherent measurements across a range of spatial and temporal scales. Productivity estimates from conventional ¹⁴C-uptake experiments require discrete bottle sampling (and suffer potential experimental artefacts), while those from mixed layer dissolved gas measurements (O₂, CO₂ etc.) do not directly measure gross photosynthesis, and lack the temporal resolution needed to validate daily remote-sensing observations. Active chlorophyll a (Chla) fluorescence-based measurements can overcome these challenges. First introduced several decades ago, techniques such as Fast Repetition Rate fluorometry have significantly advanced our understanding of environmental controls on phytoplankton physiology and productivity. However, rapidly growing capacity to engineer and deploy sea-going fluorometers now poses a major time-sensitive challenge: Conceptual, operational and computational approaches to extract and interpret fluorescence parameters are rapidly diverging. While an increasing number of (often custom-built) sensors, protocols and processing algorithms is being produced, no standard best practices have been formally adopted by the research community. Rapidly growing data sets may thus become increasingly difficult (perhaps impossible) to reconcile, thereby limiting our capacity to integrate observations over large-scales. This SCOR working group will address this challenge by producing international standards for best-practices in the acquisition and interpretation of active Chl fluorescence data, while also creating a framework for a global synthesis of existing and future data.

2. Scientific Background & Rationale

2.1. **Importance of high-resolution primary productivity measurements**

Marine primary productivity sets the carrying capacity of oceanic ecosystems and exerts a profound influence on the cycling of nutrients and carbon in the biosphere. Global climate change has created a pressing need to understand the environmental controls on marine productivity, its variability over space and time, and its potential responses to altered upper ocean conditions (Behrenfeld et al. 2006, Moore et al. 2018). Addressing these questions requires consistent and coherent measurements of oceanic primary productivity across a range of scales. Historically, most measurements of marine primary productivity have come from ship-board ¹⁴C incubation methods (e.g. Halsey & Jones 2015). Over the past half century, the oceanographic community has built a large global repository of ¹⁴C uptake data (<http://www.science.oregonstate.edu/ocean.productivity>), and used these to inform our understanding of spatial and temporal trends in marine productivity (Behrenfeld & Falkowski 1997). The ¹⁴C method, while highly sensitive and simple in principle, has limitations. Most notably, the technique requires the collection of discrete samples, which limits the spatial resolution of measurements, whilst introducing potential experimental artefacts ('bottle effects') via sample containment.

Over the past two decades, there has been an increasing focus on the use of autonomous sensors to quantify marine primary productivity. Satellite-based algorithms are becoming increasingly used to infer productivity from remotely sensed variables (typically, chlorophyll, carbon, light and sea surface temperature) (e.g. Behrenfeld & Falkowski 1997, Behrenfeld et al. 2015). This approach has the advantage of providing synoptic spatial coverage of the surface ocean, but it requires field-based measurement for parameterization of physiological models and algorithm validation (e.g. Lin et al. 2016). More recently, a number of groups have begun using automated chemical sensors to measure mixed layer dissolved gases (e.g. O₂, N₂, Ar, and CO₂) as tracers of net

community productivity. These measurements capture bulk productivity on the time-scale of days to weeks, but do not directly measure gross photosynthetic production or physiological responses, nor do they provide appropriate validation for daily remote-sensing observations.

2.2. Rapid expansion of active chlorophyll fluorometers to assess primary productivity

Active chlorophyll fluorometers were introduced to oceanography in the late 1980s. Seminal papers detailed methods to quantify photosynthetic electron transfer rates (ETR), by resolving the induction of chlorophyll a (Chla) fluorescence following rapid modulation of an excitation light source (Kolber & Falkowski 1993, Kolber et al. 1998). As a component of the photosynthetic process, ETR is inherently coupled to the rate of light-dependent water splitting, oxygen evolution and ATP and NADPH production, and, as such, provides an estimate of gross primary productivity. Early studies demonstrated that ETRs derived from active Chla fluorescence measurements correlated well with parallel ^{14}C -uptake rates (Kolber & Falkowski 1993) and gross oxygen evolution rates (Suggett et al. 2003). Others demonstrated important applications of Chla fluorescence data to understand the physiological status of phytoplankton in situ, including cellular responses to iron limitation (e.g. Kolber et al. 1994).

Motivated by these pioneering studies, and facilitated by technological developments, there was a surge of interest in the application of active fluorometry for oceanic productivity and photo-physiological studies. The first commercially available Fast Repetition Rate Fluorometer (FRRf; and derivative FIRE fluorometers, Gorbunov & Falkowski 2005) instruments were released in the early 2000s (Chelsea Technologies Group Ltd., Satlantic Inc.). Most efforts aimed at further reconciling ETRs with ^{14}C -uptake (Corno et al. 2006, Suggett et al. 2006, Moore et al. 2006), and growing data sets repeatedly demonstrated strong covariance between parallel ETRs and ^{14}C -uptake measurements throughout the world's oceans. However, the results of this work demonstrated that the relationship between these measurements varied depending upon the prevailing phytoplankton taxa and/or environmental conditions (see Suggett et al. 2009, Lawrenz et al. 2013). Within a decade, FRRfs (and FIRE fluorometers) became standard instrumentation on many large-scale oceanographic programs (e.g. Atlantic Meridional Transect; Suggett et al. 2006, Hawaii Ocean Time-Series; Corno et al. 2006), and biogeochemical studies of ocean productivity (e.g. Behrenfeld et al. 2006).

While the application of FRRfs and related active Chla induction instrumentation continues to grow, routine derivation of primary productivity from these measurements still faces significant challenges. Operational and technological constraints, as well as complexities associated with the algorithms used to derive ETRs from raw fluorescence data have hampered efforts to derive robust productivity estimates. A major EU program (PROTOOL) brought together a group of experts in an attempt to develop new and more robust ETR algorithms (Oxborough et al. 2012), whilst also incorporating multi-spectral measurements to better resolve the influences of diverse light harvesting across phytoplankton groups (see Silsbe et al. 2015). These critical developments catalysed renewed interest in the use of FRRf as an oceanographic measurement tool (e.g. Schuback et al. 2017, Zhu et al. 2017). This renewed interest, alongside new technological advances in light sources and detectors (PicoF and mini-FIRE, Lin et al. 2016; Hoadley & Warner 2017), point the way towards global-scale oceanographic deployment of active Chla induction fluorometers, using a new generation of systems on a range of platforms, including ships, gliders, mooring and floats.

Our capacity to quantify the spatial and temporal variability in oceanic primary productivity has thus never been greater. However, ***our rapidly growing capacity to engineer and deploy active Chla induction fluorometers now poses a major time-sensitive challenge***: Conceptual, operational and computational approaches used to extract and interpret fluorescence parameters are rapidly diverging. No standard best practices have yet been formally adopted as a large number of (increasingly custom-built) sensors, protocols and processing algorithms are deployed worldwide. As a result, rapidly growing data sets may become increasingly difficult (if not impossible) to reconcile, thereby limiting our ability to build global data compilations and examine large-scale responses of marine productivity to environmental forcing.

2.3. Need and Timeliness for a SCOR working group

A meeting of world experts in active Chla induction fluorometry was recently held in Sydney (AQUAFLUO II: *Chlorophyll fluorescence in the aquatic sciences*, December 2017). Discussions identified a time-critical need for more robust practices to overcome uncertainties and inconsistencies associated with instrument operation, deployment and data fitting and interpretation. As more groups custom-build Chla induction fluorometers, there remains no objective set of international standards for hardware configurations (e.g. excitation-emission wavelengths) or data analysis protocols, and no conventions to validate and inter-calibrate data from these sensors. **Such inter-comparability is critical if we seek to build a global repository of active fluorescence data.** Practices should be based upon minimal, robust assumptions, with clear information on how taxonomic and environmental factors may affect the choice of operating conditions. Establishing guiding principles and models that will allow comparability across research groups is paramount.

Previous working groups have inter-compared active fluorescence data from different commercially available instruments (e.g., AQUAFLUO 2007; GAP-2008, Suggett et al. 2009; PROTOOL, Silsbe et al. 2015). **These efforts, however, did not include an explicit focus on standardized data collection and analysis, nor did they produce recommendations, best-practice guides and software tools to help non-experts employ this method. Moreover, the rapid development of new cheaper and miniaturised instrumentation, along with a number of conceptual advances in our understanding of chlorophyll fluorescence, has created a need to revisit inter-comparisons of operability and data output.** Progress must be driven by the broader community's need to establish and embed standardized operation, data retrieval and reporting/archiving. To this end, our proposed working group will assemble a diverse set of scientists to move the research community forward in the application of active Chla induction fluorometry to understand global-scale patterns in marine productivity.

3. Terms of Reference

Our proposed working group will work to achieve the following specific objectives.

- i. To inter-compare active Chla induction measurements across instruments and approaches, identifying key aspects of instrument configuration, deployment and parameter acquisition that may introduce variability in retrieved data.
- ii. To develop, implement and document internationally-agreed best practice for data acquisition, standardised output formats and archiving approaches.
- iii. To develop, implement and document internationally-agreed best practice for processing raw fluorescence data to retrieve photosynthetic parameters and primary productivity estimates, taking into account taxonomic and environment factors driving diversity in chlorophyll fluorescence signals in the oceans. From this work we will develop freely available software and documentation to allow non-specialist users to process fluorescence data according to these best practices.
- iv. To produce a new synthesis of parallel ^{14}C and active Chla induction measurements that can be used to examine the relationship between these two productivity metrics under a range of field conditions. We will also consider other metrics of Net Primary Production alongside ^{14}C .
- v. To develop a global database structure for hosting quality-controlled active Chla induction measurements, creating standards for data and meta-data collection, submission and archiving.
- vi. To build a framework through which in situ active Chla induction data can be used to validate and refine relevant remote sensing measurements (e.g. sun-induced fluorescence yields).
- vii. To share knowledge and transfer skills in instrumentation, best practice, quality control and data stewardship with the rapidly expanding user community in developing nations.

4. Working Plan and Time-line

We will meet our objectives via two dedicated in-person meetings, and additional satellite meetings and video conferences focused on implementing and/or delivering our various objectives, and managing the overall project.

Year 1: Kick-off meeting; laboratory inter-comparison study

Objectives i-ii. We will conduct a SCOR-funded laboratory inter-calibration of the state-of-the-art instrumentation, covering the broadest range of commercial and custom hardware and software (FRRf, FRRf-type single pulse, FRRf-flash, LIFT; as well as mini-FIRe and PicoF). This exercise will examine inter-comparability among existing configurations, studying the effects of various sources of variability (hardware and software) on parameter retrieval. We will conduct this exercise at a relatively central location amongst the WG members (likely Vancouver) using a range of marine phytoplankton cultures (with different pigment complements, cell size, taxonomic group) grown under various experimental conditions, including light and nutrient availability.

We will develop a standard set of protocols, including hardware configurations, parameter selection, algorithm assumptions, data formatting, sample collection/treatment. All participants will contribute in their various expertise to a user guide and best-practices report. This work will also likely lead to a significant peer-reviewed publication.

We will also begin to consider how challenges in ship-board deployment may potentially limit capability to meet best practice. This will be addressed, in part, through a parallel set of experiments focusing on known variables (e.g. dark exposure time) that create potential for uncertainty in field-based measurements. Thorough field tests addressing specific at sea deployment challenges be addressed in year 2.

Year 2: Field evaluations of best-practice

An annual meeting will be conducted in year 2 to evaluate project progress. As Working Group members will likely be required to fund their participation, this will be timed to coincide with a large international meeting such as ASLO. Full video conferencing facilities will be made available to maximize participation among all members.

The focus for this second year is:

Objectives i-ii and iv. Working Group members will critically assess application of ‘best practice’ (developed from the initial laboratory cross-instrument screening) to their own at-sea deployments. Where WG members are able to exploit existing funded opportunities for oceanographic fieldwork, ‘best practice’ will be evaluated relative to other possible field- deployable configurations. The goal of this is to (a) examine precision and accuracy achievable through a universally applied ‘best practice’ under any given scenario (e.g. ultra-oligotrophic waters) and specific instrumentation or mode of deployment (e.g. profiling versus underway). Exercises will also include a standardized comparison of FRRf-based estimates of productivity against parallel NPP (¹⁴C measurements) as an independent productivity benchmark. This work will be conducted independently by WG members, following standard protocols established by the group in year 1, including the collection of ancillary data that can be used to interpret results.

These field-based evaluations will enable us to examine how ‘best practice’ developed from the laboratory can scale to field applications, and to recommend modified approaches for the collection of robust and inter-comparable field studies. The work will also lead to a new synthesis of parallel ¹⁴C-FRRf measurements that can be used to analyse the relationship between these two productivity metrics (and potentially others) when obtained using standardized methodologies. All participants will contribute their expertise to compile these results into a report best-practices guide (objectives ii-iii), and a significant peer reviewed article.

Year 3: Begin ‘legacy phase’ through software and database development

Objectives iii-v. A SCOR funded annual meeting in year three will focus on developing the software and database ‘legacy’ phase. Based on the documents from objectives (i-iv) detailing the optimised workflows for processing and parameterising raw fluorescence data, we will initially conceptualise and then produce an open source software platform for broad scale and cross-instrument data processing. We envisage that this will take the form of a “CO2-sys” type product, enabling user selectable algorithms, and ensuring that ‘first order’ data sets (e.g. raw induction curves) are archived in order to enable re-processing of data at a future date. In this way, users will be able to select different specific parameterisation routines, with the flexibility needed to include data from across different approaches in deployment and configuration. The long-term motivation for this work will be the production of a global database (likely hosted by NASA), designed to archive both raw data and derived parameters. We envisage a data entity similar to (or as part of) NASA’s SeaBASS archive (<https://seabass.gsfc.nasa.gov>) built on defined standardised parameters (and units etc.), paralleling one already in existence for carbon-uptake data: [:\(http://www.science.oregonstate.edu/ocean.productivity/field.data.fl.readme.php\)](http://www.science.oregonstate.edu/ocean.productivity/field.data.fl.readme.php).

Significantly, we have developed this proposal with specific input from Chris Proctor and Susanne Craig at NASA. They are not listed as WG members, but they have both expressed strong interest in this work, and are expected to participate in relevant meetings, with support from NASA.

Year 4: Remote sensing integration and public release

Objective v-vi: As part of our final meeting, we will formalise all documentation and (beta-version) software for public release as part of an international and community wide meeting. For example, dedicated workshops and events at ASLO or Ocean Optics (and/or a specialist meeting, e.g. AQUAFUO III). We will seek independent funding (e.g. NASA) to support both broad attendance from amongst the WG but also to support outreach and visibility. Importantly, this meeting will enable us to disseminate (‘launch’) all material to the broadest user base, thereby transforming capacity and creating the maximum visibility. Releases will also be accompanied by press releases and launches through the Working Groups’ institutions and regional networks. Working closely with NASA, we will look to host standard protocol documentation and tools through the IOCCG website as well as data archival portals.

A secondary component of this final meeting will be a one-day session for WG members to build a framework enabling non-specialist users to exploit growing databases with remotely retrieved (e.g. satellite) bio-optical data. We will produce a document detailing steps needed (and data sets required) to validate and potentially refine remotely sensed fluorescence data products, with initial proof of concept data collected earlier in this working group (Year 2).

5. Deliverables

Addressing our objectives will result in the following deliverables:

- a. Open access documents fully detailing (a) Standard Operating Procedures (and “Best Practices”) that can be applied commonly across (and/or account for differences amongst) instrument type, instrument configuration, and deployment platform; and (b) framework to apply chlorophyll fluorescence data sets to validate and potentially refine remotely sensed fluorescence data products.
 - b. Open source “CO2-sys” type data analysis tool for fluorescence induction curve processing.
 - c. New data set of NPP (^{14}C) – active Chla induction inter-comparisons across a variety of oceanographic regimes, conducted with standardized methodology
 - d. Web-based global data archival portal (and associated information repository) for data extraction according to user defined temporal-spatial criteria
 - e. Peer reviewed papers that report instrument inter-comparison exercises from both the laboratory and field.

6. Capacity Building

Fundamentally, our Working Group approach and deliverables provide broad-scale (global) capacity building towards all current users of existing active Chla induction instrumentation. However, by providing a series of standardised operating procedures and open source tools to both collect, parameterise and archive data, we aim to expand the global user group for active fluorescence data, enabling non-specialized users to deploy a highly sophisticated method. The open source nature of the software and archiving tools, as well as the community-wide release through global networks ensure that the outputs have the furthest possible reach. Importantly, our group includes Working Group Members from Developing Countries (e.g. Brazil, South Africa) as well as early career stages to embed potential capacity building from the outset of the project.

Depending on co-funding that can be sourced for the year 4 launch, we see this meeting as an opportunity to include a training event of the new products ('CO2sys'-type data processing tool and web-based archive) to the broader (and prospective future) user communities.

7. Composition of Working Group

Our Working Group will be comprised of 10 Full and 10 Associate Members that bring collective expertise from biophysics, photosynthesis, bio-optics (including remote sensing), oceanography, data archiving, and instrument and software development. Full Members are primarily responsible for the delivery of our objectives, with the Associate Members providing important input on key specific areas. Our Full members represent 8 different nations, including 1 emerging/developing nation (South Africa) and 2 early career researchers (Thomalla, Schuback). Similarly, our contributing members represent 7 different nations with further representatives from developing nations (Brazil) and early career researchers (Silsbe, Varkey). Finally, we also include a list of additional experts (7.3. Others), with particularly specialised skill sets and who have expressed interest in participating in one or more of the dedicated workshops. We fully recognize some gender imbalance in the overall WG composition, but note that half of our Associate Members are female. The oceanographic active Chl fluorescence field was initially male-dominated from its inception, and we are committed to addressing this gender imbalance moving forward.

7.1. Full Members

Name	Gender	Place of work	Expertise relevant to proposal
David Suggett (Co-chair)	M	Australia	Active chlorophyll fluorescence; phytoplankton physiology
Philippe Tortell (Co-chair)	M	Canada	Sea-going autonomous primary productivity
Zbigniew Kolber	M	USA	FRRf instrument development (LIFT); phytoplankton physiology; data analysis and computation
Sandy Thomalla	F	South Africa	Deployment platforms; remotely sensed fluorescence; data analysis, visualisation and archiving
Kevin Oxborough	M	UK	FRRf instrument development (FRRf); phytoplankton physiology; data analysis and computation
Maxim Gorbunov	M	USA	FRRf instrument development (Pico-F); phytoplankton physiology; data analysis and computation
Nina Schuback	F	Switzerland	Active chlorophyll fluorescence; phytoplankton physiology

Tetsuichi Fujiki	M	Japan	FRRf instrument development (FRRf-flash); phytoplankton physiology; data analysis and computation
Jacco Kromkamp	M	Netherlands	Active chlorophyll fluorescence; Primary productivity; phytoplankton physiology; deployment platforms
Mark Moore	M	UK	Active chlorophyll fluorescence; phytoplankton physiology; data parameterisation and analysis

7.2. Associate Members

Name	Gender	Place of work	Expertise relevant to proposal
Greg Silsbe	M	USA	Active chlorophyll fluorescence; data analysis and computation; data analysis, visualisation and archiving; Remote sensing
Kim Halsey	F	USA	Primary productivity; phytoplankton physiology, ¹⁴ C applications
Ondrej Prasil	M	Czech Republic	Primary productivity; phytoplankton physiology
Doug Campbell	M	Canada	Active chlorophyll fluorescence; Primary productivity; phytoplankton physiology
Aurea Ciotti	F	Brazil	Primary productivity; Sea-going autonomous primary productivity
Yannick Huot	M	Canada	Active chlorophyll fluorescence; remote sensing and bio-optics; data handling
Anna Hickman	F	UK	Bio-optics and fluorescence; remote sensing; modelling
Stefan Simis	M	UK	Active chlorophyll fluorescence; remote sensing and bio-optics; data handling; open source fluorometer hardware
Ilana Berman-Frank	F	Israel	Primary productivity; phytoplankton physiology
Deepa Varkey	F	Australia	Photosynthesis, Chl Fluorescence and data analytics (functional genomics)

7.3. Others:

Additional experts with specialised skill-sets will participate in one or more of the dedicated workshops. All of these individuals have confirmed their interest in our work.

Susanne Craig	F	USA (NASA)	Active chlorophyll fluorescence, Remote sensing Data archiving
Chris Proctor	M	USA (NASA)	Active chlorophyll fluorescence, Remote sensing Data archiving
Paul Falkowski	M	USA	Active chlorophyll fluorescence; Primary productivity; phytoplankton physiology;

Kenneth Hoadley	M	USA, Australia	Active chlorophyll fluorescence; open- source fluorometer development; phytoplankton physiology;
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8. Working Group contributions

Tetsuichi FUJIKI brings unique *in situ* FRRf instrumentation for inter-comparison and parameter retrieval (objectives i-iii). Access to field-based deployments in the Pacific (including autonomous platforms, and miniaturised sensors for gliders and floats) provides essential contributions to objectives ii-v.

Maxim GORBUNOV brings key expertise in hardware and software development (including data analysis and algorithm development) of various instrument approaches (FRRf, FIRE, PicoF), and applications of these instruments to different ocean systems (polar, temperate and tropical), thus contributing to objectives i-v.

Jacco KROMKAMP has key expertise developing autonomous productivity measurements (including ships of opportunity) and fluorometer inter-comparisons, contributing significantly to objectives i-v. He will also contribute to database development and data archival through parallel efforts from previous (e.g. leading PROTOOL) and current EU projects examining coastal primary productivity (objective vi).

Zbigniew KOLBER will contribute to identifying fluorescence properties indicative of photo- physiological performance, and assessing the utility of these properties as a proxy for primary production (objectives i-ii, iv). His background in developing new FRR fluorescence instruments (FRRf, LIFT) and data processing algorithms, will be critical to the project.

Mark MOORE will contribute to objectives i-iv, and help us in capacity building (objective vii), based on his previous work with groups in India. In addition to attending to both laboratory and field-based evaluation exercises, Moore will contribute equipment and data from a NERC UK funded autonomous active chlorophyll fluorometer development project ('STAFES-APP') to all activities.

Kevin OXBOROUGH has expertise developing single turnover active chlorophyll fluorometer systems for installation on marine autonomous systems. He will focus on objectives i-iii and v, with some involvement in objectives iv, vi and/or vii. His background in developing new fluorescence algorithms from terrestrial and aquatic organisms, as well as new software and hardware, will be critical.

Nina SCHUBACK will contribute significantly to instrument inter-comparisons and reconciliation of electron transfer rates with NPP (objectives i-ii, iv), in particular through her specialist focus and field opportunities in polar systems. Her computational and data handling skills will also contribute to objectives v, vii.

David SUGGETT will be responsible for joint-management and coordination of the overall project and thus contribute to the delivery of all activities. His specific expertise and unique instrumentation pool (e.g. FRRs, LIFT, multi-speQ) is essential to laboratory inter-comparisons and their associated output (i-iv, vi) and in the synthesis of larger data sets for objectives v-vi.

Sandy THOMALLA will contribute to *in situ* application of instrumentation to guide best practice, and in particular through autonomous deployments (objectives ii, iv). Her expertise in development and validation of ocean colour algorithms will contribute to handling and archiving of large data sets, and validation of sun-induced fluorescence observations from satellites (objectives v, vi).

Philippe TORTELL will be responsible for joint-management and coordination of the overall project and thus contribute to the delivery of all activities. His expertise in development and deployment of sea-going autonomous productivity measurements will contribute to all objectives. He will likely organize and host the first full WG meeting and associated inter-comparison work.

9. Relationship to other international programs and SCOR Working groups.

Some of the very first SCOR working groups, more than 50 years ago, focused on understanding large-scale patterns in oceanic productivity; WG3 “*Measurements of the Productivity of the Sea and of the Standing Crops of Phytoplankton and Zooplankton (renamed Biological Production of the Sea)*”, WG20 “*Radiocarbon Estimation of Primary Production (approved in 1965; joint with ICES and UNESCO)*”, and WG 4 “*Estimation of Primary Production under Special Conditions*”. Since that time, new technologies for ocean observations have radically transformed our ability to quantify marine productivity over a range of scales. Yet, no single SCOR Working Group has been dedicated to standardising and ensuring best practice of rapidly expanding autonomous productivity measurements.

As stated in section 2.3, previous working groups have attempted to inter-compare active fluorescence data from different commercially available instruments (e.g., AQUAFLUO 2007; GAP- 2008, Suggett et al. 2009; PROTOOL, Silsbe et al. 2015). These past efforts highlight major global demand and incentive to reconcile data from across an ever evolving and growing instrument base. However, they did not include an explicit focus on the need for standardized data collection and analysis, nor did they produce best-practices guides and software tools for wide distribution to non-experts. Our WG proposes to further advance the field by producing a singular set of openly available recourses needed to generate large inter-comparable data sets of active fluorescence (FRRf and FRRf-like) measurements. Such efforts mirror programs that broadly exist for global bio-optical data sets and ¹⁴C uptake data (e.g. Prof. Mike Behrenfeld, Oregon State University; <http://www.science.oregonstate.edu/ocean.productivity/field.data.fl.readme.php>).

Our objective to better reconcile field-based fluorescence data with remotely sensed fluorescence parallels efforts initiated by researchers working in terrestrial systems (e.g. SpecNet, <http://specnet.info/index.php>). Several of our objectives (e.g. v-vi) will directly leverage with the EU-funded Horizon 2020 project MONOCLE (www.monocle-h2020.eu; coordinated by Stefan Simis

– Associate member of this proposed WG), which is already developing state-of-the-art networking for in situ sensors, links with satellite observations, data visualisation and analysis tools (e.g. anomaly detection), which can be applied to instrumentation once best-practice is established.

By introducing quality control and best practice procedures into rapidly growing capability to measure key ocean biogeochemical metrics, we parallel SCOR WG 142 “*Quality Control Procedures for Oxygen and Other Biogeochemical Sensors ...*”, WG143 “*Dissolved N₂O and CH₄ measurements...*” and WG148 “*International Quality Controlled Ocean Database...*”. As a founding member of WG143 (which is now coming to an end), Tortell has significant experience with the implementation of a successful SCOR program. Similarly, our focus on developing inter-comparable data sets to support a global database compliments other Working Groups, such as WG147 “*Towards comparability of global oceanic nutrient data (COMONUT)*” and WG149 “*Changing Ocean Biological Systems (COBS): ...*”. Finally, by providing a means to standardise and archive active fluorometry data, we will support broader implementation of the growing instrument base of active fluorometers into existing global sampling programs. This theme underpins other Working Groups, e.g. WG154 “*Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (P-OBS)*”.

10. Key References

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Appendix

For each Full Member, indicate 5 key publications related to the proposal.

Tetsuichi FUJIKI

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Appendix 4

Proposal for a Working Group on Toward a new global view of marine zooplankton biodiversity based on DNA metabarcoding and reference DNA sequence databases (MetaZooGene)

Abstract

Marine zooplankton biodiversity remains a significant unknown throughout the global ocean. Molecular approaches, including DNA barcoding (use of short DNA sequences for species recognition and discrimination) and metabarcoding (large-scale taxonomic identification of complex samples via analysis of one or few orthologous DNA barcode regions), are expected to significantly revise global estimates of zooplankton diversity. Primary obstacles to broader use of metabarcoding for fundamental research on the biodiversity, biogeography, and trophic dynamics of marine zooplankton include lack of best practices for barcoding and metabarcoding analysis, and lack of taxonomically-comprehensive global-scale DNA sequence reference databases (libraries of DNA sequences determined for identified specimens) for the selected barcode gene regions. The MetaZooGene SCOR Working Group will develop a global vision for the continuing development of integrative molecular – morphological taxonomic analysis of marine zooplankton biodiversity through international communication, cooperation, and collaboration. Terms of Reference include: 1) create an open-access web portal for DNA barcodes for marine zooplankton; 2) design an optimal DNA barcoding pipeline for marine zooplankton; and 3) develop best practices for DNA metabarcoding of marine zooplankton biodiversity. Deliverables include a project website, web portal, and database; dissemination of best practices for DNA barcoding and metabarcoding of marine zooplankton; and publications and review papers in open access peer-reviewed journals. Workshops to build capacity for the MetaZooGene mission will be designed for early career scientists and those from developing countries, and will be held in association with international conferences.

Scientific Background and Rationale

Marine zooplankton are key players in pelagic food webs, central links in ecosystem function, and useful indicators as rapid responders to environmental variation and climate change (Beaugrand et al., 2010). Characterization of biodiversity of the marine zooplankton assemblage is complicated by many factors, including the systematic complexity of the assemblage; presence of cryptic, rare, and novel species; and high local-to-global ratios of species diversity (Snelgrove et al., 2016). Molecular approaches, including DNA barcoding (use of short DNA sequences for species recognition and discrimination) and metabarcoding (large-scale taxonomic identification of complex samples via analysis of one or few orthologous DNA barcode regions), are providing important new insights into the ‘hidden diversity’ of marine zooplankton (Bucklin et al., 2011, 2016; Lindeque et al. 2013). A compelling question driving development of new genetic and genomic tools for characterization of zooplankton biodiversity is that the number of species occurring in the pelagic realm remains unknown (Mora et al., 2013; Chust et al., 2017). Metabarcoding is expected to increase estimates marine zooplankton biodiversity dramatically, although recent studies differ in these estimations by at least several orders of magnitude (e.g., Brown et al., 2015; de Vargas et al., 2015; Sommer et al., 2017).

The MetaZooGene SCOR Working Group will seek to develop a global vision for the continuing development of integrative molecular – morphological taxonomic analysis of marine zooplankton biodiversity through international communication, cooperation, and collaboration. The overarching goal will be to promote and facilitate development and use of best-practices for molecular, statistical and bioinformatics approaches for DNA barcoding and metabarcoding, and thereby to accelerate progress in characterizing local-to-global scale patterns of biodiversity and biogeographic distributions of marine zooplankton, and contribute to better understanding of the functioning of pelagic ecosystems.

Metabarcoding relies on high-throughput DNA sequencing (HTS) technologies, which yield millions of DNA sequences in parallel and allow large-scale analysis of environmental samples. A number of different gene regions are used for metabarcoding, including several hypervariable regions of nuclear small- (18S) and large-subunit (28S) rRNA (Lindeque et al., 2013; De Vargas et al., 2015; Hirai et al., 2015). Metabarcoding studies have also used mitochondrial cytochrome oxidase I (LeRay and Knowlton, 2016), which can detect species-level diversity, but may yield inconsistent results. In addition to fundamental research on pelagic biodiversity and ecosystem functioning, promising applications of metabarcoding of marine zooplankton include rapid detection of impacts of climate change, monitoring and assessment of ecosystem health, characterization of food webs, and

detection of introduced and non- indigenous species (Aylagas et al., 2014; Bucklin et al. 2016; Deagle et al., 2017; Goodwin et al., 2017).

A primary obstacle to the widespread use of metabarcoding for fundamental research on the biodiversity, biogeography, and trophic dynamics of marine zooplankton is the lack of taxonomically-comprehensive global-scale DNA sequence reference databases (libraries of DNA sequences determined for specimens identified to species by morphological taxonomic characters) for the selected barcode gene regions.

Reference DNA databases have been shown to markedly improve the accuracy and taxonomic resolution of metabarcoding data for zooplankton diversity (Hirai et al, 2015; Machida et al., 2017; Yang et al., 2017). Among the challenges remaining for reliable and routine application of metabarcoding for analysis of zooplankton diversity are evaluation and inter-comparison of results using different barcode gene regions; development of best practices to ensure accurate identification, discrimination, and detection of taxa; and continued development of taxonomically comprehensive reference databases for all barcode gene regions.

Metabarcoding is revolutionizing the analysis of marine biodiversity and is expected to significantly revise global estimates of zooplankton diversity. Yet the remarkable promise of DNA barcoding and metabarcoding will only be realized with global-scale conversation, cooperation, and collaboration among scientists devoted to the integration of morphological and molecular taxonomic approaches. The proposed MetaZooGene WG members share a dedication to this shared goal, and will work together to promote and facilitate the broad application of DNA barcoding and metabarcoding for analysis of zooplankton diversity, to allow more rapid detection and description of the impacts of climate change, and provide a new foundation for future research, monitoring and management of the pelagic realm.

Terms of Reference

1) Create an open-access web portal for DNA barcodes for marine zooplankton

An online open-access database will be designed and populated with species and specimen metadata, photographs, and deep links to sequence data deposited in major repositories. All molecular data, metadata, and protocol information will be publicly available via one or more of the existing open-access repositories. The portal will facilitate and expedite searches for data for marine zooplankton species, which are difficult to discriminate and retrieve via usual keyword searches of online repositories.

2) Design an optimal DNA barcoding pipeline for marine zooplankton

MetaZooGene WG members will develop and recommend best practices for DNA barcoding, including evaluation of all steps necessary for the bug-to-sequence pipeline. The WG will coordinate and accelerate the augmentation of taxonomically-comprehensive DNA barcode datasets for the global ocean by setting priorities and identifying gaps.

3) Develop best practices for DNA metabarcoding of marine zooplankton biodiversity

The MetaZooGene WG will evaluate and compare the many diverse molecular, analytical, and bioinformatics approaches now used for metabarcoding. A globally-integrated metabarcoding dataset will be developed to allow comparison of results from local, regional, and global scale efforts by all participating investigators. This shared resource and the ensuing discussions and deliberations will provide the basis for high-level synthetic and review papers that recommend and promote best practices for metabarcoding of marine zooplankton biodiversity.

Working Plan

The MetaZooGene web portal and database (ToR #1) will be designed and populated with data and information (including unique identifiers) for samples, specimens and vouchers. The database will include deep links via accession numbers or other unique identifiers for DNA sequence data available on established public open access repositories. Only repositories that assure fully open and public access to all data by any user – without password control, registration, or other impediments to open access – will be included in the MetaZooGene database and web portal.

The MetaZooGene WG members will develop and recommend a sequence and set of procedures for barcoding pipelines (ToR #2), designed to guide related efforts in laboratories or facilities throughout the world. Description

of best practices for DNA barcoding will include morphological identification of species by taxonomic experts, photographs of specimens, archives of specimen and DNA vouchers, DNA sequencing primers and protocols for all agreed-upon barcode gene regions, inclusion of all specimen data and metadata in open access websites and portals, and submission of all DNA sequence data to existing open access data repositories. Information and advice will be sought from several WG members who are currently engaged in bug-to-database multi-gene semi-automated DNA barcoding pipelines at their home universities and institutes.

MetaZooGene WG members will develop recommendations for best practices for metabarcoding of marine zooplankton biodiversity (ToR #3), based on examination, review, comparison and evaluation of key issues, including selection of marker gene regions, design of PCR primers and sequencing protocols, comparisons of analytical and bioinformatics parameters and approaches, and benefits of taxonomically comprehensive global-scale reference DNA sequence databases. Particular attention will be given to ongoing programs that have implemented metabarcoding for routine local-to-regional monitoring and assessment of zooplankton biodiversity. The MetaZooGene WG will meet three times over the 4 years in association with international scientific conferences (see *Timeline*). Four MetaZooGene workshops will be organized (one each year) to provide in-depth training for graduate students and early-career scientists, especially from developing countries (see *Capacity Building*).

Timeline

Year 1 (January 1 – December 31, 2019)

- Create MetaZooGene database and web portal; populate the database with all available specimen data and metadata (including unique identifiers), and deep links to DNA sequences in existing open-access repositories.
- Develop and describe best practices for multi-gene DNA barcoding “pipelines” from bug-to- database, including sample collection, preservation and archiving; specimen identification and vouchering; DNA extraction, PCR and sequencing primers and protocols; submission of data and metadata to open-access repositories.
- Convene first MetaZooGene Working Group meeting following the ICES 2019 Annual Science Conference; September 9-12, 2019; Gothenburg, Sweden.
- Organize a MetaZooGene Workshop to review and compare present approaches and best practices for multi-gene DNA barcoding pipelines from bug-to-database. The workshop will be held following the International Council for the Exploration of the Sea (ICES) 2019 Annual Science Conference; September 9-12, 2019; Gothenburg, Sweden.

Year 2 (January 1 – December 31, 2020)

- Conduct comparative examination of metabarcoding approaches and protocols for analysis of marine zooplankton biodiversity.
- Convene the second MetaZooGene Working Group meeting following AGU/ASLO/TOS Ocean Sciences Meeting; February 16-21, 2020; San Diego, California, USA.
- Organize a workshop to evaluate and compare use of DNA sequence databases for different barcode gene regions for analysis of zooplankton diversity based on DNA barcoding and metabarcoding. The workshop will be held following the AGU/ASLO/TOS Ocean Sciences Meeting; February 16-21, 2020; San Diego, California, USA
- Publish comprehensive review paper in open access peer-reviewed journal summarizing and assessing the current view of marine zooplankton biodiversity based on metabarcoding.

Year 3 (January 1 – December 31, 2021)

- Organize an intensive hands-on ‘DNA-to-data’ training workshop in DNA barcoding and metabarcoding targeted for graduate students and early-career scientists. The workshop will be held at Academia Sinica (Taipei, Taiwan) and hosted by WG member Ryuji Machida.

- Publish comprehensive review paper in open access peer-reviewed journal summarizing current status of multi-gene reference DNA sequence database, with demonstration of the usefulness of reference databases for improved identification of taxa from metabarcoding analysis of zooplankton diversity.
- Fully populate the MetaZooGene database, with specimen data and metadata for described species of marine holozooplankton, including DNA sequences for multiple barcode gene regions and multiple specimens throughout each species' geographic range.

Year 4 (January 1 – December 31, 2022)

- Convene the third MetaZooGene Working Group meeting following the AGU/ASLO/TOS Ocean Sciences Meeting; February 27-March 4, 2020; Honolulu, Hawaii, USA
- Organize a workshop to educate and encourage use of best practices, including use of taxonomically-comprehensive global-scale reference DNA sequence databases, for metabarcoding analysis of marine zooplankton biodiversity. The workshop will be scheduled to follow the AGU/ASLO/TOS Ocean Sciences Meeting; February 27-March 4, 2020; Honolulu, Hawaii, USA
- Publish and distribute a comprehensive recommendation for best practices for metabarcoding of marine zooplankton biodiversity, including use of taxonomically comprehensive global-scale reference DNA sequence databases.

Deliverables

Project website, web portal, and database: The MetaZooGene WG will have a dedicated website and web portal for display and distribution of project updates and results, as well as a login section for exchange of information among WG Full and Associate members. Database design, development and maintenance will be the responsibility of WG member Todd O'Brian, with costs provided by the NOAA National Marine Fisheries Service. All data and metadata associated with the MetaZooGene WG efforts will be publicly available and open access, without password control or required registration.

Best practices for DNA barcoding and metabarcoding: The MetaZooGene WG members will produce recommendations for best practices for both DNA barcoding pipelines and metabarcoding analysis of marine zooplankton diversity.

Publications in peer-reviewed journals: MetaZooGene WG members will publish and acknowledge WG contributions for papers in peer-reviewed open access journals on topics relevant and related to the WG mission. The anticipated goal is a total of 25 publications over the active years of WG effort.

Review papers: Three comprehensive review papers will be co-authored by WG members and published in peer-reviewed open access journals. The reviews will provide summary evaluation and analysis consistent with the MetaZooGene primary goals, including: 1) overview of available DNA sequence reference DNA databases for marine zooplankton; 2) evaluation of best practices for "bug-to-sequence" pipelines for production of DNA sequences for barcode marker genes; and 3) evaluation and recommendation of best practices for metabarcoding analysis of marine zooplankton biodiversity.

Capacity Building

Four workshops are planned to address the key themes central to the MetaZooGene mission. Workshops will be designed for early career scientists and those from developing countries, and will be held in association with international oceanographic conferences. Announcements and invitations will seek to recruit participation by the target groups. The workshops are:

- Best practices for multi-gene DNA barcoding pipelines from bug-to-database. Will be held following ICES 2019 Annual Science Conference; September 9-12, 2019; Gothenburg, Sweden
- Use of DNA reference sequence databases for analysis of zooplankton diversity based on DNA barcoding and metabarcoding. Will be held following the AGU/ASLO/TOS Ocean Sciences Meeting; February 16-21, 2020; San Diego, California, USA.
- Hands-on 'DNA-to-data' training workshop in DNA barcoding and metabarcoding. Will be held

during Fall, 2021 at Academia Sinica (Taipei, Taiwan) and hosted by WG member Ryuji Machida.

- Best practices for metabarcoding analysis of marine zooplankton biodiversity. Will be held following the AGU/ASLO/TOS Ocean Sciences Meeting; February 27-March 4, 2020; Honolulu, Hawaii, USA

The MetaZooGene workshop participants will have top priority for invitations for collaborative research visits to WG members' laboratories. A mailing list will be maintained and used for frequent announcements and updates on the activities of the WG. The workshop participants will be used for invitations to special sessions at international conferences and symposia on relevant research topics. The goal will be to ensure significant and continued influence and impact on this group of early career scientists.

Working Group composition

	Full Members	Gender	Place of work (Country)	Expertise relevant to proposal	Geographic Region(s)
1	Bucklin, Ann (Chair)	F	University of Connecticut (United States)	DNA barcoding; Metabarcoding	North Atlantic Ocean
2	Kosobokova, Ksenia (Vice-Chair)	F	Russian Academy of Sciences (Russia)	Zooplankton taxonomy; DNA barcoding	Arctic Ocean
3	Peijnenburg, Katja (Vice-Chair)	F	University of Amsterdam (Netherlands)	DNA barcoding; Metabarcoding	North / South Atlantic Ocean
4	Blanco-Bercial, Leocadio	M	Bermuda Inst. Ocean Science (Bermuda)	Zooplankton taxonomy; DNA barcoding; Metabarcoding	N Atlantic Ocean, NE Pacific Ocean
5	Cepeda, Georgina	F	Instituto Nacional de Investigación y Desarrollo Pesquero (Argentina)	Zooplankton taxonomy, DNA barcoding; Metabarcoding	South West Atlantic Ocean
6	Falkenhaug, Tone	F	Institute of Marine Research (Norway)	Zooplankton taxonomy; DNA barcoding	North Sea, Norwegian Fjords, NE Atlantic Ocean
7	Huggett, Jenny	F	Dept of Environmental Affairs (South Africa)	Zooplankton ecology, parataxonomy	SE Atlantic, SW Indian, Southern Ocean
8	Li, Chaolun	M	Institute of Oceanology (China)	Zooplankton taxonomy; DNA barcoding	NW Pacific Ocean; coastal areas of China
9	Machida, Ryuji	M	Academia Sinica (Taiwan)	DNA barcoding; Metabarcoding; Reference Databases	W Pacific Ocean
10	O'Brien, Todd	M	NOAA National Marine Fisheries Service (United States)	Web site design; Data base management	Global Ocean (database management)

	Associate Members	Gender	Place of work (Country)	Expertise relevant to proposal	Geographic Region(s)
1	Escribano, Ruben	M	Universidad de Concepción (Chile)	Zooplankton ecology; taxonomy	S Pacific Ocean
2	Goetze, Erica	F	University of Hawaii (United States)	DNA barcoding; Metabarcoding	N Pacific Ocean
3	Hirai, Junya	M	University of Tokyo (Japan)	DNA barcoding; Metabarcoding	Western N Pacific Ocean
4	Hosia, Aino	F	University of Bergen (Norway)	Zooplankton taxonomy (gelatinous); DNA barcoding	North Sea, Arctic, NE Atlantic Ocean
5	Laakmann, Silke	F	Helmholtz Institute for Functional Marine Biodiversity (Germany)	Zooplankton integrative taxonomy	North Sea
6	Lindeque, Pennie	F	Plymouth Marine Lab (United Kingdom)	DNA barcoding; Metabarcoding	North Atlantic
7	Mazzochi, Maria Grazia	F	Stazione Zoologica Anton Dohrn (Italy)	Zooplankton ecology; integrative taxonomy (copepods)	Mediterranean Sea, Atlantic Ocean, Southern Ocean
8	Noblezada, Mary Mar	F	Univ. of Phillipines (Phillipines)	Zooplankton taxonomy; DNA barcoding	Phillipine Sea, tropical W Pacific Ocean
9	Rodriguez-Espeleta, Naiara	F	AZTI Tecnalia (Spain)	Metabarcoding	Mediterranean Sea, NE Atlantic Ocean
10	Weydmann, Agata	F	University of Gdansk (Poland)	DNA barcoding; Metabarcoding	Arctic, N Atlantic Ocean

Working Group contributions

Ann Bucklin (Chair) has international leadership experience as lead scientist for a Census of Marine Life project, Census of Marine Zooplankton, and as a national delegate and working group chair for the International Council for Exploration of the Sea (ICES). Her research uses diverse molecular genetic/genomic/transcriptomic approaches; she is author of review papers on DNA barcoding and metabarcoding and population genomics of marine zooplankton.

Katja Peijnenburg (Vice-Chair) uses multidisciplinary approaches to resolving global-scale species boundaries and diversity patterns of different groups of marine zooplankton; she is experienced with semi-automated DNA barcoding pipelines, including archives of voucher specimens and DNA. As a WG Vice-Chair, she will lead and contribute to discussions about best practices for metabarcoding, including comparisons among genes and gene regions and identification of taxa using reference databases.

Ksenia Kosobokova (Vice-Chair) is a recognized expert on taxonomy, biodiversity, and ecology of Arctic marine zooplankton, including the full spectrum from jellyfish to crustaceans, with established collaborations for DNA barcoding and metabarcoding studies. As a WG Vice-Chair, she will ensure coordination among morphological and molecular approaches necessary to achieve WG goals, and lead WG efforts to evaluate and guide development of taxonomically-comprehensive reference databases.

Leocadio Blanco-Bercial has expertise and extensive experience in DNA barcoding and metabarcoding of marine zooplankton, with interests in phylogenetic analysis and taxonomic relationships of various groups, including copepods and gastropods. He has participated in several international programs, and has a particular interest in integrating morphological and molecular analysis of marine zooplankton.

Georgina Cepeda is an expert copepod morphological taxonomist, with experience in developing DNA barcoding protocols and metabarcoding methods. She is committed to the MetaZooGene goal of building global consensus for best practices for these methods and approaches.

Tone Falkenhaus has expertise in zooplankton ecology and taxonomy, especially copepods, gelatinous zooplankton, pelagic decapods, and euphausiids. She has led a comprehensive and ambitious DNA barcoding effort focused on planktonic copepods and cladocerans in Norwegian waters.

Jenny Huggett is a zooplankton ecologist and parataxonomist, who has participated in sampling initiatives in the Benguela upwelling regions and Southern Ocean, and is currently most active in the SW Indian Ocean. Among her current projects is the DNA barcoding of meroplankton.

Chaolun Li conducts broad-ranging research in marine zooplankton ecology. He established the first zooplankton DNA barcode database in China, and is now engaged in the application of environmental DNA (eDNA) analysis of zooplankton diversity.

Ryujia Machida has expertise and research interests in mechanisms of diversity maintenance in pelagic zooplankton. He has pioneered the development of molecular approaches and protocols, including DNA barcoding, genomic sequencing, and reference DNA sequence datasets for marine zooplankton.

Todd O'Brien has developed and led international database efforts, serving as plankton lead for the World Ocean Database. He is a member of two SCOR WGs, Global Comparisons of Zooplankton Time Series (WG125.net) and Global Patterns of Phytoplankton Dynamics in Coastal Ecosystems (WG137.net); two ICES WGs, Working Group on Zooplankton Ecology (WGZE.net) and Working Group on Phytoplankton & Microbial Ecology (WGPME.net); and the IMBER Data Management Committee.

Relationship to other international programs and SCOR Working Groups

There is no other equivalent effort focused on this or any closely-related goals in molecular approaches to zooplankton biodiversity among current SCOR Working Groups. Marine zooplankton have been largely overlooked in previous and ongoing efforts focused on building genomic and transcriptomic resources for marine organisms (GIGA, 2014). As an example, there are few – or perhaps none – model species for genome sequencing efforts (Bucklin et al., 2018).

This effort follows two very successful inter-related multi-year programs, the Census of Marine Life (CoML) and Marine Barcode of Life (MarBoL), which laid useful foundations for the proposed MetaZooGene WG effort. In particular, the Census of Marine Zooplankton (CMarZ, see <http://www.cmarz.org/>) was funded by the Alfred P. Sloan Foundation during 2004-2010, with the ambitious goal of producing a global assessment of marine zooplankton biodiversity, including accurate and complete information on species diversity, biomass, biogeographical distribution and genetic diversity.

The name of the proposed WG stems from an international effort led by Ann Bucklin called ZooGene (see <http://www.zoogene.org/>), which had the goal of a DNA sequence database for calanoid copepods and euphausiids, and was funded by the US National Science Foundation during 2000-2004.

The topic of DNA barcoding and metabarcoding is central to the mission and goals of the ICES Working Group on Integrative Morphological and Molecular Analysis (WGIMT, see <http://wgimt.net/> and <http://www.ices.dk/community/groups/Pages/WGIMT.aspx>). In contrast to SCOR WG, the focus of ICES WGs is necessarily regional, with a priority on the North Atlantic Ocean.

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Appendix I. For each Full Member, indicate 5 key publications related to the proposal.

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Appendix 5
Integrated Marine Biosphere Research (IMBeR) Project



Integrated Marine Biosphere Research (IMBeR)

Annual Report to SCOR 2017-2018 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 new 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 new 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.

A. Science Plan (2016-2025)

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 topics for IMBeR where research is needed and where it is believed that major achievements can be made within three to five years. The Innovation Challenges also

provide a means for IMBeR to adjust its focus as major science discoveries are made and new priorities arise. During 2017 we mapped the activities of the regional programmes, working groups and innovation challenges on to the objectives of the Grand Challenges and allocated specific members of the scientific steering committee to oversee each of these objectives (Figure 1).

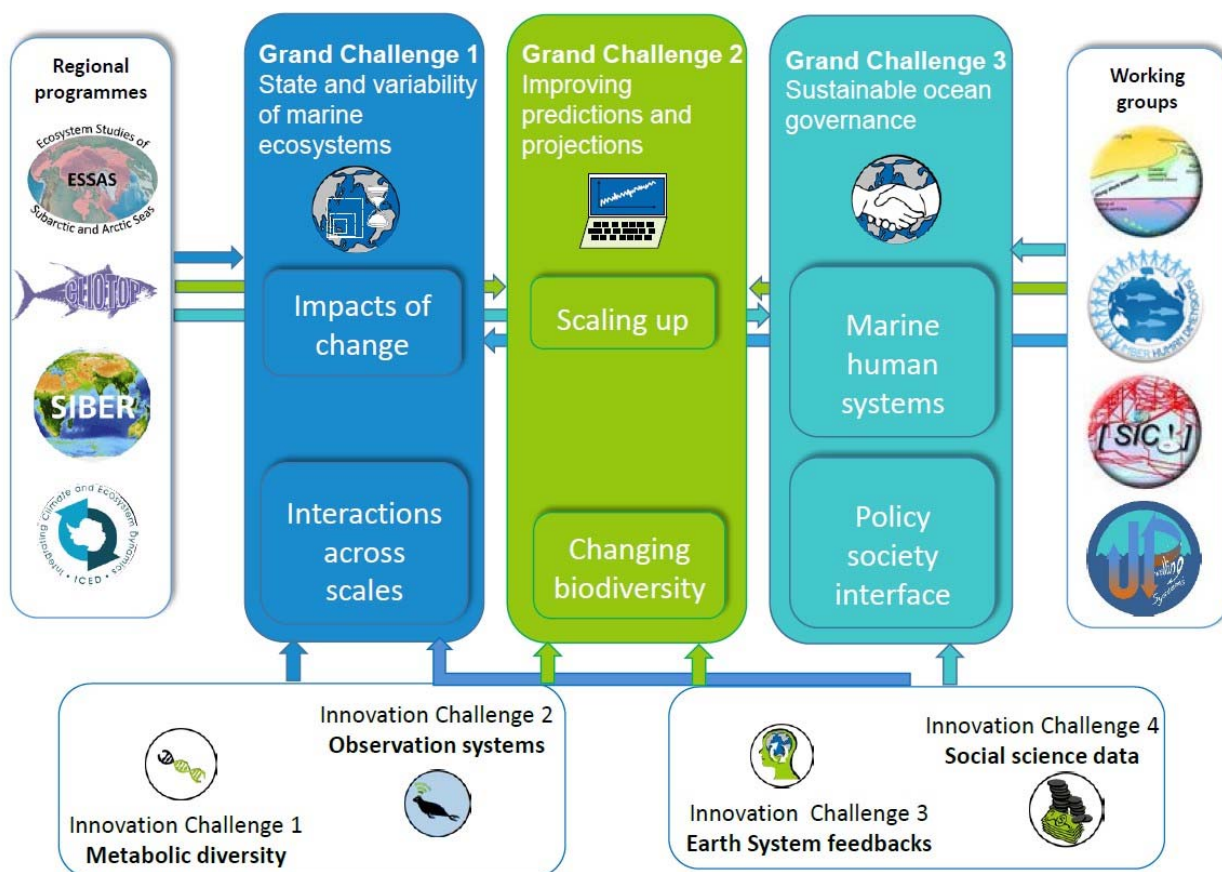


Figure 1. Contribution of the regional programmes, working groups and Innovation Challenges to the objectives of the Grand Challenges

B. Selected science highlights in 2017

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 where IMBeR has contributed to the progression of fundamental knowledge in marine ecology and biogeochemistry.

1. ICED scientists led a multidisciplinary study to assess potential climate change impacts on Southern Ocean ecosystems. The study, which was published in *Frontiers in Marine Science* <http://dx.doi.org/10.3389/fmars.2017.00308>, and featured as a research highlight in *Nature Climate Change* <https://www.nature.com/articles/nclimate3408.pdf?origin=ppub> stresses the need for an integrated approach to best use climate-model data for ecological insights. As an example, they consider the implications for Antarctic marine ecosystems of changes in sea-ice.
2. ICED has emphasized the importance of developing quantified understanding of the life cycles of key species such as Antarctic krill (*Euphausia superba*) in Southern Ocean ecosystems. This study developed and applied an empirical relationship of growth rate to assess seasonal spatial variability in the growth of Antarctic krill throughout the Southern Ocean. It showed that over much of the ocean, the potential for growth is limited, and indicated that there are three restricted oceanic regions where seasonal conditions permit high growth rates,

and only a few areas around the Scotia Sea and Antarctic Peninsula suitable for growth of the largest krill (>60 mm). The study demonstrated that projections of impacts of future change need to account for spatial and seasonal variability of key ecological processes within ocean ecosystems. Murphy, E.J. et al., (2017) Scientific Reports 7, 6963. <http://www.nature.com/articles/s41598-017-07205-9>

3. A special issue of *Deep-Sea Research II* outlines research arising from the CLIOTOP (Climate Impacts on Oceanic Top Predators) regional programme 2015 symposium, spanning topics such as conservation biology, trophic ecology, fisheries science, climate change and adaptive management (Hobday et al., 2017; doi:10.1016/j.dsr2.2017.03.008).
4. The CLIOTOP Task Team 2016-02 aims to build policy relevant scenarios for the sustainability of global oceanic ecosystems and fisheries. Maury et al., (2017; <http://dx.doi.org/10.1016/j.gloenvcha.2017.06.007>) developed five contrasting Oceanic System Pathways (OSPs) based on the shared socioeconomic pathways used in climate change research. These OSPs have been chosen to form the official scenario basis of the FishMIP (Fisheries Model Inter-Comparison initiative), the marine component of the Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP), used to inform model studies in the context of IPCC and IPBES.
5. SIBER has been working to motivate synthesis papers related to the research themes that are articulated in the SIBER Science Plan. The first of these papers on biogeochemical and ecological impacts of boundary currents in the Indian Ocean was published in *Progress in Oceanography* in 2017 (Hood et al. 2017 <https://www.sciencedirect.com/science/article/pii/S0079661117301507>). Evidence from the paleoceanographic record suggests that boundary currents in the Indian Ocean basin have changed significantly over glacial to interglacial timescales. These changes are explored as a means of providing insight into the potential biogeochemical and ecological impacts of climate change in the Indian Ocean.
6. The SOLAS-IMBeR Ocean Acidification Working Group working through the IAEA Ocean Acidification International Coordination Centre (OA-ICC) has continued efforts to improve the computation of derived variables of the marine carbonate system in earth system models in order to project the impacts of decreasing pH on marine organisms (Kwiatkowski, L., & Orr, J. C. 2018. Diverging seasonal extremes for ocean acidification during the twenty-first century. *Nature Climate Change*, 8(2), 141 <http://www.nature.com/articles/s41558-017-0054-0>). Results suggest that projected seasonality changes will tend to exacerbate impacts during the summer and ameliorate impacts during the winter.
7. The Arctic Ecosystem Integrated Survey (Arctic Eis) in the Pacific Arctic (Northern Bering Sea and Chukchi Sea) is an ESSAS affiliated project which came to an end in 2017. Detailed results can be accessed at <https://web.sfos.uaf.edu/wordpress/arcticeis/> and were published in a special issue of Deep-Sea Research Part II (<http://dx.doi.org/10.1016/j.dsr2.2016.11.005>). A few of the highlights include: (a) High densities of young-of-year Arctic cod (*Boregadus saida*), an ecologically important species in the Arctic that is also of potential commercial interest, were, for the first time, observed in the northeast Chukchi Sea in 2012, 2013, suggesting that this area is an important nursery area for the early life history stages of Arctic cod in the Pacific Arctic. (b) Plankton, fish and invertebrate species of Pacific origin typically dominate demersal and pelagic communities throughout the Chukchi Sea, highlighting the importance of advection of Pacific waters through Bering Strait into the Chukchi Sea. However, distinct Arctic populations of some species are associated with Arctic water masses on the northeast Chukchi Sea shelf, reflecting the intrusion of Arctic water masses from the basin onto the shelf. (c) Fishes and crab consume a large variety of pelagic and benthic prey in the Chukchi Sea and diets typically differ among species, water masses and with predator size. While juveniles and small forage fish rely primarily on zooplankton advected from the Bering Sea, there is an increasing reliance on benthic prey with increasing predator size.

C. Regional Programmes

Ecosystem Studies of Subarctic and Arctic Seas (ESSAS)

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.

The third ESSAS Open Science Meeting was held in Tromsø, Norway in June 2017. The title of the meeting was *Moving in, out and across the Subarctic and Arctic marine ecosystems: shifting boundaries of water, ice, flora, fauna, people and institutions*. Nine theme sessions were on Paleo-Ecology; Advection and Mixing; Phenology;

Shifting habitats and hotspots; Future Climate and its ecosystem effects; Multiple Stressors; Ocean Acidification; Science, Policy and Management; and a General Open Session. A total of 187 scientists of different disciplines from 11 countries attended the meeting. A special issue of the *ICES Journal of Marine Science* will be published by the end of 2018 containing some of the papers presented at the ESSAS OSM.

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. It is a 3-year project, with the objective to synthesize information from completed and ongoing regional studies in order to examine how variability and changes in advection, temperature, pH and ice dynamics in the Subarctic to Arctic transition zone may affect future marine ecosystems of the Pacific and Atlantic Arctic. Of particular interest is how fish populations and their prey respond to, and may adapt to, natural and anthropogenic changes in the Arctic and how these responses are expected to affect existing and future fisheries, subsistence harvests, and the socio-economic systems that depend upon them. The second meeting was held in March 2017, in Juneau, Alaska, USA. It began with a 1-day stakeholder's meeting and was followed by a 2-day meeting of the Principal Investigators and other contributors. The main activity was the development of outlines for scientific papers on future climate scenarios, their ecological impacts and the challenges these represent for management.

ESSAS held its 2018 Annual Science Meeting in Fairbanks, Alaska in June 2018. A primary focus of the meeting was on remote sensing applications in the study of climate change impacts on high-latitude ecosystems. Additional sessions and workshops focused on ocean acidification and other stressors; the biology, ecology and paleoecology of Arctic gadids, and the use of Integrated Ecosystem Assessments (IEA) as a framework for understanding and managing subarctic and Arctic marine ecosystems.

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

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. www.iced.ac.uk/index.htm.

ICED scientist Jess Melbourne Thomas was selected as lead author of the Polar Regions Chapter for the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate. The Special Report will build on the work of the IPCC's Fifth Assessment Report (AR5). A report outline was agreed in March 2017 and the report is scheduled to be finalized 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.

The Marine Ecosystem Assessment for the Southern Ocean: Assessing Status and Trends of Habitats, Key Species and Ecosystems in the Southern Ocean (MEASO2018) conference was organized in 2018 by ICED SSC member Andrew Constable. MEASO2018 marks the 10 year anniversary of ICED and provided an important opportunity for the ICED community to present their results. The outcomes of the conference are also expected to provide significant input to the Committee on Environment Protection, the Scientific Committee for the Conservation of Antarctic Marine Living Resources, the International Whaling Commission's Scientific Committee and other organisations interested in the management and conservation of Southern Ocean ecosystems.

CLimate Impacts on Oceanic TOP Predators (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. CLIOTOP scientists edited and contributed to a special issue of *Reviews in Fish Biology and Fisheries* <https://link.springer.com/journal/11160/27/4/page/1> focused on safeguarding the sustainability of tuna fisheries.

CLIOTOP scientists attended a number of regional and international meetings during 2017 including the VOICE (Variability in the Oxycline and its ImpaCts on the Ecosystem) GO2NE (Global Ocean Oxygen Network) meeting, Regional workshops for the South Pacific and Indian Ocean in support of the second World Ocean Assessment, International Commission for the Conservation of Atlantic Tunas Standing Committee on Research and Statistics sub-committee on ecosystems, XIIth SCAR Biology Symposium, 6th Biologging Symposium, 22nd Biennial conference on the biology of marine mammals, and the 6th Mediterranean Oceanography Network for the Global Ocean Observing System (MonGOOS) meeting.

CLIOTOP Task team 2016-03 will co-convene a session with the PICES forecasting group at the Fourth International Effects of Climate Change on the World's Oceans symposium in June 2018. CLIOTOP will hold its fourth international symposium in October 2018 at the National Taiwan Ocean University in Keelung, Taiwan.

Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER)

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. SIBER is now leading the development of a Science Plan to guide US participation in IIOE-2. This effort was initiated with a US IIOE-2 Science Planning Workshop, convened at Scripps Institution of Oceanography in September 2017. The draft US IIOE-2 Science Plan is currently undergoing peer-review, with the anticipation that it will be completed by June 2018. SIBER SSC members also helped to organize and participated in a joint South Korea-US workshop in Seoul in December 1, 2017 that was aimed at developing a Science Plan to guide South Korea's participation in IIOE-2.

D. Working Groups

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

The CMWG aims to undertake and compare two socio-ecological case studies, one on the sparsely-populated but rapidly changing Arctic continental margin, and one on the densely populated Chinese marginal seas. A first workshop to plan the Chinese marginal seas case study was convened at the XMAS-III conference in Xiamen, China in early 2017, and the second is planned to take place during the China/Japan/Korea Symposium to be held in Shanghai in October 2018.

Human Dimensions Working Group (HDWG)

The publication of the I-ADApT Synthesis book *Global Change in Marine Systems: Integrating natural, social and governing responses* was the major activity and output from the HDWG in 2017. The 7th HDWG meeting was held in France in 2017, members of the HDWG led the workshop on *Management Strategy Evaluation: Achieving transparency in natural resource management by quantitatively bridging social and natural science uncertainties* at IMBIZO5 in October 2017, and plan to provide a training course at the CJK symposium in September 2018.

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

In 2017 EBUS submitted a successful proposal to form a SCOR working group #155 with the aim to synthesize existing knowledge on the different physical mechanisms occurring over diurnal, intraseasonal, interannual, decadal, and multidecadal timescales and their implications on water column properties, biogeochemical cycles, biodiversity, ecosystem structure and functioning and the regional climate of EBUS.

In collaboration with the CLIVAR EBUS Research Focus, EBUS organized a Session on EBUS at the 2018 Ocean Sciences Meeting on *Biophysical Dynamics of Eastern Boundary Upwelling Ecosystems in a Changing Ocean: Closing the Gap Between Wind Stress and Ecosystem Productivity*, and a session on *Eastern Boundary Upwelling Systems: diversity, coupled dynamics and sensitivity to climate change* is proposed for the 4th International Symposium on the Effects of Climate Change on the World's Oceans, to be held in June 2018.

EBUS is engaged with the Ocean KAN (Knowledge-Action Network) of the Future Earth Program through the membership of Ruben Escribano on the Development Team. A number of virtual and in-person meetings have taken place through 2017-18.

SOLAS IMBeR IOCCP Carbon working group (SIC)

A new carbon working group with participation of IMBeR, SOLAS, the Global Carbon Project and the SCOR and IOC-UNESCO International Ocean Carbon Coordination project (IOCCP) is being planned. A small group of scientists representing IMBeR, SOLAS, CLIVAR and IOCCP met at the International Carbon Dioxide Conference (ICDC10) in Switzerland in August 2017 and again at the Portland Ocean Sciences meeting in February 2018. A

proposal for an integrated ocean carbon working group under the auspices of IOC will be presented to the IOC Executive Council in July 2018, with a first meeting scheduled for early 2019.

Version 6 of the Surface Ocean CO₂ Atlas (SOCAT) was released <https://www.socat.info/> in 2018. SOCAT is a synthesis activity for quality-controlled, surface ocean fCO₂ (fugacity of carbon dioxide) observations by the international marine carbon research community (>100 contributors). The latest SOCAT version (version 6) has 23.4 million observations from 1957 to 2017 for the global oceans and coastal seas. Calibrated sensor data are also available. SOCAT data is publicly available, discoverable and citable. SOCAT enables quantification of the ocean carbon sink and ocean acidification and evaluation of ocean biogeochemical models.

SOLAS-IMBeR Ocean Acidification (SIOA)

The SOLAS-IMBeR Ocean Acidification Working Group provides a key advisory role to the Ocean Acidification International Coordination Centre (OA-ICC), at the International Atomic Energy Agency in Monaco. During 2017, the SIOA has led efforts of the OA-ICC to continue to support the establishment of the Global Ocean Acidification Observing Network (GOA-ON), a worldwide collaborative approach with the goal to expand ocean acidification monitoring and capacity building, especially in areas where there is little or no data, to improve software used by the scientific community working on ocean acidification to calculate carbonate chemistry parameters, and to update and improve best practices guidelines for ocean acidification research.

In June 2017, the OA-ICC co-organized a meeting of the SCOR Working group 149 focused on new best practices guidelines for complex multiple stressor experiments, including ocean acidification. A training workshop using the new tools is planned for October 2018, also in Monaco.

Selected highlights of SIOA can be found in the quarterly releases from the OA-ICC available on their web page at <https://www.iaea.org/ocean-acidification>.

E. Endorsed projects

Atlantic Meridional Transect (AMT)

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). The data has produced over 300 scientific papers, and the long-term nature of the data collected is useful in analysing trends and forecasting future outcomes.

Gulf of Trieste Time series (GoTTs)

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.

Living-resource & Ecosystem Dynamics on the Slope of the South China Sea (LEDS)

The northern slope region of the South China Sea (SCS) is the breeding and nursing ground for commercially-valuable fish species such as octopus and tuna. Their vertical migration behaviour potentially forms a key link between lower and higher trophic levels as they act as predators on zooplankton and as prey for bottom and pelagic fishes, and feed in the surface layer during the night while resting and excreting in the deep layer (400-1000m) during the day. This project aims to progress understanding of the role of mesopelagic fish in marine ecosystems, resource protection and utilization, and carbon sequestration in the ocean. Three cruises in the SCS have been conducted in the spring 2017, summer 2015 and fall 2014. During these cruises, remote sensing results of altimetry, ocean colour and sea surface temperature and model results of circulation, nutrient-chlorophyll distributions and Lagrangian Coherent Structure were used for planning and guiding survey areas and station locations; measurements and samples of hydrography, nutrients, microbes, plankton and nekton were taken by sensors, water samplers, plankton nets, trawls and acoustic devices at the same or near-same times and locations; and 2 moorings were deployed at the study area for long term observations of hydrography and acoustic

backscatter. The results revealed that while the surface ocean of the SCS is classically defined as an oligotrophic ocean with low nutrient and phytoplankton concentrations, there is an active layer of mesopelagic fish living in waters between 50 and 1000 m below the surface.

Ocean acidification and Biogeochemistry: variability, trends and vulnerability (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 in selected ecosystems, and by studying the larger scale biogeochemistry of ocean waters impinging on those ecosystems. Fine-scale sampling will focus 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 April/May 2017. The survey had strong international collaboration with on-board teams from Canada, Germany, the UK, and the USA, and additional support from experts in Denmark and France. All GO-SHIP Level 1 parameters were sampled. Analysis of all biogeochemical samples was carried out on board, with a number of laboratory containers set up on the deck of the ship. The last time the full A02 line was carried out was in June 1997 by WOCE.

Ocean Foodweb Patrol – Climate Effects: Reducing Targeted Uncertainties with an Interactive Network (OCEAN CERTAIN)

The goals of OCEAN CERTAIN, which ended in 2017, were to 1. Determine qualitative and quantitative changes in the functionalities of the foodweb and the efficiency of the biological pump to export carbon as a response to multi-stressors, 2. Identify the interactions (impacts and feedbacks) between climate-related oceanic processes and global climate dynamics, 3. Integrate marine ecosystem scenarios with probable socio- economic scenarios to help estimate/quantify human feedbacks to the coupled socio- ecological system, relevant to mitigation and adaptation pathways, 4. Develop scenario- based impact prediction capacity, and 5. Produce and test decision support tools and systems and assess their ability to support the sustainable exploitation of marine resources. Results from the Ocean Certain project showed an enhanced link between temperature and jellyfish abundance after the 1980s. In the Mediterranean, the synergistic effects of climate and commercial fishing have shifted the pelagic food web dynamics to a state of recurrent massive jellyfish bloom events. The massive jellyfish blooms have had dramatic impacts on ecosystem functioning, fisheries and tourism in the Mediterranean. Ocean Certain also developed a user-friendly decision support system (DSS) that allows for an integrated analysis of the environmental and social-economic impacts of changes to the ocean food web under different stressor/policy combinations. This DSS combines scientific knowledge and data with local stakeholder knowledge for the three case studies (Mediterranean, Barents Sea and Patagonia). The DSS setup files, and documentation will be made available through the Ocean Certain web site (www.oceancertain.eu).

Processes and Approaches of Coastal Ecosystem Carbon Sequestration (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)

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)

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)

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 will be tackled. Marine ecosystem variability will be addressed at the interface of different systems, parameterizations optimized 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.

Variability of Ocean Ecosystems around South America (VOCES)

The goal of this project is to assess the impact of climate variability - both natural and anthropogenic - on the Humboldt, Patagonia and South Brazil Large Marine Ecosystems (LMEs) which are amongst the most productive in the southern hemisphere.

Integrated Arctic Observation System (INTAROS)

INTAROS will develop 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), in order to strengthen the societal and economic role of the Arctic region.

F. Implementation of the Science Plan in 2017

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 2017 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.

Progress towards this challenge is led by IMBeR SSC members Cisco Werner and Alistair Hobday.

ESSAS contributes to this challenge through The Resilience and Adaptive Capacity of Marine Ecosystems in the Arctic (RACArctic) initiative, which examines how variability and changes in advection, temperature, ocean acidity and ice dynamics in the Subarctic to Arctic transition zone may affect future marine ecosystems of the Pacific and Atlantic Arctic.

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. They have focused detailed work on key species from phytoplankton to whales (Arthur et al 2017, Kaufman et al 2017, Meyer et al 2017), and the structure of food webs (e.g. Saunders et al 2017). They have also examined physical, chemical and biological interactions (e.g. Belcher et al 2017, Beekmans 2017) and the effects of past (Tarling et al 2018) and recent variability and change, such as ocean acidification (e.g. Manno et al 2017, Peck et al 2017, Trimboune et al 2017).

The long-term overarching goal of SIBER is to improve understanding of the role of the Indian Ocean in global biogeochemical cycles and the interaction between these cycles and marine ecosystem dynamics. In order to quantify the state and variability of Indian Ocean ecosystems, and importantly, the physical forcing that drives this variability, SIBER was instrumental in fostering the development of the 2nd International Indian Ocean Expedition (IIOE-2) and the Eastern Indian Ocean Upwelling research Initiative (EIOURI).

CLIOTOP Task team 2017-01 has been progressing work analysing isotope data from mid- top predators collected across multiple regions and ocean basins and developing methods for integrating multiple trophic assessment methods (isotopes, fatty acids, mercury and ecosystem models) to better understand marine trophodynamics. The task team has grown its membership, expanding the scope of methodologies that the task team uses to understand climate impacts on marine food webs and the regions from which data have been collected. The task team provided a summary of their work for the IMBeR website (<http://www.imber.info/en/news/expanding-marine-predator-isotopework-community-level-metrics-mercury-isotopes-and-data-modellinkages>) and published the following

paper: Houssard, P. et al. 2017. Trophic position increases with thermocline depth in yellowfin and bigeye tuna across the Western and Central Pacific Ocean. *Progress in Oceanography*, 154, pp.49-63.

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.

Progress towards this challenge is led by IMBeR SSC members Laurent Bopp and Eugene Murphy and was the focus of one of the workshops at the IMBIZO5 conference in October 2017.

An initiative to produce policy-relevant future scenarios of ecosystem services in the oceanic realm was recently published (Maury et al., 2017), and the five contrasted Ocean System Pathways (OSPs) developed have been chosen to form the official scenario basis of FishMIP (the Fisheries Model Inter-comparison initiative).

A dataviz tool is under development to provide easy access to the recent CMIP5 climate model projections for ocean ecosystem stressors (warming, pH, oxygen, primary productivity). This tool will enable selection of any ocean region, and show visualization of projections for surface temperature, surface pH, sub-surface oxygen, integrated primary production.

ICED has continued their Model Development Activity 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. Recent work includes: Dinniman et al 2017, Freer et al 2017, Kruger et al 2018, Silber et al 2017, Murphy et al. 2017, Meyer et al, 2018, and Klein et al. 2018.

ICED have continued their work on developing scenarios of key drivers and projections of ecological change in the Southern Ocean. This has included the publication of the community paper Cavanagh et al. 2017 A Synergistic Approach for Evaluating Climate Model Output for Ecological Applications doi:10.3389/fmars.2017.00308 and the organisation in collaboration with the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) of a workshop in April 2018 to further the scenarios and projections work.

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.

This challenge is led by SSC members Marion Glaser, Ingrid van Putten and Mark Dickey-Collas.

One of the objectives of ICED is to determine how Southern Ocean ecosystem structure, functioning and projections should be incorporated into adaptation, mitigation and sustainable management procedures by improving communication and understanding between science, policy and society.

ICED scientists have been involved in the agreement to establish the world's largest Marine Protected Area (MPA), in Antarctica's Ross Sea, via the Commission for the Conservation of Antarctic Marine Living Resources CCAMLR. This new MPA, came into force in December 2017, and will limit, or entirely prohibit, certain activities in order to meet specific conservation, habitat protection, ecosystem monitoring and fisheries management objectives. Seventy-two percent of the MPA will be a 'no-take' zone, which forbids all fishing, while other sections will permit some harvesting of fish and krill for scientific research. This is a significant achievement and has been several years in the making.

ICED scientists have also continued to engage with CEP (the Antarctic Treaty's Committee for Environmental Protection) and submitted an Information Paper to the 2017 ATCM (ICED, 2017) outlining the role that ICED can continue to play in providing information on climate change impacts on ecosystems to the Antarctic Treaty.

CLIOTOP Co-chair Karen Evans led the chapter on the South Pacific for the first global integrated marine assessment (produced by the United Nations), providing an assessment on the state of the marine environment throughout the region, key pressures impacting the marine environment and associated ecosystem services, and identifying factors for sustainability throughout the region. Karen also contributed to a series of three technical abstracts developed from the first assessment for use by policy makers focused on (i) the conservation and sustainable use of marine biological diversity in areas beyond national jurisdiction, (ii) the impacts of climate change on the oceans and (iii) the ocean and sustainable development goals under the 2030 Agenda for Sustainable Development. The assessment and technical abstracts were endorsed by the General Assembly of the United Nations and launched at the Oceans Conference in June 2017. The assessment and technical abstracts are available at http://www.un.org/Depts/los/global_reporting/global_reporting.htm.

There is a heightened demand from countries to build capacity to report on Target 3 of the UN Sustainable Development Goal 14 that specifically addresses Ocean Acidification. The SIOA and OA-ICC provide coordination, activities, and resources to help Member States address this target. Several SIOA members, GOA-ON, and the OA-ICC are involved in developing methodologies for the SDG14.3.1 indicator (ocean acidity) led by IOC- UNESCO. They attended an expert meeting focused on that topic in January 2018 in Paris. More information can be found at <https://news.oceanacidification-icc.org/2018/02/22/update-to-sdg14-3-voluntarycommitment-enhancing-global-ocean-acidification-monitoring-and-research-by-go-on/>.

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

Progress towards completion of this challenge was led by SSC members Gerhard Herndl and Tatiana Rynearson. The first activity was a workshop at the IMBIZO5 meeting in October 2017 and the preparation of a synthesis paper describing current understanding of metabolic diversity in the light of environmental change and identification of approaches needed to include metabolism and evolution in marine ecosystem models. Future conference sessions are planned, including one at the ASLO meeting in early 2019, and one at the IMBeR Open Science Conference in June 2019.

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.

IMBeR aims to achieve this challenge through collaboration with ongoing international observing initiatives. One of the most relevant is the Global Ocean Observing System of the IOC-UNESCO (GOOS) through their Biology and Ecosystems Panel whose membership includes two IMBeR SSC members: Dan Costa and Frank Muller-Karger.

Dan Costa and CLIOTOP Co-Chair Kevin Weng participated in the GOOS and the OceanObs Research Coordination Network workshop on **Implementation of Multi- Disciplinary Sustained Ocean Observations** in February 2017. This workshop was tasked with identifying priorities for improving the coordinated planning and implementation of multi-disciplinary observing activities and demonstrations, by bringing together experts in physical, biogeochemical and biological/ecosystems ocean observations and modelling, users of established observing networks, and communities of practice.

Dan Costa is a co-author of a SOOS manuscript on the Western Antarctic Peninsula for *Progress in Oceanography*, a contributing author for the IPCC special report for **Oceans and Cryosphere in a Changing Climate** and attended the **Biologging conference** in Germany in September 2017.

Several CLIOTOP members provided feedback on a draft paper on essential ocean variables (EOVs) for fish abundance and distribution, and Dan Costa is drafting the EOVS text for marine mammals and seabirds for the GOOS Biology and Ecosystems Panel.

CLIOTOP Task team 2016-04 Operational Oceanography in support of Sustainable Top Predators (OOSTOP) launched their website in late 2017 aimed at improving knowledge transfer between people working on operational oceanography, marine species biology, conservation and management; i.e. improving the ocean observation-science-policy interface. See <https://oostop.wixsite.com/oostop>

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

This challenge is led by SSC members Laurent Bopp and Eugene Murphy, who have prepared a scoping document assessing which Earth System Models enable potential feedbacks to occur and which do not. Following Hense et al. (2017) *Biogeosciences* 14, 403, they reviewed the three major climate feedback loops of atmospheric CO₂ and the biological carbon pump, marine biota and air-sea fluxes of climate forcing agents such as dimethylsulphide and nitrous oxide, and the influence of marine ecosystems on heat transfer and mixing of the oceans. Links with the WCRP Grand Challenge on Carbon Feedbacks in the Earth System, the SOLAS, IMBeR, IOCCP carbon working group, the SCOR IMBeR SOLAS CLIVar EBUS working group and FISH-MIP were identified as potential ways to progress the research questions of this challenge possibly through a workshop at the IMBeR Open Science Conference.

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

This Innovation Challenge is championed by the Human Dimensions Working Group. They have initiated conversations with the Human Dimensions groups of other projects including MSEAS, ICES and PICES about using social science data in ocean management, and are planning to organise a workshop possibly at the IMBeR Open Science Conference to plan the way forward.

ICED scientists have been actively developing studies to expand analyses of ecosystems to consider human social and economic system interactions. Following IMBIZO IV, Stuart Corney and Eugene Murphy have been working on an opinion piece “Integrating human dimensions into marine ecosystem models will improve management” that is under review with *Fish and Fisheries*.

G. Other IMBeR activities

IMBIZO 5

The fifth IMBIZO conference ‘Marine biosphere research for a sustainable ocean: Linking ecosystems, future states and resource management’ was held in October 2017 at the Woods Hole Oceanographic Institution, USA. Three concurrent but interacting workshops aim to progress specific aspects of the IMBeR Science Plan. These are: 1) Critical Constraints on Projections of Marine Systems (Laurent Bopp and Eric Galbraith), 2) Metabolic Diversity and Evolution in Marine Biogeochemical Cycling and Ocean Ecosystem Processes (Gerhard Herndl and Tatiana Rynearson) and 3) Managing Strategy Evaluation: Achieving Transparency in Natural Resource Management by Quantitatively Bridging Social and Natural Science Uncertainties (Ingrid van Putten and Cisco Werner).

Early Career Researcher Network

The Interdisciplinary Marine Early Career Network (IMECaN) was recently established to provide opportunities for the growing network of IMBeR early career researchers and students, to become more involved with IMBeR and to create more networking and collaborative possibilities. Terms of Reference were approved by the IMBeR Executive Committee, and Chris Cvitanovic (Australia) was appointed as the first early career representative on the IMBeR SSC in January 2018.

IMECaN convened a capacity building workshop in Losinj, Croatia in June 2018, to enable EU-based early career marine researchers to operate effectively at the science-policy- society interface. The IMECaN Organising Committee held its first meeting in conjunction with the workshop to plan future events and activities. The next IMECaN event will be a workshop at the IMBeR Future Oceans2 Open Science Conference in June 2019.

ClimEco6 summer school August 2018

The sixth IMBeR ClimEco summer school will be held at the Gadjamada University in Yogyakarta, Indonesia from 1-8 August 2018. Almost 200 applications from 57 countries were received for the 60 available places. The theme of the summer school is “Interdisciplinary approaches for sustainable oceans” and participants will be provided with practical ways to deal with the challenges arising from working across social and natural science disciplines.

IMBeR is very grateful to SCOR for the travel support provided to five participants from developing countries.

IMBeR China / Japan / Korea Symposium 2018

The next CJK symposium will be held in Shanghai in September 2018.

IMBeR Open Science Conference 2019

The next IMBeR OSC will be held in Brest, France in June 2019.

International Project Office (IPO, Norway)

Gro I. van der Meeren resigned as the Executive Officer in June 2017. Lisa Maddison became Acting Executive Officer until June 2018 when John Claydon was appointed as Executive Officer.

IMR have confirmed that a renewal of funding after 2020 is unlikely, and so IMBeR has begun to investigate other possible hosts for the IPO from 2020.

Regional Project Office (RPO, China)

Yi Xu resigned from the Deputy Executive Officer post in December 2017 and Fang Zuo became the Acting Deputy Executive Officer. After an international recruitment campaign Fang was appointed to the Deputy Executive Officer post in July 2018. Recruitment is currently underway for an Assistant Administrative Officer for the RPO. 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 hosted the 2017 SSC meeting and will host the 2018 China/Japan/Korea IMBeR symposium.

H. Scientific steering committee

The 2017 scientific steering committee consisted of a chair, Carol Robinson (F, UK), *ex officio* member Eugene Murphy (M, UK) and 15 members (9 male and 6 female). Alida Bundy (*ex officio* F, Canada), Ratana Chuenpagdee (F, Canada), Masao Ischii (M, Japan), Svein Sundby (M, Norway) and Tatiana Rynearson (F, USA) rotate off the SSC at the end of 2017. Ruben Escribano will serve a second term, rotating off at the end of 2020.

An open call for nominations for four new SSC members was advertised in 2017. From 36 applications, four new 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 IMR liaison), Chris Cvitanovic (M, Australia; as an early career representative) and Frank Muller Karger (M, USA; as a liaison with GEO BON to contribute to Innovation Challenge 2).

I. 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.

a. 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.

b. Ocean Carbon Biogeochemistry (OCB)

OCB continues to actively support IMBeR by advertising its activities and events, and by providing financial support for activities. OCB hosted and co-sponsored IMBIZO5 at Woods Hole in October 2017.

c. *World Climate Research Programme (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 and SOLAS. A representative from the China CLIVAR office attended the IMBeR SSC meeting in Shanghai in April 2017, and discussions are ongoing for a CLIVAR contribution to a newly formulated SOLAS IMBeR IOCCP carbon working group.

d. *GOOS*

SIBER has strong connections with the Global Ocean Observing System in the Indian Ocean – IOGOOS. Patricia Miloslavich gave a presentation at the IMBeR SSC meeting in 2018, highlighting opportunities for interaction between GOOS and IMBeR. These include a contribution to the specifications for an emerging EOVS on microbes and linking EOVS to human society. IMBeR were invited to contribute to the draft GOOS 10-year strategy and to be represented at the GOOS Steering Committee meeting in Columbia in June 2018.

e. *ICES*

Collaboration with ICES continues through the membership of Mark Dickey-Collas (ICES) on the IMBeR scientific steering committee.

f. *PICES*

IMBeR and PICES continue to collaborate, with representatives from both communities attending and funding each other's summer schools and science meetings. Cisco Werner is the IMBeR liaison with PICES, Carol Robinson is a member of the ICES/PICES working group on Climate Change and Biologically-driven Ocean Carbon Sequestration (WGCCBOCS) and represented IMBeR on the organizing 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.

J. Selected IMBeR Publications

IMBeR has produced more than 2500 refereed research papers since 2005, with around 150 papers published in 2017-2018.

ICED

- Ancel, A. Cristofari, R. Trathan, P.N., Gilbert, C., Fretwell, P.T., Beaulieu, M. 2017. Looking for new emperor penguin colonies? Filling the gaps. *Global Ecology and Conservation*, 9. 171-179. [10.1016/j.gecco.2017.01.003](https://doi.org/10.1016/j.gecco.2017.01.003) <http://dx.doi.org/10.1016/j.gecco.2017.01.003>
- Arthur, B., Hindell, M., Bester, M., De Bruyn, P.J.N., Trathan, P., Goebel, M., Lea, M.-A. 2017 Winter habitat predictions of a key Southern Ocean predator, the Antarctic fur seal (*Arctocephalus gazella*). *Deep Sea Research Part II: Topical Studies in Oceanography*, 140: 171-181. <https://doi.org/10.1016/j.dsr2.2016.10.009>
- Barnes, D.K.A., Tarling, G.A. 2017. Polar oceans in a changing climate. *Current Biology*, 27 (11): R454-R460. <https://doi.org/10.1016/j.cub.2017.01.045>
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- Freer, J.J., Partridge, J.C., Tarling, G.A., Collins, M.A., Genner, M.J. 2018 Predicting ecological responses in a changing ocean: the effects of future climate uncertainty. *Marine Biology*, 165 (1), 7. 18. <https://doi.org/10.1007/s00227-017-3239-1>
- Gardner, J., Manno, C., Bakker, D.C.E. et al. *Mar Biol* (2018) 165: 8. <https://doi.org/10.1007/s00227-017-3261-3>
- Goedegebuure, M., Melbourne-Thomas, J., Corney, S.P., Hindell, M.A., and Constable, A.J. (2017) Beyond big fish: The case for more detailed representations of top predators in marine ecosystem models. *Ecological Modelling* 359, 182-192.
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Together with this report, we submit a request for funding to support students and researchers from developing countries to attend the IMBeR Open Science Conference to be held in Brest, France in June 2019.

Appendix 6 Surface Ocean – Lower Atmosphere Study (SOLAS)

SOLAS Annual Report to SCOR

Reporting period: May 2017 - May 2018 Version of 14
May 2018 by Jessica Gier

I. 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

Over the period of 2015 and early 2016, the comments from 14 reviewers, selected by the SOLAS four sponsors WCRP, SCOR, ICACGP and Future Earth, were implemented. After we got the official approval of the four sponsors, the final hard copy document was released in May 2017. 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.

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 will be integrated in efforts to understand key environments, e.g. upwelling systems, polar oceans, and coastal waters, as well as to evaluate the environmental efficacy and impacts of geoengineering proposals, policy decisions, and societal developments.

I.b. SOLAS 2015-2025. Implementation Strategy 2016-2018

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 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.

I.c. Collaboration with IMBER-SOLAS-IOCCP-GCP-CLIVAR-WCRP on Ocean Carbon

A new ‘Carbon Think Tank’ evolved from an IMBER-SOLAS-IOCCP-GCP-CLIVAR-WCRP meeting on future ocean carbon cycle research which took place in August 2017 in Interlaken, Switzerland. SOLAS committed 5000 €, and both IMBeR and IOCCP also confirmed financial support. In addition, SOLAS confirmed on average one day per week of its IPO staff time (Project Officer) to facilitate the development of the group. A first meeting is currently planned for end 2018 or beginning 2019, to be held in Paris, France.

I.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, the data originator, and where it is currently stored. 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. Access the portal [here](#).

The SOLAS metadata portal is an on-going effort. Scientists can help expanding the SOLAS Metadata base by completing a [simple template](#) and emailing it to solas@geomar.de. In addition, SOLAS has strong connections to the Surface Ocean CO₂ Atlas (SOCAT) and the Global Ocean Data Analysis Project (GLODAP) through the carbon working group(s). The *in-situ* observations are brought together in global collections through SOCAT and

GLODAP, internationally supported and endorsed by SOLAS, the Integrated Marine Biogeochemistry and Ecosystem Research project (IMBER), the International Ocean Carbon Coordination Project (IOCCP), and numerous national funding bodies.

I.e. SOLAS Workshops on Core Themes 4 and 5

The parallel workshops will take place 27-29 November 2018 in Rome, Italy.

Workshop on: Influence of coastal pollution on marine atmospheric chemistry: effects on climate and human health, Maria Cristina Facchini, Alfonso Saiz-Lopez, and Hiroshi Tanimoto. Coastal pollution (air and water) is currently increasing and will most likely continue in the future as anthropogenic environmental pressure upon coastal marine areas increases. Coastal pollution has the potential to contribute to changes in marine atmospheric chemistry including air quality in coastal areas, in addition to contributing to global air pollution and climate. Furthermore, the influence of the coastal pollution on the atmospheric chemistry of gas and particles can have adverse effects on human health in populated coastal environments. Within this context, this 2-day workshop invites contributions on laboratory, field, and modelling work in the following topics:

- How coastal pollution (air and water) affects gas and particles emitted over the coasts and human health;
- Effects on air quality-climate system (regional scale) and human health.

The Workshop is structured as a series of oral and poster presentations, and it will include discussion time for several specialized working groups on:

- Coastal Air pollution and marine emission of gas and particles
- Water pollution and coastal marine emission of gas and particles
- Effects on climate and human health.

This Workshop is co-sponsored by SOLAS and IGAC.

Workshop on the Interconnections between aerosols, clouds, and marine ecosystems in contrasting environments, Maurice Levasseur, Ilan Koren, and Emmanuel Boss.

Several large national and international research programs have been initiated during the last five years in order to improve our understanding of the complex and highly dynamical interconnections between aerosols, clouds, and marine ecosystems (e.g. NAAMES, NETCARE SOAP, ACE, MarParCloud, R2R, PEACETIME, and Tara Pacific). These interconnections were investigated in the North Atlantic, the Arctic, the Southern ocean, the Pacific Ocean, the Mediterranean Sea, and coral reef regions. The number and size of these programs illustrate the dynamical nature of this field of research. Participants in these different programs, as well as all interested researchers working on this topic are invited to attend the workshop in order to share and compare their findings to cross-fertilize between these programs and contribute to a community paper.

I.f. SOLAS Open Science Conference 2019

The SOLAS Open Science Conference 2019 will take place on 21-25 April 2019 in Sapporo, Hokkaido, Japan. The Local Organising Committee (LOC) from Hokkaido University is composed of Jun Nishioka, Yuzo Miyazaki, and Sohiko Kameyama. The organising committee for the Early Career Scientist Event is composed of Yoko Iwamoto of Hiroshima University, Sohiko Kameyama of Hokkaido University, and Martine Lizotte from Laval University, Canada. The venue and banquet place are booked. Hotels will be blocked. The OSC website was released in April 2018, and the registration and abstract submission, as well as travel support application will open in May 2018. The abstract submission and registration website is prepared. The first flyer version and a post card were designed by the IPO. The IPO visited the conference venue in Sapporo and consulted with the LOC. Website: www.solas-int.org/osc2019.html

I.g. Collaboration with Climate and Cryosphere (CliC) and the Scientific Committee on Antarctic Research (SCAR) on Biogeochemical Exchange Processes at Sea Ice Interfaces (BEPSII)

Biogeochemical Exchange Processes at Sea-Ice Interfaces (BEPSII) started in 2011 with a focus on sea-ice biogeochemistry. BEPSII was a SCOR working group from 2012 until September 2016, and has since been endorsed as a SOLAS-CliC Activity (2016) and as a SCAR Action Group. The 2017 BEPSII annual meeting was co-sponsored by SOLAS. BEPSII is now coordinating community activities linked to the biogeochemistry of sea ice-influenced environments, with ~120 involved scientists. Website:

<https://sites.google.com/site/bepsiiwg140/home>

I.h. Collaboration with International Global Atmospheric Chemistry (IGAC)

The Cryosphere and Atmospheric Chemistry (CATCH) mission is to facilitate atmospheric chemistry research within the international community, with a focus on natural processes specific to cold regions of the Earth. Cold regions include areas which are seasonally or permanently covered by snow and ice, from the high mountains to the polar ice sheets and sea ice zones, as well as regions where ice clouds are found. CATCH scientists achieve these objectives by de- signing joint projects in the field and lab, and via modeling studies, as well as collaborating across disciplines. CATCH takes advantage of the inherently international nature of polar and cold region research. CATCH addresses overarching science questions that are not achievable by any single nation. New website:

<https://sites.google.com/view/catchscience/home>

SOLAS/IGAC Task Team: Halogens in the Troposphere (HitT). The primary objective of the SOLAS/IGAC Halogens in the Troposphere task team (HitT) is to determine and quantify the importance of reactive halogen compounds in tropospheric chemistry and climate forcing. The goal of HitT is to facilitate international collaboration between laboratory, field, and model activities regarding tropospheric halogen chemistry especially in the following domains: polar regions, salt lakes, marine boundary layer (both remote and coastal), volcanoes, free troposphere, and urban areas. During the EGU meeting in 2017 a 'Halogens in the troposphere' session took place with convener Alfonso Saiz-Lopez, co-conveners Rolf Sander, Ulrich Platt, and Nicole Bobrowski.

I.i. Collaboration with Integrated Marine Biosphere Research project (IMBeR) The SOLAS-IMBeR Ocean Acidification Working Group (SIOA) and OA-ICC annual meeting 2018 will take place in Monaco from 26-28 June 2018. The SIOA provides a key advisory role to the Ocean Acidification International Coordination Centre (OA-ICC) at the International Atomic Energy Agency in Monaco. The SIOA/ IAEA OA- ICC continue 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 information 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 2017 for 52 researchers from 24 IAEA Member States. That adds similar capacity building efforts for more than 200 scientists from over 50 countries during the project's life time.
- 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 equipping countries to report towards that target.

I.j. Collaboration with Ocean Carbon & Biogeochemistry (OCB)

A New Ocean-Atmosphere Interaction Subcommittee has been build and members Elected. Overall, 28 nominations were send and a small committee of scientists from the OCB and SOLAS scientific leadership

independently reviewed all of the nomination packages and then engaged in an open discussion, followed by a ranking/voting process. The inaugural subcommittee includes the following 12 members: Rachel Stanley (Wellesley College, subcommittee chair), Thomas Bell (Plymouth Marine Laboratory), Yuan Gao (Rutgers), Cassandra Gaston (Univ. Miami, RSMAS), David Ho (Univ. Hawaii), David Kieber (SUNY Syracuse), Katherine Mackey (Univ. California, Irvine), Nicholas Meskhidze (NC State Univ.), Bill Miller (Univ. Georgia), Henry Potter (TAMU), Penny Vlahos (Univ. Connecticut), and Patricia Yager (Univ. Georgia).

The scientific focus of this subcommittee is on ocean-atmosphere interactions and their role in marine biogeochemical cycles. There is a substantial overlap between the scientific goals of the OCB and SOLAS communities, and this subcommittee seeks to strengthen communication and collaboration between ocean and atmospheric scientists to create a thriving, collaborative air-sea interaction research community in the US. The OCB Project Office will host and provide logistical support for this subcommittee. More information [here](#).

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

II.a. SOLAS Science and Society workshop

At the SOLAS Open Science Conference in Sept 2015, a discussion session on SOLAS Science and Society took place and suited a lot of interest. In 2017 Erik van Doorn, a social scientist specializing in the law of the sea, including aspects from deep-sea mining to fisheries and marine protected areas, was appointed to the SOLAS SSC. Erik is also keen to work with natural scientists and involved with the Future Ocean Cluster of Excellence Kiel. He is also a co-author of a massive open online course on the oceans (MOOC-<http://www.oceanmooc.org/en/index.php>), experience that will be an asset to the SSC while exploring new avenues for capacity building.

Following the success of the SOLAS Science and Society workshop in Brussels, Belgium on 26- 27 October 2016, three more workshops were organised in 2017. Erik van Doorn was on two of the three organising committees. A 'SOLAS event report' was published for the events.

- 1. Valuing carbon in the ocean, 30 March - 1 April, 2017.** The physical uptake of carbon dioxide by the oceans has increased in response to anthropogenic carbon input to the atmosphere, but this has potentially negative consequences on ocean ecosystems through ocean acidification. While there have been extensive, ongoing discussions in the scientific community about roles and vulnerabilities of the physical, biological and microbial carbon pumps in regulating CO₂ uptake from the atmosphere, we rather consider manageable options to enhance the shallow ocean's carbon uptake. The related trade-offs between sequestration benefits and negative consequences were discussed. A further point of discussion was devoted to the time-scale of carbon storage.
- 2. Air-sea interaction and policy, Rome, Italy, 14 - 15 June, 2017.** Participants discussed the interactions between the lower atmosphere and the upper layer of the ocean and whether such interactions are sufficiently considered in regulation. They concluded that regulations do not need to target the air-sea interface directly, because regulating the source of pollution (e.g., atmospheric sources at the national level) or designated protected areas would be more effective. Although there is a general obligation under international law for states to prevent, reduce, and control pollution of the marine environment from or through the atmosphere, the regulation of activities on land or ships is mostly a sovereign act of states, which is exercised pursuant to their national policies. For CO₂, regulation was an evolutionary process and consideration of CO₂ crossing the air-sea interface came only after its confirmed role as a pathway to that leads to lower pH (i.e., ocean acidification). International law increasingly strives to require states to act collectively through international or regional organisations, or to adopt measures at a regional or national levels, as agreed in binding agreements (hard law) or voluntary instruments (soft law) to regulate threats to the marine environment, such as airborne pollutants, dumping at sea, and trace metals, as well as implement general requirements to conduct environmental impact assessment prior to conducting harmful activities and the prerogative to establish marine protected areas.

3. International conference on Shipping and the environment-From Regional to Global Perspectives, Gothenburg, Sweden, 24-25 October 2017. Given its importance for the transport of goods on a global scale, there is a growing interest on the sustainability of the shipping industry. Shipping seems a very carbon-efficient transport medium, but there is an increasing focus on its broader environmental consequences. The Bonus SHEBA project addresses a wide range of environmental impacts of shipping in the Baltic Sea, including air pollution, marine pollution, underwater noise, and climate change, as well as the socio-economic consequences of these impacts. The conference and the SOLAS workshop on “Shipping” on 26 October, 2017, provided a unique opportunity to review the latest research across a broad interdisciplinary perspective and to discuss priorities for future work.

II.b. Contribution to 2017 Joint IAPSO-IAMAS-IAGA Assembly

Good Hope for Earth Science: Atmospheric Chemistry and Physics for the 21st Century, Cape Town, South Africa, 27 Aug-1 Sept 2017

SOLAS organised the sub-session ‘A tribute to Prof. Roland von Glasow’ within session M01: Atmospheric Chemistry and Physics for the 21st Century. Convenors of the session were James Drummond, Melita Keywood, and John P. Burrows. In the sub-session, SOLAS invited and supported Maria Kanakidou and Rainer Volkamer to present their work and pay a tribute to Roland von Glasow’s contributions to SOLAS science. Two main aspects of his work were highlighted, namely “Halogens in the Troposphere” and “Coastal Megacities”.

A ‘SOLAS event report’ was published on the event.

II.c. SOLAS Representation at the Ocean Sciences Meeting, Portland, Oregon, USA, 12-16 February, 2018.

Town Hall Meeting: A SOLAS Town Hall on ‘Expanding involvement and setting priorities’ was held on 13 February, 2018, to introduce the SOLAS science plan and international activities, to discuss how SOLAS can be useful to the research community, to generate ideas for new initiatives and collaborations, and to explore priorities for expanding the US SOLAS program. The US SOLAS national representative [Rachel Stanley](#) hosted this event. The Town Hall was joined by the SOLAS SSC Chair Lisa Miller and SSC members Philip Boyd, Peter Minnett, Jun Nishioka, and Guiling Zhang. They presented their research and how they are connected with SOLAS. The SOLAS IPO was represented by Jessica Gier and Li Li.

Exhibition booth: Thanks to SCOR, SOLAS participated in an exhibition booth shared among a number of global research projects. The project office and members of the SSC provided conference attendees with information about SOLAS science and how to get involved with SOLAS and distributed copies of the *SOLAS 2015-2025: Science Plan and Organisation*, SOLAS flyers, and SOLAS giveaways.

II.d. Collaboration with ESA and NASA

In October 2016, Ilan Koren and Brian Ward replied to an ESA/Future Earth call for funding for a workshop. The proposal was successful and SOLAS received 12k Euros to organise a follow up event to the 2016 Frascati workshop on Harnessing Remote Sensing to Address Critical Science Questions in the Ocean-Atmosphere.

This SOLAS/ESA/NASA workshop on **Remote Sensing for Studying the Ocean-Atmosphere** took place on March 12-15, 2018 in Washington DC, USA in order to encourage participation from NASA scientists. The workshop convener was SOLAS SSC member Peter Minnett. The goal of the workshop was to facilitate the exchange of ideas and information about recent developments in remote sensing that can provide new information about the ocean-atmosphere interface, and to help forge collaborations between workshop participants and the wider community. The workshop was attended by about 50 participants, including many NASA scientists, and was a combination of presentations and discussion sessions, and accompanied by a poster session. NASA keynote speakers were directly sponsored by the agency.

Keynote speaker Diego Fernández-Prieto, ESA ESRI, mentioned ESA’s very high interest in continuing the collaboration with SOLAS, for example through joint activities. A SOLAS ‘event report’ is in preparation.

II.e. Collaboration with PICES

The North Pacific Marine Science Organization (PICES; <http://www.pices.int>) is an intergovernmental scientific organization with the mandate to promote and coordinate marine research in the northern North Pacific and

adjacent seas. The present members are Canada, Japan, the People's Republic of China, the Republic of Korea, the Russian Federation, and the United States of America. SOLAS is engaged with the scientific planning of the 4th International Symposium on 'The Effects of Climate Change on the World's Oceans', Washington DC, USA, 4-8 June 2018. SOLAS is a co-sponsor. This is a PICES, ICES, IOC, FAO event.

The PICES-2018 annual meeting will take place in Yokohama, Japan, 25 October-4 November 2018. Lisa Miller will attend that meeting and represent SOLAS.

II.f. SOLAS Summer School 2018

The SOLAS Summer School 2018 is scheduled to take place from 23 July to 3 August 2018 in Cargèse, Corsica, France. The program of the school has been finalised, and all lecturers have confirmed. The French Vessel 'Tethys' has been guaranteed for the practicals. The website for the school is active and a registration website for students and lecturers was prepared for release. In total, 70 students were accepted. Two proposals are still in the pipeline and if granted the budget is balanced. The latest proposal to be granted was the NASA proposal, and as of now, the school is missing 15k €. Website: <http://www.solas-int.org/solas-summer-school-18.html>

II.g. SOLAS time series in Cape Verde

Former SOLAS SSC member Anja Engel and Christa Marandino (SOLAS national representative of Germany) are establishing a SOLAS time series in Cape Verde (SLIC), which was borne out of the Cargèse Workshop on SOLAS Theme 2 in May, 2017. Cape Verde would be an ideal location for such a time series site, as it already houses the Cape Verde Atmospheric Observatory and Cape Verde Ocean Observatory. Arne Körtzinger, SOLAS SSC member, is picking up the thread. Christa Marandino, Anja Engel, Arne Körtzinger, Jessica Gier, are working with Cordula Zenk, the coordinator of the Ocean Science Centre Mindelo, to further the SLIC time series concept.

II.h. Additional SOLAS events

Past events not mentioned in detail:

- 17th SSC meeting, Bologna, Italy, June 2017 Side event with IMBeR, CLIVAR, and IOCCP at the 10th International Carbon Dioxide Conference, Interlaken, Switzerland, 21-25 August 2017
- Global Ocean Oxygen Network (GO2NE) meeting, Monterey, USA, 11-13 September 2017
- SCOR China Meeting, Beijing, China, 28-29 December 2017
- ECV-Ice Intercalibration Experiment, Saroma-Ko, Japan, March 1-8, 2018
- 39th session of the Joint Scientific Committee (JSC-39), Nanjing, China, 16-20 April 2018
- 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.

Upcoming events not mentioned in detail:

- POLAR2018, A SCAR & IASC Conference, Davos, Switzerland, 15-26 June 2018
- BEPSII & ECV-Ice annual meetings, Davos Switzerland, June 15-17, 2018.
- SFB 745 Ocean Deoxygenation conference, Kiel, Germany, Sept 2018
- OCB Workshop on Oceanic Methane and Nitrous Oxide: The present situation and future scenarios, Los Angeles, USA, 28-31 October 2018
- ECV-Ice Intercalibration Experiment, University of East Anglia, UK, autumn 2018
- The 4th Xiamen Symposium on Marine Environmental Sciences, Xiamen, China, 6-9 January, 2019
- Geoengineering Workshop focussing on lab- and mesocosm-based fundamental science opportunities, 2019

II.i. SOLAS IPO welcomed a school pupil

In August 2017, the SOLAS IPO welcomed a school pupil for a week and showed her what an Ocean Research Institute has to offer and what a project like SOLAS is. Her report is available on the SOLAS website: <http://solas-int.org/events-archive.html>.

II.i. SOLAS publications

- Review paper that evolved from the SOLAS Science and Society workshop in Brussels, October 2016: Endres, S, Maes, F, Hopkins, F, Houghton, K, Mårtensson, EM, Oeffner, J, Quack, B, Singh, P, and Turner, D (2018) A New Perspective at the Ship-Air-Sea- Interface: The Environmental Impacts of Exhaust Gas Scrubber Discharge. *Frontiers in Marine Sciences*. 5:139. doi: 10.3389/fmars.2018.00139.
- Boyd, PW, Collins, S, Dupont, S, Fabricius, K, Gattuso, JP, Havenhand, J, Hutchins, AD, Riebesell, U, Rintoul, MS, Vichi, M, Biswas, H, Ciotti, H, Gao, K, Gehlen, M, Hurd, CL, Kurihara, H, McGraw, CM, Navarro, JM, Nilsson, GE, Passow, U, and Pörtner, HO (2018) Experimental strategies to assess the biological ramifications of multiple drivers of global ocean change-A review. *Global Change Biology*. doi: 10.1111/gcb.14102.
- Breitburg, D, Levin, LA, Oschlies, A, Grégoire, M, Chavez, MP, Conley, DJ, Garçon, V, Gilbert, D, Gutiérrez, D, Isensee, K, Jacinto, GS, Limburg, KE, Montes, I, Naqvi, SWA, Pitcher, GC, Rabalais, NN, Roman, MR, Rose, KA, Seibel, BA, Telszewski, M, Yasuhara, M, and Zhang, J (2018) Declining oxygen in the global ocean and coastal waters. *Science*. doi: 10.1126/science.aam7240.
- Ovadnevaite, J, Zuend, A, Laaksonen, A, Sanchez, KJ, Roberts, G, Ceburnis, D, Decesari, S, Rinaldi, M, Hodas, N, Facchini, MC, Seinfeld, JH, and O' Dowd, C, (2017) Surface tension prevails over solute effect in organic-influenced cloud droplet activation. *Nature*. doi:10.1038/nature22806.
- Engel, A, Bange, HW, Cunliffe, M, Burrows, SM, Friedrichs, G, Galgani, L, Herrmann, H, Hertkorn, N, Johnson, M, Liss, PS, Quinn, PK, Schartau, M, Soloviev, A, Stolle, C, Upstill-Goddard, RC, van Pinxteren, M, and Zänker, B (2017) The Ocean's Vital Skin: Toward an Integrated Understanding of the Sea Surface Microlayer. *Frontiers in Marine Sciences*. doi: 10.3389/fmars.2017.00165.

II.k. SOLAS communications

SOLAS website <http://www.solas-int.org/>

Monthly SOLAS e-news: Distribution of 10 SOLAS e-news sent to over 2,500 SOLAS scientists since the last SCOR report in May 2017. The e-news contain news from SOLAS, opportunities for meetings, abstract submission deadlines, recent publications, vacancies and news from relevant partner project and collaborators. The circulation of the e-news is back onto a monthly basis (1st Wednesday of each month, if not permitted 2nd Wednesday). Past issues of the e-news can be viewed on the SOLAS website: <http://solas-int.org/archive.html>

SOLAS event Report series is a new approach to reporting on SOLAS sponsored or co-sponsored events. An event report is published after each SOLAS related event. These reports are sent to the sponsors and are released in combination with the monthly e-news.

[Issue 08- December 2017](#)- Conference on: "Shipping and the Environment - From Regional to Global Perspectives", Workshop on: "Shipping", October, 2017, Gothenburg, Sweden.

[Issue 07- November 2017](#)- 'Good Hope for Earth Science: Atmospheric Chemistry and Physics for the 21st Century, SOLAS sub-session: A tribute to Prof. Roland von Glasow', August 2017, Cape Town, South Africa.

[Issue 06- September 2017](#)- Workshop series on SOLAS Science and Society, October 2016, Brussels, Belgium, March 2017, Monaco, and June 2017, Rome, Italy.

[Issue 05- September 2017](#)- Workshop on 'Frontiers in ocean-atmosphere exchange: Air-sea interface and fluxes of mass and energy', France, May 2017, Cargèse, Corsica.

[Issue 04- July 2017](#)- Community workshop of CATCH (Cryosphere and Atmospheric Chemistry), April 2017, Guyancourt, France.

[Issue 03- June 2017](#)- Annual meeting of the Biogeochemical Exchange at the Sea Ice Interfaces, BEPSII, April 2017, La Jolla, USA.

[Issue 02- June2017](#)- Ocean Acidification practical training and networking meeting, February 2017, Dakar, Senegal.

[Issue 01- May2017](#)- Two GESAMP WG38 workshops in parallel on 'Changing Atmospheric Acidity and its Impacts on the Oceanic Solubility of Nutrients' and on 'The Impact of Ocean Acidification on Fluxes of Non-CO₂ Climate Active Species', 27 Feb-2 March 2017, Norwich, UK.

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: The IPO created a SOLAS Twitter account in late 2016. Regular posts (currently 386) have been sent out since Jan 2017, and the number of followers is steadily increasing (currently 357).

III. SOLAS national networks

Implemented in Jan 2009, the national representatives of the SOLAS nations are asked to report annually about the SOLAS activities in their country. To facilitate the reporting effort, a template form is provided.

In April 2018, 20 reports were received and will be 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 to disseminate the results and progress from some nations to the rest of the SOLAS community. Information provided through the reports is also used to update the implementation strategy.

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

- 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): *
- 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: Jun Nishioka
- Korea: Kitack Lee
- Mexico: Jose Martin Hernandez Ayon
- Netherlands: Jacqueline Stefels *
- 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 2017 report

II.m. Endorsed projects since the previous year's report

- October 2017: Processes Influencing Carbon Cycling: Observations of the Lower limb of the Antarctic Overturning (PICCOLO)
- Not yet endorsed but will be in May 2018: BIODisponibility and SOLUBility of iron content in desert dust and volcanic ash (BISOU)

Information on 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

III.a. SOLAS Scientific Steering Committee

In December 2017 Véronique Garçon's (F, France) term as SOLAS Scientific Steering Committee (SSC) ended. Since January 2018 Lisa Miller (F, Canada), has served as SOLAS SSC Chair. Lisa Miller will be the 5th SOLAS SSC Chair, serving for 3 years.

SOLAS has an Executive Committee composed of the Chair, Lisa Miller, and Ilan Koren, Maurice Levasseur, and Cristina Facchini.

The following SSC members rotated off in December 2017:

- Emmanuel Boss
- Anja Engel
- Huiwang Gao
- Véronique Garçon
- Michelle Graco
- VVSS Sarma

Maurice Levasseur and Cristina Facchini ended their first terms on the SSC and were selected for second terms.

In January 2018, five new SSC members were appointed:

- Katie Altieri (F, South Africa)
- Laura Gallardo (F, Chile)
- Santiago Gassó (M, USA)
- Arne Körtzinger (M, Germany)
- Mohd Talib Latif (M, Malaysia)

The current membership of the SOLAS SSC:

Last name	Country	Gender	Scientific expertise	SOLAS expertise	Term	End
Parvatha Suntharalingam	UK	F	Numerical model-ing / C, N, S bgc cycles	Theme 1, cross themes	1	2018
Arne Körtzinger	Germany	M	Carbon cycle, Ocean observation	Theme 1	1	2020
Guiling Zhang	China	F	Bgc of trace gases	Theme 1	1	2019
Peter Minnett	USA	M	Remote sensing, physical air-sea exchange	Theme 2	1	2018
Anna Rutgersson	Sweden	F	Air-sea physical interaction	Theme 2 WCRP rep	1	2019
Mohd Talib Latif	Malaysia	M	Microlayer, atmosph. aerosols	Theme 2	1	2020
Katye Altieri	South Africa	F	Atmospheric molecules, climate policy	Theme 3 Society	1	2020
Phil Boyd	Australia	M	Marine bgc	Theme 3, geoengineering	1	2018
Santiago Gasso	USA	M	Remote sensing, aerosols, dust transport	Theme 3 and 4 NASA connection	1	2020
Ilan Koren	Israel	M	Cloud physics	Theme 4	2	2018
Maurice Levasseur	Canada	M	Ocean bgc, dimethylsulfide, Arctic, ice algae	Theme 4	2	2020
Laura Gallardo	Chile	F	Atmospheric modeling, pollutants	Theme 4 IGAC connection	1	2020
Cristina Facchini	Italy	F	Physical and chemical processes in multiphase atm. systems	Themes 4 and 5	2	2020
Alfonso Saiz-Lopez	Spain	M	Atm. halogens/ modelling	Theme 5, IGAC connection	2	2019
Jun Nishioka	Japan	M	Oc. trace metal bgc cycle, Polar oceanography and sea-ice bgc	Integrated topics	1	2019
Erik Van Doorn	Germany	M	Law of the Sea	SOLAS Science and Society	1	2019

The current gender and country balance of the SSC is as follows, for a total of 17 members including the chair:

- 7 female members and 10 male members
- 4 members from developing countries and 13 from developed countries

III.b. SOLAS International Project Office, Kiel

The SOLAS IPO is hosted at the GEOMAR Helmholtz-Centre for Ocean Research Kiel in Kiel, Germany. The office was staffed until October 2017 with Emilie Brévière, Executive Director, and from April 2017 with Jessica Gier as Project Officer. In October 2017, Jessica Gier was appointed interim Executive Director. A search committee including Lisa Miller, Véronique Garçon, Arne Körtzinger, and Emilie Brévière interviewed applicants for Executive Director in February 2018. In April 2018, Jessica Gier was appointed.

Minhan Dai secured funding in China for a SOLAS regional hub at MEL, Xiamen University, including a project officer. The search committee appointed Li Li for the Project Officer position in September 2017 for 3 years, full time.

The salary of the Executive Director is supported by GEOMAR until 2020. Salary funding for a second Project Officer position based in Kiel, from IGBP and the US-NSF via SCOR, would last for about another six months, and someone new will be appointed to replace Jessica Gier, who was in that position before her appointment as interim Executive Director. Another request to NSF will be made to maintain the Project Officer position at GEOMAR after the SSC meeting in May 2018. GEOMAR provides office space for the IPO until December 2020.

Appendix 7 GEOTRACES

GEOTRACES SCIENTIFIC STEERING COMMITTEE ANNUAL REPORT TO SCOR 2017/2018

1 May - March 2018

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

The GEOTRACES programme is enjoying a very successful implementation, with 105 cruises completed, 935 peer-review publications published and its second Intermediate Data Product released in August 2017.

2.1 Status of GEOTRACES field programme

The GEOTRACES field programme is progressing excellently. Overall 105 cruises have been completed (this included 11 International Polar Year cruises).

During the past year (May 1st, 2017 to March 30th, 2018), 10 cruises have been completed. This includes 3 new section cruises, one from Australia in the Southern Ocean, one from Japan in the Pacific Ocean and one from UK in the Atlantic Ocean (see map below) and 6 process studies (with a total of 7 cruises) from Brazil, Canada France, Netherlands, South Africa and UK.

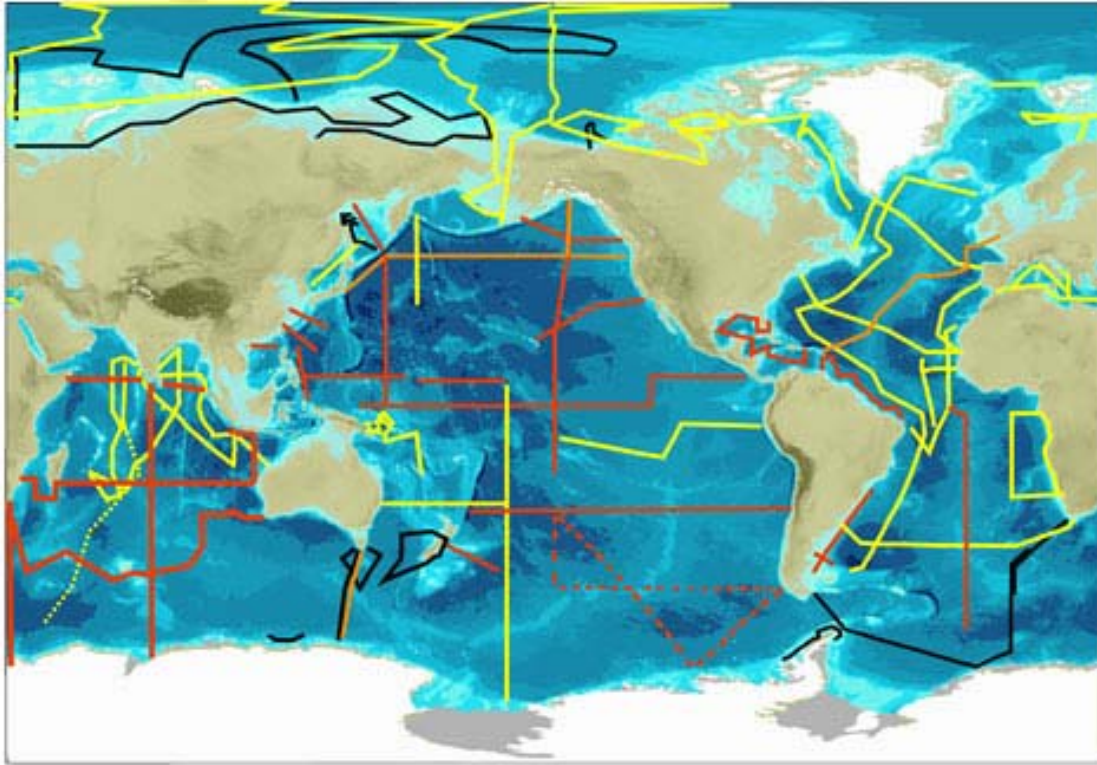


Figure 1. Status of GEOTRACES global survey of trace elements and their isotopes. In black: Sections completed as the GEOTRACES contribution to the International Polar Year. In yellow: Sections completed as part of the primary GEOTRACES global survey. In orange: Sections completed during the past year. 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

Release of GEOTRACES Intermediate Data Product 2017

The second GEOTRACES Intermediate Data Product (IDP2017) was successfully released on 16 August 2017 at the Goldschmidt 2017 Conference in Paris (France). More than 350 persons attended the launch event.

The new product includes hydrographical and biogeochemical data from 41 cruises (1,866 stations) across all five ocean basins. More than 325 scientists from 22 countries have contributed data from 51,005 samples to the product. In total 470 parameters are included in the new product, ranging across micronutrients, contaminants, and radioactive and stable isotopes of trace elements. An exciting new feature compared with the first data product, released in 2014, is that the 2017 IDP also includes biological, aerosols and rain parameters.

The IDP consist of two parts:

The **digital data** (available at www.bodc.ac.uk/geotraces/data/idp2017/) contains hydrographic and biogeochemical data from more than 1,800 stations from 39 cruises. The data covers the global ocean, with the data density being highest in the Atlantic Ocean.

A new feature of the IDP2017 is that it offers a new user-friendly on-line interface **webODV** that allows selecting and downloading subsets of digital data. This new interface was developed by Reiner Schlitzer and Sebastian Mieruch (AWI, Bremerhaven, Germany) and it is available here: <https://webodv.awi.de/geotraces>
The **eGEOTRACES Electronic Atlas** (available at www.egeotraces.org) is based on the digital data package and

provides section plots and animated 3D scenes for many of the parameters, allowing quick overviews of the occurrence of geochemically relevant tracers. It includes 590 section plots and 130 animated 3D scenes.



Figure 2 and 3. *GEOTRACES Intermediate Data Product release event at Goldschmidt 2017.*

IDP2017 version 2

A corrected and updated version of the GEOTRACES Intermediate Data Product 2017 (IDP2017v2) was made available in February 2018 during a Town Hall event at the 2018 Ocean Sciences Meeting. A document describing the main revisions made is available here:

http://www.geotraces.org/images/stories/geotraces/idp/IDP2017_V2_CHANGES.pdf

IDP2017 publication

A publication describing IDP2017 has been submitted and accepted by the journal *Chemical Geology*:

Schlitzer, R., et al., The GEOTRACES Intermediate Data Product 2017, *Chemical Geology*, in press.

Acknowledgments

The IDP2017 is the result of a truly international effort involving 326 researchers from 22 countries and the giant work of a core group of about 15 persons, including members of the Standards and Intercalibration Committee, the GEOTRACES Data Assembly Centre, the Data Management Committee, the International Project Office under the leadership of Reiner Schlitzer (AWI, Germany) and Bob Anderson (Lamont, NY, USA). Special thanks to all of them.

Intermediate Data Product download statistics

Overall the GEOTRACES Intermediate Data Products have been downloaded more than 2,000 times (as per April 2018). That is, the IDP2017 has been downloaded more than 600 times since its release in August 2017, while the IDP2014 has been downloaded 1,451 times since its release in February 2014.

2.3. GEOTRACES Publications

During the reporting period, 117 new peer-reviewed papers have been published. In total the GEOTRACES peer-reviewed papers database includes 935 papers.

It is important to highlight that an on-line search tool functionality has been added to the GEOTRACES publication database. This new feature allows for simple searches (e.g., author, title or journal), but it also allows for more GEOTRACES-specific searches such as by GEOTRACES cruise or GEOTRACES parameter (please see the International Project Office report below for further details on this new functionality).

Publicity articles to promote GEOTRACES continue to be published nationally and internationally. The complete list of promotional articles is available here: <http://www.geotraces.org/outreach/publicity-documents>

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>

2.4. GEOTRACES Science highlights

The GEOTRACES International Project Office regularly edits highlights of published articles, which are posted on the website (<http://www.geotraces.org/science/science-highlight>) and in the electronic newsletter (<http://www.geotraces.org/outreach/geotraces-e-newsletter>). Among the numerous highlights published since last year's report, we selected the following five:

Climate change-induced spectacular increase of the land-ocean inputs in the Arctic Ocean

Measurements of radium-228 (^{228}Ra) in the framework of the 2015 U.S. GEOTRACES Arctic Transect (GN01), revealed that the surface water content of this tracer has almost doubled over the last decade, specifically in the Transpolar Drift near the North Pole.

Radium isotopes are excellent tracers of land-ocean inputs. A mass balance model for ^{228}Ra allowed Kipp and co-workers (2018, see reference below) to suggest that this increase is due to an intensification of shelf-derived material inputs to the central basin (Figure 4). These coastal changes, in turn, could also be delivering more nutrients, carbon, and other chemicals into the Arctic Ocean and lead to dramatic impacts on Arctic food webs and animal populations.

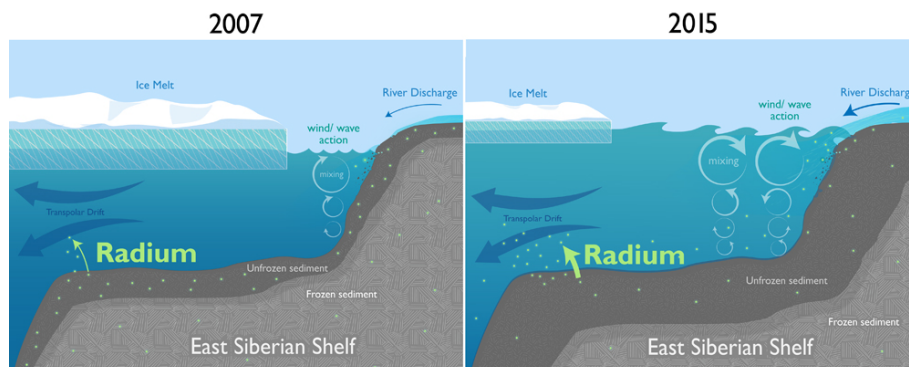


Figure 4. Diminishing sea ice near the Arctic coast leaves more open water near the coast for winds to create waves. The increased wave action reaches down and stirs up sediments on shallow continental shelves, releasing radium and other chemicals that are carried up to the surface and swept away into the open ocean by currents such as the Transpolar Drift. Artwork: Natalie Renier, Woods Hole Oceanographic Institution.

Reference:

Kipp, L. E., Charette, M. A., Moore, W. S., Henderson, P. B., & Rigor, I. G. (2018). Increased fluxes of shelf-derived materials to the central Arctic Ocean. *Science Advances*, 4(1), eaao1302.

DOI: <http://doi.org/10.1126/sciadv.aao1302>

Barium isotope measurements help constraining the oceanic barium cycle

Hsieh and Henderson (2017, see reference below) propose a compilation of the oceanic barium (Ba) concentrations together with its isotopic profiles measured so far. Their review covers the main oceanic basins, comparing data obtained in the North and South Atlantic, North Pacific and the Southern oceans.

Their main conclusions are that near-surface Ba isotope values are controlled by basin-scale balances rather than by regional or short-term processes; isotope Ba fractionation during its removal from the surface is significant: the global Ba isotope data can be fit by mixing and removal/addition of Ba with a single isotope fractionation of 1.00058 ± 0.00010 ; the resulting Ba isotope composition of the upper ocean waters is correlated with the fraction of Ba utilization at the basin scale; and in the deep waters, it is suspected that external inputs of Ba (released by sediments or hydrothermal sources) can be traced by their specific isotopic signatures. See Figure 5 below.

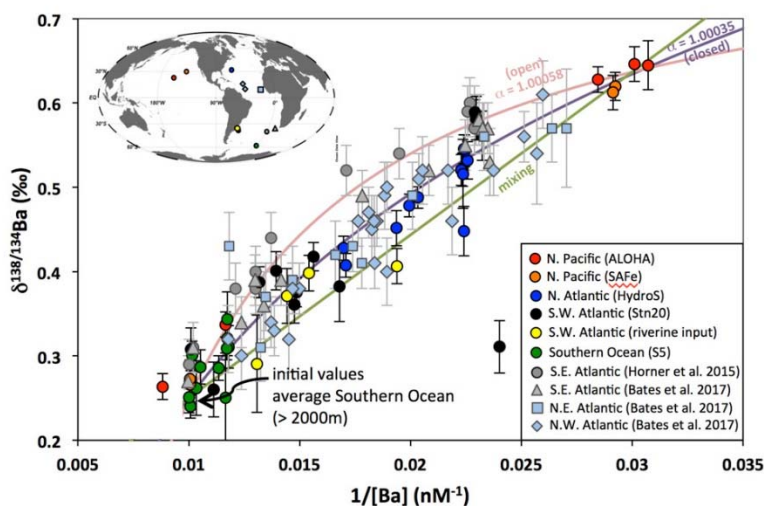


Figure 5. Seawater Ba isotope compositions versus $1/[Ba]$ in the global ocean. The data are fitted with three curves generated by a steady-state (open) model, a Rayleigh fractionation (closed) model and a mixing model, each constrained using an initial composition equal to the average value in the deep Southern Ocean and a final value equal to the surface values in the Pacific Ocean. The results show that seawater Ba isotope compositions are controlled by basin-scale Ba utilization, remineralisation, and ocean mixing during the internal oceanic Ba cycle. External Ba inputs also play important roles in the oceanic Ba isotope budget. For example, riverine input introduces light Ba isotopic signatures to the surface ocean; and sediment or hydrothermal inputs may introduce heavy Ba isotopic compositions to the deep water, which have been identified with the non-conservative behaviour of Ba isotopes during the N-S Atlantic deep water mixing. Such distinct Ba isotope signatures from these sources can become useful tracers for constraining Ba inputs in the present and past ocean.

Reference:

Hsieh, Y.-T., & Henderson, G. M. (2017). Barium stable isotopes in the global ocean: Tracer of Ba inputs and utilization. *Earth and Planetary Science Letters*, 473, 269–278.
<http://doi.org/10.1016/j.epsl.2017.06.024>

Why did the concentration of atmospheric carbon dioxide rise so much and so quickly during the last deglaciation?

During the Last Glacial Maximum, the deep southern Pacific waters were stratified, efficiently accumulating old, CO₂-rich waters. Basak and co-authors (2018, see reference below) measured neodymium isotopes in sediment

cores that clearly show that when these deep waters became less stratified as the climate warmed, they released their carbon, which could escape to the atmosphere...what a tempting prospect and beautiful teaser for the forthcoming PAGES-GEOTRACES workshop of December 2018!



View from RV Polarstern while collecting sediment samples used in the study by [Basak et al.](#)

Reference:

Basak, C., Fröllje, H., Lamy, F., Gersonde, R., Benz, V., Anderson, R. F., Molina-Kescher, M., Pahnke, K. (2018). Breakup of last glacial deep stratification in the South Pacific. *Science*, 359(6378), 900–904.
DOI: <http://doi.org/10.1126/science.aao2473>

[Shelf sediment dissolved iron source via non-reductive dissolution in the Gulf of Alaska](#)

Crusius and co-workers (2017, see reference below), reveal temporal and spatial variability in the sources of iron (Fe) to the northern Gulf of Alaska, based on data from cruises from three different seasons from the Copper River (AK) mouth to beyond the shelf break. April data are the first to show late winter Fe behavior before surface-water nitrate depletion began. Sediment resuspension during winter and spring storms generated high “total dissolvable Fe” (TDFe) concentrations of $\sim 1000 \text{ nmol kg}^{-1}$ along the entire continental shelf, which decreased beyond the shelf break. In July, high TDFe concentrations were similar on the shelf, but more spatially variable, and driven by low-salinity glacial meltwater. Conversely, dissolved Fe (DFe) concentrations in surface waters were far lower and more seasonally consistent, ranging from $\sim 4 \text{ nmol kg}^{-1}$ in nearshore waters to $\sim 0.6\text{--}1.5 \text{ nmol kg}^{-1}$ seaward of the shelf break during April and July, despite dramatic depletion of nitrate over that period. The April DFe data can be simulated using a simple numerical model that assumes a DFe flux from shelf sediments, horizontal transport by eddy diffusion, and removal by scavenging. Calculations suggest dust is an important Fe source beyond the shelf break. See Figure 6 below.

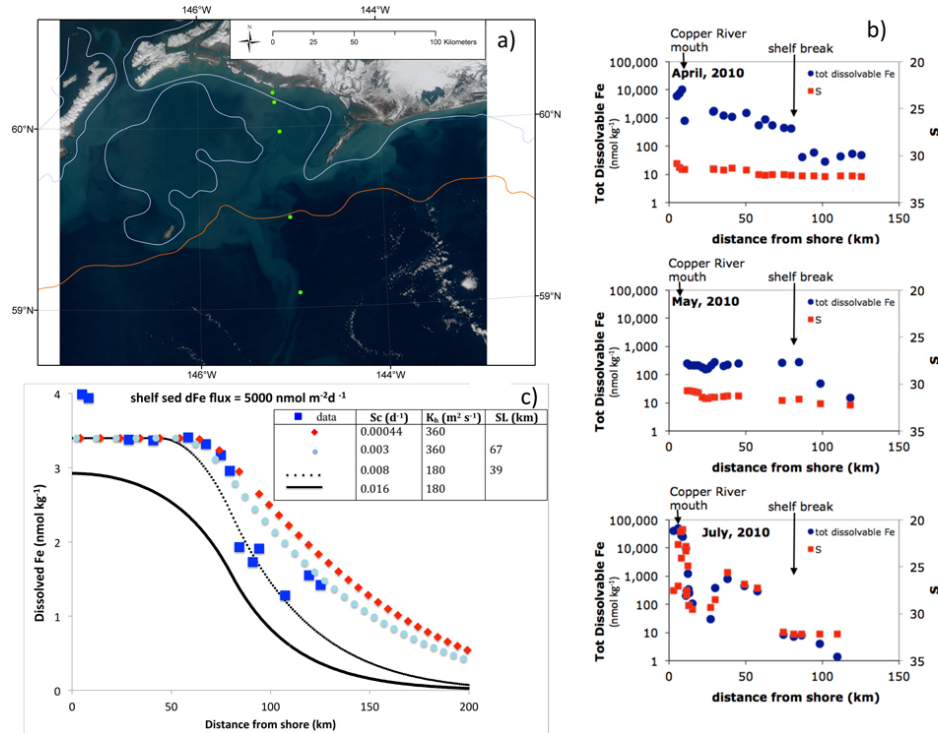


Figure 6. Seasonal and spatial variability in Fe in the northern Gulf of Alaska: a) Sampling region in the northern Gulf of Alaska extending from the Copper River Mouth to ~50 km beyond the shelf break. The surface water transect was carried out along the line defined by the green dots (which define sampling stations). This is superimposed upon a MODIS image from 9 April, 2010 that shows resuspended sediments (light blue) landward of the 500-m depth contour (orange line). b) Surface water total dissolvable Fe (TDFe) concentrations and salinity plotted versus distance from shore during April, May and July. c) Dissolved Fe (DFe) data (blue squares) from April, along with several time-dependent model simulations that bracket the data, with varying flux of DFe from the shelf sediments, horizontal eddy diffusion, and removal by chemical scavenging.

Reference:

Crusius, J., A. W. Schroth, J. A. Resing, J. Cullen, and R. W. Campbell (2017), Seasonal and spatial variabilities in northern Gulf of Alaska surface-water iron concentrations driven by shelf sediment resuspension, glacial meltwater, a Yakutat eddy, and dust, *Global Biogeochem. Cycles*, 31, doi:[10.1002/2016GB005493](https://doi.org/10.1002/2016GB005493).

Widespread nutrient co-limitation discovered on GEOTRACES cruise

Browning and co-workers (2017, see reference below) find that multiple nutrients must be supplied to stimulate phytoplankton growth on the southeast Atlantic GEOTRACES GA08 cruise. The paper has been published in *Nature*.

Experiments to date have suggested that across most of the ocean surface marine phytoplankton are limited by either nitrogen or iron. But simultaneously low concentrations of these and other nutrients have been measured over large extents of the open ocean, raising the question: are phytoplankton in these waters only limited by one nutrient?

Browning and co-workers tested this by conducting experiments throughout the SE Atlantic GEOTRACES GA08 cruise, where seawater samples were amended with nitrogen, iron, and cobalt—alone and in all possible combinations. They found that adding both nitrogen and iron in combination was needed to stimulate any significant phytoplankton growth over 1000s of kilometers of ocean. Furthermore, addition of cobalt in combination with nitrogen and iron further enhanced phytoplankton growth in a number of experiments. See Figure 7 below.

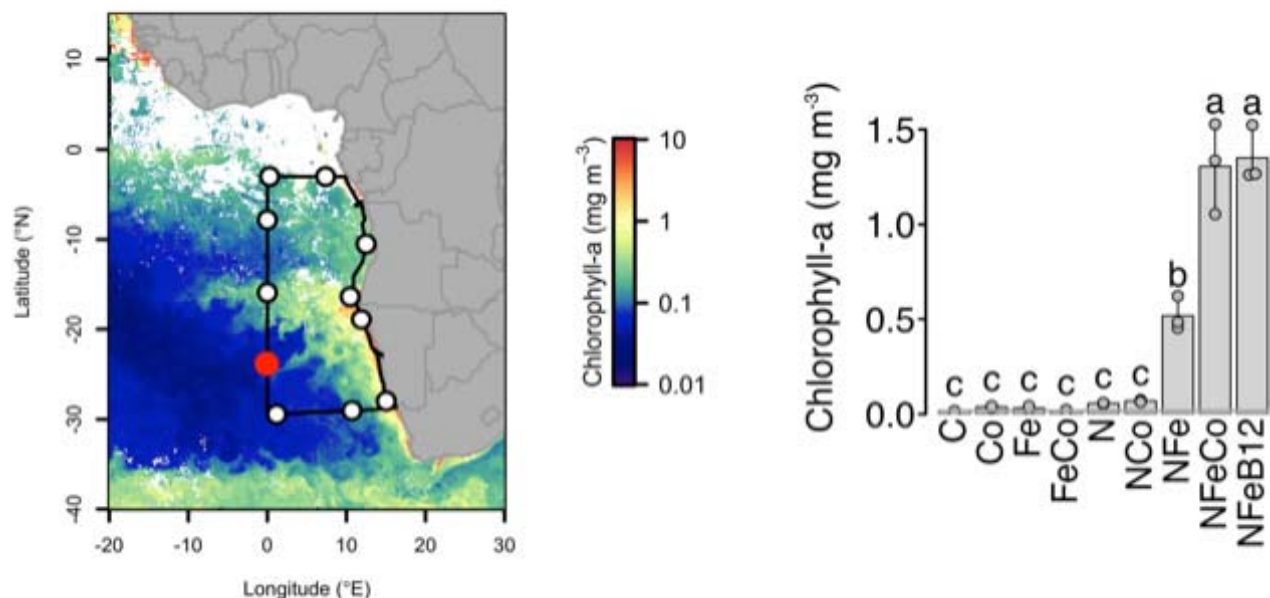


Figure 7. Experiments were conducted throughout the SE Atlantic GEOTRACES cruise transect (lines and dots on the map) and demonstrated that nitrogen and iron had to be added to significantly stimulate phytoplankton growth. Supplementary addition of cobalt (or cobalt-containing vitamin B12) stimulated significant additional growth. Experimental responses illustrated in the right panel are from the site indicated by the red point on the map.

Reference:

Browning, T.J., Achterberg, E.P., Rapp, I., Engel, A., Bertrand, E.M., Tagliabue, A. and Moore, C.M., 2017. Nutrient co-limitation at the boundary of an oceanic gyre. *Nature*. 551, 242–246 doi:[10.1038/nature24063](https://doi.org/10.1038/nature24063).

3. Activities

3.1 GEOTRACES intercalibration activities

The S&I Committee said goodbye to Greg Cutter and Peter Croot and we thank them for all their hard work over many years. We 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 S&I Committee is currently composed of Ana Aguilar-Islas, Karen Casciotti, Tina van de Flierdt, Walter Geibert, Lars-Eric Heimbürger, Yoshiko Kondo, Maeve Lohan, Hélène Planquette, Peter Sedwick and Alyson Santoro. Maeve Lohan and Walter Geibert serve as co-chairs.

The S&I had no in-person meetings during this time period but had virtual meetings:

Virtual meetings (GoToMeeting):
22 May 2017

Virtual S&I-DMC co-chair meetings:
20 May 2017

In addition, the committee is in constant communication via email and through a shared online platforms, and the co-chairs are in regular personal exchange with members of the DMC and BODC at their respective locations.

Intercalibration for IDP2017:

For IDP 2017, all new data was intercalibrated prior to the release. Overall, the S&I committee approved 111 intercalibration reports and intercalibrated 458 different parameters. During the meetings of the S&I Committee, all datasets were introduced by the assigned committee members, and discussed by the full committee. In nearly all cases, questions of the committee about data quality could be easily resolved and only a limited number of parameters did not pass intercalibration, mostly due to issues with sampling methods.

New intercalibration procedures were constructed for the many new parameters released in IDP2017:

- Aerosols and rain
- HPLC pigments
- Single cell trace metals
- Targeted Metaproteomics
- Leachable particulate trace metals
- Artificial radionuclides

In addition, more than 85% of data from IDP2014 that were not previously intercalibrated were intercalibrated for IDP2017.

The S&I Committee handled the records for the inventories of all data submitted for intercalibration, which benefited a lot from the well-defined parameter names when preparing IDP2017. Just prior to the release of IDP2017, the S&I Committee was involved in communications about the status of various datasets based on these records. The Committee was involved in identifying issues with IDP2017 and helping Reiner Schlitzer with intercalibrated data for IDP2017 v2.

The Cruise and Methods manual (Cookbook) was updated (new methods and sampling handling procedures) by the S&I Committee in time for the release of IDP2017. This is third version and is now available on the GEOTRACES website (<http://www.geotraces.org/images/Cookbook.pdf>).

New Intercalibration activities:

Lars-Eric Heimbürger led a large ship-based intercalibration effort in the Mediterranean Sea in June 2017 for mercury speciation, in particular for gaseous dimethyl mercury. This involved collecting samples onboard and running analyses in a laboratory back on land. Ana Aguilar-Islas and Peter Sedwick are leading a sea-ice intercalibration effort and collected ice cores from the Ross Sea in April-June 2017. They will be distributing samples for analyses soon.

S&I on www.geotraces.org and other support by the International Project Office (IPO)

With the help of the IPO in Toulouse, the web resources for standards and intercalibration on www.geotraces.org were carefully reorganised and updated with the latest information on intercalibration procedures throughout the year. In general, support of the IPO in setting up the meetings, communicating with the GEOTRACES community and co-ordinating interaction of the S&I Committee with the other GEOTRACES committees proved to be extremely useful.

3.2 Data management for GEOTRACES

The GEOTRACES Data Assembly Centre (GDAC) is hosted by the British Oceanographic Data Centre (BODC), with the head office located in Liverpool; the GEOTRACES Data Manager (Helen Snaith) is based at the BODC office in Southampton, UK. Regular communication is maintained between the two sites so that support and assistance can be offered to the GEOTRACES Data Manager when required.

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

- interaction between PIs and national data centres in order to encourage regular and timely data and metadata submissions
- liaising with the Data Management Committee and S&I Committee to ensure issues and questions relating to GEOTRACES and its progress can be discussed, and deadlines can be met.
- input of metadata and data into the BODC database and compilation of documentation to include analysis methodologies
- Collation of data and metadata for the IDP2017 and IDP2017v2
- 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/>).

Helen Snaith took over as the GEOTRACES Data Manager in May 2017 when the previous data manager, Chris Daniels, had to take extended sick leave. Helen has carried out the overall project management for the position. In addition, Donna Cockwell, also based at BODC in Southampton, has acted as the lead for data ingestion and data and metadata collation, with additional ingestion time provided by Emma Slater, based in BODC in Liverpool. Since April 2017, Donna has been working almost full time on data ingestion and preparation for the IDP2017 release in August 2017, and then on the corrections and addition of data for the release of IDP2017v2.

Data overview

The data management of the GEOTRACES Project is a large undertaking with a total of 105 cruises (including all cruise legs) associated with the project (this takes into account all section cruises, process studies and compliant data). More than 800 scientists have taken part in the GEOTRACES cruises, with 15 different nations having run a major GEOTRACES IPY/section/process study cruises.

Summary of completed GEOTRACES cruises to date:

Section cruises	IPY cruises	Process studies	Compliant data
38	11	47	9

In addition, 2 intercalibration cruises have been completed.

Delivery of IDP2017

The data and metadata for the first release of IDP2017 were delivered to AWI over a very tight timeframe. The loss of the principle data manager in late April 2017 resulted in a compressed delivery that overran on the original planned delivery. Additional issues in integrating some specific data types resulted in a few datasets not being included in the August 2017 release.

Working with the S&I Committee, GDAC was able to prioritise data expected to be approved in March 2017, meaning that all data delivered were included as in scope – not just those delivered by the April 2016 ‘guaranteed inclusion’ deadline. The following table provides the number of datasets approved by S&I (IDP2014 and IDP2017), received by BODC, ingested into the BODC system and delivered for inclusion in IDP2017 by August 2017. A number of datasets were included into the IDP without full ingestion into the GDAC system first. These were primarily CTD data that were still awaiting sufficient metadata to allow full ingestion, but had sufficient documentation to be incorporated into the IDP release.

Summary of data delivered for IDP2017

	Approved by S&I Number	Received by BODC Number	% Approved	Ingested Number	% Received	of	Delivered Number	% of Approved
Atlantic	781	774	99%	671	87%		756	98%
Pacific	242	229	95%	229	100%		229	100%
IPY	29	29	100%	29	100%		29	100%
Process	37	36	97%	28	78%		30	83%
Cruises								
Compliant	50	34	68%	34	100%		34	100%
Data								
Total	1139	1102	97%	991	90%		1078	98%

Delivery of IDP2017v2

After the first release of IDP2017, there were several issues identified in the datasets and it was decided to create a second release, IDP2017v2. During the period from September 2017 to January 2018, GDAC worked closely with the S&I Committee to identify any data that had been approved and submitted, but not correctly ingested into BODC.

Some errors in parameter naming were identified, as well as one identified mis-labelling of units, and an issue where errors reported as 2sigma had been reduced to the required 1sigma values, but the same scaling had inadvertently been applied to the values as well as the errors.

Inconsistency in flag definitions between data submission, storage at BODC and usage in the IDP were identified and consensus reached as to how to provide consistent flag values across datasets.

During this period, a solution was reached to enable the single cell trace metal data, not ingested or included in the original release, to be delivered to GEOTRACES and included in the second release. A Summary of data delivered for IDP2017v2 by February 2018 is given below, with the changed figures highlighted.

Summary of data delivered for IDP2017v2

	Approved by the S&I No	Received by BODC No	%age of App.	Ingested No	%age of Rec.	No	%age of Rec.
Atlantic	780	774	99%	774	100%	774	100%
Pacific	242	229	95%	229	100%	229	100%
IPY	29	29	100%	29	100%	29	100%
Process	37	37	100%	31	84%	31	84%
Cruises							
Compliant	50	49	98%	49	100%	49	100%
Data							
Total	1138	1118 (+16)	98%	1112 (+121)	99%	1112 (+34)	99%

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 new products:

- GEOTRACES eNewsletter Special Issue – Outreach #2 – Questions and Answers

A second issue of the GEOTRACES eNewsletter devoted to Outreach was published in December 2017. This special issue featured a video introducing the International GEOTRACES Programme. Following a suggestion from Ed Urban, short video interviews to selected SSC members were conducted during the 2016 Scientific Steering Committee held in Toulouse. Questions related to the GEOTRACES programme were asked to these members as for example: how was the programme developed, why was it important for the programme to commit to developing a merged global database with rigorous data quality control, what is the international coverage of the programme, and others... The interviews were conducted in both English and French (with subtitles). Later, the IPO worked with Jean-Hugues Babary from Centre for the Development of the Pedagogy at the Université Paul Sabatier and the journalist Jean François Hait in editing the videos which are presented in this eNewsletter.

This issue is available here: <http://www.geotraces.org/outreach/geotraces-enewsletter/listid-12/mailid-861-geotraces-outreach2>.



Figure 8. GEOTRACES eNewsletter Special Issue devoted to Outreach.

- New query capability for the GEOTRACES Publications database

The GEOTRACES publication database existing in Mendeley has been made into a searchable on-line database available on the following GEOTRACES web page: <http://www.geotraces.org/library-88/scientific-publications/peer-reviewed-papers>. This database includes publications that are relevant for GEOTRACES research, along with Master and PhD dissertations.

Three types of search functionalities are available:

- (1) Simple search: users can search publications by “author”, “title” or “journal” entering the desired term into a search box,
- (2) Advanced search: by means of dropdown menus, users can select publications by “author”, “title”, “GEOTRACES cruise”, “year” or “type of document”, and
- (3) Parameter search: allows users to access a list of publications by specific TEI. In addition, users can retrieve publications by group of parameters (e.g., Aerosols, Dissolved TEIs, etc.) or by pre-defined subgroups (e.g., dissolved trace elements, etc.).

In each case, search queries for “parameter” or “GEOTRACES cruise” will only list those publications linked to data included in the IDP2017.

This facility has been accomplished thanks to a grant from the Observatory Midi-Pyrenees (OMP; Toulouse, France). To develop this database we benefited greatly from the help of Guillaume Brissebrat from the OMP’s Data Centre (SEDOO).

- Intermediate Data Product 2017 Reference List

Based on the above-described GEOTRACES Publication Database, and thanks to the help of Guillaume Brissebrat, we have been able to create a URL system that allows linking each IDP2017 data point to an up-to-date list of relevant publications for these data (see Figure 9 showing a list of publications for Fe_D_CONC_BOTTLE from the GP16 cruise track). This reference database is dynamic and updated whenever new papers are published, so future requests of the publication list related to Fe_D_CONC_BOTTLE along GP16 will, in addition to what is shown in Figure 9, also include new papers published since then. This dynamic inclusion of papers published after the release of the data product was a required feature for the IDP2017, because many datasets included in it were unpublished at the time of data submission.

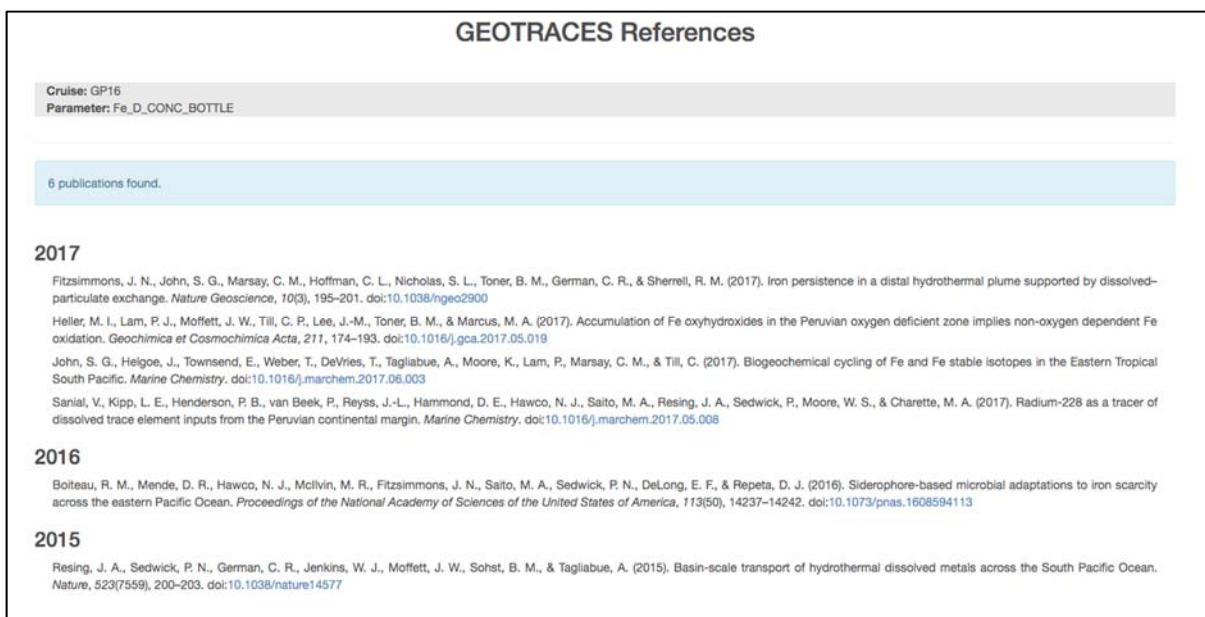


Figure 9. List of publications related to Fe_D_CONC_BOTTLE along GP16 cruise track.

- Release of the Intermediate Data Product 2017

In order to ensure the successful release of the IDP2017, we have

1. Proposed solutions to the different committees to facilitate their task. For example, we developed an on-line Google form that allowed collection of user's permissions to publish their data along with the list of publications for these data.
2. Developed the GEOTRACES Publication database and IDP2017 reference list mentioned above.
3. Organised the communication (advertising) of the new data product internationally by: (1) publishing special online newsletters and announcements that were distributed via the GEOTRACES mailing list, via other international programme's mailing lists, and sent directly to all identified GEOTRACES stakeholders; and (2) coordinating the organisation of two Town Hall meetings (in Goldschmidt 2017 and Ocean Sciences 2018).
4. Developed the IDP2017 promotional materials (one brochure and one roll-up banner).
5. Helped in organising the SCOR booth at Ocean Sciences.
6. Coordinated the production of the USB cards that contained the *eGEOTRACES Atlas* and were distributed at the Town Halls that were organised at the Goldschmidt 2017 and Ocean Sciences 2018 International Conferences.

All these tasks were completed under significant time pressures.

- GEOTRACES website (<<http://www.geotraces.org>>)

As a special feature to be highlighted, we would like to announce that a new web page devoted to GEOTRACES Synthesis of Results Initiative and products has been added on the GEOTRACES site: <http://www.geotraces.org/science/synthesis-of-results>

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.

- Some statistics

20 new highlights published (155 in total)
 6 eNewsletter published, including one special issue (bimonthly 32 in total)
 117 new peer-reviewed papers included in the GEOTRACES Publication Database (935 in total)
 116 new articles published on the GEOTRACES website
 105 new announcements sent through the GEOTRACES mailing list
 110 new posts on Facebook and 440 likes (top post reached 1.6K)
 532 tweets and 700 followers (top tweet reached 3.1K)
 117 new subscribers on the GEOTRACES website

3.4 GEOTRACES Workshops

A list of completed or planned GEOTRACES Workshops is available below:

Explore GEOTRACES IDP 2017 data with Ocean Data View, 2-3 May, Qingdao, China.

A hands-on workshop to teach standard and advanced Ocean Data View (ODV) methods for the exploration and scientific analysis of environmental data was held on May 2-3, 2018, in Qingdao, China. A total of 82 participants attended the workshop, including graduate and undergraduate students as well as young scientists, from Ocean University of China. During the workshop, the GEOTRACES Intermediate Data Product 2017 (IDP2017) was used as an example dataset. For Day 1, participants learned how to use ODV software, creating maps, property-property plots, sections and surface plots. In addition, participants learned how to create ODV data files with their own datasets. For Day 2, part of the participants (14 students) gave presentations based upon the topics in which they have interest, which cover global physical water circulation, GEOTRACES IDP2017 data, time-series data (Station Aloha), their own datasets, etc. Lastly, participants learned some tips for using advanced levels of ODV to work on their own datasets. Thanks to Mariko Hatta for delivering the lectures.

Further information is available at the following GEOTRACES web page:

http://www.geotraces.org/images/stories/documents/workshops/2018_ODV/ODV%20workshop%20report_OUC_final.pdf

Training Workshop on Metal Speciation and Isotopes, 12-17 May 2018, Xiamen, China.

A training workshop on metal speciation and isotopes in the ocean for GEOTRACES and beyond was organised by the State Key Laboratory of Marine Environmental Science (MEL) in Xiamen, China. The purpose of this workshop was to train graduate students and professionals who are interested in or will study trace metal and isotope biogeochemistry.

It is hoped that the workshop will also serve to enhance capacity of GEOTRACES-related studies. The training included classroom lectures and hands-on experiments in the laboratory equipped with a variety of measurement tools. Subjects covered included electrochemistry, metal speciation, trace metals and their isotopes.

Further information is available at the workshop web page: <http://mel.xmu.edu.cn/conference/geotraces/>

Forthcoming:

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, will be 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.

In 2015, GEOTRACES launched a three-pronged initiative to synthesise and exploit GEOTRACES results following the three main scientific themes of the programme. Three workshops were planned. The first one focused on sources and sinks of TEIs at ocean boundaries, synthesising results obtained in the Atlantic Ocean basin (December 2015, Royal Society, synthesis paper published in October 2016 at *Philosophical Transactions of the Royal Society A*, DOI: [10.1098/rsta.2016.0228](https://doi.org/10.1098/rsta.2016.0228)). The second one focused on the internal cycling of TEIs within the ocean and was jointly organised with the U.S. Ocean Carbon and Biogeochemistry Programme (OCB) in August 2016. This workshop stimulated dialog and common research projects between a community working on carbon fluxes and another one more focused on trace element cycles. Following this workshop, several products are currently in preparation (see a complete list of the anticipated products on the workshop web page: <https://web.whoi.edu/geotraces-synthesis/>).

The synthesis effort will continue in 2018 with a third workshop, jointly organised with the Past Global Changes (PAGES programme), on the synthesis of geochemical proxies used in paleoceanography (3-5 December 2018, Aix-en-Provence, France). By establishing an optimal understanding of the present-day cycles of tracers that are exploited as paleo-proxies, GEOTRACES is providing fundamental information to paleoceanographers who are applying these tools to their reconstructions. The workshop aims at fruitful exchanges within the paleoceanographic community, the GEOTRACES community and the broader oceanographic community of observationalists and modellers to exploit new data to provide a more rigorous calibration of proxies and interpretation of their records.

Further information is available at the workshop web page: <https://geotracespages.sciencesconf.org/>

BioGEOTRACES Workshop, November 2018, Woods Hole Oceanographic Institution.

A small, 3-day workshop meeting (<20 people) will take place in November 2018 at the Woods Hole Oceanographic Institution. This workshop will focus on the next steps in designing a new international programme—tentatively called GEOBIOMICS—to further the efforts of BioGEOTRACESs beyond those within the GEOTRACES programme. The focus of this initial workshop will be discussing capacity building, intercalibration and challenges of implementing such a programme, as well as identifying its overarching research goals and questions. The vision is for a fully integrated programme that delivers mechanistic insights into how environmental variability shapes biological activity in the ocean. This workshop will finalise a perspective paper (white paper) to submit to a high-profile journal showcasing studies that have linked ‘omics’ data with trace metal distributions in the ocean. This article would highlight the benefits of combining geochemical, physiological and molecular approaches and serve as the basis for future modeling efforts. Many of these insights have been facilitated by BioGEOTRACES efforts within the existing GEOTRACES programme.

3.5 GEOTRACES Summer School

The first GEOTRACES Summer School was held from 20 to 26 August 2017 in Brest, France. The summer school aimed at teaching the skills and knowledge necessary for a good understanding of the biogeochemical cycles of trace metals. It brought together 60 students and 26 world-leading international scientists (Figure 10).



Figure 10. 2017 GEOTRACES Summer School Participants.

Throughout the week, a combination of lectures, practical sessions in the laboratory, poster presentations and drop-in sessions were held (Figure 11). The practical sessions included mass spectrometry (MC-ICPMS, MC TI-MS and HR-ICP-MC), modeling, Ocean Data View, voltametry, flow injection analysis, and sampling and sample handling.

The programme is available to download from the Summer School web page:

<https://geotraceschool.sciencesconf.org/>



Figure 11. Images from the first GEOTRACES Summer School.

The summer school was an absolute success, allowing PhD students and early-career researchers to see how their work fits within the international community of GEOTRACES, as well as permitting them to build a network of collaborations that will help them in their careers.

GEOTRACES is grateful to the organising committee: Hélène Planquette, Thomas Gorgues, Geraldine Sarthou, Aurélie Pinna and Nadine Reniers, the Scientific Committee, the sponsors (LabexMER and SCOR), and all the lecturers who made this summer school possible.

GEOTRACES plans to organise a second summer school in 2019 in Cadiz, Spain. For further information: <https://geotraceschool.sciencesconf.org/>.

3.6 Special sessions at international conferences featuring GEOTRACES findings

The major event this year was the release of the GEOTRACES Intermediate Data Product 2017 at the 2017 Goldschmidt Meeting (August 2017, Paris, France) during a Town Hall session. A second Town Hall session to introduce the Intermediate Data Product 2017 was also held at 2018 Ocean Sciences Meeting (February 14, Portland, Oregon, USA). Also during this conference a joint U.S. GEOTRACES-OCB Town Hall session was organised aiming at assessing community interest in developing a framework for trace element, isotope, and other biogeochemical research in the Gulf of Mexico and Caribbean Sea (see U.S. national report for further details).

In addition, several GEOTRACES special sessions were held in major international conferences, including the following:

IUPAC 2017 - World Chemistry Congress, 9-14 July 2017, Sao Paulo, Brazil.

For further information: <http://www.iupac2017.org/>

GEOTRACES-session:

***5.8 Trace elements cycling, processes and fluxes across interfaces**

Energy, Water and Environmental Sciences (EE)

Symposium Organisers: Roberto M. Torresi and Daniel Belanger.

Co-organiser: Vanessa Hatje

Goldschmidt 2017, 13- 18 August 2017, Paris, France.

For further information: <http://goldschmidt.info/2017/>

GEOTRACES or GEOTRACES-related sessions:

***10i: Cycles of Trace Elements and Isotopes in the Ocean: GEOTRACES and Beyond**

Convenors: Tim Conway, Geraldine Sarthou, Tianyu Chen, Gregory de Souza, Aridane G. González, Kristen Buck, Tina van de Flierdt, Walter Geibert, Zhimian Cao, Catherine Jeandel

***10g: Submarine Groundwater Discharge: Forms, Delivery, Timing, Processes, Pathways and Scaling of Biogeochemical Fluxes**

Convenors: Hans Dürr, Nils Moosdorf, Michael Böttcher, Hannelore Waska, Jing Zhang, Walter Geibert

***10h: Non-Conventional Stable Isotopes in the Ocean: Novel Applications, Technological Advances and Future Applications**

Convenors: Horner Tristan, Pearce Christopher, Philip Pogge von Strandmann, Kathleen Scheiderich, Juan Carlos Silva-Tamayo

***10m: Insights into Ocean Processes Through the Application of Radioactive Tracers**

Convenors: Paul Morris, Guizhi Wang, Virginie Sanial

***10n: Nutrient Biogeochemistry in the Ocean: Past, Present and Future**

Convenors: Scott Wankel, Sinhué Torres-Valdés, Kimberly Popenoer, William Haskell, Christian März, Damien Cardinal, Wiebke Mohr, C. Mark Moore, Francois Fripiat, Xingchen Wang, Jia-Zhong Zhang

*17g: Paleoceanographic and Paleoclimate proxies: Their standing on Elderfield's proxy development Curve

Convenors: Marie-Laure Bagard, Marie Boye, Oscar Branson, Sambuddha Misra, Guillaume Paris, Kauzyo Tachikawa

Ocean Sciences 2018, 11- 16 February, Portland, Oregon, USA.

For further information: <http://osm.agu.org/2018/#>

GEOTRACES or GEOTRACES-related sessions:

*The Behavior of Trace Elements and Isotopes in Different Ocean Basins: New Insights from Comparisons and Contrasts

Primary Chair: Gregory A Cutter, Old Dominion University, Ocean, Earth and Atmospheric Sciences, Norfolk, VA, United States

Co-chairs: Adrian Burd, University of Georgia, Athens, GA, United States, Jay Thomas Cullen, University of Victoria, Victoria, BC, Canada and Tung-Yuan Ho, Research Center for Environmental Changes Academia Sinica, Taipei, Taiwan

*Abiotic and Biotic Retention, Recycling, and Remineralization of Metals in the Ocean

Primary Chair: Philip W Boyd, University of Tasmania, Institute for Marine and Antarctic Studies, Hobart, Australia

Co-chairs: Kristen N Buck, University of South Florida Tampa, College of Marine Science, Tampa, FL, United States; University of South Florida, College of Marine Science, St. Petersburg, FL, United States, Jessica N Fitzsimmons, Texas A&M University, Department of Oceanography, United States and Alessandro Tagliabue, University of Liverpool, Liverpool, United Kingdom

*The Dawn of BioGEOTRACES: Metal-Microbe Interactions in the Ocean

Primary Chair: Adrian Marchetti, University of North Carolina, at Chapel Hill, Department of Marine Sciences, Chapel Hill, NC, United States

Co-chairs: Maria Teresa Maldonado, University of British Columbia, Vancouver, BC, Canada, Alessandro Tagliabue, University of Liverpool, Liverpool, United Kingdom and Yeala Shaked, Hebrew University, Interuniversity Institute for Marine Sciences, Eilat, Israel

*Biogeochemical Processes Across Oxic-Anoxic Transitions

Primary Chair: Jeffry V Sorensen, University of Victoria, School of Earth and Ocean Sciences, Victoria, BC, Canada

Co-chairs: Roberta Claire Hamme, University of Victoria, School of Earth and Ocean Sciences, Victoria, BC, Canada and Tim M Conway, University of South Carolina, Columbia, SC, United States

*Ocean Biogeochemistry and Air-Sea Interactions

Primary Chair: Francesc Peters, Institute of Marine Sciences (ICM, CSIC), Barcelona, Spain

Co-chairs: William M Landing, Florida State University, Department of Earth, Ocean, and Atmospheric Science, Tallahassee, FL, United States, Oliver Wurl, Carl von Ossietzky Universität Oldenburg, Institute for Chemistry and Biology of the Marine Environment, Wilhelmshaven, Germany and Brian Ward, National University of Ireland, Galway (NUIG), School of Physics, Galway, Ireland

*Bridging Microbial, Stable Isotope, and Micronutrient Approaches to Marine Carbon and Nitrogen Recycling

Primary Chair: Patrick A Rafter, University of California Irvine, Irvine, CA, United States

Co-Chair: Robert T Letscher, University of New Hampshire, Earth Sciences, Durham, NH, United States and Alexis Pasulka, California Polytechnic State University

Forthcoming:

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.

3.7 Capacity building

Activities

In an effort to help build GEOTRACES capacity in East Asia, Bob Anderson (director of the U.S. GEOTRACES project office) participated in two meetings in the Republic of (South) Korea in late 2017. Korea has recently acquired the NIOZ-TITAN clean sampling system for use aboard their new global-class research vessel ISABU. Following a successful test of their system in the summer of 2017, Korean scientists are keen to begin developing an ambitious GEOTRACES programme, with a focus on the Indian Ocean, where they plan to use the ISABU during each of the next several years. During these meetings, Anderson offered advice about the design and scientific goals of Korean GEOTRACES research. For further information please read the U.S. GEOTRACES national report available in the Annex.

Thanks to the sponsorship of the SCOR Visiting Scholars Programme, Catherine Jeandel, director of the GEOTRACES IPO, was enabled to travel to Brazil in June 2017 to give a 3-week course on “Tracers in the Oceans: applications of isotopes to unveil processes controlling trace element distributions” and provide training on isotope dilution techniques for the determination of rare earth elements at the laboratories of CIEnAm at Universidade Federal da Bahia. Sixteen graduate students from various universities of Brazil attended the course and had the opportunity to discuss their work with Jeandel. As a continuation of this activity one student will visit Jeandel for a few weeks to deepen her knowledge and practical skills in Nd chemistry. For further information, please read the Brazilian national report available on the Annex.

Travel Grants

GEOTRACES gratefully acknowledges support from SCOR to enable scientists from developing countries and countries with economies in transition to participate in the 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.

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	Complete	Powder coated aluminium, autonomous 1018 intelligent rosette system	12 x 10-L Teflon-lined Niskin-1010X	6000 m; 6 mm Dynex rope
Australia	2nd system (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 with 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 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
South Africa	Complete	Powder coated aluminium, titanium housing/fittings	24 X 12-liter GO-Flo	6500 m; Kevlar cable
South Korea	Complete	Pristine Titanium frame	24 X 12-liter 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 Programs	Complete	Powder coated aluminium with titanium pressure housings and fittings	12 X12-L Niskin-X	3000 m; conducting Kevlar

4. **Plans for the coming year**

Intermediate Data Product 2021

GEOTRACES aims for the next Intermediate Data Product (IDP) to be released in 2021. This is an interval of 4 years following the release of the second IDP, one year more than between the 1st and 2nd IDPs, to allow maximization of new data submissions and to give additional time to the different committees and scientists involved in building the IDP to work on the development of a new on-line metadata portal (see below).

New on-line GEOTRACES metadata portal

Since the GEOTRACES IDPs have been extremely successful, the amount of data to be reviewed, managed and processed has increased considerably. To facilitate the tasks of the core group of persons working on the construction of the product, GEOTRACES aims to create an on-line GEOTRACES data portal that allows (1) major participation of data contributors in directly filling in the information necessary for the evaluation and management of their data into the portal, (2) quick and easy access to this information for all people involved in the construction of the product, and (3) more automatic management of these data to allow easier updating and evaluation.

The development of this portal will be an important activity in 2018-2019 and the release of this portal will represent a significant achievement of the GEOTRACES programme. It is anticipated that this portal will be of interest of other scientific communities and international programmes.

Capacity building through GEOTRACES Summer Schools

Following the successful GEOTRACES Summer School organised in August 2017 in Brest, France, GEOTRACES plans to organise a summer school in Spain in 2019, and another one in 2020-2021 in Germany.

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 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 and other workshops:

GEOTRACES plans to design a new strategy to continue its synthesis efforts initiated by the suite of three synthesis workshops described earlier. This strategy could include, for example, a multi basin-scale synthesis workshop that seeks to connect GEOTRACES datasets with the broader datasets and understanding that exist for these regions (e.g., ocean physics, carbon cycle, biological productivity). This will have the potential to place GEOTRACES data within a broader framework of ocean science questions. In any case, the synthesis will continue to respond to the expectation that GEOTRACES results benefit other oceanographic disciplines.

In this context, GEOTRACES will continue its 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. Indeed, the use of GEOTRACES data by joint observational-modelling studies has led to important insights into TEI cycling via the development of new TEI models (for instance, on manganese, cobalt, aluminium, zinc, radium and Th/Pa) and it is for example, facilitating a critical assessment of how the models used for climate projections represent iron cycling (FeMIP, 2016, Tagliabue, A.32). In addition, following the release of the IDPs, modellers have started developing new complementary modelling toolboxes/software linked to GEOTRACES data (one example is the AWESOME OCIM, 2018, John, S. mentioned earlier). GEOTRACES will encourage and explore synergies within these modelling communities, and develop tools that can lead to the organisation of new data-model workshops.

BioGEOTRACES effort

As mentioned before, a new international programme may emerge to further the efforts of BioGEOTRACES efforts beyond those within the GEOTRACES programme. GEOTRACES investigators and the IPO will provide advice and recommendations, as appropriate, to help launch this new initiative.

Education and Outreach

Promotion of the use of the IDP data by the broad oceanographic community will be a priority in the next years leading to the release of the next data product. To date, GEOTRACES has developed several promotional and outreach materials, including printed materials (brochures, posters, banners, postcards, etc.) and other media products (e.g., promotional videos, <http://www.geotraces.org/outreach/other-outreach-materials/videos/1468-21-questions-and-answers>) and it uses social networks such as Twitter, Facebook, YouTube, etc. to promote its science and products. Several GEOTRACES PIs have collaborated with schools and teachers and have developed educational materials, including educational books for children. In addition, GEOTRACES is very active in organising sessions at international conferences, with about 50 sessions organised in the last 3 years including Ocean Sciences, ASLO, and Goldschmidt international conferences.

All these actions have given GEOTRACES visibility within the broad international oceanographic community. While GEOTRACES will continue this effort, GEOTRACES effort will also be placed in developing specific new products focused on stimulating the use of IDP data within the broader ocean science community. These products may include, for example, hands-on workshops to work with Ocean Data View (ODV) (similar to the Workshop Exploring GEOTRACES data with ODV held on August 2016 in Yokohama, Japan, during the Goldschmidt Conference and in May 2018 in Qingdao, China) or development of videos to show examples of successful data access and use (e.g., video informing investigators about the use and maintenance of GO-Flo bottles: <http://www.geotraces.org/sic/historical-resources/1083-learn-how-to-disassemble-and-clean-go-flo-bottles-2>).

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³²Tagliabue, A., Aumont, O., DeAth, R., Dunne, J. P., Dutkiewicz, S., Galbraith, E., Misumi, K., Moore, J. K., Ridgwell, A., Sherman, E., Stock, C., Vichi, M., Völker, C., Yool, A. (2016). How well do global ocean biogeochemistry models simulate dissolved iron distributions? *Global Biogeochemical Cycles*, 30(2), 149–174. doi:[10.1002/2015GB005289](https://doi.org/10.1002/2015GB005289)
See also the FeMIP SCOR Working Group web page: http://www.scor-int.org/SCOR_WGs_WG151.htm

Appendix 8 International Quiet Ocean Experiment (IQOE)

IQOE News – June 2018

IQOE has been busy since the last message to the IQOE email list in January. The IQOE Science Committee (SC) met for the third time on 12-14 March 2018 at the Bremerhaven, Germany at the Alfred Wegener Institute. The SC received national reports from SC members, updates from IQOE working groups and endorsed projects, and presentations from related projects, organizations, and agencies conducting IQOE-relevant work. Decisions included the following:

- IQOE will continue to seek additional liaisons and endorsed projects
- A supplement to the *IQOE Science Plan* will be written, to update the Executive Summary and implementation activities.
- IQOE will consider draft terms of reference and membership for a working group on opportunities for observing ocean soundscapes before and after moving of shipping lanes, before and after infrastructure projects, etc.
- The IQOE brochure will be revised and distributed at relevant meetings.

Publications Referring to IQOE—Three publications appeared since January referring specifically to IQOE:

- [Miksis-Olds, J.L., B. Martin, and Peter L. Tyack. 2018. Exploring the Ocean Through Soundscapes. *Acoustics Today* 14\(1\):26-34.](#)
- [Williams, R., C. Erbe, I.M.I. Dewantama, and I.G. Hendrawan. 2018. Effect on ocean noise: Nyepi, a Balinese day of silence. *Oceanography* 31\(2\)](#)
- [POGO Task Force on Ocean Biological Observations. 2018. White paper.](#)

Endorsed projects—IQOE has issued five endorsement letters and three of the endorsed projects have been funded; one is still under consideration. IQOE would like to endorse any research project or observation activity that is relevant to IQOE. Information about the endorsement process and endorsed projects can be found at <http://www.iqoe.org/projects>.

Website Improvements and Needs for Input: Features continue to be added to the IQOE Website to make it more useful for the global community of scientists working in the area of ocean acoustics and bioacoustics. Since January, we have added a portal to acoustic data (<http://www.iqoe.org/acoustic-data-portal>), a portal to Websites with information about marine animal sounds (<http://iqoe.org/marine-animal-sounds>), and a page listing organizational liaisons to IQOE (<http://iqoe.org/liaisons>). The IQOE Aquatic Acoustic Archive (<http://iqoe.org/library>) now includes 4,493 references and abstracts.

We still need help from the community to do the following:

- update the database of passive acoustic observatories (<http://iqoe.org/systems>),
- submit IQOE-relevant papers for the IQOE literature database,
- submit entries for the portal to acoustic data,
- submit entries for the portal to marine animal sounds, and
- submit projects for endorsement.

WG Progress—IQOE currently supports four working groups, each of which has made progress since January:

- *WG on Acoustic Measurement of Ocean Biodiversity Hotspots* (chaired by Aran Mooney, USA): this group held its first in-person meeting on 20-21 May 2018 at the Woods Hole Oceanographic Institution. The group is working on a “perspectives” paper on the use of passive acoustics to assess and monitor diversity of marine life. The group also explored the issue of how to help with the identification of unknown sounds made by marine organisms, through an on-line portal, publication, or some other approach.
- *WG on Arctic Acoustic Environment* (co-chaired by Hanne Sagen, Norway and Philippe Blondel, UK): the co-chairs of this group met in February 2018 to do planning for the group’s activities. Dates are being sought for the first in-person meeting; in the meantime, subgroups of the working group will meet at POLAR-2018 in Davos, Switzerland in June 2018 and at the Acoustical Society of America Meeting in Victoria, B.C., Canada in November 2018.
- *WG on Data Management and Access* (chaired by Rob McCauley, Australia): members of this group have held two conference calls and are discussing with the IQOE Science Committee the requirements for IQOE data management.
- *WG on Standardization* (co-chaired by Christ de Jong and Michael Ainslie, Netherlands): this group has created an [Inventory of Existing Standards for Observations of Sound in the Ocean](#) and is working on an overview of calibration facilities for hydrophones.

POGO IQOE Working Group—This group, formed and supported by the Partnership for Observation of the Global Oceans (POGO), conducted two tasks: (1) liaison with the IQOE Web developer to create the online version of the IQOE database of observing systems (<http://iqoe.org/systems>) and (2) creation of an acoustic Essential Ocean Variable (EOV) specification, which is being considered by the Global Ocean Observing System (SOOS) Steering Committee.

ASA Forum—IQOE convened a Forum on Approaches for Studying Effects of Sound on Marine Organisms and Ecosystems on 6 May 2018, in conjunction with the meeting of the Acoustical Society of America meeting in Minneapolis, Minnesota, USA. The recommendations of the meeting have been forwarded to the IQOE Science Committee for action. Forum participants were interested in forming an IQOE working group to make it easier for acoustic and bioacoustic data to be used by managers.

OceanObs’19—The OceanObs series of meetings, at 10-year intervals, have been a major tool of the ocean observation and research communities and agencies to shape the development of GOOS. OceanObs’19 will be held in Honolulu, Hawaii, USA on 16-20 September 2019.

Scientists involved in IQOE submitted an abstract to propose a white paper on adding passive acoustics to GOOS. The ideas in this abstract will be combined with the ideas contained in three abstracts on active acoustics, to create a white paper on ocean acoustics for OceanObs’19. From IQOE, Hanne Sagen and Jennifer Miksis-Olds are on the leadership team for this white paper.

Capacity Building—The Scientific Committee on Oceanic Research (SCOR), one of IQOE’s sponsors, is supporting the participation of two students from Brazil to participate in the [SeaBASS Summer School](#) on 8-13 July 2018 at the University of New Hampshire. IQOE is exploring the possibility of holding an international summer school on IQOE-related topics in 2019 or 2021.

Stakeholder Engagement

- **United Nations**—The United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea picks a topic for consideration each year. For 2018, the topic is anthropogenic underwater noise (see http://www.un.org/Depts/los/consultative_process/consultative_process.htm). This issue will be the focus of discussions at the UN Headquarters in New York City on 18-22 June 2018. Peter Tyack (participating on a science panel) and Jesse Ausubel will represent IQOE at this event.

IQOE submitted a list of peer-reviewed references regarding sound effects in the ocean, organized by sound source in 2017 (see <http://iqoe.org/sites/default/files/files/References%20to%20UN.pdf>), which was updated in 2018 (see [http://iqoe.org/sites/default/files/files/References%20to%20UN-V2\(1\).pdf](http://iqoe.org/sites/default/files/files/References%20to%20UN-V2(1).pdf)).

- Industry—Jesse Ausubel made a presentation on IQOE to the World Ocean Council in Halifax, Nova Scotia, Canada in November 2017.

National/Regional Activities

- Europe: The first tethered underwater sound measurement station has been deployed in the North Sea as part of the IQOE-endorsed project JOMPANS (<http://www.northsearegion.eu/jomopans/>).
- UK: The [UK Sound Forum](#) met on 20 June 2018.
- USA: The [U.S. Quiet Ocean Project](#) will hold a data “standards” workshop on 6-7 August 2018 in Washington, D.C. The IQOE-endorsed ADEON project (<https://adeon.unh.edu/>) is well underway, with the next ADEON cruise on the R/V *Endeavor* leaving on 6 June and returning on June 25. The cruise blog is at <https://adeon.unh.edu>.

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Appendix 9

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

2018 Report of the Second International Indian Ocean Expedition (IIOE-2) to SCOR

The IIOE-2 Steering Committee held its second meeting in Jakarta, Indonesia on 19 – 21 March 2018. The meeting was funded from a variety of sources. SCOR supported the participation of one chair of each Science Theme:

- ST-1: Human Benefits and Impacts
- ST-2: Boundary Current Dynamics, Upwelling Variability, and Ecosystem Impacts
- ST-3: Monsoon Variability and Ecosystem Response
- ST-4: Circulation, Climate Variability and Change
- ST-5: Extreme Events and Their Impacts on Ecosystems and Human Populations
- ST-6: Unique Geological, Physical, Biogeochemical, and Ecological Features of the Indian Ocean

The chairs of these six Science Themes comprise the membership of the IIOE-2 Science and Research Working Group. SCOR has assumed special responsibility for this working group and will support a meeting of this group in Kiel, Germany on 28-30 November 2018.

The purpose of the Steering Committee meeting was to review implementation of each Science Theme and Working Group of IIOE-2. In addition, a special workshop was held on IIOE-2 data management.

The meeting began with an overview of the first meeting of the Steering Committee (on 2-4 Feb 2017 in Perth, Australia; a report on the IIOE-2 Joint Project Office, and a presentation by Vladimir Ryabinin about the UN Decade of Ocean Science for Sustainable Development 2021-30 and its relevance to IIOE-2. Representatives of each working group gave reports about their work. Participants discussed how well the working group system was working, particularly whether the working groups would be effective in achieving the goals of the IIOE-2 Science Plan by 2020, with the approach described in the IIOE-2 Implementation Plan. Is the IIOE-2 infrastructure effective?

The discussion identified that there is a need for greater effectiveness and output in terms of IIOE-2 capacity building and communications. For IIOE-2 to succeed, it would be important to identify 'heroes' who can drive interest and engagement in IIOE-2 in those regions currently underrepresented. It was recommended that IIOE-2 consider narrowing the scope of the IIOE-2 Science Plan to focus on a few key questions, and that there might need to be periodic turnover of Working Group and Science Theme leaders. WG leaders often lack the time and resources to conduct their work, so it was recommended that the JPO take more responsibility for WGs 3-7. The Core Group and Joint Project Office will review and simplify the structure of Working Groups and Science Themes and provide recommendations at the 2019 Steering Committee meeting.

National committees reported on national IIOE-2 implementation in Australia, France, India, Japan, UK, and USA. This session also included presentations on NOAA's IIOE-2 Partnership Activities for 2018, the Eastern Indian Ocean Upwelling Research Initiative (EIOURI), and the EAF-NANSEN Project. The next discussion concerned whether the IIOE-2 national committee activities and endorsed projects are optimally integrated into IIOE-2 and well linked with STs and WGs. Can we collaborate better? Are there new opportunities?

1530-1700	<p><i>A 20-minute general discussion on this topic was chaired by Satheesh Shenoi.</i></p> <p><i>Key discussion points raised included:</i></p> <ul style="list-style-type: none"> • <i>The challenges in convincing proponents of Indian Ocean science projects/programs to seek IIOE-2 endorsement as well as the lack of awareness by many researchers that there exists an IIOE-2 National Committee in their respective countries.</i> 	
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	<ul style="list-style-type: none"> • The benefits of streamlining the endorsement process with a view to increasing the number of IIOE-2 endorsed projects. • The idea of introducing a two-tiered, or multi-tiered, endorsement structure in order to include those projects that are not yet able to fulfil all of the endorsement criteria (e.g. data sharing). One suggestion put forward was to create a two-tiered system with 1) fully endorsed projects and 2) ancillary or affiliated projects. • Overall, National Committee chairs indicated that they were satisfied with their current level of engagement in the IIOE-2. <p><u>Early Career Scientists Network (ECSN)</u></p> <p>Riaan Cedras (ECSN Co-Coordinator) gave a 15-minute progress report on the work of the IIOE-2 Early Career Scientists Network. This was followed by a discussion, chaired by Satheesh Shenoi, on the effectiveness of the ECSN and how well it is integrated with the broader IIOE-2 science program.</p> <p>Key discussion points raised included:</p> <ul style="list-style-type: none"> • The need for greater coordination both within the ECSN and between the ECSN and the IIOE-2, particularly in the West Indian Ocean. 	
Wednesday 21 March 2018		
0830-1130	<p><u>Grand Opening Ceremony for IIOSC 2018 at BMKG</u></p> <p>The IIOSC 2018 Grand Opening Ceremony was held at the headquarters of the Indonesian Agency for Meteorological, Climatological and Geophysics (BMKG). It began with a traditional Saman dance performed by the BMKG folkloric dance group.</p> <p>This was followed by welcoming speeches from:</p> <ul style="list-style-type: none"> • Prof. Dr. Arief Rachman, Executive Chair of the Indonesian National Commission for UNESCO. • Prof. Dr. Shahbaz Khan, Director of the UNESCO Cluster Office in Jakarta and Regional Bureau for Science in Asia and the Pacific. • Ir. Hari Purwanto, Representative for the Ministry of Research, Technology and Higher Education of the Republic of Indonesia. • Prof. Dr. Ir. Bambang Subiyanto, Acting Chairman of the Indonesian Institute of Sciences • Drs. Herizal, Deputy for Climatology at BMKG. <p>IIOSC 2018 participants were then escorted on guided tours of BMKG's forecasting centre and Tsumani Early Warning System before being transported back to the conference venue.</p>	
1200-1300	<p><u>Our future – plenary discussion.</u></p> <p>Peter Burkill chaired the IIOE-2 SC2's concluding session on future planning. Key questions and discussion points included:</p> <p><i>Will IIOE-2 be complete by 2020?</i></p> <ul style="list-style-type: none"> • It was agreed that the scientific objectives of the IIOE-2 would not be completed by 2020. There was strong support for continuing the IIOE-2 beyond 2020. • The idea of continuing IIOE-2 received in-principle support from sponsors (IOC, IOGOOS and SCOR) though it was highlighted that 	<p>ACTIONS:</p> <p><i>Raleigh Hood, Jerome Vialard and Nick D'Adamo to coordinate a joint</i></p>

	<p><i>continued sponsorship would hinge on the IIOE-2 community demonstrating the IIOE-2's scientific achievements and their benefits to society as well as explaining why a continuation is necessary.</i></p> <ul style="list-style-type: none"> <i>It was noted that the IIOE-2 would potentially play an important role in the implementation of recommendations arising from the IndOOS Review, due to be completed by late 2018 or early 2019.</i> <i>It was also suggested that a combined representation of IndOOS and the IIOE-2 at OceanObs'19 in September 2019 would be a good way to raise awareness of these programs.</i> <p>How do we see IIOE-2 metamorphosing?</p> <ul style="list-style-type: none"> <i>It was suggested that IIOE-2 could be framed as an Indian Ocean focal point for the upcoming UN Decade of Ocean Science. Thus the revised IIOE-2 science objectives could be aligned with the UN Sustainable Development Goals.</i> <i>While it was agreed that the UN Decade of Ocean Science would be a driving force in the next decade, the SC agreed that it was important to keep the IIOE-2's science goals broad so as not to lose other sources of funding.</i> <i>It was agreed that the Core Group and JPOs should deliberate on the nature of an updated/revised IIOE-2 Science Plan and report back to IIOE-2 SC3 in 2019.</i> <i>The idea that the next stage of the IIOE-2 should foster more active engagement with private partners was also strongly supported.</i> <p>Next meetings</p> <p>2019 IIOE-2 Steering Committee 3 (SC3)</p> <ul style="list-style-type: none"> <i>There was strong support for the idea of IIOE-2 SC3 being held in the Western Indian Ocean region. South Africa (two potential sites- Port Elizabeth and Cape Town), Tanzania, Mauritius and Seychelles were mentioned as potential locations. Several members offered to explore these various options and report back to the SC within one month: Mike Roberts (South Africa, Tanzania), Francis Marsac (Seychelles) and Rezah Badal (Mauritius, Seychelles).</i> <i>Nelly Florida (BMKG, Jakarta) indicated that Indonesia could host the next SC meeting if required. Nick D'Adamo (UNESCO IOC PPO, Perth) also offered to host SC3 in Perth if required.</i> <i>It was suggested that January-March would be the best time for the SC3. Members were asked to identify key dates (i.e. when major conferences are being held) with which the SC3 should avoid overlapping.</i> <i>In terms of meeting format, it was agreed to adhere to the practice of holding it in collaboration with associated meetings (annual meetings of SIBER, IORP, IOGOOS, IRF).</i> <i>It was also suggested that the ST and WG leaders should convene a 2-day workshop to be followed by a 3-day SC3, which would include planning for the 2020 Science Symposium.</i> <p>2020 IIOE-2 Science Symposium</p> <ul style="list-style-type: none"> <i>The SC agreed to hold a Science Symposium in 2020 to bring together and reflect on the outcomes of the IIOE-2.</i> <i>In order to align with the meeting dates for the IOC and SCOR in 2020, it was agreed that the Symposium should be held early in the year, preferably late January/early February.</i> <i>It was noted that the 2020 AGU Ocean Sciences Meeting would be held on 11-16 February 2020 and that these dates should be avoided.</i> 	<p><i>IndOOS/IIOE-2 submission to OceanObs'19.</i></p> <p><i>Core Group and JPOs to discuss the nature of an updated/revised IIOE-2 Science Plan to be implemented if the IIOE-2 is extended beyond 2020.</i></p> <p><i>JPO to liaise with potential IIOE-2 SC-3 hosts and confirm the meeting venue/dates ASAP.</i></p> <p><i>Sateesh Shenoï to confirm details of 2020 IIOE-2 Science Symposium.</i></p>
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	<ul style="list-style-type: none"> • <i>India offered to host the Symposium in Goa and agreed to report back to the SC on the symposium duration and dates.</i> • <i>In order to facilitate planning, it was agreed that the scientific themes/format of the symposium should be confirmed as early as possible.</i> • <i>It was also agreed that broad geographical representation would be important at the Symposium. One idea put forward was to invite at least 2 people from each of the Indian Ocean rim countries to attend and to come up with a plan for funding their attendance.</i> <p><u>Closing comments</u></p> <p><i>Closing remarks were given by Nick D'Adamo and Rajan Sivaramakrishnan (for the JPO), Peter Burkill (for SCOR and as IIOE-2 Steering Committee Co-Chair), Satheesh Shenoi (for IOGOOS and as IIOE-2 Steering Committee Co-Chair) and Nelly Florida (on behalf of BMKG and LIPI).</i></p>	<p><i>IIOE-2 Core Group and JPOs to work with WG/ST leaders in confirming the science themes for the 2020 Symposium.</i></p>
<p>End of meeting: 1300 hrs, Wednesday 21 March 2018</p>		

Appendix 1: IIOE-2 SC2 List of Participants

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Appendix 2: IIOE-2 SC2 Presentation Summaries

Monday 19 March 2018		
0900-1030	Welcome by hosts & JPO	
	Zainal Arifin (LIPI)	Welcomed IIOE-2 Steering Committee members and all 2018 International Indian Ocean Science Conference participants to Jakarta.
	Scene-setting talks by IIOE-2 Co-Chairs	
	Peter Burkill (SCOR)	Noted that we are halfway through a very ambitious 5-year programme. Considered that this meeting should address three questions: 1) What have we found out so far that is new, exciting and worthwhile? 2) What important research challenges remain to be tackled? 3) What time scale is needed to address them?
	Vladimir Ryabinin (IOC)	Welcomed IIOE-2 Steering Committee. Thanked sponsors especially LIPI and BMKG. Highlighted the critical role of Indian Ocean science and the IIOE-2 to society. Stated that the UN Decade of Ocean Science is highly relevant to the IIOE-2.
	Satheesh Shenoi (IOGOOS)	Welcomed participants and thanked local hosts. Reiterated that the IIOE-2 was supporting our understanding of the Indian Ocean and thus beneficial to decision-makers. Sees the IIOE-2 as being directly relevant to the UN Sustainable Development Goals and a precursor to the UN Decade. This meeting will help us to see what has been achieved in the first two years of IIOE-2.
	Report from JPOs	
	IIOE-2 SC1 Meeting (Perth, 2-4 Feb 2017) – Nick D'Adamo (IOC PPO, Australian JPO)	<ul style="list-style-type: none"> - Highlighted Action Items completed since SC1 e.g. establishment of an IIOE-2 SC Executive Core Group (Action Item 14) - Of the 19 Action Items arising from SC1, six are still pending.
	Australian JPO Report – Nick D'Adamo	<ul style="list-style-type: none"> - Outlined the structure of IIOE-2 WGs and STs. 7 IIOE-2 National Committees have now been established. - Highlighted the work of JPO to profile IIOE-2 at international forums - Need to consider the effectiveness and functionality of WG and ST teams.
	Indian JPO – Rajan Sivaramakrishnan	<ul style="list-style-type: none"> - Overviewed the work of the Indian JPO including updates to the IIOE-2 website. In Jan-Feb 2018, 1687 visitors from 62 countries. - Highlighted growth in IIOE-2 project endorsement. From 8 projects by 10 countries in Feb 2017 to 26 projects in 23 countries in March 2018. - JPO work to develop an IIOE-2 Metadata Portal, Web GIS Portal for IIOE-2 projects and publish IIOE-2 newsletter, Ocean Bubble.
	Keynote talk	
	UN Decade of Ocean Science for Sustainable Development 2021-30 and relevancy to IIOE-2 both now and beyond 2020 – Vladimir Ryabinin	<ul style="list-style-type: none"> - Overviewed UN Sustainable Development Goals. Ocean science plays a strong role in achieving UN SDGs. The IIOE-2 a key Indian Ocean focal point for The Decade. - The Decade to focus on transformative science that is useful for policy and decision-making. - Potential science breakthroughs: complete ocean bottom mapping; knowledge of deep sea and ocean floor; ocean literacy in schools and comprehensive genetic picture of ocean – eDNA. - IIOE-2 and IOCINDIO may help the Indian Ocean Region to create a strong plan for the Decade in the Region, and expand IIOE-2 stakeholders/partnerships.
1100-1500	Science Theme Progress Reports	
	ST1 Human benefits and impacts – Ben Milligan	<ul style="list-style-type: none"> - Placed IIOE-2 activities in a policy and political context. - Science Theme 1 activities in 2017: pursuit of funding opportunities, mapping & connecting to other initiatives, discussions about organisation of data, call for evidence document. - 2018 planned activities: evidence synthesis, guidance documents, data collection and organisation (indirect).

		<ul style="list-style-type: none"> - Outlined funded projects connected with ST1: SOLSTICE WIO, IIED/SIDA, WWF activities in the region, UK NERC Strategic Programme proposal.
	ST2 Boundary current dynamics, upwelling variability and ecosystem impacts – Yukio Masumoto	<ul style="list-style-type: none"> - Introduced ST2 members. Noted that they have been exchanging info on ST2-related activities via email e.g. cruises/research plans, research highlights, thoughts on future directions. - Outlined Indian Ocean boundary regions and highlighted current projects. - <u>Western Boundary</u>: Agulhas System Climate Array (ASCA); Gliders in the Agulhas (GinA). - <u>Eastern Boundary</u>: R/V Mirai MR17-08 Cruise; 2018 Hakuho-maru EIO Cruise; Throughflow Indonesian seas, Upwelling and Mixing Physics (TRIUMPH). - <u>Central Boundary</u>: Bay of Bengal Boundary Layer Experiment (BoBBLE) 2016; Trans-disciplinary Research for improved forecasting of Indian Marine Fisheries (TRIMFish); Biogeochemistry-Atmosphere Processes in the Bay of Bengal (BIOCAT IIOE2). - <u>Open Ocean Upwelling</u>: Korean Ship R/V Isabu, Colombo-Mauritius, 2-26 July 2017; NOAA Ship Ronald H. Brown, February-April 2018. - Considers ST-2 related observations are taking place and planning underway at national/bilateral/multi-lateral level. Science outcomes are emerging. - Need more coordination among the projects and consideration for data management and dissemination.
	ST3 Atmospheric and monsoon Variability and ecosystem response – Joaquim Goes	<ul style="list-style-type: none"> - Overviewed ST3 core science questions, systems or modes of monsoon variability and ecosystem response. - Current ST3-related projects: BoBBLE (Bay of Bengal Boundary Layer Experiment) Ocean-Atmosphere Interaction and its Impact on the South Asian Monsoon; ELO (Equatorial Line Observations) Convectively Coupled Kelvin Waves; Asian Monsoon Gateway Monitoring; ThThroughflow Indonesian seas, Upwelling and Mixing PHysics (TRIUMPH); Trans-disciplinary Research for improved forecasting of Indian Marine Fisheries (TRIMFish); Decision and Information System for the Coastal waters of Oman (DISCO).
	ST4 Circulation, climate variability and ecosystem change – Jerome Vialard	<ul style="list-style-type: none"> - Overviewed decadal, interannual and intraseasonal variability in Indian Ocean circulation as well as relationship between Indian Ocean warming and monsoonal variability. - Outlined ST4-relevant endorsed projects, 17 in total - ST4 accomplishments: BoBBLE, OMM-ASiRI, Challenger (EP08-1 cruise), RAMA servicing (Feb-April 2018), NOAA ship Ronald H. Brown (Feb-April 2018). - Future projects: Centre for Southern Hemisphere Ocean Research (CSHOR) Indo-Pacific Interbasin Exchange (2017-2020); RV Investigator Voyage – 13th May-13th June 2019 – 110°E, 40°S-10°S: A coupled bio-physical, ecosystem-scale, examination of Australia's International Indian Ocean Expedition line; R/V Hakuho-maru. - Outlined IndoOS (Review) and relationship to IIOE-2. IndoOS provides background for IIOE-2 process experiments while IIOE-2 cruises are great opportunities to service/complete IndoOS. Encouraged more collaboration between the two. - Suggestions that at time of IIOE-2 endorsement, when cruise funded, planned: systematically inform IIOE-2 relevant ST leaders; and systematically inform IORP, SIBER, IRF.
	ST5 Extreme events and their impacts on ecosystems and human populations – Chari Pattiaratchi	<ul style="list-style-type: none"> - Gave overview of core ST5 questions - Examples of extreme events: hurricanes, droughts, severe storms, floods, heat waves, cold snaps – can have costly and far-reaching impacts on society. - Addressed misconceptions of extreme events. Unscientific predictions. e.g. colossal earthquakes and mega tsunamis. Important to articulate science to general public.

		<ul style="list-style-type: none"> - Challenges: this ST does not have cruises, small membership, difficult to attract members - One possibility: to document extreme events prediction systems and identify how IIOE-2 can contribute/add value to them.
	ST6 Unique geological, physical, biogeochemical and ecological features of the Indian Ocean – Jerome Dymont	<ul style="list-style-type: none"> - Gave an overview of the unique geological features of the Indian Ocean: ridges, hot spots, basins, subductions. - Role of ST6 not entirely clear to members - Actions of ST6 thus far: raising awareness of IIOE-2 and encouraging projects to seek IIOE-2 endorsement; SCOR has proposed that InterRidge hold a joint meeting on the Geology of the Indian Ocean in late 2018. SCOR/ST6 members have begun organising. - Thinks the best way to attract geoscientist interest to IIOE-2 is to acquire and make readily available "piggy-back data" (e.g. multibeam bathymetry, gravity, magnetics).
1530-1720	Working Group Progress Reports	
	WG1 Science and Research – Raleigh Hood (on behalf of Hermann Bange)	<ul style="list-style-type: none"> - Gave an overview of WG1 objectives and the extent to which they are being achieved. Most are, but WG1's influence not always clear. - Summarised the relevant publications and endorsed projects associated with each Science Theme: ST1 = 2 pubs, 0 projects; ST2 = 3 pubs, 3 projects; ST3 = 1 pub, 10 projects; ST4 = 1 pub, 9 projects; ST5 = 1 pub, no projects; ST6 = 2 pubs, 7 projects. - Update on IIOE-2 research initiatives: YMC, EIOURI, WIOURI, RAMA Cruises - Summary of national IIOE-2 efforts. Noted high level of participation at national level. - Status of the IIOE-2 DSR II Special Issues on IIOE-2. Vol 1: 21 manuscripts submitted and under review. Vol 2: new accepting submissions. Deadline: 31 May 2018.
	WG2 Data and Information Management – Cynthia Chandler	<ul style="list-style-type: none"> - Reviewed progress on addressing WG2 ToRs. - Draft IIOE-2 Data Policy to be reviewed this week in D&IM workshop. Supports FAIR data principles. Aligned with IOC policies. - Data exchange: encouraged members to use ORCID (person ID) and DOI (Digital Object ID). - Long-term IIOE-2 data storage a combination of IODE network of NODCs and ADUs (OBIS nodes) and INCOIS IIOE-2 data portal. - Metadata catalog completed (by JPO/INCOIS) and now publically available. Encouraged contributions. - Proposed flow of IIOE-2 data: Acquisition to National Data Centre to INCOIS. - Training Courses: IOC/IIOE2-OTGA and IORA 2016 Joint Training Course, Research Data Management; IODE OTGA online course.
	WG3 Capacity Development –Nugroho Hananto (on behalf of Zainal Arifin)	<ul style="list-style-type: none"> - Facilities to support Capacity Development (Indonesia): 1) Regional Training and Research Center for Marine Biodiversity and Ecosystem Health (MarBEST Centre) - Floating School: 1) ASEAN – IOC WESTPAC Summer Floating School on Marine Geoscience and Geohazard; 2) FUSION: Floating University of the Southwestern Indian Ocean; 3) South Java Deep Sea Expedition for Deep Sea Marine Biodiversity
Tuesday 20 March 2018		
0900-1030	Working Group Progress Reports (continued)	
	WG4 Operational Coordination – Rajan Sivaramakrishnan	<ul style="list-style-type: none"> - Overview of WG4 structure; has oversight of all WGs. - WG4 chair convened the first telephonic hookup meeting with the Chairs of the other WGs on 30th May, 2017. - WG Chairs/Co-Chairs asked to provide a short write-up on the plans of their respective WGs in implementing the IIOE-2 goals. - Outlined WG4 objectives & progress: developed a WebGIS application on status/progress of endorsed; currently expanding application to

		include relevant, non-endorsed projects; liaising with JCOMMOPS to gain access to operations that support maintenance of observation systems in the Indian Ocean; as first step, INCOIS is overlaying the existing data buoy locations with details on the IIOE-2 WebGIS application.
	WG6 Translating Science for Society – Rezah Badal	<ul style="list-style-type: none"> - Gave an overview of WG6 ToRs. - Indian Ocean Conference on ‘Marine Spatial Planning – Towards Sustainable Use of the Indian Ocean’, held 22-23 November 2017 in Mauritius, included a session on IIOE-2 data collection and initiatives. Aim of the session: to channel all information gathered previously during the conference and come up with concrete ways to make society benefit from Ocean Science & Research. - Way forward/strategic plan: 1. Are there a science to society component in your projects/studies? Users end/ benefit to society/ Communication Media/ (Extreme events, PFZ,) 2. What are the scientific results of direct benefit to society? CC variability/ Resource management/Mixed Layer processes/ 3. How and when are society involved in the programme/projects?
	WG 7 Resources and Sponsorship –Nick D'Adamo & Rajan Sivaramakrishnan	<ul style="list-style-type: none"> - Sources of financial and in-kind support to IIOE-2: 1) Support of ST and WG chairs: SCOR 20-25K per year, in-kind support from Chairs’ host institutions to attend meetings; Support of IOGOOS members: IOGOOS (10K/yr); 3) Support of ECSN members; 4) Catalytic funding to underpin new ideas, meetings: SCOR - -InterRidge meeting 2018 (10K). - IIOE-2: Endorsed projects ~30 cruises. 50-70K USD per day in value plus value of scientists, follow up research. - Australian govt: Bureau of Meteorology provides staff, admin for JPO (Australia-Node) - INCOIS: operational day-to-day resourcing for activities of the JPO (India-Node); financial support for one full-time person plus the requisite administrative and hosting resources for coordinating the IIOE-2 activities; facilitates WG4 activities; establishing and managing of a Regional Coordination Unit for IIOE-2 Data and Information Management; Coordination and implementation of selected Capacity Development projects under IIOE-2, including through ITCOcean in Hyderabad.
	Progress Reports: IOC Regional Bodies	
	IOC WESTPAC – Kentaro Ando (on behalf of Somkiat Khokiattiwong)	<ul style="list-style-type: none"> - WESTPAC established an IIOE-2 WG. - WESTPAC members' IIOE-2 efforts include: Chinese-Indonesian joint cruise off Sumatra region for understanding the upwelling dynamics by using Baruna Jaya; Japan to conduct the Hakuho-Maru cruise in December 2018 in the eastern Indian ocean; Korean-US RAMA cruise. - WG recognised Eastern Indian Ocean observations and research as a capacity building opportunity for WESTPAC Member States. - WG recommend supporting the IIOE-2 via the EIOURI project and its associated CD activities; a draft plan for supporting the two activities is under discussion.
	IOCINDIO – M.A. Atmanand	<ul style="list-style-type: none"> - Gave overview of IOCINDIO mandate, purpose and mission. - IOCINDIO reactivated in June 2009; IOCINDIO-VI held in Kuwait City, Kuwait, from 24 to 25 May 2017. - IOCINDIO endorsed projects: A) Effects of human induced changes: Ocean acidification, eutrophication, hypoxia, harmful algal blooms (HABs) in coastal waters of the Northwestern Indian Ocean; B) Coastal vulnerability assessment for sea level rise and storm surges; C) Ocean observations, coastal zone management, circulations and fisheries; D) Monitoring with Responsible Response of Oil Spill in inner ROPME Sea Area; E) 2050 Integrated Ocean Policy Advice for Proactive Planning and Managements for IOCINCIO Member States; F) Blue Economy Business opportunities in the context of climate change adaptation and

		<p>Disaster Risk Reduction; G) IOCINDIO Networking Research Infrastructures, Facilities and Human Resources.</p> <ul style="list-style-type: none"> - IOCINDIO invites IIOE-2 SC2 participants to indicate their preference for any of the 7 areas of the above project proposals and to attend next IOCINDIO meeting. - Hope to hold IOCINDIO-VII back to back with IIOE-2 related meetings or other Indian Ocean science conference.
1100-1500	IIOE-2 National Committee Reports	
	Australia - Lynnath Beckley	<ul style="list-style-type: none"> - Aus IIOE-2 Nat Committee formed in May 2015, comprises representatives of about 20 institutions; Representatives provide conduit into most institutions engaged in Indian Ocean research. - 100+ Australian-led Indian Ocean research projects. - Important role of IMOS in research by Australia in IIOE-2: Moorings, gliders, Argo, radar, remote sensing, acoustics. - IIOE-2 endorsed projects: 1) Challenger glider mission; 2) Physical drivers of Arafura Sea Large Marine ecosystem; 3) 110°E repeat line. - Aims of 110°E line: Quantification of change from 1960s benchmark in the physical, chemical & biological properties of the water column along 110°E (since IIOE-1).
	France – Francis Marsac	<ul style="list-style-type: none"> - French Nat Comm formed in June 2014. - Gave overview of France's IIOE-2 projects by Science Theme. - ST1: SINDIA project; ST2: Physical processes of the Agulhas leakage, Role of the Agulhas in the Benguela current system; ST3: PHYSINDIEN: Marginal sea outflow dynamics and regional consequences; ST4: Water cycle and circulation in Bay of Bengal, Physical and biogeochemical responses, Climate change in the Arabian Sea; ST5: IFCPAR project (IRD-NIO): Global assessment of tropical cyclones intensity; ST6: RHUM-RUM project (France-Germany 2012-2016), MIRAGE project (France-Indonesia-Singapore 2016-2020), MAGOFOND project (France-Israel-Japan 2017-2020). - Feedback from French IIOE-2 groups: Atmospheric interface well represented in IIOE-2 themes, does not look to be the case for the continent-ocean interface; Improve international collaboration in designing/developing research cruises - processes occurring at different space-time scales require cruises developed on a synchronized way; IIOE-2 cruises should strengthen IndOOS (contact CLIVAR IO panel). IndOOS provide observations to cruises, in return cruises can assist in deploying instruments; Stimulate projects endorsement by IIOE-2; Better inform Regional Fisheries Management Organisations on progress, knowledge gained and explore ways of collaboration.
	India – Sateesh Shenoi	<ul style="list-style-type: none"> - Indian IIOE-2 Nat Committee formed in 2015. - 8 Indian IIOE-2 endorsed projects. - Played a lead role in organizing 2015 International Symposium in Goa commemorating 50th anniversary of IIOE. - First meeting July 2017. Decisions and recommendations included: exploring feasibility of synergising IIOE-2 India activities with the planned National Mission on Deep Ocean Research; endorsing projects in the Indian sector of the Southern Ocean; initiating data management, capacity building and outreach exercises directed at the Indian Ocean Rim countries, utilising the facilities and expertise in India; developing an integrated multi-institutional National Science Plan focused on the (Northern) Indian Ocean within the overall goals of IIOE-2. - ASEAN-India Research Training Fellowship.
	Japan – Yukio Masumoto	<ul style="list-style-type: none"> - Japanese IIOE-2 National Committee will officially form on 3rd April, 2018 under the SCOR sub-commission of Science Council of Japan. - Present interests: Dynamics of Ocean/Climate Variations; Nitrogen Cycle in the Bay of Bengal; Mapping of biogeography and biogeochemistry; Bio-Physical Relations in Upwelling Regions.

		<ul style="list-style-type: none"> - Cruises include: Repeat Hydrography in GO-SHIP; R/V Mirai MR17-08 Cruise; 2018 Hakuho-maru EIO Cruise; planned R/V Hakuho-maru cruise in August/September 2020. - Gave overview of Japanese research results relevant to IIOE-2.
	UK – Greg Cowie	<ul style="list-style-type: none"> - Gave overview of recently endorsed UK IIOE-2 projects: Bay of Bengal Boundary Layer Experiment (BoBBLE), Equatorial Line Observations (ELO), SOLSTICE. - Other funded UK IIOE-2 activity: IIOE2-EP25 - Integrated Heat Dynamics of the Indian and Global Oceans; IIOE2-EP28 - Responses of biological productivity and fisheries to changes in atmospheric and oceanographic conditions in the upwelling region associated with the East African coastal current (PEACC). - UK Nat Committee did not know about these other projects. Asks that relevant endorsements be communicated back to Nat Comms. - Chagos Archipelago – MPA studies. - Nekton Deep Sea Exploration has been communicating with us. GANGA BOB – UK/India joint project. Announced by end of March 2018 and meeting June 2018. Not endorsed yet.
	USA - Raleigh Hood	<ul style="list-style-type: none"> - Introduced US IIOE-2 Steering Committee and Terms of Reference. - Indian Ocean Science Workshop convened at Scripps Institution of Oceanography, San Diego, USA, September 11-13, 2017 to identify scientific priorities to guide US participation in IIOE-2. - Five research themes and a draft document emerged: 1) Physical, Biogeochemical and Ecological Dynamics of the Seychelles-Chagos Thermocline Ridge; 2) Inter-Ocean Physical and Biogeochemical Exchanges; 3) Monsoon dynamics; 4) Physical, Biogeochemical and Ecological Contrasts Between the Arabian Sea and the Bay of Bengal; 5) Marine Geology and Deep Ocean Biogeochemistry and Ecology. - Next steps: Draft implementation plan to be reviewed and NSF/OCB community and program managers. Motivate coordinated proposal submissions to NSF, NASA and NOAA in 2018/2019. Secure funds for a US project office?
	Contingency session. Invited IIOE-2 Endorsed Project presentations not covered by National Committee talks	
	NOAA's IIOE-2 Partnership Activities 2018 – Sidney Thurston	<ul style="list-style-type: none"> - Long-term Partnership with India's Ministry of Earth Sciences (MoES). - Goa Science Colloquium, June 11-13, 2018, building a foundation for the next decade of NOAA-MoES ocean-climate collaborations. - InaPRIMA/RAMA Partnership with BMKG: 12th Annual Workshop held Bali May 2017; a synergy between BMKG and NOAA for Delivery of Information for Climate Decision Support Services. - New Partnership with Korea's Institute for Ocean Science and Technology (KIOST): cruise on R/V Isabu Columbo-Mauritius, 2-26 July 2017. - NOAA Ship Ronald H. Brown 2018 Multidisciplinary Expedition to the Indian Ocean. - Western Indian Ocean Capacity Building Workshops.
	Eastern Indian Ocean Upwelling Research Initiative (EIOURI) – Yukio Masumoto	<ul style="list-style-type: none"> - EIOURI planning underway; focusing on the upwelling regions that develop seasonally off Java, Sumatra, and northwestern Australia. - EIOURI cruises: Dec 2015 – Feb. 2016 : R/V Mirai cruise (GO-SHIP I10); Nov 2017 – Jan 2018 : R/V Mirai cruise (YMC); Nov 2018 – Dec 2018: R/V Hakuho-maru cruise; late 2018: FIO-LIPI cruise (Through TRIUMPH); mid 2020: R/V Hakuho-maru cruise (proposal submitted). - EIOURI webpage created; Science Plan available for download; Research activities outlined online. - Recent progress: EIOURI is cooperating with SCOR Working Group 155 "Eastern boundary upwelling systems (EBUS): diversity, coupled dynamics and sensitivity to climate change".

		<ul style="list-style-type: none"> - IIOE-2 / EIOURI related session at 15th annual AOGS meeting, June 2018; all encouraged to participate.
	EAF-NANSEN Project (R/V Dr Fridtjof Nansen Surveys – SW Indian Ocean) – Rezah Badal	<ul style="list-style-type: none"> - Characterizing the Marine Ecosystem and Morphology of the Saya de Malha Bank. - Marine landscape map of Saya de Malha Bank was created using data derived from surveys conducted by Soviet vessels. - 2018 surveys designed to enhance knowledge on the marine ecosystem and morphological structure of the Saya de Malha Bank - Outlined track survey and Sampling design: Optimisation of seafloor mapping (bathymetry data acquisition); Identification of appropriate stations to validate the marine landscape map; Samplings for benthic habitat assessment: depths > 10 m; Pelagic trawls (zooplankton sampling): depths > 50 m; Replicate survey stations of 2008 ASCLME cruise for comparison. - Opportunities for Nansen programme: Local Scientist to develop organization skills; Cruise plan elaboration; Take leadership role in MSR; Partake in exchange of expertise; Capacity building.
1530-1700	Early Career Scientists Network (ECSN)	
	ECSN Progress Report – Riaan Cedras	<ul style="list-style-type: none"> - Background: IIOE-2 ECSN established during IIOE-2 symposium in India in 2015 to provide a platform for early career scientists to demonstrate and present their work; Contributed to IIOE-2 publications and ECSN research featured in Indian Ocean Bubble; Early Career Scientist Session at IIOSC 2017 in Perth, Australia. - WIO-ECSN formed through WIOMSA to strengthen the capacity of early career scientists in the region through partnership with relevant stakeholders. - Challenges facing early career researchers: Improved training; Shared access to technical help; Accessing on innovative research tools; Administrative assistance; Data management; Grant writing resources/post graduate training. - Support/initiatives: Scholarships and Fellowships for BSc, MSc and postdoc; Archive/database of abstracts of theses and publications of ECS; Capacity development programs (trainings and workshops); Role players/Mentors.

Appendix 10
2018 Audited SCOR Statement of Activities

SCIENTIFIC COMMITTEE ON OCEANIC RESEARCH, INC.
STATEMENT OF ACTIVITIES
YEAR ENDED DECEMBER 31, 2017

	Without Donor Restrictions	With Donor Restrictions	Total
SUPPORT AND REVENUE			
Grant and contract revenue	\$793,723	-	\$793,723
Contribution revenue		\$93,227	\$93,227
Membership dues	\$365,944	-	\$364,944
Meeting registration fees and miscellaneous income	\$4,800	\$6,073	\$10,873
Interest income	\$804	-	\$804
NET ASSETS RELEASED FROM RESTRICTIONS			
Satisfaction of program restrictions	\$61,250	(\$61,250)	-
Total support and revenue	\$1,226,521	(\$38,050)	\$1,264,571
EXPENSES			
Program services			
Scientific programs	\$834,486	-	\$834,486
Travel and subsistence programs	\$76,986	-	\$76,986
Other conferences and meetings	\$18,311	-	\$18,311
Total program services	\$929,783	-	\$929,783
Supporting services			
Management and general	\$302,956	-	\$302,956
Total expenses	\$1,232,739	-	\$1,232,739
CHANGE IN NET ASSETS	(\$6,218)	\$38,050	\$31,832
NET ASSETS			
BEGINNING OF YEAR	\$215,441	\$50,919	\$266,360
END OF YEAR	\$209,223	\$88,969	\$298,192

Appendix 11
SCOR-Related Meetings (2018-2021)

2018		
10 February	WG 154 on Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs (P-OBS)	Portland, Oregon, USA
11 February	WG 143: Dissolved N ₂ O and CH ₄ measurements	Portland, Oregon, USA
11 February	WG 145 on Modelling Chemical Speciation in Seawater to Meet 21st Century Needs (MARCHEMSPEC)	Portland, Oregon, USA
11 February	WG 150 on Translation of Optical Measurements into particle Content, Aggregation & Transfer (TOMCAT)	Portland, Oregon, USA
11 February	WG 151: Iron Model Intercomparison Project (FeMIP)	Portland, Oregon, USA
14-15 February	WG 147: Towards comparability of global oceanic nutrient data (COMPONUT)	Portland, Oregon, USA
11 March	WG 153 on Floating Litter and its Oceanic TranSport Analysis and Modelling (FLOTSAM)	San Diego, Calif., USA
13-14 March	IQOE Science Committee	Bremerhaven, Germany
19-23 March	IIOE-2 Steering Committee	Lomboc, Indonesia
10-12 April	GlobalHAB Scientific Steering Committee	Villefranche-sur-Mer, France
16-18 April	WG 148: International Quality Controlled Ocean Database: Subsurface temperature profiles (IQuOD)	Oostende, Belgium
16-19 April	IMBeR Scientific Steering Committee	Hobart, Tasmania, Australia
16 April-11 May	5 th Research Discovery Camp	Namibia
2-4 May	SOLAS Scientific Steering Committee	Victoria, BC, Canada
6-9 May	SOOS Scientific Steering Committee	Hangzhou, China
2-3 June	WG 155 on Eastern boundary upwelling systems (EBUS): diversity, coupled dynamics and sensitivity to climate change	Washington, DC, USA
15-17 June	WG 152 on Measuring Essential Climate Variables in Sea Ice (ECV-Ice)	Davos, Switzerland
13-15 July	WG 149 on Changing Ocean Biological Systems (COBS): how will biota respond to a changing ocean?	Waterville, New Hampshire
23-25 July	GEOTRACES Scientific Steering Committee	Taipei, Taiwan
23 July-4 August	SOLAS Summer School 2018	Cargese, Corsica, France
1-8 August	IMBeR ClimECO6 Summer School	Yogyakarta, Indonesia
2-7 September	GICPWS/BIPM/IAPWS Seawater Workshops (sponsored by the Joint Committee on Seawater)	Prague, Czech Republic
4-7 September	2018 SCOR Annual Meeting	Plymouth, UK

28-31 October	OCB/WG 143 Workshop on Oceanic Methane and Nitrous Oxide: The Present Situation and Future Scenarios	Lake Arrowhead, California, USA
7-9 November	WG 154 (P-Obs) Theme Leader Meeting	Villefranche-sur-Mer, France
14-16 November	SCOR-InterRidge Workshop on Mid-Ocean Ridges and Other Geological Features of the Indian Ocean	Goa, India
28-30 November	IIOE-2 Science WG Meeting	Kiel, Germany
3-5 December	GEOTRACES-PAGES Synthesis workshop: Trace Element and Isotope Proxies in Paleoceanography	Aix-Marseille, France
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