

### **3.0      LARGE-SCALE OCEAN RESEARCH PROJECTS**

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### 3.1 GEOTRACES

*Lam, Duce*

#### **Terms of Reference:**

- Organize national and international planning workshops as well as special sessions at international conferences to obtain community input on the design and implementation of GEOTRACES.
- Establish priorities for research on the sources, sinks, internal cycling, transport, speciation and fate of TEIs, and develop this information into an International Science Plan.
- Promote intercalibration of analytical methods, and the development of standard reference materials.
- Identify new instrumentation and related infrastructure that will help achieve GEOTRACES objectives.
- Define a policy for data management and sample archival.
- Forge scientific linkages with other research programs holding overlapping interests to create synergies where possible and avoid duplication of efforts. To the extent practical, this will involve cross-membership between the GEOTRACES Planning Group and the Planning Groups and Science Steering Committees of other programs.
- Interact with SCOR Working Groups that share common interests including, but not limited to, SCOR/IMAGES WG 123 on Reconstruction of Past Ocean Circulation (PACE) and SCOR/IMAGES WG 124 on Analyzing the Links Between Present Oceanic Processes and Paleo-Records (LINKS).

**Co-Chairs:** Andrew Bowie (Australia) and Phoebe Lam (USA)

**Other Members:** Eric Achterberg (Germany), Adrian Burd (USA), Zanna Chase (Australia), Jay Cullen (Canada), Susanne Fietz (South Africa), Tina van de Flierdt (UK), Vanessa Hatje (Brazil), Marina Kravchishina (Russia), Rob Middag (The Netherlands), Hajime Obata (Japan), Haojia Abby Ren (China-Taipei), Yeala Shaked (Israel), Kazuyo Tachikawa (France), Antonio Tovar-Sanchez (Spain), And Liping Zhou (China-Beijing)

#### **Ex Officio Members:**

Maeve Lohan (UK), Co-Chair of the Standards and Intercalibration Committee  
 Walter Geibert (Germany), Co-Chair of the Standards and Intercalibration Committee  
 Alessandro Tagliabue (UK), Co-Chair of the Data Management Committee  
 William Landing (USA), Co-Chair of the Data Management Committee

**IPO Executive Officer:** Elena Masferrer Dodas

**IPO Science Director:** Catherine Jeandel

**Executive Committee Reporter:** David Halpern

## **GEOTRACES SCIENTIFIC STEERING COMMITTEE ANNUAL REPORT TO SCOR 2018/2019**

1 April 2018 to 31 March 2019

### 1. SCOR Scientific Steering Committee (SSC) for GEOTRACES

#### *Co-Chairs*

Andrew Bowie, Australia

Phoebe Lam, USA

#### *Members*

Eric Achterberg, Germany

Adrian Burd, USA

Zanna Chase, Australia

Jay T. Cullen, Canada

Susanne Fietz, South Africa

Tina van de Flierdt, UK

Vanessa Hatje, Brazil

Marina Kravishina, Russia

Rob Middag, Netherlands

Hajime Obata, Japan

Haojia (Abby) Ren, China-Taipei

Yeala Shaked, Israel

Kazuyo Tachikawa, France

Antonio Tovar-Sanchez, Spain

Liping Zhou, China-Beijing

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

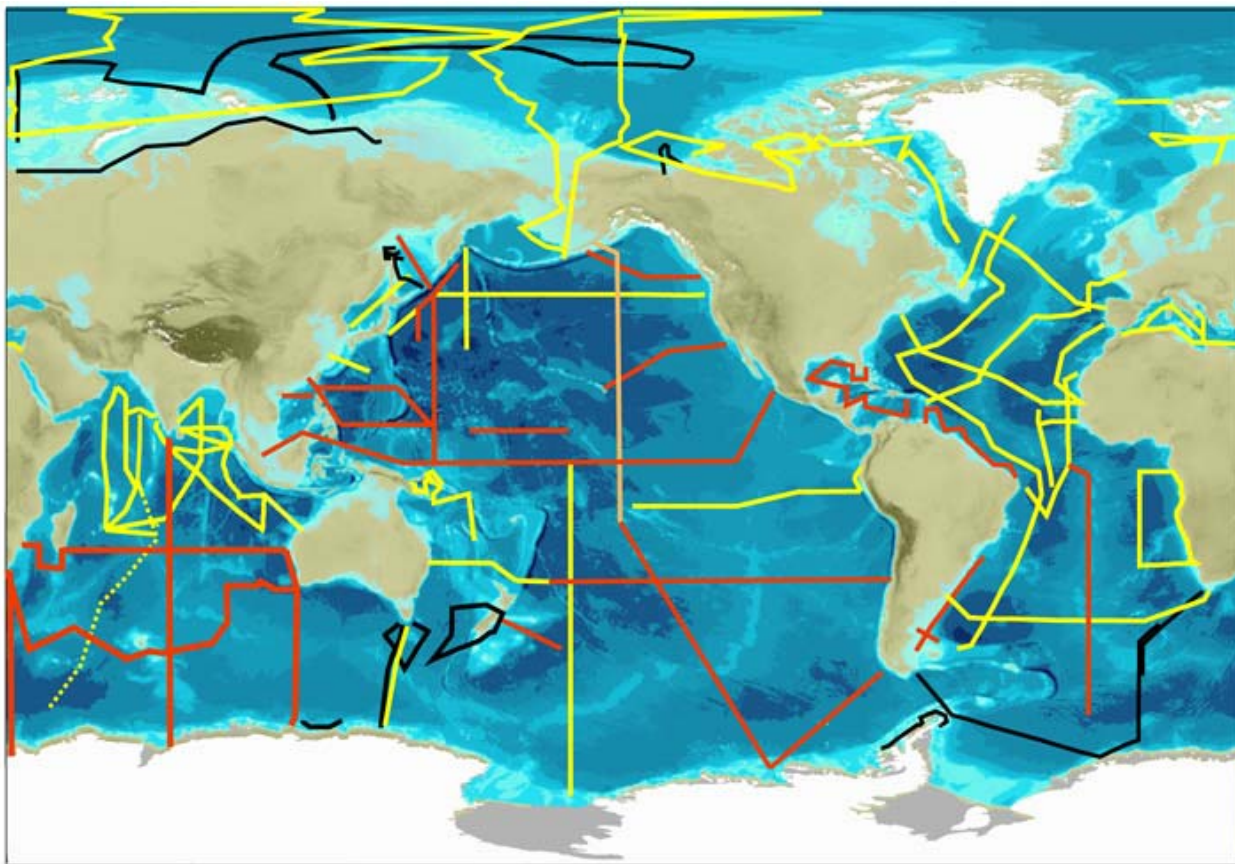
## 2. Progress on implementation of the project

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

### 2.1 Status of GEOTRACES field programme

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

During this reporting period, 5 cruises were completed, including one new section cruise by U.S. scientists (with 2 cruises, see map below, section in orange) and 3 process studies from Australia, Germany and The Netherlands (see data management section below for additional details).



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

## 2.2 GEOTRACES Intermediate Data Products

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

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

### ***Intermediate Data Product download statistics***

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

### **2.3 GEOTRACES Publications**

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

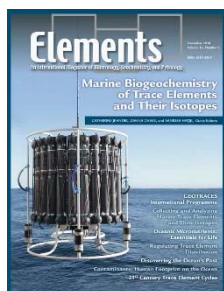
### ***Synthesis papers***

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

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

### ***Publicity documents***

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



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

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

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

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

## 2.4 GEOTRACES Science highlights

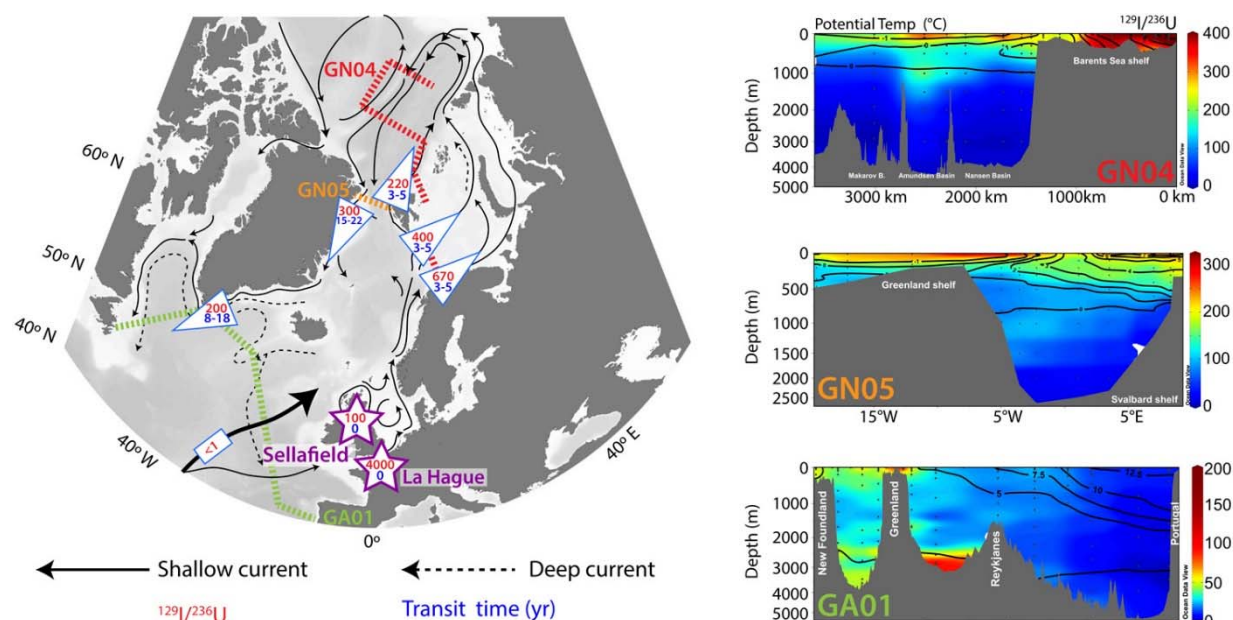
The GEOTRACES International Project Office regularly generates science highlights of notable published articles, which are posted on the website (<http://www.geotraces.org/science/science-highlight>) and in the electronic eNewsletter (<http://www.geotraces.org/outreach/geotraces-enewsletter>). So far,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

### [The circulation loop in the North Atlantic and Arctic oceans depicted by the artificial radionuclides](#)

Atlantic waters have been recently recognised to play an increasing role in reducing sea-ice extent in the Arctic Ocean at a rate now comparable to losses from atmospheric thermodynamic forcing. Beyond the Arctic Ocean, the water mass transport and transformation processes in the North Atlantic Ocean substantially contribute to the Atlantic meridional overturning circulation (AMOC). Artificial radionuclides can be used as transient tracers that provide crucial information on pathways, time scales and processes of key water masses that cannot be obtained from hydrographic properties alone. In particular, radionuclides released from the two European Nuclear Reprocessing Plants have proven to be useful to trace the circulation of Atlantic waters into the Arctic and sub-Arctic oceans. Within this context, the three recent articles by Castrillejo et al. (2018), Wefing et al. (2019) and Casacuberta et al. (2018, see references below) describe the journey of the two long-lived anthropogenic radionuclides iodine-129 ( $^{129}\text{I}$ ;  $T_{1/2}=15.7 \cdot 10^6\text{y}$ ) and uranium-236 ( $^{236}\text{U}$ ;  $T_{1/2}=23.4 \cdot 10^6\text{y}$ ) from their sources up through the Arctic Ocean and back into the North Atlantic Ocean. Each paper corresponds to one GEOTRACES expedition that took place between 2014 and 2016 in the North Atlantic Ocean ([GA01 section](#)), Arctic



Ocean ([GN04 section](#)), and Fram Strait ([GN05 section](#)). Main results show that the combination of  $^{129}\text{I}$  and  $^{236}\text{U}$  serves very well to identify the different Atlantic branches entering the Arctic Ocean: Barents Sea Branch Water (BSBW) and Fram Strait Branch Water (FSBW). Due to the uneven mixing of  $^{129}\text{I}$  and  $^{236}\text{U}$  from the two European Reprocessing Plants of Sellafield and La Hague in the North Sea, each branch brings a different  $^{129}\text{I}/^{236}\text{U}$  ratio. Furthermore, this ratio allowed identification of a third Atlantic branch evolving from the Norwegian Coastal Current (NCC), which stays within the upper Polar Mixed Layer and carries a significantly larger proportion of  $^{129}\text{I}$  and  $^{236}\text{U}$  releases from the European reprocessing plants compared to the FSBW and the BSBW. The evolution of the NCC with a strong  $^{129}\text{I}$  and  $^{236}\text{U}$  signal is further observed when it returns to the Atlantic Ocean as Polar Surface Water (PSW) in the Fram Strait. This allowed estimation of a transit time of 15-22 years for the PSW flowing through the Arctic Ocean. In the subpolar North Atlantic Ocean (SPNA), an increase of  $^{129}\text{I}$  was observed in the deep overflow waters in the Labrador and Irminger Seas, confirming the major pathways of Atlantic Waters in the SPNA that were previously suggested by other authors: a short loop through the Nordic seas into the SPNA (8-10 years) and a longer one, which includes transport all the way through the Arctic Ocean (>16 years). This research proves the potential use of  $^{129}\text{I}$  and  $^{236}\text{U}$  as tools for investigating the circulation within and exchanges between the Arctic and sub-Arctic Seas.



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

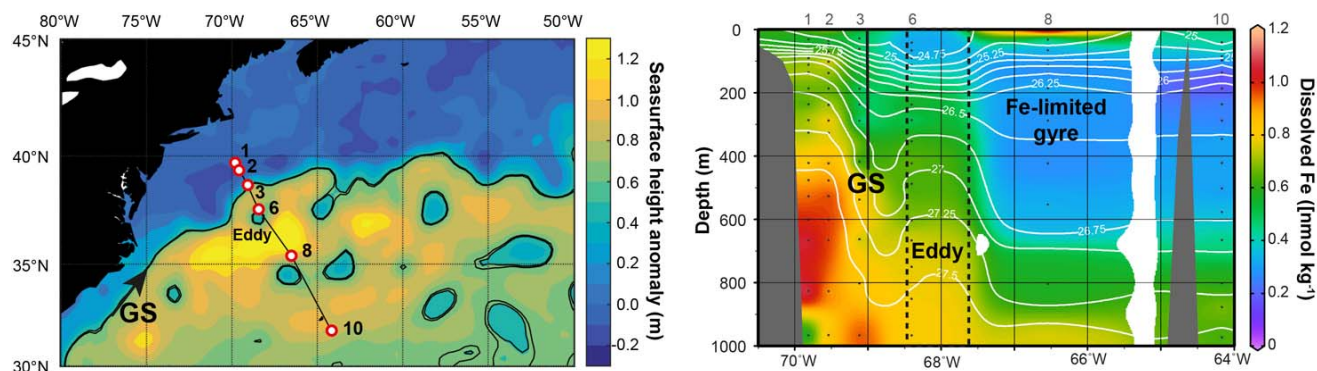


## References:

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

### Gulf stream eddies are fertilizing the Western Atlantic Ocean

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



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

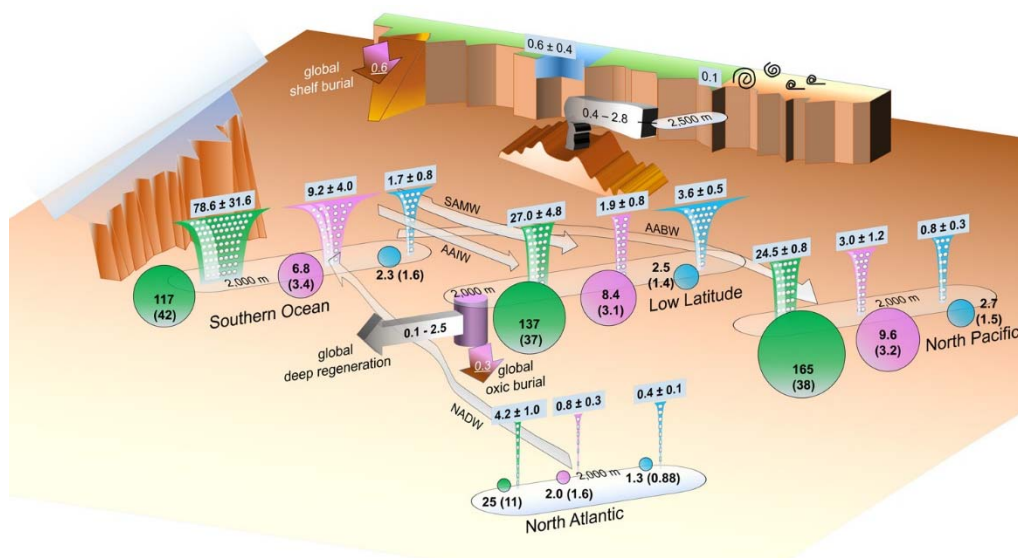
## Reference:

- Conway, T.M., Palter, J.B., & de Souza, G.F. (2018). Gulf Stream rings as a source of iron to the North Atlantic subtropical gyre. *Nature Geoscience*, 11. DOI: <http://doi.org/10.1038/s41561-018-0162-0>

### Artificial intelligence helps investigate the oceanic zinc cycle

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

Roshan and co-workers (2018, see reference below) used an artificial neural network (ANN, a machine learning technique inspired by biological neural systems) to produce a global climatology of dissolved Zn concentration, the first such global climatology of a trace metal. They first used an ensemble of ANNs to produce climatological maps of dissolved Zn with the same spatial resolution as the World Ocean Atlas 2013 (WOA13) and then coupled these dissolved Zn maps, and those of phosphate ( $\text{PO}_4^{3-}$ ) and silicate ( $\text{SiO}_4^{4-}$ ) from WOA13, to a data-constrained ocean circulation model. They then employed a restoring model to compute the biogeochemical sources and sinks of dissolved Zn,  $\text{PO}_4^{3-}$  and  $\text{SiO}_4^{4-}$ .



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

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The main results of this study are the following:

- The Zn:  $\text{PO}_4^{3-}$  uptake ratio varies by approximately tenfold across latitude and is modulated by Fe availability;
- Zn remineralizes like  $\text{PO}_4^{3-}$  in the upper ocean, but its accumulation in deep waters exceeds that of  $\text{PO}_4^{3-}$ ;
- The strong Zn- $\text{SiO}_4^{4-}$  correlation is caused by a combination of surface uptake, desorption from particles, and hydrothermal input, and is therefore completely fortuitous.

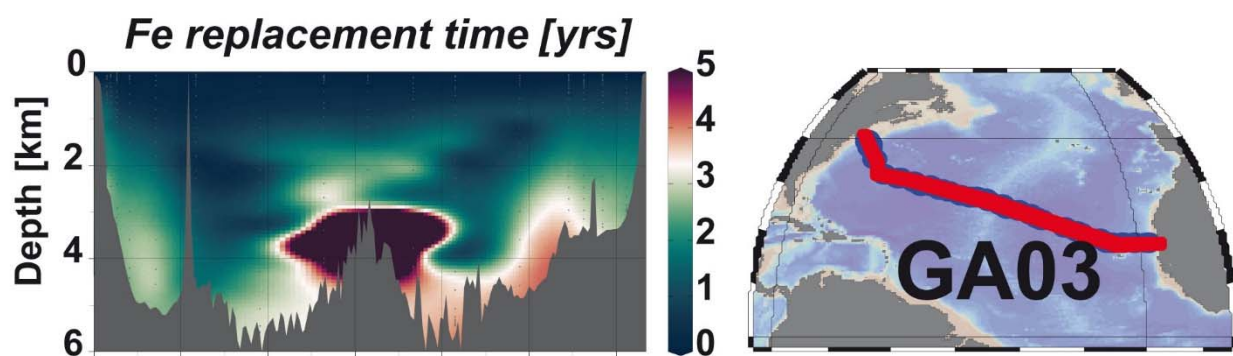
Reference:

Roshan, S., DeVries, T., Wu, J., & Chen, G. (2018). The Internal Cycling of Zinc in the Ocean. *Global Biogeochemical Cycles*, 32(12), 1833-1849.

DOI: <http://doi.org/10.1029/2018GB006045>

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

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



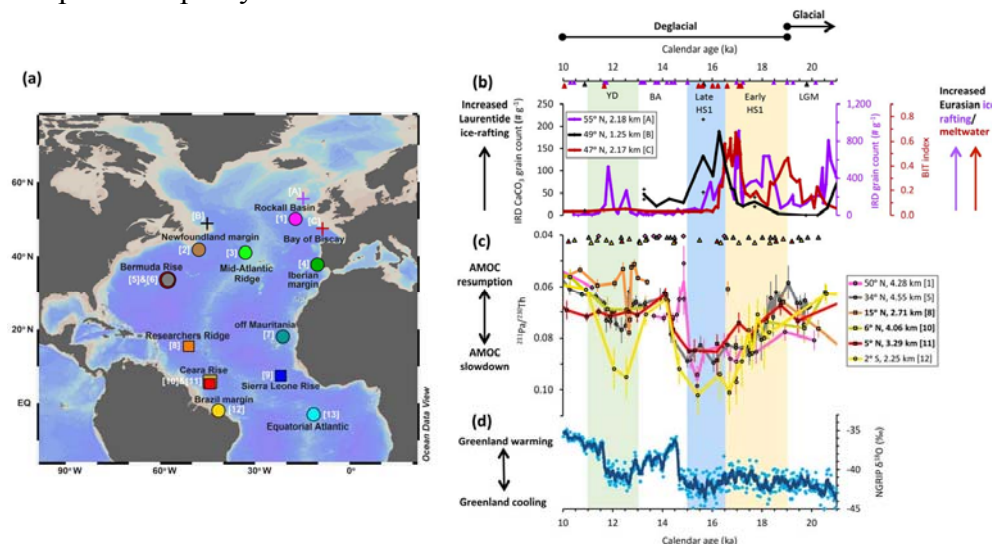
**Figure 5.** (Left) Replacement time of dissolved Fe across the GEOTRACES cruise section [GA03](#). This replacement time is how long it would take to replace all of the iron in the North Atlantic Ocean with a source of iron derived from the quantifiable delivery of the crustal isotope thorium-232 to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

## Reference:

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

**The role of melting ice in driving the slowdown of circulation in the western Atlantic Ocean revealed by protactinium-thorium ratio**

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



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

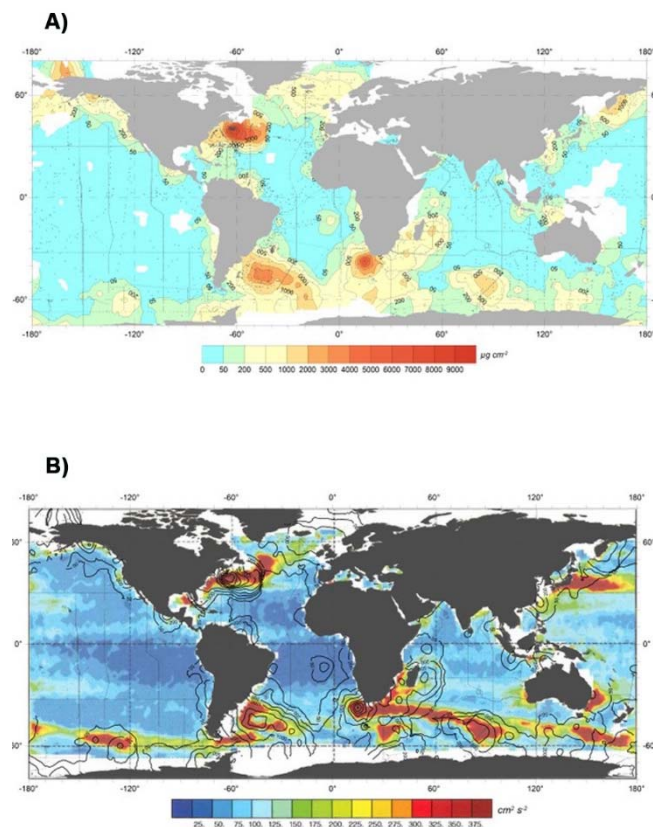


# 3-12

*Atlantic  $^{231}\text{Pa}/^{230}\text{Th}$  records, (d) Northern Greenland temperature proxy record. The AMOC slowdown observed (c) is consistent with the timing of an increased Eurasian ice melting (b).*

Reference:

Ng, H.C., Robinson, L.F., McManus, J.F., Mohamed, K.J., Jacobel, A.W., Ivanovic, R.F., Gregoire, L.J., Chen, T. (2018). Coherent deglacial changes in western Atlantic Ocean circulation. *Nature Communications*, 9(1), 2947. DOI: <http://doi.org/10.1038/s41467-018-05312-3>



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

## 52 years of benthic nepheloid layer data!

A database of 2,412 profiles collected using the Lamont Thorndike nephelometer from 1964 to 1984 is used to map turbid nepheloid layers globally by Gardner and co-workers (2018, see reference below).

The authors compare maps from that period with maps based on data from 6,392

profiles measured using transmissometers from 1979 to 2016. Beyond this comparison, the final goal is to gain insight about the factors creating/sustaining Benthic Nepheloid Layers (BNLs). Eleven maps, including mean surface Kinetic Energy (KE), are discussed here. The similarity between general locations of high and low particle concentration BNLs during the two time periods indicates that the driving forces of erosion and resuspension of bottom sediments are spatially persistent during recent decadal time spans, though in areas of strong BNLs, intensity is highly episodic. This work confirms that topography, well-developed current systems, and surface KE and EKE play a role in generating and maintaining BNLs.

Reference:

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

### 3. Activities

### 3.1 GEOTRACES intercalibration activities

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

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

The focus for the past reporting period was almost completely shifted away from the intercalibration of datasets towards the preparation of procedures for the upcoming Intermediate Data Product, implementing improvements of the S&I report submission procedure, together with the data management committee and the International Project Office. The main focus has been on the development of an on-line portal system for analysts to submit their data to be calibrated. This system will track all the data and the permissions for future IDPs. This involved the participation of the S&I co-chairs at a DMC meeting in Liverpool (17-18 April 2018) and in Toulouse on 24-26 September 2018 for the IDP data portal meeting.

During the S&I Committee meeting in December 2018, a key task was the introduction of the new committee members to the existing intercalibration procedures for labs, cruise data sets, and materials. The existing procedures for the submission of intercalibration reports to the S&I Committee, and the subsequent review and approval were discussed in detail, before agreeing on suggestions how these procedures should be reflected in the data submission portal. The S&I Committee produced a template for the portal whereby an analyst will download a form with a series of questions to be answered that will act as the intercalibration report. The analyst will then upload this back through the portal.

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

# 3-14

## Laboratory intercomparisons & Consensus Materials:

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

### Sea ice:

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

### Seawater Consensus materials:

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

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

### Leachable Particulate data:

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

### Next Meeting:

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

## 3.2 Data management for GEOTRACES

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

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



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

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

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

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

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

The DMC meeting was one month after Mohamed took on the post of GEOTRACES data manager. Discussions focused on data quality control of IDP2017 and future IDPs, as well as the control of datasets submission workflow and how to track the data sets approved by the S&I Committee and author permissions.

During the SSC meeting, the following points, among others, were addressed under GDAC perspectives:

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

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**Contribution to GEOTRACES metadata portal effort:** Although GDAC is not in charge of the development and the future deployment of GEOTRACES metadata portal, GDAC contributed in defining the functional requirement of such a web portal (GEOTRACES Metadata Portal meeting, 25-26 September in Toulouse, France). One of the major tasks assigned to GDAC from the Toulouse meeting was to review the list of cruise identifiers and GEOTRACES cruise names and aliases, and to find a way to standardise these different labels in order to avoid using free-text for cruise names in the metadata portal. This list was established and circulated in a spreadsheet, as a first step, to the Toulouse meeting participants. GDAC is working on providing this standardised cruise list through a webservice enabling “real-time” updates to be distributed instantly.

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

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

## *Summary of GEOTRACES cruises that have taken place in the period April 2018-April 2019:*

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

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

Cruise	Chief scientist	GEOTRACES scientist	Type	Period	Location
TONGA (GPpr14)	Cecile Guieu & Sophie Bonnet	Géraldine Sarthou, Matthieu Bressac & Hélène Planquette	Process Study	2019-10-31 — 2019-12-06	Western Tropical South Pacific
KK1902 (GP09)	Yihua Cai & Kuanbo Zhou	Zhimian Cao, Minhan Dai & Liping Zhou	Section Cruise	2019-04-25 — 2019-06-10	North West Pacific
IN2019_V02 (GIpr08 bis)	Tom Trull	Philip Boyd	Process Study	2019-03-12 — 2019-04-05	Southern Ocean (East Indian sector)
BAIT* (GApr13)	Rod Johnson	Peter Sedwick	Process Study	2019-03* — 2020-03*	Sargasso Sea (BATS site)

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

**In summary**

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

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

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

### 3.3 GEOTRACES International Project Office

The GEOTRACES International Project Office (IPO) is based at the Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS) in Toulouse, France. The IPO is staffed by one 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 GDAC in securing information about upcoming cruises; and
- interacting with GEOTRACES national committees and groups, as well as other international projects.

This year, we want to highlight the following activities:

- On-line GEOTRACES metadata portal

An important activity conducted this year by the IPO is supporting the development of an on-line GEOTRACES metadata portal. Following the success of the GEOTRACES Intermediate Data Products, the amount of data to be reviewed, managed, and processed has increased considerably. In order to facilitate the tasks of the core group of persons working on the construction of the product (co-chairs of S&I Committee, Data Management Committee, Parameter Naming Committee, GDAC, IPO, and Reiner Schlitzer), this group met in Liverpool in April 2018 for a joint DMC and GEOTRACES Executive meeting to review the lessons learned from the IDP2017 and to propose to the SSC the creation of a on-line GEOTRACES metadata portal that should allow: (1) a major participation of the data contributors in directly filling in the information necessary for the evaluation and management of their data, (2) quick and easy access to this information for all people involved in the construction of the product, (3) and more automatic management of these data to allow easier updating and evaluation. The SSC approved the development of this portal by Guillaume Brissebrat (head) and Arnaud Mière (IT) from the Observatory Midi-Pyrénées Data Center (SEDOO, Toulouse, where the IPO is hosted), as they have already successfully worked with the IPO in developing the GEOTRACES publication database. In September 2018, the IPO organised a working meeting with Guillaume and the IDP core group in order to define the structure and functional requirements of the portal

(GEOTRACES Data Portal meeting, 25-26 September 2018, Toulouse, France). The IPO contributed to this meeting by proposing a working document defining a possible structure for the portal. Following the meeting, the IPO is assisting the developers (Guillaume and Arnaud) in providing input when needed, chasing the information from GEOTRACES senior scientists and pushing developers to get the portal done in time. Regular meetings are held between the IPO and the SEDOO every two weeks.

- GEOTRACES Publications Database (<<http://www.geotraces.org/library-88/scientific-publications/peer-reviewed-papers>>)

New search functionalities have been added to the database. For instance, it is now possible to make more complex searches equivalent to using Boolean operators such as “AND”, “OR” and “NOT”.

- Guide for cruise PI (<<http://www.geotraces.org/cruises/cruise-summary/cruise-guide>>)

The IPO has developed an interactive flow chart to guide cruise leaders on the overall process from getting their cruise designated as a GEOTRACES cruise or compliant data until the data resulting from the cruise are included in the IDP. A short version of the guide is also available for cruise leaders to distribute to cruise participants to guide them on the process to get their data in the IDP (<<http://www.geotraces.org/dp/submit-data/flow-chart>>).

- GEOTRACES Best Practices (<<http://www.geotraces.org/about-us/geotraces-policies/geotraces-best-practices>>)

The IPO has published a list of best practices for GEOTRACES researchers, with the objective of (1) informing scientists of the actions needed in order for the IPO to properly broadcast their GEOTRACES scientific results and activities and (2) reinforcing information on the process to get cruise data included in the next IDP. The best practice list covers the following topics: data; cruise information; scientific publications; special sessions and issues; outreach and educational materials and activities; national events and activities; and networking.

- New GEOTRACES Programme Brochure

A new GEOTRACES brochure presenting the GEOTRACES programme, along with the Intermediate Data Products, is being developed.

- GEOTRACES website (<<http://www.geotraces.org>>)

The main menu bar of the GEOTRACES website has been improved in order to simplify access to the Intermediate Data Product and GDAC web site resources. During the 2018 SSC meeting, the IPO distributed a survey to SSC members asking for feedback and suggestions for improvement. Ninety per cent of the respondents found the web site well organised and have no suggestions for improvement. The main proposal for improvement is to enhance the search engine. In the coming reporting period, the IPO plans to undertake a major overhaul of the web

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site that will imply moving the web site from Joomla! to WordPress. All the suggestions received will be taken into account during this process.

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

- GEOTRACES Science Highlight keyword search cloud

The IPO has now published almost 200 science highlights on the GEOTRACES web site. In order to improve the search functionality, the IPO is currently working on setting up a GEOTRACES Science Highlight keyword cloud that will allow for users to click on a keyword and get a list of science highlights corresponding to the keyword selected. This functionality will be available on the new GEOTRACES web site.

- Logistics for meetings

The IPO hosted the GEOTRACES Data Portal Meeting (25-27 September 2018) and has provided assistance in the organization of the GEOTRACES Data Management Meeting (April 2018, Liverpool, UK), the GEOTRACES SSC Meeting (July 2018, Taiwan), the GEOTRACES-PAGES Workshop (November 2018, Aix-Marseille, France) and the GEOTRACES S&I meeting (November 2018, Marseille, France).

- Some statistics

- 36 new highlights published (191 in total)
- 6 eNewsletters published, including one special issue (bimonthly 33 in total)
- 295 new peer-reviewed papers included in the GEOTRACES Publication Database (1,230 in total)
- 108 new articles published on the GEOTRACES website
- 72 new announcements sent through the GEOTRACES mailing list
- 546 likes in Facebook (top post reached 1.6K)
- 780 likes and 1,007 followers for Twitter (top tweet reached 3.1K)
- 157 new subscribers on the GEOTRACES mailing list

***Featured outreach activity: Float Your Boat Project***

The 2015 U.S. Arctic GEOTRACES initiative participated in a novel outreach project coordinated with Dave Forcucci (U.S. Coast Guard Marine Science Coordinator) to involve students and the public with an Arctic research cruise on the U.S. Coast Guard Ice-breaker *Healy*. GEOTRACES was a perfect match for the inaugural kick off of "Float your Boat" < <https://www.facebook.com/explorethearctic/> >. More than one thousand 8-inch (20-cm) long cedar boats were commissioned (funded by the National Science Foundation) from the Center for Wooden Boats (CWB.org) in Seattle, Washington, USA and distributed to school groups, scout troops, and science open-house events around the country. Students personalized their boats with bright colours and after returning to Seattle the boats were branded with floatboat.org

and packed into the hold of the *Healy* for the journey to the North Pole. During the GEOTRACES cruise, four groups of boats were deployed on ice floes between 87.5°N and 80°N on the 150°W meridian, each with a small satellite buoy (deployed by the University of Washington Applied Physics Laboratory to study ice movement). The Iridium satellite-linked buoys provided an opportunistic chance for high-resolution, real-time tracking of the boats for about a year and a half. After drifting with the Arctic ice, it was hoped that the boats would eventually be freed from its grasp and float to a distant shore to be discovered and reported. This project is described by our teacher-at-sea, Bill Schmoker, at <https://www.polartrec.com/expeditions/us-arctic-geotraces/journals/2015-09-16> and by Prof. Timothy Kenna, the scientist who was in charge of deploying the boats: <https://blogs.ei.columbia.edu/2015/09/21/arctic-magic-one-research-vessel-multiplies-to-hundreds/>



In October 2018, three years after deployment, one of these small wooden boats was found by a gentleman in Iceland, Bolli Thor (in the picture). He wrote: “These are the coordinates 63.962285, -22.734055 where I found one of your little wooden boats, near small town called Sandgerði in Iceland where I live. I found it at my favorite spot, where I usually walk with my dog called Tyra.”. Remarkably, we identified the pre-deployment picture, the student and school (Upper Nyack Elementary School).

The drift track data stopped in February, 2017. Two groups of boats ran aground in northern Canada, while two groups, deployed near the North Pole, were entrained in the Trans Polar drift and travelled south, through Fram Strait, into the East Greenland Current. A boat from these groups made it to Iceland.

### 3.4 GEOTRACES Workshops

A list of completed or planned GEOTRACES Workshops is available below:

#### GEOTRACES Taiwan Training Workshop, 26 July 2018, Taipei, China-Taipei

A GEOTRACES-Taiwan training workshop was organised the day immediately after the SSC meeting in Taipei. The workshop was organised by Tung-Yuan Ho (Academia Sinica) and attended by 62 participants from Taiwan. GEOTRACES lectures were given by 8 SSC members (Phoebe Lam, Andy Bowie, Maeve Lohan, Hajime Obata, Reiner Schlitzer, William Landing and Tung-Yuan Ho), including topics such as GEOTRACES and an IDP2017 introduction; seawater trace metal clean sampling and pre-treatment; particle sampling and analysis; TEIs on-board sampling and FIA&CSV analysis; and Ocean Data View and marine biogeochemistry. The workshop was followed by a fruitful debate between GEOTRACES international scientists and local scientists.



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For further information please visit the GEOTRACES web page:

<http://www.geotraces.org/images/stories/documents/workshops/2018-GEOTRACES-Workshop-Info.pdf>

Introduction to the Awesome OCIM, 12 August 2018, Boston, USA

A workshop to introduce Awesome OCIM (AO), a new modeling toolbox designed to bring cutting-edge transport matrix models to a wide community of users, was held in August in Boston in the vicinity of the Goldschmidt 2018 meeting. The AO uses Ocean Circulation Inverse Model (OCIM) transport for realistic global 3D circulation. Within this circulation, broad features of the distribution of many marine TEIs can be achieved by combining just a few processes. For example, iron might be modeled as a combination of atmospheric and sedimentary sources, biological uptake, and remineralization. Thorium might be modeled with radioactive production and decay, plus scavenging. A clickable interface allows the user to include processes such as these, and tune their magnitude to match observed GEOTRACES data. Further adjustments to biogeochemical cycling can be achieved with changes to the underlying Matlab code.

For further information please visit the GEOTRACES web page:

<http://www.geotraces.org/meetings/meetings-by-year/eventdetail/331/-/introduction-to-the-awesome-ocim>

GEOTRACES-PAGES Synthesis workshop: Trace Element and Isotope Proxies in Paleoceanography, 3 - 5 December 2018, Aix-Marseille, France

60 researchers from the PAGES and GEOTRACES communities participated to an intensive 2.5-day workshop on 3-5 December 2018 in Aix en Provence, France. The aim of the workshop was to conduct open discussions on the applicability and scientific gaps regarding the use of some proxies exploited to infer past circulation, surface productivity and particle fluxes. Indeed, thanks to the GEOTRACES programme, these tracers are more and more documented in the modern ocean, raising important caveats in the understanding of their present behaviour and distributions. Fruitful discussions were conducted between the two communities to identify common exciting perspectives and workshop products.

Further information is available at the workshop web page:

<https://geotracespages.sciencesconf.org/>



**Figure 8.** *Participants at the Joint GEOTRACES-PAGES Workshop.*

Biogeosciences Workshop, 8-10 November 2018, Johnsson Center, Woods Hole, USA  
 In November 2018, approximately 28 international scientists from the fields of chemical oceanography, -omics, physiology and modeling met to explore the need and scope of a new international programme loosely aimed around coupling the potential insight onto ocean ecosystems from new advances from different fields (primarily arising from the Tara Oceans and GEOTRACES efforts). The meeting was sponsored by the Scientific Committee on Oceanic Research, the Ocean Carbon and Biogeochemistry programme, and the Moore Foundation. Four invited speakers highlighted the insight and added value gained from integrating observations of micronutrients and -omics. Reflection on previous programmes identified the importance of intercalibration and data management, and the need for -omics intercalibration efforts and investment in novel data management and open-access, user-friendly platforms. Equally, the need for new ecosystem modelling approaches, capable of integrating the mechanisms and feedbacks emerging from omics datasets was noted. Time was spent discussing the potential extent and impact of a new program, as well as choosing Biogeosciences as the name. The role of different types of contributions from different nations, including the routes to funding Biogeosciences activities were discussed, and the overall outcome of the meeting is summarised in the broad mission statement above. This preliminary broad mission of Biogeosciences will be improved by further input and feedback from the international community. It is anticipated that feedback from the wider community will occur first via national meetings during 2019 and then in a larger international forum, which would shape the preliminary science plan in much more detail.

For further information please visit: [www.biogeosciences.org](http://www.biogeosciences.org)

BioGEOTRACES-Japan begins, 19-21 September 2018, Nagasaki, Japan

A workshop, entitled "BioGEOTRACES-Japan begins" was held on 19-21 September 2018 in Nagasaki, Japan to evaluate the potential of biological studies related to trace elements and their isotopes (TEI) in the ocean, and to find the future directions of these studies in Japan. For three days, 15 registered Japanese scientists took part in the workshop. Drs. Maria Maldonado

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(University of British Columbia, Vancouver) and Tung-Yuan Ho (Academia Sinica, Taipei) were invited as guest speakers. The workshop consisted of 3 invited talks, 3 keynote talks and 11 research topics related to GEOTRACES & BioGEOTRACES. During the workshop, recent scientific findings, and possible future collaborations among TEI chemists, biologists and modellers were discussed. It was decided to organise BioGEOTRACES-Japan in order to promote these comprehensive studies and cooperate with the international community.

7<sup>th</sup> Kaplan Symposium: Tracers in the Sea: Trace Elements and their Isotopes in the Oceans, Future Directions and Instrumental Frontiers, 11-13 February 2019, Eilat, Israel

The 7<sup>th</sup> Kaplan Symposium was dedicated to GEOTRACES research with the title “Tracers in the Sea: Trace Elements and their Isotopes in the Oceans, Future Directions and Instrumental Frontiers”. The workshop was attended by 72 scientists and it was organised by Adi Torfstein and Yeala Shaked at the Institute of Earth Sciences of the Hebrew University of Jerusalem. The symposium had four scientific themes: trace element cycling in seawater and marine particulates; the role of atmospheric dust in marine biogeochemistry; novel isotope systems in the oceans; and instrumental developments in marine geochemistry. Several GEOTRACES senior scientists were invited speakers, including Eric Achterberg, GEOMAR, Germany; Mark Altabet, U. Massachusetts Dartmouth, USA; Bob Anderson, Lamont-Doherty Earth Observatory, Columbia University, USA; Gideon Henderson, Oxford University, UK; Catherine Jeandel, LEGOS, University of Toulouse, France; William Landing, Florida State University, USA; Claire Rollion-Bard, Institut de Physique du Globe de Paris, France; and Derek Vance, ETH, Switzerland.

For further information please visit the symposium web site: <https://sites.google.com/view/7th-kaplan-symposium/home>

## 3.5 GEOTRACES Summer School

The second GEOTRACES Summer School will be held from 23 to 28 September 2019 in Cadiz, Spain. It aims at teaching the skills and knowledge necessary for a good understanding of the biogeochemical cycles of trace metals. It will bring together 36 students and 10 world-leading international scientists.

Particular objectives of the summer school are:

- Gaining knowledge and experience on oceanographic sampling campaigns for collection of samples for the analysis of trace metals.
- Students should be capable to properly select and conduct analytical strategies for the study of trace metals in marine samples.
- Gaining knowledge on bio-geochemical cycles of metals in the ocean and their speciation.
- Data management to analyse the role of trace metals in the ocean.

The summer school is organised by the International GEOTRACES programme, the University of Cádiz (UCA), the Andalusian Institute of Marine Sciences of the Spanish National Research Council (ICMAN-CSIC), and the International Campus of Excellence of the Sea (CEI·MAR); with funding from the Scientific Committee on Oceanic Research (SCOR)/GEOTRACES, the

General CSIC Foundation, the International Doctorate School of Marine Studies (EIDEMAR), and CEI-MAR.

For further information please visit the Summer School web site: <https://geotraces.uca.es/>

### 3.6 Special sessions at international conferences featuring GEOTRACES findings

Several GEOTRACES special sessions were held or are planned in major international conferences including the following:

Association for the Sciences of Limnology and Oceanography (ASLO) 2018 Summer Meeting, 10 -15 June 2018, Victoria, BC, Canada

For further information: <https://aslo.org/victoria2018/main>

*GEOTRACES-related session:*

\*SS82: Emerging Models of Trace Metal Bioavailability to Aquatic Organisms

Conveners: David Semeniuk, Randelle Bundy and Anne Cremazy

Goldschmidt 2018, 12- 17 August 2018, Boston, USA

For further information: <https://goldschmidt.info/2018/index>

*GEOTRACES session:*

\*Session 07i: New Insights in Marine Trace Element Biogeochemistry

Conveners: Christian Schlosser, Florian Scholz, Rene Boiteau, Tim Conway, Daniel Ohnemus, Jennifer McKay, William Homoky and Jessica Fitzsimmons

Fourth Xiamen Symposium on Marine Environmental Sciences (XMAS), 6-9 January 2019, Xiamen China

For further information: <http://mel.xmu.edu.cn/conference/4xmas>

*GEOTRACES session:*

\*The role of trace metals in controlling structure and function of microbial communities in contemporary oceans

Conveners: Punyasloke Bhadury, Yeala Shaked, Maria Maldonado, Yihua Cai and Chris Bowler

ASLO 2019, Aquatic Sciences Meeting, 23 February - 2 March 2019, San Juan, Puerto Rico

For further information: <https://aslo.org/sanjuan2019/main>

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*GEOTRACES session:*

\*SS51. New views on the biological transformation of metals in the marine environment

Conveners: Randelle Bundy, Shane Hogle, Katherine Heal, Kristen Buck and P. Dreux Chappell

***Forthcoming:***

SOLAS Open Science Conference, 21-25 April 2019, Sapporo, Japan

For further information: <https://www.confmanager.com/main.cfm?cid=2778>

*GEOTRACES session:*

\*Atmospheric deposition of iron, ocean biogeochemistry and marine emission of biological aerosols

Conveners: Akinori Ito (JAMSTEC), William M. Landing (Florida State University) and Douglas S. Hamilton (Cornell University)

27th IUGG General Assembly, 8-18 July, 2019, Palais des Congrès in Montréal, Québec, Canada

*GEOTRACES relevant sessions:*

\*P02 Physics and biogeochemistry of semi-enclosed, shelf seas and coastal zones

Conveners: Peter Zavialov, Jianping Gan, Osmar Moller Jr, Katrin Schroeder

\*P09 Marine biogeochemistry through time: nutrient, trace metal, oxygen, and carbon cycling in the past, present and future

Conveners: Kate Hendry, Zanna Chase, Katja Fennel and Patrick Rafter

Goldschmidt 2019, 18-23 August 2019, Barcelona

For further information: <https://goldschmidt.info/2019/>

*GEOTRACES or GEOTRACES-related sessions:*

\*10c: Arctic and sub-Arctic Large Scale Ocean Processes: What can We Learn from Tracers?

Conveners: Núria Casacuberta, Michael Karcher

\*10j: Biogeochemical Cycles of Low Oxygen Zones and their Response to Ocean Deoxygenation

Conveners: Nicole Bale, Darci Rush, Ruifang Xie, Tim Conway, Insa Rapp, Laura Bristow

\*10k: Trace Metal Cycling and Radioisotope Tracers of Ocean Biogeochemistry (GEOTRACES)

Conveners: Aridane G. González, Hannah Whitby, Amber Annett, Emilie Le Roy

\*08j: Dynamics and Fluxes of the Exogenic Carbon Cycle and Interactions with Biogeochemical Cycling

Conveners: Gerhard Kuhn, Norbert Frank, Thomas Chalk, William Gray

Keynote: Robert Anderson

\*10a: Linking Marine Silicate Alteration to Carbon Cycle and Trace Elements Budgets in the Ocean and Sediment

Conveners: Wei-Li Hong, Jianghui Du, Antoine Crémière

Keynote: Catherine Jeandel

\*10h: The Oceanic Particle Flux and its Cycling within the Deep Water Column

Conveners: Maureen Conte, Rut Pedrosa Pamies, Phoebe Lam, Henry Ruhl

\*12a: Hydrobiogeochemical Processes at the Sediment-Water Interface: Wetlands, River Corridors and Coastal Zones

Conveners: Dipankar Dwivedi, Xingyuan Chen, Joseph Tamborski, Valentí Rodellas, Edward O'Loughlin, Yamin Deng, Virginie Sanial

Keynote: Christof Meile

\*13e: Radionuclides in the Environment: Modeling, Experimental, Scaling, Controlling Chemical/Microbial/Hydrological Processes

Conveners: Peter H. Santschi, Daniel Kaplan

\*13f: Trace Elements Speciation: Novel Methodologies and Insights into Transformations Influencing their Global Biogeochemical Cycle

Conveners: Sylvain Bouchet, Adrien Mestrot

### 3.7 Capacity building

Activities It is a GEOTRACES strategy to organise training workshops for one day or two days immediately after a SSC meeting in order to increase the local impact of these meetings (e.g., the GEOTRACES-Taiwan training workshop held in July 2019, see GEOTRACES Workshops above for further details). In this sense, the capacity building benefits are considered at the time of selecting the host of the meeting. During the training workshops selected SSC members give lectures, along with local scientists, to national scientist and students. Note that SSC meetings are also an occasion for a fruitful exchange with local scientists and often-parallel scientific meetings are organised during the breaks all along the SSC meeting.

#### Travel Grants

GEOTRACES has requested support from SCOR to enable scientists from developing countries and countries with economies in transition to participate in the second GEOTRACES Summer School.

Sampling Systems

It

is a goal of GEOTRACES that every nation carrying out oceanographic research should have access to a trace metal-clean sampling system. GEOTRACES offers guidance based on past experience in the design and construction of sampling systems, as well as advice in operating these systems as shared facilities. At the time of writing this review, a document “Recommendations for nations developing a trace metal-clean sampling system” is being prepared by Greg Cutter (Old Dominion University, past S&I Committee co-chair). This document will summarise the lessons learned during past guidance experiences and it will be a great resource for other countries wishing to develop trace metal-clean sampling. This document will be available on the GEOTRACES Capacity Building web page

<http://www.geotraces.org/science/geotraces-activities>.

An updated status of trace metal-clean sampling systems to support GEOTRACES research is provided in the table below. Scientists interested in developing one of these systems for their own use are encouraged to contact the GEOTRACES IPO or any member of the SSC, who will arrange for contact with an appropriate person to provide technical information about the design, construction, and cost of a system.

<b>Nation</b>	<b>Status</b>	<b>System/ Carousel</b>	<b>Bottles</b>	<b>Depth</b>
Australia (Australia National University)	Complete	Powder coated aluminium, autonomous 1018 intelligent rosette system (General Oceanics)	12 x 10-L Teflon-lined Niskin-1010X (General Oceanics)	6000 m; 6 mm Dynex rope
Australia (Marine National Facility)	Complete	Polyurethane powder-coated aluminium autonomous Seabird rosette with CTD and other sensors, auto-fire module, and all titanium housings and fittings	12 x 12-L Teflon-lined OTE external-spring Niskin-style bottles	1750 m 9mm Dyneema rope or 200 m 6 mm Dyneema rope wth coupling to 6000 m CTD wire
Australia (Marine National Facility)	Complete (backup system)	Polyurethane powder-coated aluminium autonomous Seabird rosette with CTD and other sensors, auto-fire module, and all titanium housings and fittings	12 x 12-L Teflon-lined OTE external-spring Niskin-style bottles	1750 m 9mm Dyneema rope or 200 m 6 mm Dyneema rope wth coupling to 6000 m CTD wire
Brazil	Complete	GEOTRACES WATER SAMPLER - 24-bottle sampler for use with modem equipped 911plus CTD	24 X 12-L GO-Flo	3000 m; Kevlar cable



Canada	Complete	Powder coated aluminium with titanium CTD housing, Seabird Rosette	24 X 12-L GO-Flo	5000 m conducting Vectran
China - Beijing	Complete	Seabird Rosette. Powder coated aluminium with titanium pressure housings and fittings	24 x 12-L OTE GO-Flo; 24 X 12-L Teflon-lined Niskin-X	8000 m; conducting Kevlar
China – Taipei	Complete	Teflon coated rosette	Multi- size GO-Flo	3000 m; Kevlar line
France	Complete	Powder coated aluminium with titanium pressure housing for CTD	24 X 12-L GO-Flo	8000 m; conducting Kevlar
Germany	Complete	Powder coated aluminium with titanium pressure housings and fittings	27 x 12-L OTE GO-Flo	8000 m; conducting Kevlar
India	Complete	Powder coated aluminum with titanium pressure housings and fittings	24 X 12-L Niskin-X	8000 m; conducting Kevlar
Israel	Complete	Powder coated aluminium, SeaBird Rosette	12 X 12-L Niskin; 8 X 12-L GO-Flo (Teflon coated)	2000 m, steel conducting cable
Italy	Complete	Go-Flo bottles on Kevlar line	5 x 20-L Go-Flos	Kevlar
Japan	Complete	Powder coated aluminium	12-L Niskin-X	7000 m; Vectran conducting Cable
Netherlands	Complete	Titanium frame	24 X 24-liter ultraclean polypropylene	10000 m; conducting Kevlar* <i>*There is only one cable 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	Standard 12 positions	5-L Niskin-X	

# 3-30

	development	CTD Rosette GO		
Poland	Complete* (although the cable is steel)	Powder coated aluminum, SeaBird Rosette	8x 10L GoFlo	3000m, steel conducting cable
Poland	Complete	Single bottle	10l G-FLO X Teflon coated	300m Kevlar
Poland	Complete	Teflon pump on-line	Surface water pump	1.5m fixed
Poland	In development	Pump CTD	Teflon hose 10mm	Up to 200m
Russia	Complete* (although the cable is steel)	Powder coated aluminium, SeaBird Rosette SBE9p occupied CTD SBE 9+	24 × 12-L Niskin bottles	4000 m, steel conducting cable
Russia	In development (by 2021–2024)	Powder coated aluminium, SeaBird Rosette and all titanium housings and fittings	GO-FLO, Niskin-X, 24 × 12-L	10000 m, conducting Kevlar
South Africa	Complete	Powder coated aluminium, titanium housing/fittings	24 X 12-liter GO-Flo	6500 m; Kevlar cable
South Korea	Complete	Titanium frame	24 × 12L PVDF	10,000 m; conducting Kevlar
UK	Complete	2 x Titanium frame, Ti pressure housings	24 10-L OTE 24 10-L OTE	2 x 8000m conducting Kevlar
USA - CLIVAR	Complete	Powder coated aluminium	12 X 12-L GO-Flo	1500 m; conducting Kevlar
USA - GEOTRACES	Complete	Powder coated aluminium with titanium pressure housings and fittings	24 X 12-L GO-Flo	8000 m; conducting Kevlar
USA- University of Alaska Fairbanks	Complete	Seabird Rosette. Powder coated aluminium with Ti parts and pressure housing. Fires at pre-programmable depths	12 X 5-L Teflon-lined Niskin-X	No Kevlar line available yet.
USA- Old Dominion University	Complete	Seabird Rosette. SBE-19plusV2 CTD unit. Powder coated aluminium with Ti parts and pressure housing. Fires at pre-	12 X 5-L Teflon-lined Niskin-X	2000 m 0.5-inch Kevlar wire

		programmable depths		
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

##### ***Towards Intermediate Data Product 2021***

The development of the web-based metadata portal will continue over the next reporting period, with the goal for it to be functional for data contributors to use for the IDP2021. GEOTRACES hopes that this data portal will not only smooth the production of the remaining intermediate and final data products for the GEOTRACES programme, but will provide a data management framework for future programmes.

Also, having completed over half of the global survey (Figure 1) GEOTRACES plans to continue to advance the GEOTRACES field programme through section cruises (with one section cruise from China scheduled so far for the next reporting period), supplemented by process studies (3 already planned for next year) that have investigated particular physical, chemical, and biological processes regulating the distributions of these TEIs.

##### ***Capacity building through GEOTRACES Summer Schools***

Following the successful GEOTRACES Summer School organised in August 2017 in Brest, France, GEOTRACES has decided to organise GEOTRACES summer schools every two years. GEOTRACES is currently preparing the second summer school, to be held in September 2019 in Cadiz, Spain as reported previously. The third GEOTRACES summer school is already planned to be held in 2021 in Germany.

In addition, a workshop “Southern Ocean Biogeochemistry in a Changing World” will be held in Hobart, Australia, on 12-13 September 2019, immediately after the 2019 SSC meeting. The workshop will bring together national and international GEOTRACES scientists as well as local students and researchers in biogeochemical oceanography, modelling and paleoceanography focused on the Southern Ocean’s response to climate change.

##### ***Scientific workshops***

The following scientific meetings will be organised:

##### ***Regional and Basin Workshops:***

A fourth East Asia GEOTRACES Workshop will be organised in Xiamen in fall 2019 (initially planned for early 2019). This workshop will continue collaboration advanced by the third East Asia Workshop (16-18 January 2017, Sapporo, Hokkaido, Japan), where a first picture of the current status of the studies in the Northwestern Pacific Ocean (NWPO) was completed and important scientific questions and directions for regional collaborative studies were defined.

## *Future synthesis of results workshops:*

GEOTRACES plans to continue its synthesis efforts initiated by the suite of three synthesis workshops (in 2015, 2016 and 2018, <http://www.geotraces.org/science/synthesis-of-results>) by organising a synthesis workshop on sensitivity to trace elements and isotopes cycles to global change to be held in 2021 (tentatively) in Germany. This workshop will combine new knowledge gained from GEOTRACES with the latest models of TEIs. The workshop should also continue the efforts in bringing together the observational and modelling communities fostered by the three Data-Model Synergy Workshops that GEOTRACES organised in 2007, 2009, and 2011. In any case, the synthesis will continue to respond to the expectation that GEOTRACES results benefit other oceanographic disciplines.

## ***Biogeosciences effort***

GEOTRACES investigators and the IPO will provide advice and recommendations, as appropriate, to help launch this new programme as needed.

## Acknowledgements

Once more, we wish to express our gratitude to SCOR and Ed Urban for the continuous support and valuable advice generously given to help with the implementation of the GEOTRACES programme.

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Maeve Lohan and Walter Geibert (Co-Chairs of the GEOTRACES S&I Committee)

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May 2019

### 3.2 Surface Ocean–Lower Atmosphere Study (SOLAS) (joint with Future Earth, WCRP, and CACGP)

*Miller, Penner*

#### Terms of Reference:

- To develop the Surface Ocean - Lower Atmosphere Study (SOLAS) Science Plan and an Implementation Strategy, in accordance with guidance of the sponsoring organisations.
- To oversee the development of SOLAS in accordance with its Science Plan/Implementation Strategy.
- To collaborate, as appropriate, with other related projects of IGBP, WCRP, SCOR and CACGP and related projects and programmes (e.g., IHDP, DIVERSITAS, IOC and the Global Ocean Observing System (GOOS), etc.)
- To establish appropriate data management policies to ensure access to, sharing of, and preservation of SOLAS data, taking into account policies of the sponsors.
- To report regularly to SCOR, IGBP, WCRP and CACGP on the state of planning and accomplishments of SOLAS.
- The SOLAS SSC, its subsidiary groups and International Project Office shall operate in accordance with the operating procedures for IGBP Projects and as required by other co-sponsors.

**Chair:** Lisa Miller (Canada)

**Other Members:** Katye Altieri (South Africa), Philip Boyd (Australia), Erik van Doorn (Germany), Cristina Facchini (Italy), Laura Gallardo (Chile), Santiago Gassó (USA), Arne Körtzinger (Germany), Mohd Talib Latif (Malaysia), Maurice Levasseur (Canada), Anoop Mahajan (India), Peter Minnett (USA), Jun Nishioka (Japan), Jurgita Ovadnevaite (Ireland), Anna Rutgersson (Sweden), Parvatha Suntharalingam (UK), Guiling Zhang (China-Beijing)

**Executive Officer:** Jessica Gier

**Executive Committee Reporter:** Joyce Penner

*SOLAS Annual Report to SCOR*

Reporting period: May 2018 - May 2019

Version of 11 June 2019 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**

The SOLAS science mission is organised around five core themes:

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

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

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

**I.b. SOLAS 2015-2025. Implementation Strategy**

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

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

- iCACGP annual meeting, Montreal, Canada, 6-8 July 2019
- BEPSII annual meeting at the IGS Sea Ice Symposium, Winnipeg, Canada, 16-18 August 2019
- Global Ocean Oxygen Network (GO<sub>2</sub>NE) summer school, Xiamen, China, 2-7 September 2019
- Shipping & the Environment II, Gothenburg, Sweden, 4-6 September 2019
- OceanObs'19, Hawai'i, USA, 16-20 September 2019

- SCOR annual meeting, Toyama, Japan, 23-25 September 2019
- IGAC SSC meeting, Mexico City, Mexico, 29-30 October 2019
- CATCH annual meeting at the AGU, San Francisco, USA, 9-13 December 2019
- CATCH Open Science workshop, Berkeley, USA, 7-8 December 2019
- Ocean Sciences Meeting, San Diego, USA, 16-20 February 2020
- Treatise on basic research needs in evaluating proposed climate intervention strategies
- 8<sup>th</sup> International Symposium on Gas Transfer at Water Surfaces, Plymouth, United Kingdom, 19-22 May 2020
- Asian SOLAS-remote sensing workshop, 2020
- 8<sup>th</sup> international SOLAS Summer School, Cape Verde, 2021
- SOLAS Open Science Conference, 2022

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

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

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

**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, where they are stored, and the data originators. The portal is hosted by NASA and the metadata files are stored on the international standard Global Change Master Directory (GCMD). The resource is freely available to the entire community at <http://www.solas-int.org/solas-metadata-portal.html>.

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



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

Biogeochemical Exchange Processes at Sea-Ice Interfaces (BEPSII) started in 2011 with a focus on sea-ice biogeochemistry and was a SCOR working group from 2012 until September 2016, and has since been endorsed as a SOLAS-CliC Activity (from 2016) and as a SCAR Action Group (from 2017). Following a workshop in Switzerland in 2018, the BEPSII community is now preparing a Position Analysis on Arctic sea-ice biogeochemical responses to climate change for submission to *Nature Communications*. The BEPSII [Special feature](#) in *Elementa: Science of the Anthropocene* has been finalised (18 accepted contributions), the 5- year activity plan was completed, and a new website and logo were launched. SOLAS will support the BEPSII annual meeting, which is planned for 16-18 August 2019 in Winnipeg, Canada.

**I.f. *Collaboration with International Global Atmospheric Chemistry (IGAC) on Cryosphere and Atmospheric Chemistry (CATCH)***

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

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

**I.g. *Collaboration with Integrated Marine Biosphere Research project (IMBeR): SOLAS/IMBER Ocean Acidification (SIOA)***

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

- Ensuring that scientists have access to recently updated, state-of-the-art software to calculate ocean acidification parameters, and that ocean acidification data collected across the globe is properly archived, accessible, and comparable. This is particularly relevant in the context of reporting of countries on the UN SDG 14.3.
- Acting as a hub for global stakeholders interested in ocean acidification, providing unique resources such as its comprehensive bibliographic database and a news stream updated daily with info on ocean acidification scientific articles, media coverage, jobs, and meetings.
- Providing increased awareness about ocean acidification with contributions to major reports and working groups, highly visible international events and meetings, training courses, the OA-ICC web site, news stream, and communication products.
- Providing enhanced capacity in ocean acidification research and networking opportunities

in 2018 for 53 researchers from 32 IAEA Member States.

- Contributing to the development of international and regional coordination activities and networks, such as GOA-ON, LAOCA, and OA-AFRICA.
- Contributing to methodology development for UN SDG14.3 on Ocean Acidification and helping countries to get ready to report towards that target.
- [Improved software](#) used by the scientific community working on ocean acidification to calculate carbonate chemistry parameters, e.g. to offer new options to allow for uncertainty propagation and to use of new oceanographic standards (TEOS-10) for temperature and salinity. The most recent work on uncertainty propagation is described in [Orr et al. 2019](#).
- The largest OA community meeting, “The Ocean in a High CO<sub>2</sub> World”, will take place in Lima, Peru, 7-10 September 2020.

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

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

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

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

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

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

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

**II.a. SOLAS Workshops on Core Themes 4 and 5**

**SOLAS Event Report Issue12**

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

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

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

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

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

Aerosol Production ([SOAP](#)); North Atlantic Aerosols and Marine Ecosystems Study ([NAAMES](#)); Reef to Rain Forest ([R2R](#)); Impact of Biogenic versus Anthropogenic emissions on Clouds and Climate: towards a Holistic Understanding ([BACCHUS](#)); and Variability of the American Monsoon Systems Ocean-Cloud-Atmosphere- Land Study ([VOCALS](#)).

**II.b. SOLAS Open Science Conference 2019**

[www.solas-int.org/osc2019.html](http://www.solas-int.org/osc2019.html)

The 7<sup>th</sup> **SOLAS Open Science Conference** 2019 took place on 21-25 April 2019 in Sapporo, Hokkaido, Japan, and was organised by a committee of 31 people, hailing from 17 countries. We welcomed 190 attendees from 30 countries to share their research and knowledge of SOLAS science. The five core themes and three cross-cutting themes outlined in the current [SOLAS Science Plan 2015-2025](#) were covered by plenary lectures. These were complemented by poster session for each of the Themes in the afternoons, as well as nine discussion sessions (three in parallel on three days) which provided an opportunity for the community to identify new frontiers to explore. Details about the speakers, plenary/poster/discussion sessions can be found on the SOLAS OSC website, and a SOLAS Event Report will be published.

In addition to the main conference, a day-long **Climate Intervention Workshop** (<https://www.confmanager.com/main.cfm?cid=2778&nid=16739>), led by Philip Boyd of the Institute of Marine and Antarctic Studies at the University of Tasmania, Australia, and Cliff Law of the National Institute of Water and Atmospheric Research, New Zealand, brought together observationalists, modellers, and legal experts working on the interactions between the ocean and the atmosphere. The workshop assessed how SOLAS science can contribute to the debate around negative CO<sub>2</sub> emission technologies (NETs) and geoengineering. In addition to considering different NET approaches and how SOLAS science can add rigour to their assessment, the workshop examined international governance frameworks and discussed how the air-sea research community can help inform the decision-making process in climate intervention. SOLAS recognises our responsibility in investigating the scientific basis of many carbon dioxide removal and solar radiation management techniques, such as iron fertilisation, alkalinity addition or increasing surface ocean reflectivity.

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

## **II.c. SOLAS Summer School**

### **SOLAS Event Report Issue 11**

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

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

## **II.d. Collaboration with ESA**

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

## **II.e. Collaboration with PICES**

### **SOLAS Event Report Issue 10**

SOLAS was engaged with the scientific planning of the 4<sup>th</sup> International Symposium on "The Effects of Climate Change on the World's Oceans", Washington DC, USA, 4-8 June 2018. SOLAS organised a session on Eastern Boundary Upwelling Systems: Diversity, Coupled Dynamics and Sensitivity to Climate Change. This was a PICES, ICES, IOC, FAO event. PICES jointly sponsored the Early-Career Scientist Day during the SOLAS Open Science Conference, 21 April 2019, in Sapporo, Japan. A report about the event will be published in the next PICES newsletter. The PICES-2018 annual meeting took place in Yokohama, Japan, 25 October-4 November 2018. Lisa Miller attended the meeting and represented SOLAS. The next PICES annual meeting will take place 16-27 October 2019 in Victoria, BC, Canada. Lisa Miller will represent SOLAS at the meeting.

## **II.e. SOLAS Integrated Atmosphere-Ocean time-series station in Cape Verde**

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

Project partners:

- GEOMAR, Kiel, Germany: Christa Marandino, Anja Engel, Arne Körtzinger
- University of York, York, UK: Lucy Carpenter

- Weizmann Institute of Science, Rehovot, Israel: Ilan Koren
- Instituto Nacional de Desenvolvimento das Pescas, Cape Verde: Osvaldina Silva
- Instituto Nacional de Meteorologia e Geofísica, Cape Verde: Bruno Faria

#### **II.f. Additional SOLAS events**

Past events:

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

#### **II.g. SOLAS publications**

- Version 3 of the FluxEngine toolbox, which is an output from the joint ESA - SOLAS project, 'OceanFlux GHG' and is an open source toolbox for calculating air-sea CO<sub>2</sub> gas fluxes from in situ, model, and Earth observation data. The FluxEngine can be used through the web portal (<http://www.ifremer.fr/cersat1/exp/oceanflux/>).
- A discussion of new methods for inferring CO<sub>2</sub> fluxes at high resolution from satellite data: Hernández-Carrasco I, Garçon V, Sudre J, Garbe C, and Yahia H (2018) Increasing the Resolution of Ocean pCO<sub>2</sub> Maps in the South Eastern Atlantic Ocean Merging Multifractal Satellite-Derived Ocean Variables. *IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING*, 56(11): 6596 - 6610. DOI: 10.1109/TGRS.2018.2840526
- SOLAS remote sensing priorities identified at the ESA-SOLAS workshop in Frascati, Italy, 2016:



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

- A new tool for assessing uncertainties in the ocean CO<sub>2</sub> system from the SOLAS-IMBeR Ocean Acidification working group:

Orr JC, Epitalon J-M, Dickson AG, and Gattuso J-P (Nov 2018). Routine uncertainty propagation for the marine carbon dioxide system. *Marine Chemistry* 207: 84-107.

- A synthesis of the results from the SOLAS-sponsored NETCARE project:  
Abbatt JPD, Leaitch WR, Aliabadi AA, Bertram AK, Blanchet JP, et al. (2019) New insights into aerosol and climate in the Arctic. *Atmospheric Chemistry and Physics Discussions*, European Geosciences Union, 19, 2527–2560, 2019.  
<https://doi.org/10.5194/acp-19-2527-2019>
- A synthesis of the results from the SOLAS-sponsored NAAMES project:  
Behrenfeld MJ, Moore RH, Hostetler CA, Graff J, Gaube P, Russell LM, Chen G, Doney SC, Giovannoni S, Liu H, Proctor C, Bolaños LM, Baetge N, Davie-Martin C, Westberry TK, Bates TS, Bell TG, Bidle KD, Boss ES, Brooks SD, Cairns B, Carlson C, Halsey K, Harvey EL, Hu C, Karp-Boss L, Kleb M, Menden-Deuer S, Morison F, Quinn PK, Scarino AJ, Anderson B, Chowdhary J, Crosbie E, Ferrare R, Hair JW, Hu Y, Janz S, Redemann J, Saltzman E, Shook M, Siegel DA, Wisthaler A, Martin MY, and Ziemba L (2019) The North Atlantic Aerosol and Marine Ecosystem Study (NAAMES): Science Motive and Mission Overview. *Frontiers in Marine Science*. 6:122. doi: 10.3389/fmars.2019.00122
- SOLAS Event Report series:
  - [Issue 13, March 2019](#). SOLAS session at XMAS IV, Xiamen, China, 6-9 January 2019.
  - [Issue 12, January 2019](#). Two consecutive workshops on SOLAS Core Themes 4 and 5, Roma, Italy, 27-29 November 2018.
  - [Issue 11, December 2018](#). The 7th international SOLAS Summer School, Cargèse, Corsica, France, 23 July - 4 August 2018.
  - [Issue 10, August 2018](#). Session on: „Eastern Boundary upwelling systems: diversity, coupled dynamics and sensitivity to climate change” at ECCWO, Washington DC, USA, 2-8 June, 2018.
  - [Issue 09, May 2018](#). Workshop on: “Remote Sensing for Studying the Ocean Atmosphere Interface”, Potomac, Maryland, USA, 13-15 March, 2018.
- SOLAS Position Statement on Climate Intervention  
<http://solas-int.org/statement-on-geoengineering.html>

- SOLAS Code of Conduct  
<http://solas-int.org/code-of-conduct.html>

#### **II.h. SOLAS communications**

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

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

**Monthly e-news:** 13 SOLAS e-news have been sent to over 1000 SOLAS scientists since the last SCOR report in May 2017. The monthly e-news releases compile news from SOLAS, opportunities for meetings, abstract submission deadlines, recent publications, vacancies, and news from relevant partner projects and collaborators. In May 2018, with implementation of the General Data Protection Regulation, the SOLAS mailing list was deleted and re-established. Before deletion, the mailing list included 2500 subscribers and is now back to 1060. Past issues of the e- news can be viewed on the SOLAS website: <http://solas-int.org/archive.html>.

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

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

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

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

#### **II.i. SOLAS national networks**

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

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

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

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- Australia: Sarah Lawson and Andrew Bowie
- Belgium: Nathalie Gypens
- Brazil: Leticia Cotrim Da Cunha \*
- Canada: Jon Abbatt
- Chile: Laura Farias \*
- China (Beijing): Minhan Dai
- China (Taipei): Chonlin Lee
- Denmark: Lise Lotte Soerensen and Mikael Sejr \*
- Finland: Lauri Laakso
- France: Rémi Losno \*
- Germany: Christa Marandino and Hartmut Herrmann
- India: VVSS Sarma \*
- Israel: Yoav Lehahn
- Ireland: Brian Ward \*
- Italy: Chiara Santinelli \*
- Japan: Yuzo Miyazaki
- Korea: Kitack Lee
- Mexico: Jose Martin Hernandez Ayon \*
- Netherlands: Jan-Berend Stuut
- New Zealand: Cliff Law
- Norway: Siv Lauvset
- Peru: Michelle Graco \*
- Poland: Timo Zielinski
- Russia: Sergey Gulev \*
- South Africa: Sarah Fawcett \*
- Spain: Alfonso Saiz-Lopez
- Sweden: Katarina Abrahamsson \*
- Turkey: Baris Saglihoglu, Mustafa Koçak, Nazli Olgun
- UK: Tom Bell \*
- USA: Rachel Stanley

SOLAS has not yet received the 2018 report

## **II.i. Endorsed project since the previous year's report**

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

## ***III. Income and expenses for the past year and budget for the coming year, including funding from all sources (not only SCOR funding)***

- Executive director salary, office space and in kind provided by GEOMAR until

December 2020.

- Project officer salary provided by NSF funding via SCOR/GEOMAR. Esther Rickert was hired for 4 months in 2018 and was hired with the new NSF fund from January 2019.
- Project officer salary, office space and in kind provided by MEL until September 2020
- US-NSF via SCOR annual grant of 25kUSD through 2018, 2/3rd cover the cost of the SSC meetings.
- US-NSF via SCOR annual grant of 32-35kUSD until September 2021. About half to cover the cost of the SSC meetings.
- Future Earth annual block grant of 15kEUR contributing to the costs of the SSC meetings.

#### **IV. Update on the Scientific Steering Committee and International Project Office status since the last report**

##### **IV.a. SOLAS Scientific Steering Committee**

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

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

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

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

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

In January 2019, two new SSC members were appointed:

- Anoop Mahajan (M, India)
- Jurgita Ovadnevaite (F, Ireland)

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

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

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

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

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

**IV.b. SOLAS International Project Office**

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

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

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



### 3.3 International Quiet Ocean Experiment

*Urban, Halpern*

**Terms of Reference:**

The IQOE Science Committee (SC) has the primary responsibility for coordination and management of IQOE activities that are international in nature. The main duties of the IQOE SC include the following:

- Advocate for and coordinate international activities of the IQOE Science Plan
- Review and report annually on progress in project implementation
- Refine the future project agenda annually and propose updates to the Science Plan as necessary
- Develop and oversee any subcommittees, working groups, and task teams necessary to implement international activities related to the IQOE Science Plan
- Establish and oversee the IQOE International Project Office (IPO) and its staff
- Serve as a resource for national committees
- Organize planning workshops as needed to establish research and observational priorities
- Promote partnerships with other projects and organizations to achieve IQOE goals
- Promote discussion about IQOE benefits with and among all stakeholders
- Endorse proposals for activities that are directly within the IQOE Science Plan or whose results can add to IQOE
- Define IQOE products
- Seek financial resources from national and international funding sources to support the implementation of IQOE
- Foster dissemination of the findings of the IQOE program
- Define indicators and metrics for evaluation and demonstration of IQOE progress

**Co-Chairs:** George Frisk (USA) and Peter Tyack (UK)

**Other Members:** Olaf Boebel (Germany), Christ de Jong (The Netherlands), Robert McCauley (Australia), Jennifer Miksis-Olds (USA), Hanne Sagen (Norway), Steve Simpson (UK), Jakob Tougaard (Denmark), and Alexander Vedenev (Russia)

**Executive Officer:** Ed Urban

**Executive Committee Reporter:** David Halpern



## IQOE News #3 August 2019

**Endorsed projects (7):** ADEON, JOMOPANS, JONAS, PHYSIC, QUIETMED2, SanctSound, TANGO

**Publications in Aquatic Acoustic Archive:** 4,689

**IQOE Email List:** 211

### **IQOE Co-founder Knighted**

IQOE co-founder Ian Boyd was knighted at the 2019 Queen's Birthday Honors in June 2019 "for services to Science and Economics on Food and the Environment" and for his "visionary leadership in his role as Chief Scientific Advisor at DEFRA", the UK Department for Environment, Food and Rural Affairs. Congratulations, Sir Ian!

### **ECO Magazine Special Issue on Underwater Sound**

IQOE sponsored development of a [special issue](#) of *ECO Magazine* focused on ocean sound. This issue is a well-balanced presentation of the issues related to sound in the ocean, with excellent articles on science, technology, management, and the environment. This publication will be helpful for public outreach related to IQOE. The embedded sounds from the ocean from DOSITS (<https://dosits.org/>) should be especially helpful to attract public interest to the issue of sound in the ocean.

### **IQOE Data Office**

The Alfred Wegener Institute in Bremerhaven, Germany has recently announced that it is seeking one data scientist and one data engineer to develop a data system for ocean acoustics data. These individuals will work with the IQOE Working Group on Data Management and Access and Working Group on Standardization to implement their terms of reference. Advertisements for these positions are available at [Data Scientist](#) and [Data Engineer](#). The deadline for applications is 31 August 2019. Please contact [Olaf Boebel](#) if you have questions.

### **OceanObs'19**

IQOE Science Committee members Jennifer Miksis-Olds and Hanne Sagen teamed with Bruce Howe, Eric Rehm, Peter F. Worcester, and Georgios Haralabus to produce a community white paper for OceanObs'19 entitled "[Observing the Oceans Acoustically](#)". This paper combines information about the use of both passive and active acoustics to study the global ocean. The paper has been published in *Frontiers in Marine Science*.

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IQOE and the IQOE WG on Arctic Acoustic Ecosystems have submitted abstracts for posters to be presented at the meeting.

Please let [Ed Urban](#) know if you will be attending OceanObs'19. We are hoping for a good showing of people interested in observations of acoustics and bioacoustics in the ocean, and may plan some acoustics-focused event.

## **Ocean Sound Essential Ocean Variable (EOV)**

The Biology and Ecosystems Panel of the Global Ocean Observing System (GOOS) has adopted an [Ocean Sound EOV](#), under the responsibility of IQOE. An IQOE Panel supported by the Partnership for Observation of the Global Ocean (POGO) proposed this EOV and created the specification sheet. IQOE and GOOS are discussing next steps to progress this EOV, including the potential for an implementation meeting in the coming year.

## **News from Endorsed Projects**

### **JOMOPANS: Joint Monitoring Programme for Ambient Noise North Sea**

Contributed by Niels Kinneging: “Jomopans implements a monitoring strategy for continuous sound in the North Sea. The project responds to requirements of the European Marine Strategy Framework Directive, but the resulting data will also be available for the wider community of underwater sound specialists.

The second year of Jomopans is crucial for the project. All activities are now in full swing and Jomopans scientists are enthusiastically working on the results. Most of the 14 measurement stations around the North Sea are now operational and data will be gathered for all seasons in 2019. In addition, the first soundscape maps are being produced through propagation modelling.

In the first half of 2019, the development of the GES Tool resulted in great progress. Michael Carder Ltd. was contracted to build the tool and in a very animated workshop the functionality of the tool was further detailed. After a short delay in 2018, the tool is now on track again.

Apart from the technical developments, the future use of Jomopans results is being discussed with the marine managers of all participating countries. In this way, the results can be adapted to the needs of the marine managers and the system can be made operational shortly after the project's end.

Jomopans participated in the Aquatic Noise conference in The Hague from 7 to 12 July and organized (in co-operation with IQOE) two workshops on monitoring underwater sound on 13 July, also in The Hague.

On 8 October, the Jomopans Midterm event will be held in London. This will be an opportunity to meet the Jomopans team, discuss the progress of Jomopans, the connection with other projects and learn more about sound in the sea. More information can be found shortly in our [newsletter](#) and on the Jomopans website ([www.northsearegion.eu/jomopans](http://www.northsearegion.eu/jomopans)).”

### **PHYSIC: Ports, Humpbacks, Y Soundscapes In Colombia**

Contributed by Kerri Seger: “During the month of May, two students at Javeriana University in Bogota continued data analysis to assemble time series of sound sources at the Morro Mico site. These students also submitted an abstract to the Senalmar conference in Barranquilla, Colombia, in October to practice their presentation skills and take ownership over processing cyclical sound comparisons in the dataset. Also during the month of May, Dr. Kerri Seger (PHYSiC PI) processed the Ecological Acoustic Recorder (EAR) sound samples as power spectral density percentiles. A diel cycle in humpback whale singing activity, with nighttime peaks, was easily discernible. Boat passes were only detectable in the 99<sup>th</sup> percentile, confirming expectations that this environment is relatively pristine compared with many other passive acoustic monitoring sites in more disturbed areas of the world, where boat engine noise occurs in lower percentiles more often. These results have been requested by numerous local councils and university groups writing a manifesto to petition the Colombian government not to proceed with port construction. These results were also disseminated at the Acoustical Society of America conference in Louisville, Kentucky, with Dr. Chris Verlinden presenting on the behalf of Dr. Seger, who was unable to attend. Journalists and filming agencies from the UK and Colombia have asked for statements about the soundscape of the Gulf of Tribugá during the last few weeks. Planning for the 2019 season began in May 2019.”



### **QUIETMED2: Joint programme for GES assessment on Descriptor 11-noise in the Mediterranean Marine Region (2019-2021)**

The IQOE Science Committee approved endorsement of QUIETMED2 in May 2019. This project will support implementation of the second cycle of the European Union’s Marine Strategy Framework Directive (MSFD). QUIETMED2 will assess the extent to which Good Environmental Status (GES) on underwater noise has been achieved in the Mediterranean Region. “The project will help implement this GES standard through

- i) a joint proposal of a candidate for an impulsive noise indicator in the Mediterranean Region;
- ii) a common methodology for Competent Authorities to establish threshold values on impulsive noise in the Mediterranean region;
- iii) a data and information tool to support the implementation of the monitoring programs of impact of impulsive noise based on the current joint impulsive noise register developed under QUIETMED project, which will be demonstrated on
- iv) an operational pilot of the tool; and
- v) several activities to boost regional cooperation efforts of the Barcelona Convention.”  
(from endorsement proposal)”

The QUIETMED2 consortium is made up of 11 entities from 8 EU Member States (Spain, Italy, Malta, Greece, Cyprus, Croatia, Slovenia and Denmark) and is linked to the Barcelona Convention (UNEP/MAP) and to other Conventions as OSPAR and HELCOM. This project will

help all EU Member States cooperate in the Mediterranean Marine Region to implement the next 6-year cycle of MSFD requirements. See <http://quietmed2.eu/>.

## **SanctSound: NOAA Navy Sanctuary Soundscape Monitoring Project**

IQOE approved endorsement of SanctSound in June 2019. From the SanctSound endorsement application: “The U.S. National Oceanic and Atmospheric Administration (NOAA) and the U.S. Navy are engaged in a multi-year effort to monitor underwater sound within the U.S. National Marine Sanctuary System. The agencies are working with numerous scientific partners to study sound within 7 national marine sanctuaries and one marine national monument, in waters off the east coast region of the United States (Stellwagen Bank, Gray’s Reef and Florida Keys National Marine Sanctuaries), the west coast region (Olympic Coast, Monterey Bay and Channel Islands National Marine Sanctuaries) and the Pacific region (Hawaiian Islands Humpback Whale National Marine Sanctuary and Papahānaumokuākea Marine National Monument). The project is designed to provide standardized baseline information as a context to understand both how much sound is introduced within these protected areas by specific sources and potential impacts to the areas’ marine taxa and habitats.”

## **Get your project endorsed**

IQOE would like to endorse any research project or observation activities that are relevant to IQOE. Information about the endorsement process and endorsed projects can be found at <http://www.iqoe.org/projects>. The benefits of endorsement include increased international visibility of endorsed projects, which are usually national or regional, and the potential for joint activities with other endorsed projects and with other IQOE-involved scientists

## **Changes in the IQOE Website**

- A link was added to the passive acoustic data from the MBARI MARS Cabled Observatory (see <https://iqoe.org/acoustic-data-portal>). The system provides access to hourly spectrograms from the Monterey Bay area collected since August 2015. More information about the system and its purpose can be found at <https://www.mbari.org/technology/solving-challenges/persistent-presence/mars-hydrophone/>.
- Information has been added to the Endorsed Projects page for the two newly endorsed projects, [QUIETMED2](#) and [SanctSound](#).
- The terms of reference and membership of the Working Group on Marine Bioacoustical Standardization were approved by the IQOE Science Committee and this information was added to the IQOE Web site (see <https://www.iqoe.org/groups/marine-bioacoustical-standardization>).

We still need help from the community to do the following (send update information to Ed Urban at [ed.urban@scor-int.org](mailto:ed.urban@scor-int.org)):

- update the database of passive acoustic observatories (<https://iqoe.org/systems>),
- submit IQOE-relevant papers for the IQOE literature database (<https://iqoe.org/library>)
- submit entries for the portal to acoustic data (<https://iqoe.org/acoustic-data-portal>)

- submit entries for the portal to marine animal sounds (<https://iqoe.org/marine-animal-sounds>), and
- submit projects for endorsement.

### **WG Progress**

IQOE established four working groups in 2016 and one in 2019:

- [WG on Acoustic Measurement of Ocean Biodiversity Hotspots](#) (chaired by Aran Mooney, USA): A subset of the group (Lucia Di Iorio, Mark Lammers, Aran Mooney, Miles Parsons, Craig Radford, and Jenni Stanley) met in The Netherlands on 13 June to finalize a review paper and discuss other aspects of the group's future work. The paper will summarize the advantages and challenges of measuring biodiversity using passive acoustic methods and will provide a framework for future research. This is one of the primary tasks of the working group. The group also discussed membership changes and affirmed its terms of reference. Participants discussed and outlined future projects that the team can work on together, including a multi-site experiment measuring the same parameters in different parts of the world with comparable methods, maybe even with the same equipment. Finally, the group discussed multiple funding options for future projects and working group meetings, and several white papers, which will be the group's goal after the framework manuscript is submitted.



Meeting of Acoustic Measurement of Ocean Biodiversity Hotspots WG in The Hague



- [WG on Arctic Acoustic Environment](#) (co-chaired by Hanne Sagen, Norway and Philippe Blondel, UK): The group met for the first time in Paris, France on 29-30 January 2019 and identified actions to implement the group's terms of reference. The group was represented at the [UACE2019 Conference](#) by Philippe Blondel and will be represented at [OceanObs'19](#) by Hanne Sagen.
- IQOE and the IQOE-endorsed Jomopans project (see earlier) co-sponsored concurrent workshops on "Guidelines for observation of ocean sound" and on "Monitoring continuous underwater sound – beyond acquisition" on 13 June 2019 in The Hague, Netherlands. These workshops were held on the day after Aquatic Noise 2019 and contributed to the work of the IQOE [WG on Data Management and Access](#) (chaired by Rob McCauley, Australia) and [WG on Standardization](#) (co-chaired by Christ de Jong and Michael Ainslie, Netherlands).

For the workshop on "Guidelines for observation of ocean sound", the organizers collected, analyzed, and summarized information about existing guidelines for measuring, processing, reporting, and managing ocean sound data from various national and international projects. The organizers presented results of the collated information at the workshop, including suggestions for standardized guidelines, for discussion with the participants. Organizers will report on the discussions of the workshop in a document that will provide guidelines where consensus could be achieved and describing the obstacles to reaching further consensus. After review by workshop participants and the IQOE WG on Standardization, the final report will be published on the IQOE website.

The purpose of the workshop on "Monitoring continuous underwater sound – beyond acquisition" was to discuss the requirements for data management, sharing and to find solutions for best possible harmonisation. Workshop participants developed the following declaration.

#### Declaration from the workshop

The participants of the workshop "Monitoring continuous underwater sound: beyond acquisition" state that the sharing of knowledge and data in the field of underwater acoustics is essential to progress in the scientific field as well as on the management of underwater sound. Measured and modelled data, and corresponding metadata, including the processing pathways, should be stored with the highest resolution possible in an easy-to-find repository.

Long-term international co-operation needs to be established and supported in order to realize an operational framework for sharing and disseminating acoustical raw and/or processed data from monitoring programmes.



Meeting of IQOE WGs on WG on Data Management and Access and WG on Standardization in The Hague

- The IQOE [WG on Marine Bioacoustical Standardization](#) was approved in June 2019 and held its kick-off meeting at the Park Hotel in The Hague on 13 July 2019. Chaired by Michele Halvorsen (USA) and Michael Ainslie (Netherlands), its present membership comprises Tomonari Akamatsu (Japan), Rebecca Dunlop (Australia), Dorian Houser (USA), Robert McCauley (Australia), Sander von Benda-Beckmann (Netherlands), and Paul Wensveen (Iceland). The purpose of this group is to increase comparability of results from different locations and institutions by promoting standardization in the field of marine bioacoustics. After the terms of reference are in place, the group's first task will be to develop an inventory of existing standards.



Meeting of Marine Bioacoustical Standardization WG in The Hague

### **National/Regional Activities**

#### **Canada**

##### **The MERIDIAN Underwater Acoustic Data Discovery Portal**

Contributed by Ines Hessler: “Have you ever thought about how convenient it would be if a platform existed that enables you to find available and well-described underwater acoustic data that you may want to assess for its suitability to support your research, advance the project you are currently working on, or simply get an overview of other acoustic datasets available in your region of interest?”

If you quietly answered yes to the above question, be assured that such platform will be available soon! We at [MERIDIAN](#) (Marine Environmental Research Infrastructure for Data Integration and Application Network), a Canada Foundation for Innovation funded national CyberInfrastructure project, are currently in the process of building a data discovery portal that will provide you with the opportunity to discover available underwater acoustic resources and contribute rich descriptions of your own datasets. The interface of the discovery layer will allow for web-based searching by keywords, geographical extent and other attributes. To contribute descriptions of your individual datasets (aka metadata) we are developing a web-based and user-friendly metadata submission form. For larger collections we offer direct harvesting of information using common information exchange protocols such as CSW (Catalog Service for the Web) and OAI-PMH (Open Archives Initiative Protocol for Metadata Harvesting).

We are currently in the process of testing the discovery portal and its workflows, initially internally but soon with a selected number of community members. We are aiming at completing

testing and feedback implementation in the course of the coming few months and will, hopefully, be able to make the discovery service's prototype available later in the year. For further information and inquiries don't hesitate to send an email to [meridian@dal.ca](mailto:meridian@dal.ca)."

#### United Kingdom

The [Underwater Sound Forum](#) held a [Bioacoustics Conference](#) on 17-18 April 2019.

#### USA

- The [U.S. Quiet Ocean Project](#) held a data "standards" workshop on 6-7 August 2018 in Washington, D.C. and has released a report from the workshop on [Recommendations Related to Passive Ocean Acoustic Data Standards](#).
- The U.S. SanctSound project was endorsed by IQOE.
- The U.S. Office of Naval Research issued a Broad Agency Announcement in 2018 to respond to research areas of interest to Task Force Ocean. White papers were due on 31 January 2019. The funded research that will result is likely to stimulate ocean acoustics research and support for graduate students and post-doctoral fellows in the United States in the next several years.
- As a direct result of IQOE discussions, passive acoustic monitoring was added to the [Stones Mooring in the Gulf of Mexico](#), funded by the funded by U.S. Gulf Research Program and Shell. The first results are being analyzed.

**IQOE Email List:** IQOE maintains an email list containing your first name, surname, and email address. We do not collect or store any additional information or share our email list with other organizations. If you wish to unsubscribe from the IQOE email list at any time, please click the "Unsubscribe" link at the bottom of this page.

**Upcoming Meetings**—New meetings have been added to the [calendar of IQOE-relevant events](#).

## 3.4 Integrated Marine Biosphere Research (IMBeR) project (joint with Future Earth)

*Claydon, Burkill*

### Terms of Reference

- To develop the IMBER Science Plan and Implementation Strategy, in accordance with guidance from the sponsoring organisations.
- To oversee the development of IMBER in accordance with its Science Plan and Implementation Strategy.
- To collaborate, as appropriate, with related projects of the sponsors IGBP and SCOR, and other related programmes and organisations (e.g., IHDP, DIVERSITAS, IOC and the Global Ocean Observing System (GOOS), etc.)
- To establish appropriate data management policies to ensure access to, sharing of, and preservation of IMBER data, taking into account the policies of the sponsors.
- To report regularly to SCOR and IGBP on the state of planning and the accomplishments of IMBER.

The IMBER SSC, its subsidiary groups and International Project Office shall operate in accordance with the operating procedures for IGBP Projects and the requirements of the other co-sponsors.

**Chair:** Carol Robinson (UK)

**Vice-Chairs:** Marion Glaser (Germany), Eugene Murphy (UK), Cisco Werner (USA)

**Other Members:** Laurent Bopp (France), Dan Costa (USA), Chris Cvitanovic (Australia), Mark Dickey-Collas (Denmark), Rubén Escibano (Chile), Gerhard Herndl (Austria), Alistair Hobday (Australia), Oscar Iribarne (Argentina), Olav Sigurd Kjesbu (Norway), Frank Muller-Karger (USA), Alice Newton (Portugal), Suvaluck Satumanatpan (Thailand), David VanderZwaag (Canada), Ingrid van Putten (Australia), and Ying Wu (China-Beijing).

**Executive Committee Reporter:** Peter Burkill

**Executive Officer:** John Claydon



## Annual Report to SCOR 2018 - 2019

### A. Introduction

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

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

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

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

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



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

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

The Science Plan and Implementation Strategy (SPIS 2016-2025) is developed around three Grand Challenges (GC) focussing on climate variability, global change and drivers and stressors. The qualitative and quantitative understanding of historic and present ocean variability and change (Grand Challenge I) are the bases for scenarios, projections and predictions of the future (Grand Challenge II). These are linked in Grand Challenge III to understand how humans are causing the variability and changes, and how they in turn are impacted by these changes, including feedbacks between the human and ocean systems. Priority research areas with overarching and specific research questions are identified for each Grand Challenge. The Grand Challenges are supplemented with four Innovation Challenges (IC) that focus on new and emerging topics. Specific members of the scientific steering committee are designated as “Challenge Champions” to oversee progress towards the objectives of the Grand Challenges made by the Regional Programmes, Working Groups, Endorsed Projects, and IMBeR meetings and other activities (Figure 1).

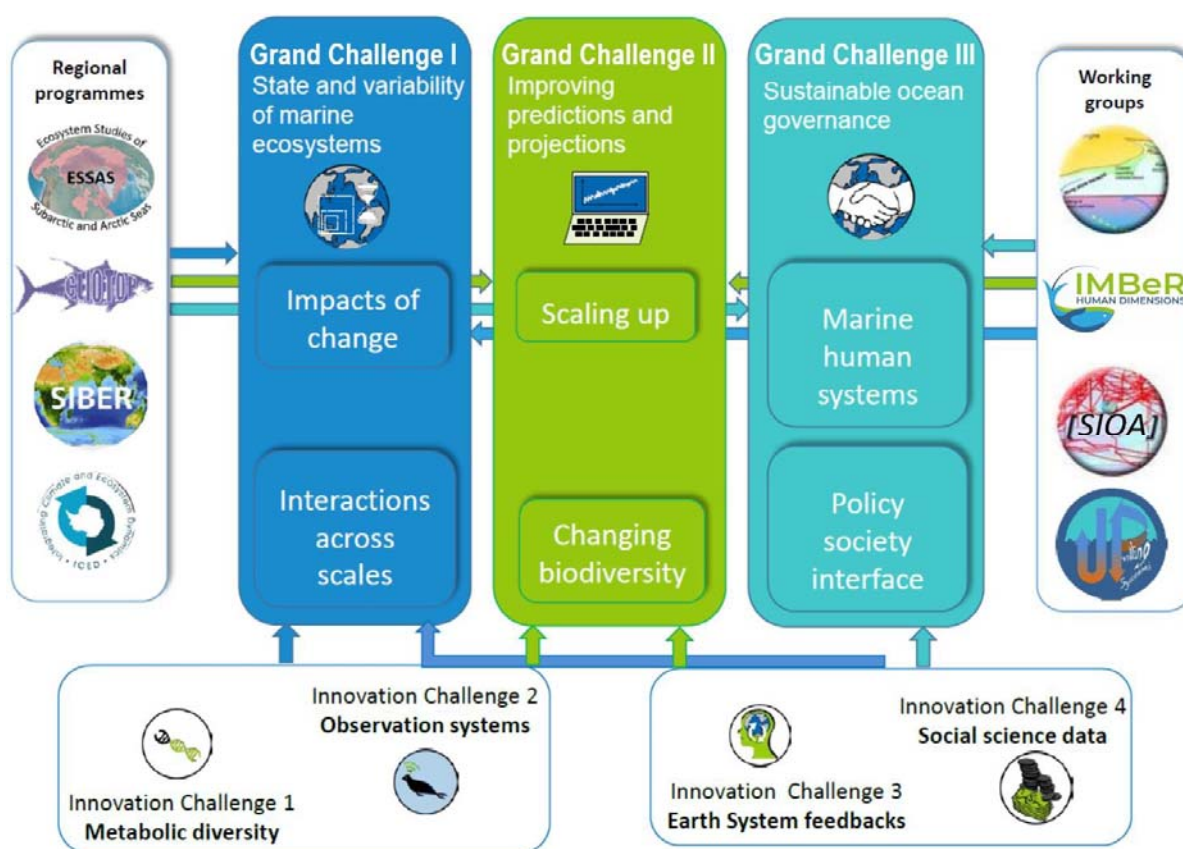


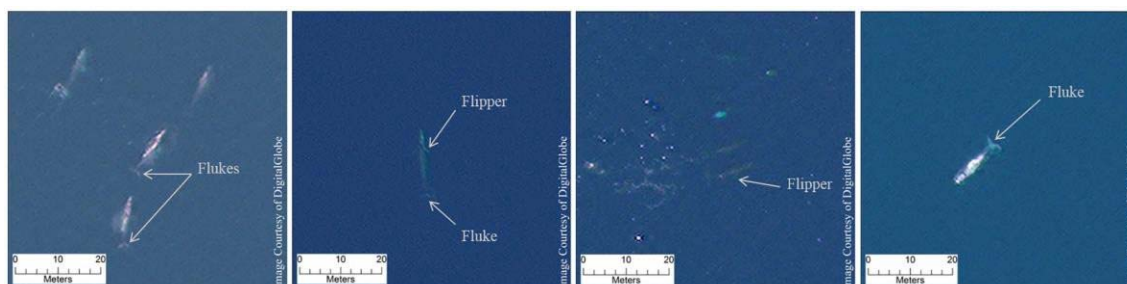
Figure 1. Contribution of the Regional Programmes, Working Groups and Innovation Challenges to the objectives of the Grand Challenges

### C. Selected science highlights in 2018-2019

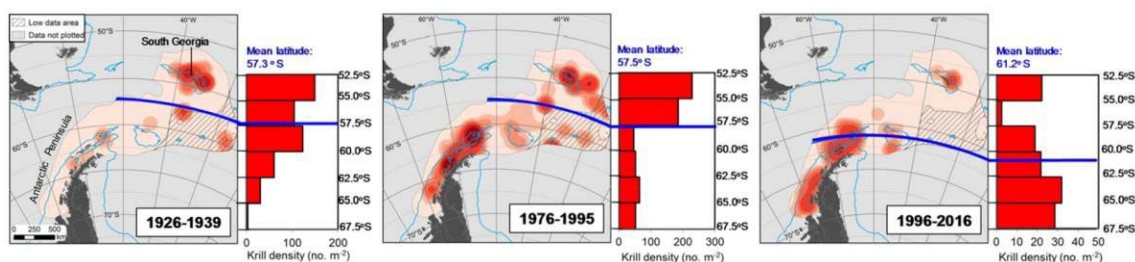
A list of publications is given in Section K, and activities which have specifically progressed the objectives of the Science Plan are given in Section G. Here we identify a selection of studies and activities where IMBeR has contributed to the progression of fundamental knowledge in marine interdisciplinary science.

[For details of the figures presented, please refer to the original publication referenced]

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



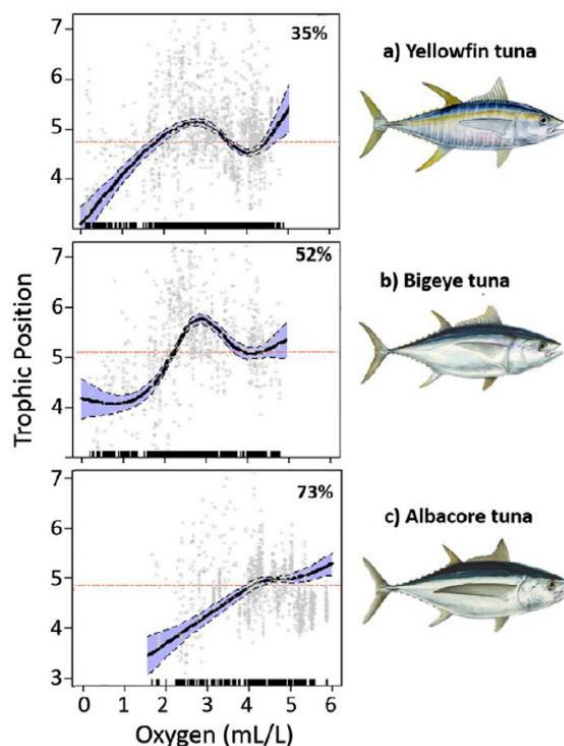
2. **Atkinson et al. (2019)** (IMBeR regional programme ICED – Integrating Climate and Ecosystem Dynamics) observed major shifts in the distribution of krill: over the last 90 years, **krill (*Euphausia superba*) have moved and contracted southwards in response to warming seas**. Along with changing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



**3. Orr et al (2018)** (SOLAS-IMBeR Ocean Acidification Working Group - SIOA) developed **new tools for estimating uncertainties for calculated ocean acidification variables**.

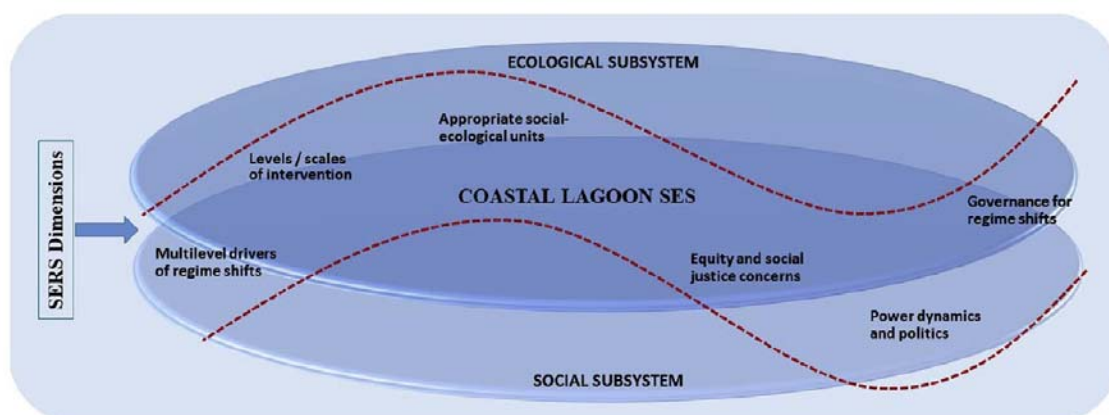
Previously, such uncertainties were seldom reported. These authors created software to propagate uncertainties and provided it as add-ons to four commonly used public packages that compute marine carbonate chemistry [CO2SYS- Excel (Visual Basic), CO2SYS-MATLAB (MATLAB), seacarb (R), and mocsy (Fortran)]. These tools, along with a new type of diagram to visualise the uncertainties, should allow propagating uncertainties to become standard practice for calculations of marine CO<sub>2</sub> system variables.

- 4.** In one of the first global studies of its kind, using stable isotopes **Pethybridge et al (2018)** identified previously unknown **effects of warming oceans on marine top predators and their food webs**. Through the network created by CLIOTOP (Climate Impacts on Oceanic Top Predators, IMBeR Regional Programme), they were able to collate samples of three species of tuna collected over a 16-year period by multiple research programmes. They found that the oxygen minimum zones – areas starved of oxygen – have a large effect on the food chain, and in the foraging behaviour of top predators, and that patterns were consistent across different regions. Because deoxygenation is a direct effect of climate change, these low oxygen zones are predicted to expand. The findings have broad implications and improve our ability to model the effects of climate change on ocean ecosystems.



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

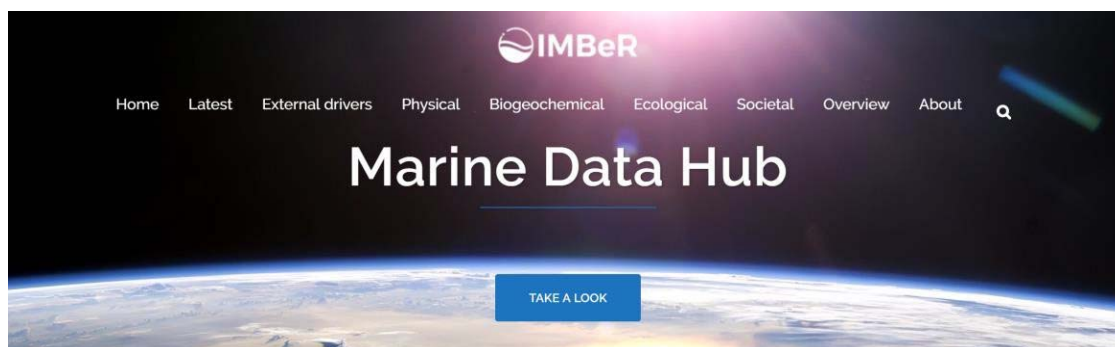




7. The IMBeR regional programme SIBER (Sustained Indian Ocean Biogeochemistry and Ecosystem Research) led the development of the first **Special Issue on the Second International Indian Ocean Expedition (IIOE-2)** for publication in **Deep-Sea Research II – The 2<sup>nd</sup> International Indian Ocean Expedition (IIOE-2): Motivating New Exploration in a Poorly Understood Basin, Volume 1**. This is the first compendium of scientific papers to emerge from IIOE-2 and three of the editors are/were SIBER SSC members. A second volume is in preparation and is scheduled to be published later in 2019, with contributions from SIBER SSC members.



8. The IMBeR **Marine Data Hub** was launched (<https://ccdatahub.ipsl.fr/>). The Marine Data Hub is a product arising from the IMBeR IMBIZO 5 *Critical Constraints on Future Projections of Marine Systems* workshop. The hub links ecological, physical, biogeochemical and societal data sets for global models. It raises awareness of high-quality data products, and encourages exchange.

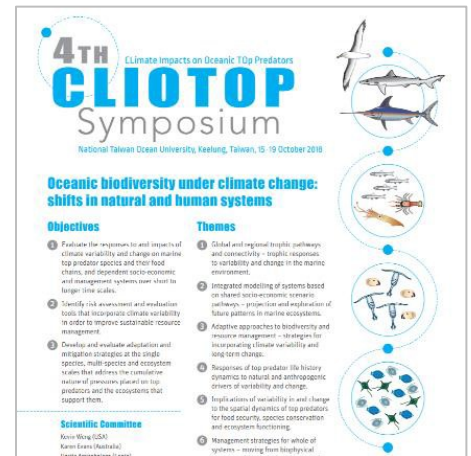


9. **Future Oceans2** – the 2<sup>nd</sup> IMBeR Open Science Conference (OSC) was held in Brest, France, on 17-21 June 2019. The meeting was attended by 553 delegates, with 27 sessions and 10 workshops, 549 oral presentations, 194 Posters, and an Early Career Researcher Day

during which IMECaN (the IMBeR Interdisciplinary Marine Early Career Network) was launched.



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



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



#### **D. Regional Programmes**

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

*Ecosystem Studies of Subarctic and Arctic Seas (ESSAS)* <https://essas.arc.hokudai.ac.jp/>

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

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

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

*Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED)*  
[www.iced.ac.uk/index.htm](http://www.iced.ac.uk/index.htm)

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

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

ICED contributed to the IMBeR *Future Oceans2* OSC, convening the session ‘Managing the effects of change on Southern Ocean ecosystems: Understanding, challenges, and solutions’. This was linked to ‘Southern Ocean ecosystems: a workshop on the Marine Ecosystem Assessment for the region (MEASO)’. The aim of the session was to reflect on the past decade of ICED science and apply insights to improve research on understanding and projecting changes in

# 3-66

Southern Ocean ecosystems so that it is relevant to conservation and management decisions. The session focussed on: (i) Southern Ocean species and ecosystems; (ii) Modelling and projections of ecological change; (iii) Policy implications and decision-making (with a focus on integrated understanding of natural and human systems interactions). The workshop explored and discussed (i) the merits of different methods for assessing the status and trends of ecosystems, (ii) the respective utilities of the results for making management decisions on mitigating or adapting to prognoses of change, and (iii) how best to communicate the results to end users. The workshop was attended by natural and social scientists.

## *CLimate Impacts on Oceanic TOP Predators (CLIOTOP)*

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

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

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

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

## *Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER)*

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

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

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

SIBER convened a session at *Future Oceans2* 'The Second International Indian Ocean Expedition (IIOE-2): Motivating New Exploration in a Poorly Understood Basin'. The session brought together observationalists and modellers to exchange information and understanding on



the current ‘state-of-knowledge’, gaps, challenges, and future directions in observing and modelling the complex physical, biogeochemical and ecological processes in the Indian Ocean in the context of anthropogenic influences and climate change.

### ***E. Working Groups***

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

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

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

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

#### ***Human Dimensions Working Group (HDWG)***

<http://www.imber.info/en/projects/imber/science/working-groups-1/human-dimensions-working-group-hdwg>

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

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

*IMBeR-CLIVAR Eastern Boundary Upwelling Systems Working Group (EBUS)*  
<http://www.imber.info/en/projects/imber/science/working-groups-1/eastern-boundary-upwelling-systems-ebus>

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

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

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

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

*SOLAS-IMBeR Ocean Acidification (SIOA)*  
<https://www.iaea.org/ocean-acidification>

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

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

## F. Endorsed projects

### *Atlantic Meridional Transect (AMT)*

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

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

### *Gulf of Trieste Time series (GoTTs)*

[http://nettuno ogs.trieste.it/ilter/GoTTs/en\\_index.html](http://nettuno ogs.trieste.it/ilter/GoTTs/en_index.html)

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

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

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

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

### *Processes and Approaches of Coastal Ecosystem Carbon Sequestration (PACECS)*

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

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

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

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

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

## *Mechanisms of Marine Carbon Storage and Coupled Carbon, Nitrogen and Sulphur cycles in response to global change (MCS-CNS)*

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

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

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

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

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

## *Integrated Arctic Observation System (INTAROS)*

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

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

## **G. Implementation of the IMBeR Science Plan**

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

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

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

### *SIBER - Grand Challenge I*

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

### *ICED - Grand Challenge I*

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

### *ESSAS - Grand Challenge I*

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

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

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

#### *CLIOTOP - Grand Challenge I*

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

1. Better identification and understanding of the environmental drivers affecting key species and ecological processes
2. Adequate parameterisation of the environmental drivers identified (by definition of appropriate indicators)
3. Development of best practices for integrating indicators into current assessment models
4. Fostering capacity building
5. Identifying successful case studies and promoting new ones

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

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

Task Team 2017-01 attended a workshop on community-level metrics, mercury isotopes, and data-model linkages and has been wrapping up a number of publications that have either been published (Álvarez-Berastegui et al. 2018, Dhurmee et al. 2018, Houssard et al. 2019, Pethybridge et al. 2018, and Regelo et al 2018), are currently in review or in the final stages of

preparation. These have focussed on improving understanding of the trophic pathways that underlie the production of tunas and other pelagic predators in the open ocean, the movements of these predators, and the natural variability forced by the environment.

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

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

### *ESSAS - Grand Challenge II*

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

### *ICED - Grand Challenge II*

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

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

### *CLIOTOP - Grand Challenge II*

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



### **Grand Challenge III: Improving and achieving sustainable ocean governance**

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

#### *SIBER - Grand Challenge III*

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

#### *ICED - Grand Challenge III*

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

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

SCAR: SCAR is tasked with providing scientific advice to the Antarctic Treaty via reports and representation at the annual Antarctic Treaty Consultative Meetings (ATCMs). ICED contributes to SCAR's annual scientific reports. This includes highlighting ICED science under GCs I, II and those that specifically address GC III. ICED provided input for SCAR's Annual Report to the

Scientific Committee of CCAMLR (SC CCAMLR), summarising the 2018 work relating to fishery management and policy.

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

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

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

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

#### *Other international organisations:*

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

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

*CLIOTOP - Grand Challenge III*

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

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

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

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

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

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

*SIBER – Innovation Challenge 2*

This IMBeR Challenge represents one of the central goals of SIBER. SIBER emerged as a result of the potential opportunity to leverage the CLIVAR/GOOS Indian Ocean mooring array (RAMA/IndOOS) and associated measurements and cruises for doing biogeochemical and ecological research. SIBER provides the biogeochemical and ecosystem research focus and counterpart for IndOOS and the IORP. This opportunity is being realised through the deployment

of biogeochemical sensors on the RAMA mooring array and the deployment of bio-Argo floats in the northern and southwestern Indian Ocean. An Australia/India 4-year BioArgo collaboration (Nick Hardmann-Mountford [CSIRO], and former SIBER SSC members Wajih Naqvi [NIO] and Ravichandran [INCOIS]) was launched in 2014 and recently completed, generating a large amount of unprecedented and valuable data; <http://biogeochemical-argo.org/key-areas-projects-io-bio-argo.php>. Plans are being developed for the deployment of many more biogeochemical sensors in the Indian Ocean as part of IIOE-2 and the second phase of IndoOOS. These efforts are all focussed on measuring biogeochemical EOVS that contribute to the development of a global ecosystem observational and modelling network.

#### *ICED – Innovation Challenge 2*

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

#### *ESSAS – Innovation Challenge 2*

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

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

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

*CLIOTOP – Innovation Challenge 2*

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

Collaboration with GOOS – Innovation Challenge 2

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

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

*ICED – Innovation Challenge 3*

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

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

*SIBER – Innovation Challenge 4*

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

*ESSAS – Innovation Challenge 4*

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

*ICED – Innovation Challenge 4*

ICED scientists have been developing studies to expand analyses of ecosystems to consider human social and economic system interactions. Following a workshop convened by ICED scientists Eugene Murphy, Stuart Corney and Jess Melbourne-Thomas at IMBIZO IV (which emphasised that ecological models are now sufficiently advanced that they are useful for decision-making), ICED continues to develop activities aimed at integrating human dimensions into marine ecosystem models. Eugene Murphy presented a talk on this topic at the MEASO2018 meeting held in Hobart, Australia in April 2018, considering how modelling can be developed to help robust decision

making. ICED scientists have also been working on understanding stakeholder perspectives on ecosystem-based management of the Antarctic krill fishery. This has been well received within CCAMLR and discussions of follow-up work in this area are underway. Work has also continued on ecosystem services in the Southern Ocean. The use of social science data in decision-making is an area ICED is keen to develop with other relevant groups (e.g., IWC and Centre for Science and Policy, University of Cambridge, CSaP) and two workshops, held in Cambridge were led by ICED scientists Rachel Cavanagh and Susie Grant. The second of these was “Ocean Plastics: Challenges and Solutions” (Cambridge, Mar 2018). These form part of a series on Science-Policy Challenges in Polar Conservation and Management in collaboration with the Cambridge Conservation Initiative (a collaboration between the University of Cambridge and 9 leading international biodiversity conservation organisations).

#### **H. Other IMBeR activities**

##### ***Future Oceans2*** <http://imber.info/en/events/osc/2019>

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

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

##### **4<sup>th</sup> CLIOTOP Symposium**

<http://imber.info/events/imber-working-groups-program-events/4th-cliotop-symposium>

The 4<sup>th</sup> CLIOTOP Symposium was held at the National Taiwan Ocean University, Keelung, Taiwan, on 15-19 October 2019

>100 Attendees • 6 Sessions • 40 Oral Presentations • 15 Posters

##### **Interdisciplinary Marine Early Career Network (IMECaN)**

<http://www.imber.info/science/imecan--interdisciplinary-marine-early-career-network>

IMECaN was officially launched at *Future Oceans2* on 16 June 2019. Stephanie Brodie will take over as Chair of IMECaN from Chris Cvitanovic on 1 January 2020.

##### **IMECaN Early Career Researcher Day**

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

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

##### **ClimEco6 Summer School**

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

ClimEco6 was held at the Gadjadara University in Yogyakarta, Indonesia, on 1-8 August 2018. The theme of the summer school was “Interdisciplinary approaches for sustainable oceans” and participants were provided with practical ways to deal with the challenges arising from working across social and natural science disciplines. About 60 participants attended.

##### **8<sup>th</sup> IMBeR China/Japan/Korea Symposium**

<http://imber.info/en/events/china-japan-korea-imber-symposia/cjk8>

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

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

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

## **Inaugural Continental Margins Working Group Workshop**

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

### ***I. IMBeR Project Offices***

#### **International Project Office (IPO, Norway)**

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

#### **Regional Project Office (RPO, China)**

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

### ***J. Scientific Steering Committee (SSC)***

An open call for nominations for four new SSC members was advertised in 2017. From 36 applications, four new 2018 SSC members were proposed and accepted by SCOR and Future Earth – Oscar Iribane (M, Argentina), Alice Newton (F, Portugal), Suvaluck Satumanatpan (F, Thailand) and David VanderZwaag (M, Canada). We also appointed *ex officio* members Olav Kjesbu (M, Norway; to act as an IMR liaison), Chris Cvitanovic (M, Australia; as the early career representative) and Frank Muller Karger (M, USA; as the liaison with GEO BON to contribute to Innovation Challenge 2). At the end of 2018, Daniel Costa (M, USA) and Cisco Werner (M, USA) rotated off the SSC as did *ex officio* member Ken Drinkwater (M, Norway), and Jeomshik Hwang (M, South Korea) was proposed and accepted as an SSC member in 2019.



## **K. Collaborative partners**

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

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

1. **Too Big To Ignore (TBTI)**  
IMBeR is a partner of the TBTI project which includes 15 partners, 62 scientists from 27 countries. TBTI is conducting a global analysis, based on information systems, to better understand small-scale fisheries and to develop research and governance capacity to address global fisheries challenges.
2. **Ocean Carbon Biogeochemistry (OCB)**  
OCB continues to actively support IMBeR by advertising its activities and events, and by providing financial support for activities.
3. **World Climate Research Project (WCRP)**  
CLIVAR, a core project of WCRP, and its Indian Ocean Panel works closely with SIBER. The IMBeR Eastern Boundary Upwelling working group is co-sponsored by CLIVAR. CLIVAR is also part of the newly established Integrated Ocean Carbon Research (IOC-R).
4. **GOOS**  
SIBER has strong connections with the Global Ocean Observing System in the Indian Ocean – IOGOOS.
5. **ICES**  
Collaboration with ICES continues through the membership of Mark Dickey-Collas (ICES) on the IMBeR Scientific Steering Committee.
6. **PICES**  
IMBeR and PICES continue to collaborate, with representatives from both communities attending and funding each other's summer schools and science meetings. Carol Robinson was a member of the ICES/PICES working group on Climate Change and Biologically-driven Ocean Carbon Sequestration (WGCCBOCS) which ended in 2018 and represented IMBeR on the organising committee of the PICES International Symposium The Effects of Climate Change on the World's Oceans (ECCWO) to be held in Washington in June 2018. PICES co-sponsored ClimEco5 in August 2018 and *Future Oceans2* in June 2019.

### *L. Selected IMBeR Publications*

IMBeR has produced more than 2500 refereed research papers since 2005, with around 150 papers published in 2018-2019.

#### **IMBeR General**

Baltar F, Bayer, B, Bednarsek N, Deppeler S, Escribano R, Gonzalez CE, Hansman RL, Mishra RK, Moran MA, Repeta DJ, Robinson R, Sintes E, Tamburini C, Valentin LE, Herndl GJ (2019) Towards Integrating Evolution, Metabolism, and Climate Change Studies of Marine Ecosystems. *Trends in Ecology & Evolution*. Available online <https://doi.org/10.1016/j.tree.2019.07.003>

#### **ICED Publications**

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

- Atkinson, A., Hill, S.L., Pakhomov, E.A., Siegel, V., Reiss, C.S., Loeb, V., Steinberg, D.K., Schmidt, K., Tarling, G.A., Gerrish, L. & Sailley, S.F. 2019. Krill (*Euphausia superba*) distribution contracts southward during rapid regional warming. *Nature Climate Change*, 9:142-147 DOI: 10.1038/s41558-018-0370-z
- Cubaynes, Hannah C., Peter T. Fretwell, Connor Bamford, Laura Gerrish, Jennifer A. Jackson. 2018. Whales from space: four mysticete species described using new VHR satellite imagery. *Marine Mammal Science* 35 (466-491). <https://doi.org/10.1111/mms.12544>
- Dinniman, M.S., Klinck, J.M., Hofmann, E.E. & Smith, W.O. 2018 Effects of Projected Changes in Wind, Atmospheric Temperature, and Freshwater Inflow on the Ross Sea. *Journal of Climate*, 31, 1619-1635. doi:10.1175/jcli-d-17-0351.1
- Krüger, L., Ramos, J.A., Xavier, J.C., Grémillet, D., González-Solís, J., Petry, M.V., Phillips, R.A., Wanless, R.M. & Paiva, V.H. (2018). Projected distributions of Southern Ocean albatrosses, petrels and fisheries as a consequence of climatic change. *Ecography* 41: 195-208 DOI: 10.1111/ecog.02590
- Saunders, R.A., Collins, M.A., Shreeve, R., Ward, P., Stowasser, G., Hill, S.L., Tarling, G.A. 2018. Seasonal variation in the predatory impact of myctophids on zooplankton in the Scotia Sea (Southern Ocean). *Progress in Oceanography*, 168, 123-144. <https://doi.org/10.1016/j.pocean.2018.09.017>
- Thorpe SE, Tarling GA, Murphy EJ (2019) Circumpolar patterns in Antarctic krill larval recruitment: an environmentally-driven model. *Mar Ecol Prog Ser* 613:77-96 doi: 10.3354/meps12887
- Capurro A, Santos MM, Cavanagh RD, Grant SM. 2018. The identification of scientific reference areas in the wider context of Marine Protected Area planning. CCAMLR WS-SM-18/17
- Murphy, E.J., Johnston, N.M., Corney, S. P., and Reid, K. (2018). Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) programme: Preliminary report of the ICED-CCAMLR Projections Workshop, 5-7 Apr 2018. WG-EMM-18-09.
- Murphy, E, Johnston, N, Corney, S and Reid, K including workshop participants and contributors Atkinson, A, Belchier, M, Bellerby, R, Bindoff, N, Cavanagh, R, Constable, A, Costa, D, Eddy, T, Emmerson, L, Grant, S, Groeneveld, J, Hill, S, Hobbs, W, Hofmann,

E, Jackson, J, Kawaguchi, S, Korczak-Abshire, M, Lenton, A, Meijers, A, Melbourne-Thomas, J, Newman, L, Nicol, S, Piñones, A, Reiss, C, Santos, M, Tarling, G, Trathan, P, Trebilco, R, Watters, G, Welsford, D, Zhu, G. (Submitted). Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) programme: Report of the ICED-CCAMLR Projections Workshop, 5-7 Apr 2018. SC-CAMLR XXXVII.

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

### *Scientific publications*

- Atkinson, A., Hill, S.L., Pakhomov, E.A., Siegel, V., Reiss, C.S., Loeb, V., Steinberg, D.K., Schmidt, K., Tarling, G.A., Gerrish, L. & Sailley, S.F. 2019. Krill (*Euphausia superba*) distribution contracts southward during rapid regional warming. *Nature Climate Change*, 9:142-147 DOI: 10.1038/s41558-018-0370-z
- Bagchi, A., A. J. Batten, M. Levin, K. N. Allen, M. L. Fitzgerald, L. A. Huckstadt, D. P. Costa, E. S. Buys, and A. G. Hindle. 2018. Intrinsic anti-inflammatory properties in the serum of two species of deep-diving seal. *Journal of Experimental Biology* 221.
- Brault, E. K., P. L. Koch, D. P. Costa, M. D. McCarthy, L. A. Huckstadt, K. T. Goetz, K. W. McMahon, M. E. Goebel, O. Karlsson, J. Teilmann, T. Harkonen, and K. C. Harding. 2019. Trophic position and foraging ecology of Ross, Weddell, and crabeater seals revealed by compound-specific isotope analysis. *Marine Ecology Progress Series* 611:1-18.
- Constable, A.J. & Kawaguchi, S. 2018 Modelling growth and reproduction of Antarctic krill, *Euphausia superba*, based on temperature, food and resource allocation amongst life history functions. *Ices Journal of Marine Science*, 75, 738-750. (doi:10.1093/icesjms/fsx190).
- Costa, D. P., L. A. Huckstadt, L. Schwarz, A. Friedlaender, B. Mate, A. Zerbini, A. Kennedy, and N. J. Gales. 2018. Assessing the Potential Exposure of Migratory Animals to Disturbance. *Integrative and Comparative Biology* 58:E44-E44.
- Costa, D. P., S. S. Kienle, S. J. Trumble, S. Kanatous, M. E. Goebel, and D. Krause. 2019. Foraging Ecology of the Leopard Seal. *Integrative and Comparative Biology* 59:E43-E43.
- Dimitrijević D, Paiva VH, Ramos JA, Seco J, Ceia FR, Chipev N, Valente T, Barbosa A, Xavier JC (2018) Isotopic niches of sympatric Gentoo and Chinstrap Penguins: evidence of competition for Antarctic krill? *Polar Biology* 41: 1655-1669  
<https://doi.org/10.1007/s00300-018-2306-5>
- Dinniman, M.S., J.M. Klinck, E.E. Hofmann, and W.O. Smith, Jr. 2018. Effects of projected changes in wind, atmospheric temperature and freshwater inflow on the Ross Sea. *J. Climate* 31: 1619-1635.
- Frazer, E. K., P. J. Langhorne, M. J. M. Williams, K. T. Goetz, and D. P. Costa. 2018. A method for correcting seal-borne oceanographic data and application to the estimation of regional sea ice thickness. *Journal of Marine Systems* 187:250-259.
- Freer, Jennifer J.; Partridge, Julian C.; Tarling, Geraint A.; Collins, Martin A.; Genner, Martin J. 2018. Predicting ecological responses in a changing ocean: the effects of future climate uncertainty. *Marine Biology*, 165 (1), 7. 18, pp. <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., McMahon, C.R. & Hindell, M.A. 2018 Modelling southern elephant seals *Mirounga leonina* using an individual-based model

- coupled with a dynamic energy budget. Article, Plos One, 13.  
(doi:10.1371/journal.pone.0194950).
- Gutt J, Isla E, Bertler AN, Bodeker GE, Bracegirdle TJ, Cavanagh RD, Comiso JC, Convey P, Cummings V, De Conto R, De Master D, di Prisco G, d'Ovidio F, Griffiths HJ, Khan AL, López-Martínez J, Murray AE, Nielsen UN, Ott S, Post A, Ropert-Coudert Y, Saucède T, Scherer R, Schiaparelli S, Schloss IR, Smith CR, Stefels J, Stevens C, Strugnell JM, Trimbom S, Verde C, Verleyen E, Wall DH, Wilson NG, Xavier JC (2018) Cross disciplinary in the advance of Antarctic ecosystem research. *Marine Genomics* 37: 1-17 doi <https://doi.org/10.1016/j.margen.2017.09.006>
- Hauck, J., Lenton, A., Langlais, C. and Mearns, R. (2018) The Fate of Carbon and Nutrients Exported Out of the Southern Ocean, *Global Biogeochemical Cycles*, 32 (10), pp. 1556-1573 .doi: <https://doi.org/10.1029/2018GB005977> , hdl:10013/epic.0cc5372f -692d-4cf5-bd31-b99209664419
- Hays, G. C., H. Bailey, S. J. Bograd, W. D. Bowen, C. Campagna, R. H. Carmichael, P. Casale, A. Chiaradia, D. P. Costa, E. Cuevas, P. J. N. de Bruyn, M. P. Dias, C. M. Duarte, D. C. Dunn, P. H. Dutton, N. Esteban, A. Friedlaender, K. T. Goetz, B. J. Godley, P. N. Halpin, M. Hamann, N. Hammerschlag, R. Harcourt, A. L. Harrison, E. L. Hazen, M. R. Heupel, E. Hoyt, N. E. Humphries, C. Y. Kot, J. S. E. Lea, H. Marsh, S. M. Maxwell, C. R. McMahon, G. N. di Sciara, D. M. Palacios, R. A. Phillips, D. Righton, G. Schofield, J. A. Seminoff, C. A. Simpfendorfer, D. W. Sims, A. Takahashi, M. J. Tetley, M. Thums, P. N. Trathan, S. Villegas-Amtmann, R. S. Wells, S. D. Whiting, N. E. Wildermann, and A. M. M. Msequeira. 2019. Translating Marine Animal Tracking Data into Conservation Policy and Management. *Trends in Ecology & Evolution* 34:459-473.
- Hindle, A. G., A. Bagchi, A. Batten, M. Levin, K. N. Allen, L. A. Huckstadt, D. P. Costa, W. M. Zapol, and E. S. Buys. 2018. Intrinsic anti-inflammatory properties of serum in deep-diving seals. *Faseb Journal* 32.
- Hughes KA, Constable A, Frenot Y, López-Martínez J, McIvor E, Njåstad B, Terauds A, Liggett D, Roldan G, Wilmotte A, Xavier JC. 2018. Antarctic environmental protection: Strengthening the links between science and governance. *Environmental Science & Policy* 83: 86-95
- Humphreys, M.P., Daniels, C.J., Wolf-Gladrow, D.A., Tyrrell, T. & Achterberg, E.P. 2018 On the influence of marine biogeochemical processes over CO<sub>2</sub> exchange between the atmosphere and ocean. Article, *Marine Chemistry*, 199, 1-11.  
(doi:10.1016/j.marchem.2017.12.006).
- Kaufman, D.E., M.A.M. Friedrichs, J.C.P. Hennings and W.O. Smith, Jr. 2018. Assimilating bio- optical glider data: time and space variability during a phytoplankton bloom in the southern Ross Sea. *Biogeosci.* 15: 73–90, <https://doi.org/10.5194/bg-15-73-2018>
- Klein, Emily S., Hill, Simeon L., Hinke, Jefferson T., Phillips, Tony, Watters, George M. Impacts of rising sea temperatures on krill increase risks for predators in the Scotia Sea. 2018. *PLOS ONE*/13. 10.1371/journal.pone.0191011
- Krüger L, Paiva VH, Finger JV, Petersen E, Xavier JC, Petry MV, Ramos JA (2018) Intra-population variability of the non-breeding distribution of southern giant petrels *Macronectes giganteus* is mediated by individual body size. *Antarctic Science*:1-7 <https://doi.org/10.1017/S0954102018000238>
- Krüger, L., Ramos, J.A., Xavier, J.C., Grémillet, D., González-Solís, J., Petry, M.V., Phillips, R.A., Wanless, R.M. & Paiva, V.H. (2018). Projected distributions of Southern Ocean

- albatrosses, petrels and fisheries as a consequence of climatic change. *Ecography* 41: 195-208 DOI: 10.1111/ecog.02590
- Meijers, A.J.S., Meredith, M.P., Murphy, E.J., Chambers, D.P., Belchier, M. & Young, E.F. 2019 The role of ocean dynamics in king penguin range estimation. *Nature Climate Change*, 9, 120-121. (doi:10.1038/s41558-018-0388-2).
- Mori, M., Corney, S.P., Melbourne-Thomas, J., Klocker, A., Kawaguchi, S., Constable, A. & Sumner, M. 2019 Modelling dispersal of juvenile krill released from the Antarctic ice edge: Ecosystem implications of ocean movement. *Journal of Marine Systems*, 189, 50-61. (doi:10.1016/j.jmarsys.2018.09.005).
- Panassa, E., Santana-Casiano, J.M., Gonzalez-Davila, M., Hoppema, M., van Heuven, S., Volker, C., Wolf-Gladrow, D. & Hauck, J. 2018 Variability of nutrients and carbon dioxide in the Antarctic Intermediate Water between 1990 and 2014. *Ocean Dynamics*, 68, 295-308. (doi:10.1007/s10236-018-1131-2).
- Panassa, E., Volker, C., Wolf-Gladrow, D. & Hauck, J. 2018 Drivers of Interannual Variability of Summer Mixed Layer Depth in the Southern Ocean Between 2002 and 2011. *Journal of Geophysical Research-Oceans*, 123, 5077-5090. (doi:10.1029/2018jc013901).
- Peck, Victoria L., Oakes, Rosie L., Harper, Elizabeth M., Manno, Clara, Tarling, Geraint A. 2018. Pteropods counter mechanical damage and dissolution through extensive shell repair, *Nature Communications* 10.1038/s41467-017-02692-w
- Pereira J.M., Paiva, V.H., Phillips, R.A., Xavier, J.C. (2018) The devil is in the detail: small scale sexual segregation despite large-scale spatial overlap in the wandering albatross. *Marine Biology* 165: 55 doi 10.1007/s00227-018-3316-0
- Pirotta, E., C. G. Booth, D. P. Costa, E. Fleishman, S. D. Kraus, D. Lusseau, D. Moretti, L. F. New, R. S. Schick, L. K. Schwarz, S. E. Simmons, L. Thomas, P. L. Tyack, M. J. Weise, R. S. Wells, and J. Harwood. 2018. Understanding the population consequences of disturbance. *Ecology and Evolution* 8:9934-9946.
- Queirós JP, Cherel Y, Ceia FR, Hilário A, Roberts J, Xavier JC (2018) Ontogenic changes in habitat and trophic ecology in the Antarctic squid *Kondakovia longimana* derived from isotopic analysis on beaks. *Polar Biology*:1-13 <https://doi.org/10.1007/s00300-018-2376-4>
- Rintoul SR, Chown SL, DeConto RM, England MH, Fricker HA, Masson-Delmotte V, Naish TR, Siegert MJ, Xavier JC (2018) Choosing the future of Antarctica. *Nature* 558:233-241 <https://doi.org/10.1038/s41586-018-0173-4>
- Seco J, Xavier JC, Coelho JP, Pereira B, Tarling G, Pardal MA, Bustamante P, Stowasser G, Brierley AS, Pereira ME (2019) Spatial variability in total and organic mercury levels in Antarctic krill *Euphausia superba* across the Scotia Sea. *Environmental Pollution* <https://doi.org/10.1016/j.envpol.2019.01.031>
- Sequeira, A. M. M., J. P. Rodríguez, V. M. Eguíluz, R. Harcourt, M. Hindell, D. W. Sims, C. M. Duarte, D. P. Costa, J. Fernández-Gracia, L. C. Ferreira, G. C. Hays, M. R. Heupel, M. G. Meekan, A. Aven, F. Bailleul, A. M. M. Baylis, M. L. Berumen, C. D. Braun, J. Burns, M. J. Caley, R. Campbell, R. H. Carmichael, E. Clua, L. D. Einoder, A. Friedlaender, M. E. Goebel, S. D. Goldsworthy, C. Guinet, J. Gunn, D. Hamer, N. Hammerschlag, M. Hammill, L. A. Hückstädt, N. E. Humphries, M.-A. Lea, A. Lowther, A. Mackay, E. McHuron, J. McKenzie, L. McLeay, C. R. McMahon, K. Mengersen, M. M. C. Muelbert, A. M. Pagano, B. Page, N. Queiroz, P. W. Robinson, S. A. Shaffer, M. Shivji, G. B. Skomal, S. R. Thorrold, S. Villegas-Amtmann, M. Weise, R. Wells, B. Wetherbee, A. Wiebkin, B.

- Wienecke, and M. Thums. 2018. Convergence of marine megafauna movement patterns in coastal and open oceans. *Proceedings of the National Academy of Sciences*.
- Schulz, I., Montresor, M., Klaas, C., Assmy, P., Wolzenburg, S., Gauns, M., Sarkar, A., Thiele, S., Wolf-Gladrow, D., Naqvi, W. & Smetacek, V. 2018 Remarkable structural resistance of a nanoflagellate-dominated plankton community to iron fertilization during the Southern Ocean experiment *Marine Ecology Progress Series*, 601, 77-95. (doi:10.3354/meps12685).
- Shero, M. R., K. T. Goetz, D. P. Costa, and J. M. Burns. 2018a. Temporal changes in Weddell seal dive behavior over winter: Are females increasing foraging effort to support gestation? *Ecology and Evolution* 8:11857-11874.
- Shero, M. R., A. K. Kirkham, D. P. Costa, and J. M. Burns. 2018b. Iron Mobilization During Lactation Draws from Aerobic Dive Capacities in Weddell seals: A Previously Unexplored Cost to a Capital-Breeding System. *Integrative and Comparative Biology* 58: E211-E211.
- Tarling, Geraint A.; Ward, Peter; Thorpe, Sally E. 2018 Spatial distributions of Southern Ocean mesozooplankton communities have been resilient to long-term surface warming. *Global Change Biology*, 24 (1). 132-142. <https://doi.org/10.1111/gcb.13834>
- Trathan, P.N., Warwick-Evans, V., Hinke, J.T., Young, E.F., Murphy, E.J., Carneiro, A.P.B., Dias, M.P., Kovacs, K.M., Lowther, A.D., Godo, O.R., Kokubun, N., Kim, J.H., Takahashi, A. & Santos, M. 2018 Managing fishery development in sensitive ecosystems: identifying penguin habitat use to direct management in Antarctica. *Article, Ecosphere*, 9. (doi:10.1002/ecs2.2392).
- Waluda CM, Cavanagh RD & Manno C (2018) A cross-sectoral approach to tackle ocean plastic pollution, *Eos*, 99, <https://doi.org/10.1029/2018EO107159>
- Wollenburg, J.E., Katlein, C., Nehrke, G., Nothig, E.M., Matthiessen, J., Wolf-Gladrow, D.A., Nikolopoulos, A., Gazquez-Sanchez, F., Rossmann, L., Assmy, P., Babin, M., Bruyant, F., Beaulieu, M., Dybwad, C. & Peeken, I. 2018 Ballasting by cryogenic gypsum enhances carbon export in a Phaeocystis under-ice bloom. *Article, Scientific Reports*, 8. (doi:10.1038/s41598-018-26016-0).
- Xavier JC, Cherel Y, Allcock L, Rosa R, Sabirov RM, Blicher ME, Golikov AV (2018) A review on the biodiversity, distribution and trophic role of cephalopods in the Arctic and Antarctic marine ecosystems under a changing ocean. *Marine Biology* 165:93 <https://doi.org/10.1007/s00227-018-3352-9>
- Xavier J, Velez N, Trathan P, Cherel Y, De Broyer C, Cánovas F, Seco J, Ratcliffe N, Tarling G (2018) Seasonal prey switching in non-breeding gentoo penguins related to a wintertime environmental anomaly around South Georgia. *Polar Biology* 41:2323-2335 <https://doi.org/10.1007/s00300-018-2372-8>
- Xavier JC, Cherel Y, Medeiros R, Velez N, Dewar M, Ratcliffe N, Carreiro AR, Trathan PN (2018) Conventional and molecular analysis of the diet of gentoo penguins: contributions to assess scats for non invasive penguin diet monitoring. *Polar Biology* 41:2275-2287 <https://doi.org/10.1007/s00300-018-2364-8>
- Xavier JC, Cherel Y, Ceia F, Queirós J, Guimarães B, Rosa R, Cunningham D, Moors P, Thompson D (2018) Eastern rockhopper penguins *Eudyptes filholi* as biological samplers of juvenile and sub-adult cephalopods around Campbell Island, New Zealand. *Polar Biology* 41:1937-1949 <https://doi.org/10.1007/s00300-018-2333-2>
- Xavier, J., Gray, A., & Hughes, K. (2018). The rise of Portuguese Antarctic research: Implications for Portugal's status under the Antarctic Treaty. *Polar Record*, 1-7. doi:10.1017/S0032247417000626

- Xavier, J. C., Mateev, D., Capper, L., Wilmotte, A., Walton, D.W.H. (2019). Education and Outreach by the Antarctic Treaty Parties, Observers and Experts under the framework of the Antarctic Treaty Consultative meetings. *Polar Record*.  
<https://doi.org/10.1017/S003224741800044X>
- Xavier, J. C., Azinhaga, P. F., Seco, J., Fugmann, G. (2018). International Polar Week as an educational activity to boost science-educational links: Portugal as a case-study. *Polar Record* 54: 360-365. <https://doi.org/10.1017/S0032247418000621>
- Young, E.F., Tysklind, N., Meredith, M.P., de Bruyn, M., Belchier, M., Murphy, E.J. & Carvalho, G.R. 2018 Stepping stones to isolation: Impacts of a changing climate on the connectivity of fragmented fish populations. *Article, Evolutionary Applications*, 11, 978-994. (doi:10.1111/eva.12613).

### ***ESSAS Publications***

- Drinkwater, K., Mueter, F., Saitoh, S.-I. (2018) Shifting boundaries of water, ice, flora, fauna, people and institutions in the Arctic and Subarctic. *ICES Journal of Marine Science*. doi: 10.1093/icesjms/fsy179
- Holsman, K., Ito, S.-I., Hollowed, A., Bograd, S., Hazen, E., King, J., Mueter, F., Perry, I. (2018). Chapter 6: The North Pacific & Pacific Arctic. In: Barange, M., Bahri, T., Beveridge, M.C.M., Cochrane, K.L., Funge-Smith, S., and Poulain, F. (eds.) *Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options*. FAO Fisheries and Aquaculture Technical Paper No. 627, Rome.
- Iken, K., Mueter, F.J., Grebmeier, J.M., Cooper, L.W., Danielson, S., Bluhm, B. (In Press) Does one size fit all? Observational Design for Epibenthos and Fish Monitoring in the Chukchi Sea. *Deep-Sea Research II*. doi: 10.1016/j.dsr2.2018.11.005
- Mueter, F.J., Baker, M.R., Dressel, S.C., Hollowed, A.B. (Editors) (2018) *Impacts of a Changing Environment on the Dynamics of High-latitude Fish and Fisheries*. Alaska Sea Grant, University of Alaska Fairbanks. doi: 10.4027/icedhlff.2018.02
- Planque, B., Mullon, C., Arneberg, P., Eide, A., Fromentin, J.-M., Heymans, J.J., Hoel, A.H., Niiranen, S., Ottersen, G., Sandø, A.B., Sommerkorn, M., Thébaud, O., Thorvik, T., 2019. A participatory scenario method to explore the future of marine social-ecological systems. *Fish and Fisheries*. doi: 0. 10.1111/faf.12356
- Vestfals, C.D., Mueter, F.J., Duffy-Anderson, J.T., Busby, M.S., De Robertis, A. (In Press). Distribution of early life stages of Arctic cod and saffron cod in the Pacific Arctic. *Polar Biology*.

### ***SIBER Publications***

- Al-Yamani, F, Naqvi, SWA (2019) Chemical oceanography of the Arabian Gulf, Deep-Research Part II, *Topical Studies in Oceanography*, 161, 72-80.
- Baer, SE Rauschenberg, S, Garcia, CA, Garcia, NS and Lomas, MW (2019) Carbon and nitrogen productivity during spring in the oligotrophic Indian Ocean along the GO-SHIP IO9N transect, Deep-Research Part II, *Topical Studies in Oceanography*, 161, 81-91.
- Beckley, L.E., Holliday, D., Sutton, A.L., Weller, E., Olivar, M.P., Thompson, P.A. 2019. Structuring of larval fish assemblages along a coastal-oceanic gradient in the macro-tidal, tropical Eastern Indian Ocean. *Deep Sea Research Part II*. 161:105-119.



- Beckley, LE, Holliday, D, A.L. Sutton, AL, Weller, E and Thompson, PA (2019) Structuring of larval fish assemblages along a coastal-oceanic gradient in the macro-tidal, tropical Eastern Indian Ocean, Deep-Research Part II, Topical Studies in Oceanography, 161, 105-119.
- Burdanowitz, N, Gaye, B, Hilbig, L, Lahajnar, N, Lückge, A, Rixen, T and Emeis, K-C (2019) Holocene monsoon and sea level-related changes of sedimentation in the northeastern Arabian Sea, Deep-Sea Research Part II, <https://doi.org/10.1016/j.dsr2.2019.03.003>.
- Chakraborty, K, Nimit, K, Akhand, A, Prakash, S, Paul, A, JayashreeGhosh, J, Udaya Bhaskar, TVS and Chanda, A (2018) Modeling the enhancement of sea surface chlorophyll concentration during the cyclonic events in the Arabian Sea, Journal of Sea Research, 40, 22-31. <https://doi.org/10.1016/j.seares.2018.07.003>
- de Lecea A, Coppin R, Noyon M, Huggett J (2018) Zooplankton adrift: Investigating transportation by cyclonic eddy. Marine Biology Research, 14: 436-477. DOI: 10.1080/17451000.2018.1426862.
- Dréo, R, Bouffaut, L, Leroy, E, Barruol, G and Samaran, F (2019) Baleen whale distribution and seasonal occurrence revealed by an ocean bottom seismometer network in the Western Indian Ocean, Deep-Research Part II, Topical Studies in Oceanography, 161, 132-144.
- Forke, S., Rixen, T., Burdanowitz, N., Luckge, A., Ramaswamy, V., Munz, P., Wilhelms-Dick, D., Vogt, C., Kasten, S., Gaye, B., 2019. Sources of laminated sediments in the northeastern Arabian Sea off Pakistan and implications for sediment transport mechanisms during the late Holocene. Holocene, 29, 130-144.
- Hood, R and Beckley, L (2019) The second international Indian Ocean Expedition (IIOE-2): Motivating new exploration in a poorly understood ocean basin (Volume 1); Deep-Research Part II, Topical Studies in Oceanography, 161, 2-4
- Landry, M.R., Beckley, L.E. & Muhling, B.A. 2019. Climate sensitivities and uncertainties in food-web pathways supporting larval bluefin tuna in subtropical oligotrophic oceans. ICES Journal of Marine Science 76(2), 359–369.
- Mahajan, A. S., Tinel, L., Sarkar, A., Chance, R., Carpenter, L. J., Hulswar, S., Mali, P., Prakash, S. and Vinayachandran, P.N. (2019) Understanding Iodine Chemistry over the Northern and Equatorial Indian Ocean, Journal of Geophysical Research-Atmosphere, [doi.org/10.1029/2018JD029063](https://doi.org/10.1029/2018JD029063)
- Mao, H, Feng, M, Phillips, H and Lian, S (2019) Mesoscale eddy characteristics in the interior subtropical southeast Indian Ocean, tracked from the Leeuwin Current system, Deep-Research Part II, Topical Studies in Oceanography, 161, 52-62.
- Martin, P, Federico M. Lauro, FM, Sarkar, A, Goodkin, N, Prakash, S, Vinayachandran, PN (2018) Particulate polyphosphate and alkaline phosphatase activity across a latitudinal transect in the tropical Indian Ocean, Limnology and Oceanography, [doi: 10.1002/lno.10780](https://doi.org/10.1002/lno.10780).
- Miller, MJ, Wouthuyzen, S, Feunteun, E, Aoyama, J, Tsukamoto, K (2019) Contrasting biodiversity of eel larvae across the central Indian Ocean subtropical gyre, Deep-Research Part II, Topical Studies in Oceanography, 161, 120-131.
- Noyon M, Morris T, Walker D, Huggett J (2018) Plankton distribution within a young cyclonic eddy off south-western Madagascar. Deep Sea Research Part II, <https://doi.org/10.1016/j.dsr2.2018.11.001>
- Noyon M, Rasoloarijao Z, Huggett J, Roberts M, Ternon J-F (submitted) Comparison of mesozooplankton communities at three shallow seamounts in the South West Indian Ocean. Deep Sea Research Part II.

- Prend, C.J., Seo, H., Weller, R. and Farrar, J. (2019) Impact of freshwater plumes on intraseasonal upper ocean variability in the Bay of Bengal, Deep-Research Part II, Topical Studies in Oceanography, 161, 63-71.
- Rixen, T., Gaye, B., Emeis, K.-C. and Ramaswamy, V. (2019) The ballast effect of lithogenic matter and its influences on the carbon fluxes in the Indian Ocean, Biogeosciences, 16, 485–503.
- Rohith, B., Paul, A., Durand, F., Testut, L., S. Prerna, S., Afroosa, M., S.S.V.S. Ramakrishna, SSVS and Shenoi SSC (2019) Basin-wide sea level coherency in the tropical Indian Ocean driven by Madden–Julian Oscillation, Nature Communications, 10: 1257, <https://doi.org/10.1038/s41467-019-09243-5>.
- Saaliim, S.M., Saraswat, R., Suokhrie, T. and Nigam, R. (2019) Assessing the ecological preferences of agglutinated benthic foraminiferal morphogroups from the western Bay of Bengal, Deep-Research Part II, Topical Studies in Oceanography, 161, 38-51.
- Sarma, V.V.S.S. and Udaya Bhaskar, T.V.S. (2018) Ventilation of oxygen to Oxygen Minimum Zone due to anticyclonic eddies in the Bay of Bengal, JGR Biogeosciences, 123, 2145-2153, <https://doi.org/10.1029/2018JG004447>.
- Singh, R., Sautya, S. and Ingole, B. (2019) The community structure of the deep-sea nematode community associated with polymetallic nodules in the Central Indian Ocean Basin, Deep-Research Part II, Topical Studies in Oceanography, 161, 16-28.
- Smith, J.A., Miskiewicz, A.G., Beckley, L.E., Everett, J.D., Garcia, V., Gray, C.A., Holliday, D., Jordan, A.R., Keane, J., Lara-Lopez, A., Leis, J.M., Matis, P.A., Muhling, B.A., Neira, F.J., Richardson, A.J., Smith, K.A., Swadling, K.M., Syahailatua, A., Taylor, M.D., Van Ruth, P.D., Ward, T.M. & Suthers, I.M. 2018. A database of marine larval fish assemblages in Australian temperate and tropical waters. Scientific Data 5:180207. doi:10.1038/sdata.2018.207.
- Srichandan, S., Baliarsingh, S.K., Prakash, S., Lotliker, A.A., Parida, C., Sahu, K.C. (2019) Seasonal dynamics of phytoplankton in response to environmental variables in contrasting coastal ecosystems, Environ Sci Pollut Res, 26(12), 12025-12041, doi: 10.1007/s11356-019-04569-5
- Subrahmanyam, B., Trott, C.B. and Murty, V.S.N. (2018) Detection of intraseasonal oscillations in SMAP salinity in the Bay of Bengal, Geophysical Research Letters, <https://doi.org/10.1029/2018GL078662>
- Suntharalingam, P., Zamora, L.M., Bange, H.W., Bikkina, S., Buitenhuis, E., Kanakidou, M., Lamarque, J.F., Resplandy, L., Sarin, M.M., Seitzinger, S. and Singh, A. (2019, in press) Anthropogenic nitrogen inputs and impacts on oceanic N<sub>2</sub>O fluxes in the northern Indian Ocean: The need for an integrated observation and modelling approach, Deep-Sea Research Part II, Topical Studies in Oceanography, <https://doi.org/10.1016/j.dsr2.2019.03.007>.
- Van der Mheen, M., Pattiaratchi, C., and van Sebille, E. (2019) Role of Indian Ocean dynamics on accumulation of buoyant debris, Journal of Geophysical Research: Oceans, 124, <https://doi.org/10.1029/2018JC014806>
- Vidya, P.J. and Kurian, S. (2018) Impact of 2015–2016 ENSO on the winter bloom and associated phytoplankton community shift in the northeastern Arabian Sea, Journal of Marine Systems, 186, 96-104, <https://doi.org/10.1016/j.jmarsys.2018.06.005>
- Waite, A.M., Raes, E., Beckley, L.E., Thompson, P.A., Griffin, D., Saunders, M., Sävström, C., O'Rourke, R., Wang, M., Landrum, J.P. & Jeffs, A. 2019. Production and ecosystem

structure in cold-core vs warm-core eddies: Implications for the zooplankton isoscape and rock lobster larvae. *Limnology & Oceanography* doi. 10.1002/lno.11192

- White, C, Woulds, C, Cowie G, Stott, A and Kitazato, H (2019) Resilience of benthic ecosystem C-cycling to future changes in dissolved oxygen availability, *Deep-Research Part II, Topical Studies in Oceanography*, 161, 29-37.
- Wojtasiewicz, B, Trull, TW, Udaya Bhaskar, TVS, Gauns, M, Trull, T, Udaya Bhaskar, TVS, Prakash, S, Ravichandran, M, Shenoy, DM, Slawinski, D, Hardman-Mountford, NJ, (2018) Autonomous profiling float observations reveal the dynamics of deep biomass distributions in the denitrifying oxygen minimum zone of the Arabian Sea (2018) *Journal of Marine Systems*, <https://doi.org/10.1016/j.jmarsys.2018.07.002>.

### **CLIOTOP Publications**

- Álvarez-Berastegui D., Coll J., Rueda L., Stobart B., Morey G., Navarro O., Aparicio- González A., Grau A. M., Reñones O. 2018. Multiscale seascape habitat of necto-benthic littoral species, application to the study of the dusky grouper habitat shift throughout ontogeny, *Marine Environmental Research* <https://doi.org/10.1016/j.marenvres.2018.09.002>
- Álvarez-Berastegui D., Ingram Jr G.W., Reglero P., Ferrà C., Alemany F. 2018. Changes of bluefin tuna (*Thunnus thynnus*) larvae fishing methods over time in the Western Mediterranean, calibration and larval indices updating. *Collective Volume of Scientific Papers of the International Commission for the Conservation of Atlantic Tunas (ICCAT)* 74(6): 2772-2783, [www.iccat.int/Documents/CVSP/CV074\\_2017/colvol74.html](http://www.iccat.int/Documents/CVSP/CV074_2017/colvol74.html).
- Álvarez-Berastegui D., Ingram Jr. G., Rueda L., Reglero P. 2018. A method for nonlinear standardization of zero-inflated CPUE to account for mesoscale oceanographic variability. *Collective Volume of Scientific Papers of the International Commission for the Conservation of Atlantic Tunas (ICCAT)* 75(2): 180-193 [www.iccat.int/Documents/CVSP/CV075\\_2018/colvol75.html#](http://www.iccat.int/Documents/CVSP/CV075_2018/colvol75.html#)
- Álvarez-Berastegui D., Saber S., Ingram W.G.Jr, Díaz-Barroso L., Reglero P., Macías D., García-Barcelona S., Ortiz de Urbina J., Tintoré J., Alemany F. 2018. Integrating reproductive ecology, early life dynamics and mesoscale oceanography to improve albacore tuna assessment in the Western Mediterranean. *Fisheries Research*, 208C (2018) pp. 329-338. <https://doi.org/10.1016/j.fishres.2018.08.014>
- Amengual J. & Álvarez-Berastegui D. 2018. Critical evaluation of Aichi target 11 and the Mediterranean Marine Protected Area network, two years ahead of its deadline. *Biological Conservation* 225: 187–196.
- Dhurmea, Z., Pethybridge, H., Chandani, C., Bodin, N. 2018 Lipid and fatty acid dynamics in mature female albacore tuna (*Thunnus alalunga*) in the western Indian Ocean. *PlosOne* PONE-D-17-33026R2
- Houssard, P., Point, D., Tremblay-Boyer, L., Allain, V., Pethybridge, H., Masbou, J., Ferriss, B.E., Baya, P.A., Lagane, C., Menkes, C.E., Letourneur, Y., Lorrain, A., 2019. A Model of Mercury Distribution in Tuna from the Western and Central Pacific Ocean: Influence of Physiology, Ecology and Environmental Factors. *Environmental science & technology* 53(3):1422-1431.
- Jonsen ID, McMahon CR, Patterson TA, Auger-Méthé M, Harcourt R, Hindell MA & Bestley S (2018) Movement responses to environment: fast inference of variation among southern elephant seals with a mixed effects model. *Ecology* 100(1), e02566. <https://doi.org/10.1002/ecy.2566>.

- Pethybridge, H., Choy, C.A., Logan, J.M., Allain, V., Lorrain, A., Bodin, N., Somes, C.J., Young, J., Ménard, F., Langlais, C. & Duffy, L., (2018) A global meta-analysis of marine predator nitrogen stable isotopes: Relationships between trophic structure and environmental conditions. *Global Ecology and Biogeography*. 27(9):1043-1055
- Pethybridge, H., Choy, C.A., Polovina, J., Fulton, E. 2018. Improving ecosystem models with biochemical tracers. *Annual Reviews Marine Science*, 10-1.
- Reglero P., Balbín R., Abascal F.J., Medina A., Álvarez-Berastegui D., Rasmuson L., Murre B., Saber S., Ortega A., Blanco E., de la Gándara F., Alemany F., Ingram G.W.Jr., Hidalgo M. 2018. Pelagic habitat and offspring survival in the Eastern stock of Atlantic bluefin tuna. *ICES Journal of Marine Science* 2018. Doi:10.1093/icesjms/fsy135.
- Reglero P., Blanco E., Alemany F., Ferrá C., Álvarez-Berastegui D., Ortega A., de la Gándara F., Aparicio A., Folkvord A. 2018. Vertical distribution of Atlantic bluefin tuna (*Thunnus thynnus*) and bonito (*Sarda sarda*) larvae related to temperature preference, as revealed by field and laboratory experiments. *Marine Ecology Progress Series* 594: 231-243. DOI: <https://doi.org/10.3354/meps12516>.
- Reglero P., Ortega A., Balbín R., Abascal F. J., Medina A., Blanco E., de la Gándara F., Álvarez-Berastegui D., Hidalgo M., Rasmuson L., Alemany F., Fiksen Ø. 2018. Atlantic bluefin tuna spawn at suboptimal temperatures for their offspring. *Proceedings of the Royal Society B: Biological Sciences*, 10, 285(1870). pii: 20171405. doi: 10.1098/rspb.2017.1405.

#### ***Human Dimensions Working Group Publications***

- van Putten, I., Boschetti, F., Ling, S., Richards, S.A. 2019. Perceptions of system-identity and regime shift for marine ecosystems, *ICES journal of Marine Science*. fsz058  
<https://doi.org/10.1093/icesjms/fsz058>
- Berkes, F., Nayak, P. K. 2019. Role of communities in fisheries management: “one would first need to imagine it”. *Maritime Studies* 17:241–251. <https://doi.org/10.1007/s40152-018-0120-x>
- Nayak, P. K. and Berkes, F. 2019. Interplay between Global and Local: Change Processes and Small-Scale Fisheries. In R. Chuenpagdee, S. Jentoft (eds.), *Transdisciplinarity for Small-Scale Fisheries Governance*, MARE Publication Series 21, pp. 203-220.  
[https://doi.org/10.1007/978-3-319-94938-3\\_11](https://doi.org/10.1007/978-3-319-94938-3_11)
- Nayak, P. K., Armitage, D. 2018. Social-ecological regime shifts (SERS) in coastal systems. *Ocean and Coastal Management* 161 (2018) 84 -95.  
<https://doi.org/10.1016/j.ocecoaman.2018.04.020>

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## 3.5 Second International Indian Ocean Expedition

*D'Adamo, Burkill*

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