3.0 LARGE-SCALE OCEAN RESEARCH PROJECTS

3.1 Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) (joint with Future Earth) *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)

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Executive Committee Reporter: Peter Burkill

Executive Officer: Einar Svendsen

Integrated Marine Biogeochemistry and Ecosystem Research (IMBER)

Annual Report to SCOR
May 2016

A. Introduction

The Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) project (see www.imber.info) is an international global environmental change research project, co-sponsored by the Scientific Committee on Oceanic Research (SCOR) and, the International Geosphere-Biosphere Programme (IGBP) until it ended in December 2015, and now by Future Earth. IMBER's International Project Office (IPO) in Bergen, Norway is sponsored by the Institute of Marine Research (IMR) and the Norwegian Research Council, and its Regional Project Office (RPO) in Shanghai is hosted and supported by the State Key Laboratory of Estuarine and Coastal Research (SKLEC) and the East China Normal University (ECNU).

IMBER's goal has been to develop a comprehensive understanding of, and accurate predictive capacity for, ocean responses to accelerating global change and the consequent effects on the Earth System and human society, as outlined in the 2005 IMBER Science Plan and Implementation Strategy (SPIS) and the 2010 supplementary update. Now, after 10 years, IMBER has a new vision: ocean sustainability for the benefit of society, and aims to understand, quantify, and compare historic and present structure and functioning of linked ocean and human systems, to predict options for securing or transitioning towards ocean sustainability. A new SPIS providing the basis for the next decade of IMBER research is under review by SCOR and Future Earth. The current structure of IMBER (Fig. 1) provides the starting point for implementation of the SPIS.

IMBER's strong commitment to curiosity-driven science provides its foundation. However, the environmental issues facing society, particularly those relating to global environmental change, are issues that challenge natural and social sciences and humanities. Integration of the understanding provided by curiosity-driven natural science and the problem-driven, societally relevant science requires research that crosses the interfaces between these disciplines (transdisciplinary research). A clear message from the 2014 IMBER Open Science Conference (OSC) and community consultation in 2015 associated with development of the SPIS, was that transdisciplinary research must be part of the future research agenda. This is underscored by the recent science highlights presented in the next section.

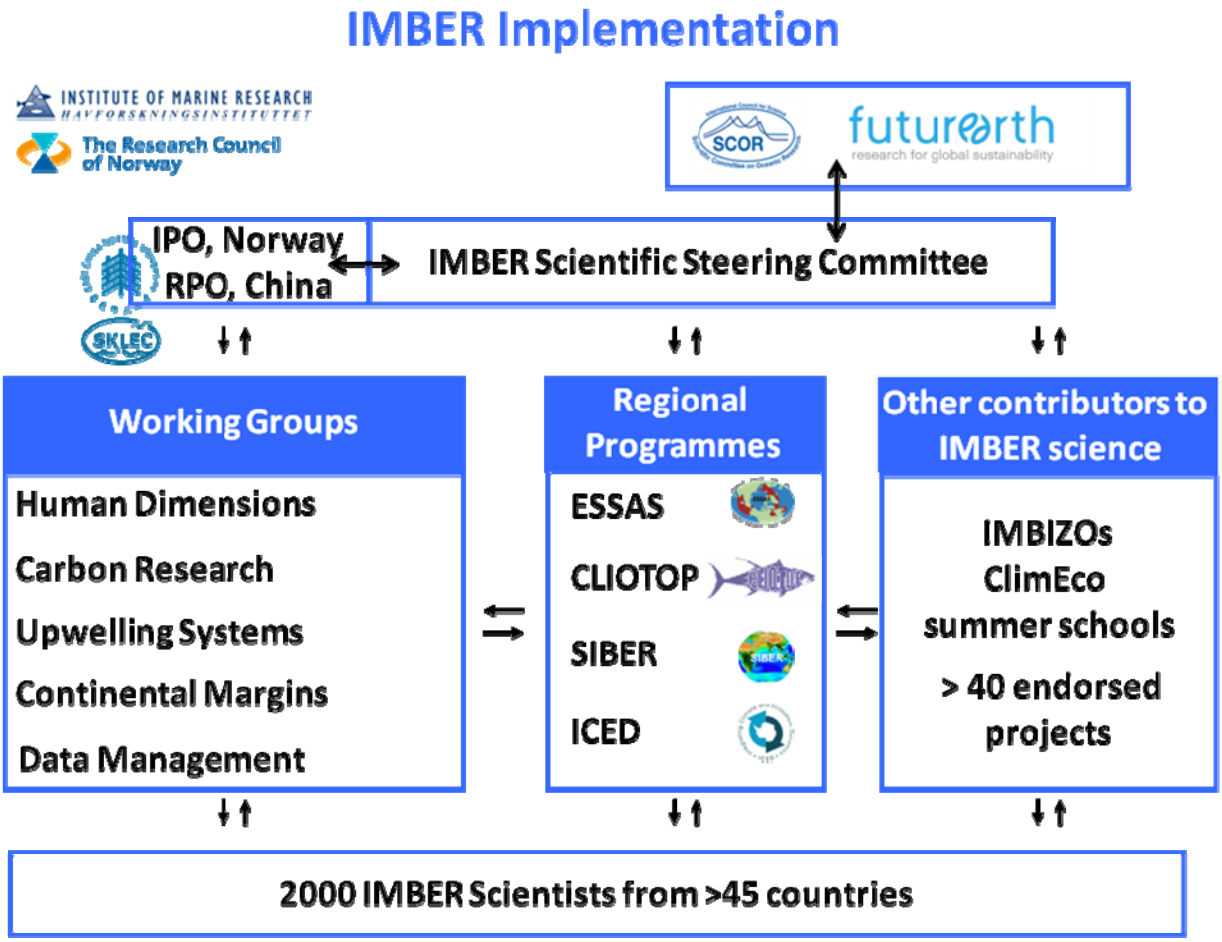

Figure 1. Structure of IMBER.

B. Selected IMBER discoveries and highlights

- IMBER advanced understanding of climate effects on marine ecosystems in the Anthropocene
- IMBER advanced understanding of natural-human science interactions in marine systems
- IMBER is developing a social-ecological decision support framework for marine systems
- IMBER promoted and undertook capacity building and knowledge transfer activities
- IMBER research informs sustainable use of marine ecosystems

Selected discoveries and highlights in 2015-16 from IMBER regional programmes, working groups and endorsed research projects. Special relevance to societal issues are marked in red.
From: Ecosystem Studies of Sub-arctic and Arctic Seas (ESSAS):

1. A new hypothesis has been proposed suggesting that the shift in Atlantic mackerel distribution from the Norwegian Sea was a result of reduced food production due to the declining nutrient concentrations (Si) along the northern European continental slope, forcing

the mackerel stock to seek new feeding grounds in the nutrient richer waters farther north and west, i.e. around Iceland and east Greenland. (Pacariz et al., submitted 2016).

2. A critical review of harvest control rules for fisheries management was undertaken. This includes their historical and institutional development, recent cases and potential harvest control rules for future fisheries management, in terms of both ideal and realistic developments. (Kvamsdal et al., submitted 2016).

3. Special Issue of *Progress in Oceanography* titled "Combining Modeling and Observations to Better Understand Marine Ecosystem Dynamics" (eds. Curchister et al. 2015) contains 19 papers on modeling marine ecosystems. The papers focus on approaches to investigate the mechanisms linking environmental influences to biological responses. An integral component is the use of observational data to ensure the credibility and appropriate interpretation of model results.

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

4. Quantifying the strength of biological feedbacks in Southern Ocean air-sea CO_2 flux is important to understanding the effects of climate change. Several global biogeochemical models under climate change to the end of the century were compared, with a focus on vertical carbon flux and changes in plankton community structure. Although there was no agreement on physical changes in the Southern Ocean, the models did agree that the biological carbon pump will be responsible for increased CO_2 uptake in a future, less well-buffered ocean (Hauck et al. 2015).

5. Understanding the key drivers of population connectivity is essential for effective management of natural marine resources. A 'seascape genetics' approach combining oceanographic modeling and microsatellite analyses was used to investigate the influences on the genetic structure of two populations of Antarctic fishes with contrasting life histories. Inter-annual variability in oceanographic flows strongly influenced the projected genetic structure, suggesting that shifts in circulation patterns due to climate change are likely to impact future genetic connectivity and opportunities for local adaptation, resilience and recovery from perturbations (Young et al. 2015).

6. The uptake of anthropogenic CO_2 is altering the carbonate chemistry and pH of the oceans, and the polar oceans are predicted to be the most severely affected. This study carried out ocean acidification (OA) manipulations of natural Arctic and Southern Ocean pelagic communities. Many responses to OA varied between environments, but there was a consistent response with regard to copepods always preferring to graze dinoflagellates compared to other phytoplankton species when in elevated pCO_2 conditions. This demonstrates that changes in food quality and altered grazing selectivity may be a major consequence of the predicted chemical changes to the polar oceans. Such altered trophodynamic interactions will impact how carbon is channelled through polar foodwebs, and the extent to which future anthropogenic CO_2 emissions can be absorbed (Tarling et al. 2016).

7. Jackson et al. (2015) summarises the findings of over a decade of work to reconstruct the population trajectories and assess the recovery status of all Southern Hemisphere humpback whale populations. The study also details methodological advances and the significant challenges overcome during the assessment, and identifies key data gaps and avenues for future work (Jackson et al. 2015).

8. From the 137-year long record of the El Niño-Southern Oscillation (ENSO), no significant trend can be detected, and the recent multi-decadal variability is similar to earlier decades. ENSO has not fundamentally changed over the period of large increase in atmospheric CO_2, and the potential of predicting the future states of the fisheries and ecosystems are quite limited (Harrison and Chiodi, 2015).

9. Major uncertainties in modeling frameworks are broadly categorised into those associated with (i) insufficient knowledge about the interactions of climate and ocean dynamics with marine organisms and ecosystems; (ii) lack of observations to assess and advance modeling efforts and (iii) an inability to predict with confidence natural ecosystem variability and longer term changes due to external drivers (e.g., greenhouse gases, fishing effort) and the consequences for marine ecosystems. As a result of these uncertainties and intrinsic differences in the structure and parameterisation of models, users are faced with considerable challenges associated with making appropriate choices on which models to use. A key research direction is the development of management systems that are robust to this unavoidable uncertainty (Evans et al. 2015).

10. Zooplankton faecal pellet production is a key control of the efficiency of deep carbon transfer in the Scotia Sea. This region contains the largest seasonal uptake of atmospheric CO_2 yet measured in the Southern Ocean (Manno et al. 2015).

11. IMBER/ICED scientists contributed to a Southern Ocean biogeographic atlas www.biodiversity.aq.

From: Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER):

12. From a biogeochemical sensor at the 80°E RAMA mooring, striking chlorophyll "spikes" were observed at the Equator during the fall Wyrtki Jets. These appear to be related to entrainment pulses and/or Yanai waves (Strutton et al. 2015).

13. A Special Issue of *CLIVAR Exchanges*, Celebrating 50 Years of Indian Ocean Research, initiated by SIBER and the CLIVAR Indian Ocean Regional Panel, was published at the launch of the Second International Indian Ocean Expedition (IIOE-2) at the International Symposium on the Indian Ocean, 30 November-4 December 2015, at the National Institute of Oceanography (NIO), Goa, India (see below) (Valiard et al. 2015).

From: Climate Impacts on Ocean Top Predators (CLIOTOP):

14. Using longline catch data from six tuna species in the Pacific, Atlantic and Indian oceans, a global, comparative perspective of habitat preferences for these species was developed based on a common dataset and consistent approaches. Results confirmed that tropical tunas prefer warm, low oxygen, stratified waters, while temperate tunas tolerate a wider range of

environmental conditions, the widest demonstrated by Atlantic bluefin tuna (*Thunnus thynnus*). This view of preferred habitats will be useful for spatial approaches to management and better predictions of the impacts of changing climate on populations and associated fisheries (Arrizabalaga et al. 2015).

15. Trials on yellowfin tuna identified increased hatch times and reduced larval growth under varying levels of increased pCO_2, with varying impacts on larval survivability. Technical challenges during experiments, and limitations on the range of pCO_2 levels used limited the assessment of potential impacts (Bromhead et al. 2015).

16. New projections of the features of the western warm pool in the Pacific Ocean suggest that while its edge is projected to warm, it is likely to remain within 10º of its present longitude. This is in stark contrast to the large projected eastward displacements of the isotherms that are usually used to define the edge (Brown et al. 2015).

17. The southwest Pacific has been identified as an area of particularly rapid warming and this trend is expected to continue. Understanding the effects of increased warming on the distribution of fisheries in the region, and management responses, is essential for the sustainable management of these fisheries. Projections from a high-resolution ocean model were used to condition a catch distribution model examining potential changes in the catches of yellowfin tuna off the east coast of Australia. Results suggest that by 2060 the core area fished by the longline fleet in the region will shift both poleward and offshore relative to existing areas. Such shifts may require modification of current fishing behaviours which, in turn, may require social and economic adjustments to the fishery (Dell et al. 2015).

18. Interactions between warming, acidification, and deoxygenation and their effects on the aerobic scope of yellowfin tuna were investigated using a physiology-based habitat suitability model. The model indicated positive non-linear interactions between temperature and acidification effects, with the largest impacts on aerobic scope occurring under conditions of high oxygen partial pressure, low temperature and low CO_2 partial pressure. Overall, the model suggests that the vertical habitat for yellowfin tuna in the eastern tropical Pacific will contract vertically and that the species will need to rely on adaptations allowing them to utilize less hospitable environments to greater extents (Del Raye and Weng, 2015).

19. Some of the most important development goals for the countries and territories of the Western and Central Pacific Ocean involve the sustainable management of their fisheries in light of environmental, economic and social uncertainties. Research priorities include (i) improved resolution of processes driving ecosystem model components via the incorporation of higher resolution climate models; (ii) development of seasonal and inter-annual forecasting tools enabling management responses to short-term variability in tuna distributions and abundances; (iii) improved understanding of the population dynamics of, and the energy transfer efficiencies between, food web components; (iv) assessment of the optimal value of access rights and overall fishery value under multiple scenarios of tuna distribution and abundance and influences on decision making by fisheries managers and fleets; and (v) utilisation of management strategy evaluation frameworks for testing fishery

management procedures to help prioritize research directions and investment. (Evans et al. 2015).

20. Finding a balance among ensuring food security, economic health, fishery sustainability, biodiversity conservation, and ecosystem function in marine systems is a challenge. Climate change may make this balancing act more difficult, as ranges and productivity of species change in time and space and will require careful and informed development of policy for managing natural resources. Insights into several conflicts and trade-offs associated with the harvesting of pelagic species, including (i) maximizing future food production given the depleted state of some stocks; (ii) minimizing bycatch of non-target species, (iii) setting ecosystem allocation rules for non-target top predators, such as seabirds, and (iv) maximizing value and livelihoods for local economies are identified. Resolving these conflicts is achievable with current approaches and technologies (Hobday et al. 2015).

21. Comparison of parameters from a eutrophic micro-/nanophytoplankton dominated ecosystem showed that systems with small primary producers (such as the oligotrophic western Pacific) have longer food chains than those with large primary producers (such as the eutrophic California Current System). Projections of ocean ecosystems suggest reductions in net primary productivity and increased contributions of picoplankton size classes associated with warming of surface waters and increased stratifcation. The response of food webs to such changes may depend on their linkage structure with ecosystems with longer food chains more resilient and capable of adaptation than those with shorter food chains (Hunt et al. 2015).

22. The end-to-end ecosystem model SEAPODYM was used to investigate the influence of environmental change and fishing on albacore abundance and distribution on past catches and on future catches under climate change scenarios. Projections suggest a decrease in biomass until 2035, stabilization and then growth after 2080 associated with the establishment of a new spawning ground in the Tasman Sea. Simulations identified particular sensitivity of the model to dissolved oxygen concentrations, projections of which include large uncertainty in the tropics. Outputs should help in developing policies for fisheries management robust to a changing environment and identify understanding of changes to oxygen availability as a key priority (Lehodey et al. 2015).

23. An investigation of larval scombrids (e.g., mackerel, tuna) from around the world in relation to water column and sea surface properties found that feeding success was distinctly different between regions, varying from 100% in the Straits of Florida and the Mediterranean Sea to as little as 40% in the Gulf of California and off northwest Australia. The number of prey species consumed was typically low and usually similar for a given scombrid taxon among regions. Larval habitat conditions were often similar, but variability among regions highlighted the potential for region-specific mechanisms regulating larval survival and, ultimately, levels of adult recruitment. This has implications for how recruitment indices are incorporated into global tuna population models (Llopiz and Hobday, 2015).

24. $\delta^{15}N$ values across multiple trophic levels and over a large spatial scale were determined in two pelagic marine ecosystems to investigate (i) if isotopic baselines could be determined from a primary consumer rather than more traditionally sampled, but more logistically

challenging, primary producers and (ii) how differing methods of baseline assessment might influence estimates of trophic position in the predator yellowfin tuna. Spatial variations of $\delta^{15}N$ from particulate organic matter, barnacles and yellowfin tuna showed similar patterns across the two ecosystems suggesting that they all can effectively reflect $\delta^{15}N$ isoscapes. Further, they suggest that variations in the isotopic composition at the base of the food web, rather than differences in diet, were the main contributors to isotopic variability. The study reinforced the importance of considering isotopic baseline variations, and provided new insights into methods that can be applied to generate nitrogen isoscapes for worldwide comparisons of marine ecosystems (Lorrain et al. 2015)

25. Many climate models describe a decrease in nutrient upwelling in the western Pacific warm pool as a result of increased stratification, leading to projections of lower surface primary production and an overall decrease in net primary productivity. Examination of high-resolution projections suggests, however, that increased mixing due to changes in currents (not fully resolved in lower resolution models), results in increased subsurface primary production. This is expected to result in almost no change in overall net primary production within the warm pool, suggesting that climate change may not have substantive impacts on marine ecosystems within the region (Matear et al. 2015).

26. Although time series of fish catches are the core of many assessments, these time series have largely been underutilised with respect to investigating variability in ecosystems. An extensive time series of drift gillnet survey data from the western North Pacific was used to analyse spatio-temporal variations in the higher trophic level community structure, revealing clear spatial and temporal patterns. Both longitudinal and latitudinal gradients in metrics calculated were evident, while temporal trends varied between metrics. Co-occurring changes in survey methods, however, prevent causal relationships from being concluded, highlighting the importance of standardized methods for the collection of time series (Okuda et al. 2015).

27. Animal daily routines represent a compromise between maximizing foraging success and optimizing physiological performance, while minimizing the risk of predation. For ectothermic predators, ambient temperature may also influence daily routines through its effects on physiological performance. Using a combination of electronic tags deployed on blacktip reef sharks (*Carcharhinus melanopterus*) and bite rates in herbivorous reef fishes, the activity rates of these predators and their prey was quantified. Activity rates varied in relation to diel cycles of temperature, with predators being most active during cooling periods, when their greater thermal mass would result in their body temperatures being higher than those of their prey. This body temperature difference likely results in an advantage for the predators (Papastamatiou et al. 2015).

28. Biochemical composition of the muscle tissues of predators provide information on dietary histories across much longer time scales than traditional investigations of stomach contents and can therefore be used to investigate longer term variability in the trophodynamics of predators. Using signature fatty acids, spatial variability in the trophic position of albacore and skipjack tuna (*Katsuwonus pelamis*) from the southwestern Pacific Ocean and underlying trophic and physiological reasons for variability were investigated. Latitudinal variability was particularly evident in albacore tuna and was attributed to differences at the base of the

food web between temperate and tropical regions. The study identified that signature fatty acids could potentially be used as indicators of thermal change in regions such as the 'tropicalisation' of subtropical and temperate waters. Latitudinal gradients in concentrations of health-benefitting omega-3 fatty acids suggest that such tropicalisation could potentially reduce the lipid quality of albacore tuna for human consumers (Parrish et al. 2015).

29. Increasing water temperature has been associated with range shifts in several marine species. While the direction and increase in rates of range shifts have been noted, identification of drivers of variation in range shifts within species and across regions within a species range in areas of intense warming, is lacking. Projected shifts in the core habitat of a number of pelagic species off the east coast of Australia were compared at varying spatial and temporal scales to investigate variability in the rate of shifts and their association with spatial gradients in temperature. Projections across all scenarios showed consistent southern (poleward) shifts in the core habitats of all species. Notably, the trailing edges of habitats shifted faster than their leading edges, due to weaker spatial gradients in water temperatures associated with (northward) trailing edges, in conjunction with relatively constant rates of warming across latitudes. This suggests that spatial gradients in temperature may be important in determining spatial variability in range shifts within species (Robinson et al. 2015).

30. The speed at which the ocean is warming and associated isotherms are moving varies considerably both temporally and spatially. Projections under business-as-usual emission scenarios suggest that the speed at which isotherms migrate will be up to seven times faster in the 21st Century compared to the last century, and speeds during summer will be greater than those in winter across most oceanic regions. In response, the thermal ranges of species will undergo sudden, rapid shifts rather than exhibiting gradual uniform movement. Such rapid shifts are likely to present challenges both in data collection and management responses (Sen Gupta et al. 2015).

31. Dynamic optimal foraging theory predicts that foraging efficiency increases with body temperature, maximising energy harvest rates and that, therefore, vertical migrations demonstrated by species such as bigeye tuna are thermoregulatory in nature. The observed behaviour of bigeye tuna was examined to determine if vertical migrations were quantitatively consistent with predictions from dynamic optimal foraging theory using a simple dynamic programming model. Modeled behaviour was found to be consistent with observed data on vertical movement, with small individuals displaying constant-depth strategies and large tuna displaying vertical migrations. The analysis supports the hypothesis that bigeye tuna behaves in such a way as to maximize its energy gains. The model developed provides insight into the processes underlying observed behavioural patterns and allows the generation of predictions of foraging behaviour in unobserved environments (Thygesen et al. in press).

32. Common oceanic sunfish (*Mola mola*) frequently occur as bycatch in fisheries worldwide and comprise the greatest portion of the bycatch in California's large-mesh drift gillnet fishery. Little is known of their movements, oceanic drivers of movements or the habitats utilised by individuals. Using data derived from electronic tag deployments, sunfish were observed to undertake seasonal movements between the southern California Bight and

adjacent waters off northern and central Baja California. Association with upwelling fronts and surface slicks indicated convergent circulation. Zooplankton sampling in the region suggest sunfish were associating with areas of dense concentrations of salps, a common food item. The study suggests that bio-physical interactions in coastal upwelling fronts create a favourable foraging habitat for this species (Thys et al. 2015).

33. Biologging instruments allow the simultaneous measurement of the fine-scale foraging behaviours of predators and their environment, revealing characterisation of foraging environments and insights into the distributions of their prey. Using such instruments, the relationship between prey encounter events by southern elephant seals and water temperature, light, and depth was investigated. Foraging environments were found to be structured by the main frontal systems of the Southern Ocean. Large physical and/or spatial differences in these environments suggest that differing prey communities are targeted by the seals depending on their location, highlighting the dietary flexibility of the species and potentially its adaptability to future environments (Vacquié-Garcia et al. 2015).

34. Fishery resource managers and policy makers in Pacific Island countries and territories will be increasingly challenged by the need to ensure food security and resource sustainability within the context of a changing climate. Pelagic fish resources available to the region, challenges to development, capacity and climate change and science needs for identifying and addressing changes to resources and potential conflicts with development goals are outlined. Key to responding to climate change will be investments aimed at expanding the capacity for research, management, and sustainable fisheries management within these countries and territories, which could be facilitated through collaboration between PICTs, RFMOs, and scientific centers of excellence (Weng et al. 2015).

35. Extinction risk is closely tied to body size, home range, and species distribution, so quantifying these features is important for conservation, to enable the use of concepts such as ‘umbrella species’, whose conservation protects other species due to shared habitat. A multi-year study of the home range of humphead wrasse in the central tropical Pacific was conducted to determine the value of this species as an umbrella species for coral reef conservation. Home ranges varied substantially and changed with ontogeny. Females had relatively large home ranges, indicating value as an umbrella species for coral reefs. The home range of the species was then compared to the size distribution of tropical marine protected areas (MPAs), and the MPA length necessary to retain humphead wrasse was estimated. It was determined that most MPAs are too small to effectively protect the humphead wrasse, so small reserves are unlikely to be an effective management tool (Weng et al. 2015).

36. Little is known of the movements and diet of albacore tuna in the South Pacific Ocean, or how variability in both might influence the vulnerability of albacore tuna to fisheries across their range. Using electronic tagging and stomach samples, the diving behaviour and diet of albacore tuna in three locations were investigated. Albacore tuna in tropical regions demonstrated a distinct diel pattern in vertical habitat and consumed significantly more deepwater prey species than those in temperate regions which tended to be limited to shallow waters above the mixed layer. This latitudinal variability in diving behaviour and diet

suggests that future changes in the vertical structure of temperate waters might influence the vertical distribution of albacore tuna and, therefore their vulnerability to oceanic fisheries (Williams et al. 2015).

37. Human pressures have resulted in declines in populations of leatherback turtles (*Dermochelys coriacea*) in the eastern Pacific Ocean. How climate change might impact these already threatened populations is not well understood. Using habitat models derived from data collected from electronic tag deployments on turtles and future ocean state derived from climate models, changes to the core habitats of leatherback turtles were investigated. Results suggest that the core pelagic habitat of the eastern Pacific leatherback turtle population will decline by approximately 15% within the next century, compounding recent declines in abundance. This reduction in available habitat may result in distributional shifts, behavioural changes, or even extinction. To ensure resilience of the population to potential habitat modification associated with climate change, existing stressors on the population such as fishing and anthropogenic impacts on nesting beaches need to be reduced (Willis-Norton et al. 2015).

38. Time series of commercial fishery catches and scientific survey data of the diet of northern fur seals (*Callorhinus ursinus*) from the waters off northeastern Japan spanning 60 years were examined to investigate potential long-term changes in the marine ecosystem. Variability in both datasets highlighted the many environmental factors influencing the observed trends and with neither dataset supporting the 'fishing down the food web' postulated for many fisheries in other regions. Inconsistencies in trends observed in the two datasets highlighted the need to use multiple datasets when investigating ecosystem variability, and also careful interpretation of results based on individual environmental time series (Yonezaki et al. 2015).

39. Classical diet studies have provided most of the historical information on trophic pathways in pelagic ecosystems, but biochemical methods (stable isotopes, fatty acid signatures) are allowing new questions to be addressed. Progress on understanding the spatial and temporal variability in the trophodynamics of marine predators was reviewed, and impacts of ocean warming on marine ecosystems from both top-down and bottom-up trophic perspectives were examined. Impacts identified included alterations to energy transfer efficiency, decreased productivity, shifts in biodiversity hotspots, shifts and restrictions in population abundances and distributions and alterations in species assemblages, which can influence food availability for higher predators. For a comprehensive understanding of the trophodynamics of marine top predators, a combination of methodologies is needed (Young et al., 2015).

From: SOLAS/IMBER Carbon (SIC) Working Group:

40. An article on the Ocean Acidification International Coordination Centre (OA-ICC) **data compilation on the biological response to ocean acidification (**https://www.iaea.org/ocean-acidification/page.php?page=2203) was published in the journal *Earth System Science Data* in February 2016. The data compilation is maintained in cooperation with the State Key Laboratory of Marine Environmental Science, Xiamen University (China) and the German

data publisher PANGAEA. It currently offers access to data sets from nearly 700 scientific papers.

41. The Surface Ocean CO_2 Atlas (SOCAT, www.socat.info), compiled by the international marine carbon community, provides access to quality-controlled surface CO_2 data (Fig. 3). The first two versions were released in 2011 and 2013, respectively. Version 2 contains 10.1 million quality-controlled, surface ocean fCO_2 (fugacity of CO_2) values from 1968 to 2011 for the global oceans and coastal seas. Version 3 of the Atlas was released on 7 September 2015 (Pfeil et al., 2015).

42. Scientific applications of SOCAT include 1) quantification of the ocean carbon sink and 2) ocean acidification and their temporal and spatial variation, 3) validation of ocean carbon models and coupled climate carbon models, and 4) provision of constraints for atmospheric inverse models used to estimate land carbon sink (Lauvset, et al. 2015; Bakker et al. 2015)

43. SOCAT synthesis products represent an impressive achievement in coordinating international researchers to deliver publicly accessible and uniformly quality-controlled data for marine carbon and ocean acidification research that can be used for research and to inform international policy and climate negotiations.

From: Capacity Building Task Team:

44. IMBER is proactive in building and strengthening the scientific capacity of early to mid-career researchers, and scientists from developing countries. A major activity in facilitating capacity building is the biannual international, transdisciplinary ClimEco (Climate and Ecosystems) summer school. To date, more than 300 students and early-career researchers, many from developing countries, have attended the four summer schools organized by IMBER (Hofmann et al. 2015).

45. The legacy and perspective document on IMBER capacity building aims to assess these activities, and outline a way forward for sustainable capacity development within the IMBER research community as it prepares for the next 10 years of marine biogeochemistry and ecosystem research. (IMBER Capacity Building Task Team (2016). IMBER Report No. 9, IMBER Regional Project Office /IMBER International Project Office, Shanghai, China. 30pp).

From: Human Dimensions Working Group (HDWG):

46. I(MBER)-ADApT (Assessment based on Description, Responses and Appraisal for a Typology) developed by the HDWG, is an integrated assessment framework built on knowledge learned from past responses to global change issues. It will enable decision makers, researchers, managers and local stakeholders to make more efficient decisions for marine sustainability, and to evaluate most effectively where resources should be allocated to reduce vulnerability and enhance resilience of coastal people and communities to global change (Bundy et al. 2015; http://www.imber.info/index.php/eng/Science/Working-Groups/Human-Dimensions/IMBER-ADApT).

From: Continental Margins Working Group:

47. The quest for resources is driving exploration and exploitation on continental margins, including the Arctic margins. Disasters, such as the 2010 BP-Deepwater Horizon oil spill, are likely to occur with increasing frequency and exacerbate on-going threats, such as coastal hypoxia. The IMBER-Future Earth Coasts Continental Margins Working Group (CMWG)

found that the prevailing Law of the Sea promotes exploitation, but with insufficient responsibility and accountability to stem unsustainable development. Recommendations from CMWG activities focus on reforms based on better understanding of the social-ecological systems (Levin et al. 2015), assessment of risks associated with development, and effective governance (Glavovic et al. 2015).

From Endorsed projects:

SWAtlantic (SACC-IAI)

48. Shelf-deep ocean exchanges and their variability are key to understand the processes that control retention of planktonic species, and therefore abundance and biodiversity over a wide range of trophic food webs, and may have a strong impact on the carbon budget of continental margins. Satellite-derived surface temperature, salinity, and currents combined with in-situ observations and numerical simulations reveal intense shelf-deep ocean exchanges in the western South Atlantic (Strub et al. 2015; Guerrero et al. 2014; Matano et al. 2014).

49. Upwelling is the main process sustaining plant growth in the open ocean. Though the most effective upwelling ecosystems are wind-forced (e.g., mid-latitude eastern boundary currents), other productive marine ecosystems, such as the Patagonia continental shelf in the SW South Atlantic must rely on other upwelling mechanisms. Theory predicts that the interaction of western boundary currents of subpolar origin with the ocean bottom lead to strong shelf break upwelling (Franco et al. 2015; Matano et al. 2014; Pisoni et al. 2014; Valla and Piola 2015).

GALATHEA

50. It is expected that ocean warming will lead to increased bacterial activity and faster remineralisation of particulate organic carbon (POC) in the surface layers, which increase POC export to deep waters, potentially decreasing the strength of the biological pump. This temperature sensitivity of remineralisation in the global ocean has now been quantified and is an important input for modelling of the ocean carbon cycle (Bendtsen et al. 2015).

PERSEUS

51. An overview of the pressures impacting the Southern European Seas (SES) and their roles in altering the environmental status was undertaken. Additional knowledge and improved understanding is needed to undertake a scientific Good Environmental Status (GES) evaluation. Some of the indicators for the Marine Strategy Framework Directive (MSFD) are almost impossible to evaluate for operational purposes (e.g., those related to biodiversity, food web structure, marine litter and microplastics, underwater noise and energy). Additional targeted scientific priorities were identified for the SES to help reduce uncertainties and gaps in data and knowledge (Crise et al. 2015).

52. The swarms of Portuguese Man-of-War (*Physalia physalis*) that appeared in summer 2010 in the Mediterranean Sea had dramatic consequences, including the region's first recorded human fatality attributed to a jellyfish sting. Analyses of the meteorological and oceanographic conditions of the Northeast Atlantic Ocean in the months prior to the appearance of *P. physalis* and simulation of the probable drift of Atlantic populations into the

Mediterranean basin suggested that the swarms resulted from an unusual combination of meteorological and oceanographic conditions the previous winter, and was not a permanent invasion due to favourable climatic changes (Prieto et al. 2015).

53. Trawls in the coastal areas of the Eastern Mediterranean and Black Sea found up to 1211 items of litter per km^2. Plastics were the most abundant (mostly bags and bottles) litter, up to 95% of the total, in all study areas. More than half of marine litter items were of medium size: 10 × 10 cm, <20 × 20 cm. The results are presented in a recent report, supporting the Marine Strategy Framework Directive (MSFD) implementation, as well as efforts to discourage plastic carrier bag use (Ioakeimidis et al. 2015).

54. A visual census of marine litter on the seafloor of the Saronikos Gulf (Greece) was combined with environmental education in a novel two-day research cruise, in which schoolchildren actively participated in using a Remotely Operated Vehicle (ROV). Marine litter proved to be an ideal theme to enhance the environmental awareness of schoolchildren (Ioakeimidis, et al. in press).

CATARINA

55. The first observation-based acidification trends in the water masses of the Atlantic basin over the past two decades were compared with climate model results. Observations and model output confirm that pH changes in surface layers are dominated by the anthropogenic component. In mode and intermediate waters, the anthropogenic and natural components are of the same order of magnitude and sign (about -0.002 yr^{-1}). Large changes in the natural component of newly formed mode and intermediate waters are associated with latitudinal shifts of these water masses caused by the Southern Annular Mode in the South Atlantic and by changes in the rates of water mass formation in the North Atlantic (Aida et al. 2015).

CARBOCHANGE

56. Several studies have suggested that the carbon sink in the Southern Ocean—the ocean's strongest region for the uptake of anthropogenic CO_2—has weakened in recent decades. This study demonstrated, on the basis of multidecadal analyses of surface ocean CO_2-observations, that this weakening trend stopped around 2002, and by 2012 the Southern Ocean had regained its expected strength based on the growth of atmospheric CO_2. The large decadal variations in the Southern Ocean carbon sink suggest a rather dynamic ocean carbon cycle that varies more than previously recognized (Landschutzer et al. 2015)

57. For the year 2014, CO_2 emissions from fossil-fuel combustion and cement production grew to 9.8 ± 0.5 GtC yr^{-1}, 0.6% above 2013, continuing the growth trend in these emissions, albeit at a slower rate compared to the average growth of 2.2%yr^{-1} that took place during 2005–2014. Cumulative emissions of CO_2 will reach about 555 ± 55 GtC for 1870–2015, whereof about 75% from fossil fuel and cement production, and 25% from change in land use (Le Quéré et al. 2015).

58. Century-scale trends and seasonality in pH and temperature for shallow zones of the Bering Sea show a long-term decline of 0.08 ± 0.01 pH units between the end of the 19^{th} and 20^{th} centuries, which is consistent with atmospheric CO_2 records. Additionally, a strong seasonal cycle (~0.22 pH units) is observed and interpreted as episodic annual pH increases caused by the consumption of CO_2 during strong algal (kelp) growth in spring and summer. The rate of acidification intensifies from –0.006 ± 0.007 pH units per decade (between the 1920s and 1960s) to –0.019 ± 0.009 pH units per decade (between the 1960s and 1990s), and the

episodic pH increases show a continuous shift to earlier times of the year throughout the centennial record. This is indicative of ecosystem shifts in shallow water algal productivity in this high-latitude habitat resulting from warming and acidification (Fietzkeet al. 2015).

Too Big To Ignore (TBTI, http://toobigtoignore.net/)

59. To address the marginalization of small-scale fisheries in policy and governance, an Information System (ISSF, http://issf.toobigtoignore.net/), containing information such as fishing area, gear type, targeted species and catch fate, has been developed. As of March 2015, ISSF contained 1,740 records contributed by 400 individuals from 140 countries. This extensive and comprehensive information system makes possible for the first time the development of evidence-based descriptions of the existence and importance of small-scale fisheries around the world (Jentoft and Chuenpagdee, 2015).

AMT

60. The Atlantic Meridional Transect (AMT) is a multidisciplinary programme since 1995 (http://www.amt-uk.org/) which undertakes biological, chemical, and physical oceanographic research during an annual voyage between the UK and destinations in the South Atlantic. The annual transect crosses a range of ecosystems from sub-polar to tropical and from euphotic shelf seas and upwelling systems to oligotrophic mid-ocean gyres. AMT informs on trends and variability in biodiversity and function of the Atlantic ecosystem during this period of rapid change to our climate and biosphere.

C. Activities of IMBER Regional Programmes

Ecosystem Studies of Subarctic and Arctic Seas (ESSAS) Regional Programme

As ESSAS research is expanding to include the Arctic, at last year´s SSC meeting its name was changed (but retaining the same acronym) to include Arctic seas.

The ESSAS Annual Science Meeting on The Role of Ice in the Sea was held in Seattle, Washington, in June, 2015 with 51 oral presentations and 13 poster presentations. Four themes were explored: (1) Humans, Ice and the Sea in the Subarctic and Arctic Past, (2) the Role of Sea Ice in the Arctic and Subarctic, (3) the Ecological Role of Tidewater Glaciers, and (4) Social Science Investigations of Changing Sea Ice Conditions. Over 100 scientists attended from 11 countries. This was the largest ESSAS ASM and by all indications one of the most successful.

The ESSAS RACArctic (Resilience and Adaptive Capacity of ARCTIC marine systems under a changing climate) project, funded by the Belmont Forum, began with fall meetings in 2015 in each of the co-sponsoring countries, Japan, the United States and Norway. The first international meeting was held on 1-3 March 2016 in Hakodate, Japan, beginning with a stakeholders' meeting. The aim of the project is to synthesize information from completed and ongoing regional studies on how climate variability and change in the Subarctic to Arctic transition zones may affect future marine ecosystems of the Pacific and Atlantic Arctic. In particular, the project will examine how fish populations and their prey are able to adapt or respond to natural and anthropogenic changes in the Arctic and how these are expected to affect existing and future fisheries, subsistence harvests, and the socio-economic systems that depend upon them.

The ESSAS 3rd Open Science Meeting is planned for June 2017 in Tromsø, Norway – "Moving in and out and across the Subarctic and Arctic – shifting boundaries of water, ice, flora, fauna, people and institutions".

A Special Issue by the ESSAS WG on modelling marine ecosystems entitled Combining Modeling and Observations to Better Understand Marine Ecosystem Dynamics and dedicated to the late Bern Megrey was published in November 2015 with 19 papers. The idea for this special issue was formulated at the ESSAS Open Science Meeting in Seattle during 2011 and was edited by Enrique Curchitser, Ken Rose, Shin-ichi Ito, Myron Peck and Michio Kishi.

ESSAS will continue with its current structure. There are currently four working groups:

WG: Modelling ecosystem response – published a special issue on modelling and observational approaches.
WG: Arctic-Subarctic interactions, had a session at the 2016 ASLO Ocean Sciences meeting.
WG: Human dimensions, has organised a session at the ESSAS Annual Science Meeting 2015 in Washington.
WG: Comparative Paleo-ecology in Sub-Arctic seas (a longer term assessment of the mechanisms linking climate, oceanography, ecology and human system relationships).

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

The ICED programme aims to better understand the climate interactions in the Southern Ocean, the implications for ecosystem dynamics, the impacts on biogeochemical cycles, and the development of sustainable management procedures (see www.iced.ac.uk/index.htm).

Highlights from ICED science over the past year are in section B. In addition, ICED scientists were involved in the following international events:

International workshop on Pteropod and Ocean Acidification, British Antarctic Survey, June 2015. The outcomes from the workshop were submitted to *Biological Review* and will be presented at the High CO_2 Symposium in May 2016. A further output may be the preparation of a paper by the joint OSPAR/ICES Ocean Acidification Study Group on the potential of pteropods as an ocean acidification bio-indicator species.

Scientific Committee on Antarctic Research (SCAR) Cross-Program Workshop on Interactions between Biological and Environmental Processes in the Antarctic, Institut de Ciències del Mar, 16-18 September 2015, Barcelona, Spain. ICED links with SCAR, in particular AnT-ERA, were strengthened through ICED involvement in this interdisciplinary activity that followed directly from and complemented the ICED Workshop on Southern Ocean Food webs and Scenarios of Change, British Antarctic Survey. The ICED workshop focused on the pelagic food web in exploring the use of climate models and data in scenarios and projections of change. The SCAR workshop focused on the benthic food web, with ICED scientists providing the link between the two towards a more complete picture of changing Southern Ocean ecosystems.

IMBER IMBIZO IV, 26-30 October 2015, Trieste, Italy. ICED scientists convened one of the workshops, on "Integrated modelling to support assessment and management of marine social-ecological systems in the face of global change." This brought together natural and social scientists from the modelling community, as well as experts in policy and the human dimensions related to the marine environment to consider approaches to integrate modelling efforts to address societal questions on marine social-ecological system change and management. ICED scientists had a leading role in developing and leading the workshop, which generated a stimulating discussion and a series of new insights. Several outputs from the workshop are in development, including a short high-profile paper and a more detailed paper on future directions. A theme section/special issue is under consideration.

EURO-MARINE Consortium General Assembly, 28-29 January 2016, Portugal. The EURO-MARINE Network is a FP7 Coordination and Support Action, launched in June 2014, and represents the merger of three former FP6 Networks of Excellence that have involved ICED Scientists (EUR-OCEANS- ICED scientists led the Southern Ocean System, MarBEF - marine biodiversity, and Marine Genomics Europe - high throughput approaches for marine biology), as well as their follow-up legacy structures the EUR-OCEANS Consortium (involving ICED scientists) and the MarBEF+ Association. EURO-MARINE represents 'a bottom-up organisation and the voice of the European marine scientific community supporting and promoting initial development of emerging science topics'. ICED scientists from the British Antarctic Survey (a paying member of EURO-MARINE) attended this year's General Assembly meeting, ensuring links between ICED and the shared vision of this European network, while building on the legacy of EUR-OCEANS in developing the ICED network and science strategy. For further information see http://www.euromarinenetwork.eu/.

ICED scientists also presented at conferences, for example, the American Geophysical Union Fall Meeting, 12-16 December 2015, San Francisco, USA; and World Seabird Conference 26-30 October 2015, Cape Town, South Africa.

In addition, ICED contributed to the annual SCAR report and Science Highlights for the Antarctic Treaty Consultative Meeting 2015; to the SCAR Cross-Program Workshop; and Richard Bellerby has led the development of a major SCAR report on ocean acidification and potential impacts in the Southern Ocean. This has involved input from a range of ICED scientists and the report is due to be formally completed in early 2016. ICED has continued its close partnership with SOOS with members of ICED also on the SOOS SSC. Collaborations are ongoing and most recently include SOOS' request for ICED to contribute to the development of a Southern Ocean database and map of field activities.

As ICED is a regional programme of IMBER, it has benefited from SCOR's financial support for various programme activities. We also appreciate SCORs work in developing science themes and capacity building.

ICED contributes to the development of the EU-PolarNet Consortium. In September, ICED scientists submitted a contribution to the newly formed EU-PolarNet Consortium's (2015-2020, see www.eu-polarnet.eu) future series of white papers addressing urgent polar research questions. ICED's contribution focused on the need to advance knowledge of polar marine

ecosystems and their influence on global cycles by coordinating strategic comparative research activities in both the Arctic and the Antarctic. The EU-PolarNet Consortium will transmit science priorities and a strategic framework to the European Polar Board, which then gives advice to the European Commission and other international bodies to strengthen polar research, optimise infrastructure, and provide tangible benefits to society.

ICED and ESSAS scientists have undertaken a series of joint activities. A joint programme paper on advection (led by George Hunt) is in review by *Progress in Oceanography* and one on Antarctic and Arctic biodiversity and ecosystem functioning (led by Eugene Murphy) is also in review. We intend to build on and develop these links and are currently investigating possible mechanisms for doing this (e.g., COST Action).

ICED is continuing 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. ICED will be represented at the second Joint Workshop of the CCAMLR Scientific Committee and the Antarctic Treaty's Committee on Environmental Protection (CEP), to be held on 19-20 May 2016 in Punta Arenas, Chile.

ICED scientists have also been involved in key International Whaling Commission work, including the completion of the Southern Hemisphere humpback whale assessment led by Jen Jackson.

CLimate Impacts on Oceanic TOp Predators (CLIOTOP) Regional Programme
CLIOTOP is an international research network open to researchers, managers, and policy makers involved in research related to large marine species. Network participants organise large-scale comparative efforts to elucidate key processes involved in the interaction between climate variability and change and human use of the ocean on the structure of pelagic ecosystems and large marine species. CLIOTOP seeks to develop predictive capability for these socio-ecological systems and evaluate adaptation options to ensure future sustainability (see www.imber.info/CLIOTOP.html).

During the 18 months since the last report to the IMBER SSC, CLIOTOP finalized activities associated with its second phase (2011-2015) and transitioned to its third phase (2016-2020) as part of IMBER under the Future Earth program. In association, CLIOTOP held its third symposium in September 2015, where activities conducted under its second phase were presented and discussions regarding its third phase occurred.

Interaction between the CLIOTOP leadership team has been through a “semi-monthly” update from the co-chairs, conference sessions and working group meetings. Every member of CLIOTOP is a volunteer, and we appreciate the efforts of all over the last 18 months. The CLIOTOP SSC met face-to-face just prior to the symposium and largely focused on development of the framework for the third phase of CLIOTOP.

Funding for CLIOTOP activities, such as workshops remains an ongoing issue, as for all the regional programs. Most activities conducted by the CLIOTOP working groups were opportunistic and largely planned in synchrony with conferences where reasonable numbers of

working group members were already attending. Several working groups have sought funds via varying avenues, but there have been few successes to date. Remaining activities (such as writing of publications) have been coordinated remotely.

Working groups have generated sever publications, either through a special issue of the journal *Deep-Sea Research II* associated with the previous CLIOTOP symposium and published in May 2015, or individually through activities associated with working groups.

At the third CLIOTOP symposium Alistair Hobday stepped down as co-chair of the SSC after six years in this role. Karen Evans (CSIRO, Australia) has formally replaced Alistair as co-chair. Osamo Abe and Robert Cowen retired from the SSC during 2015 and were formally thanked for their contributions to the SSC by the outgoing co-chair Alistair Hobday. Several candidates to join the SSC were identified during the SSC meeting and these will be followed up by the co-chairs.

Under the third phase of CLIOTOP, the SSC has agreed on a re-working of its structure. Rather than the SSC setting the science directions of working groups, with working group chairs then developing science initiatives, the SSC and the CLIOTOP community will work together to develop a series of task teams. These task teams will be cross-disciplinary, problem solving and output oriented, with varying life times (e.g., 6 months to 2 years). They will bring together experts from domains needed to resolve overarching questions orientated around the goals of CLIOTOP and be consistent with the Grand Challenges and Innovative Challenges of IMBER (www.imber.info) and, in turn, the focus of Future Earth. Task teams may be led by individuals or groups, tasks may be simple (e.g., writing a paper) or complex (developing new approaches to addressing a problem) and they may be seed funded by CLIOTOP or unfunded, but either aligned to CLIOTOP or conducting science that is consistent with CLIOTOP's objectives.

In early November 2015, the first call for task team proposals was sent out to the CLIOTOP community, resulting in eight proposals submitted to the SSC. The SSC (through online discussions) has since decided on those proposals that will form the first tranche of teams in Phase 3 of CLIOTOP. The next step in getting teams operational will be to work with the IMBER IPO in dispersing funds allocated to CLIOTOP to teams. The first tranche of teams is expected to be in place and operational before summer 2016. Formal reporting systems for task teams will require teams to report on their activities at the end of each calendar year for inclusion in CLIOTOP reports to IMBER.

Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER) Regional Programme

SIBER is a basin-wide research initiative sponsored by IMBER and 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 (www.imber.info/index.php/Science/Regional-Programmes/SIBER and www.incois.gov.in/Incois/siber).

Launch of the 2nd International Indian Ocean expedition (IIOE-2): This expedition was motivated by SCOR, SIBER, IOP and IOGOOS and it is sponsored by SCOR, IOC and IOGOOS. The IIOE-2 has become the main focus of SIBER.

Completion/publications of the IIOE-2 Science Plan (Hood et al., 2015): The IIOE-2 Science Plan was commissioned by SCOR and developed by the SCOR IIOE-2 Science Plan Development Committee beginning in April/May 2014. The development was based on several IOC-sponsored "Reference Group" planning meetings and national meetings. A progress report was delivered to SCOR in Bremen in September 2014. The first draft was completed in February 2015. The final peer-reviewed and revised draft was delivered to the IOC Interim Planning Committee in April 2015 and accepted. The plan was finalized and printed for the Goa Symposium in November 2015.

Completion/publication of the IIOE-2 Implementation Strategy (IPC, 2015): In June/July 2014 the IOC establish (through Resolution EC-XLVII.1) the IOC IIOE-2 Interim Planning Committee (IPC). The IPC was tasked to propose to the IIOE-2 sponsoring organizations (IOC, SCOR and IOGOOS) the establishment of committees to oversee the planning and implementation of IIOE-2. The IOC Executive Secretary coordinated the establishment of the IPC (through a call via IOC Circular Letter No. 2541, in September 2014). The IPC met four times by teleconference and twice in person in 2015 to undertake these assigned tasks. The IIOE-2 Implementation strategy was finalized and printed for the Goa Symposium in November 2015.

Goa IIOE 50th Anniversary Symposium and Launch of the IIOE-2: The symposium was convened at NIO in Goa, November 30 through December 4, 2015. Special sessions followed the IIOE-2 Science Plan research themes. The first cruise of IIOE-2 was launched on the last day of the symposium. The symposium was followed by the SCOR general assembly and the joint SIBER/IOP/IOGOOS/IRF meetings.

Launch of the Eastern Indian Ocean Upwelling Research Initiative (EIOURI): EIOURI is a major SIBER research initiative under IIOE-2. Planning for EIOURI is at an advanced stage. The main foci of this initiative is on the upwelling regions that develop seasonally off Java, Sumatra, and northwestern Australia. The Science Plan for EIOURI has also been completed (Yu et al. 2016).

Development of the Western Indian Ocean Upwelling Research Initiative (WIOURI) (Roberts et al., in preparation): In addition to EIOURI, planning efforts have been initiated to develop a complementary upwelling research initiative under IIOE-2 on the western side of the basin.

SIBER has strong collaborations with various regional organizations (e.g., Indian Ocean Panel of CLIVAR and IOGOOS). This collaboration provides a model for successful CLIVAR-IMBER collaboration.

D. Activities of IMBER Working Groups and Task Teams

SOLAS-IMBER Carbon (SIC!) Working Group
IMBER currently has three joint SOLAS-IMBER carbon (SIC!) working groups that consider carbon in the surface ocean systems (SOS), carbon in the interior ocean (IOC), and ocean acidification (SIOA).

Surface Ocean Systems (SIC!-SOS)
The Surface Ocean CO_2 Atlas (SOCAT) includes more than 100 contributors, and has assembled surface ocean carbon dioxide (CO_2) data in a uniform, quality-controlled format. Version 1 was made public in 2011 at the IMBER-SOLAS Carbon conference in Paris. Version 3 was released just before the SOLAS Open Science Conference 2015 in Kiel, Germany.

SOCAT Version 3 provides surface water fCO_2 (fugacity of CO_2) values from 1957 to 2014 (i.e., 58 years) for the global oceans and coastal seas with 14.5 million unique data points (4.4 million data points more than Version 2), from over 3,600 datasets. The SOCAT synthesis and gridded data products can be interrogated via interactive online viewers or downloaded in a variety of formats from the SOCAT website (www.socat.info). The quality control criteria have been adapted for Version 3 to accommodate calibrated CO_2 data from new sensors and alternative platforms. Data submitted before the end of January 2016 will be quality-controlled and made public in SOCAT version 4 on 30 June 2016. Applications of the SOCAT Atlas include process studies, quantification of the ocean carbon sink, seasonal to year-to-year variation, and ocean carbon cycle modelling. The Global Carbon Budget (www.globalcarbonproject.org/carbonbudget/) uses SOCAT for quantification of the annual ocean carbon sink.

The Surface Ocean pCO_2 Mapping intercomparison (SOCOM) is a recent initiative that compares a total of 14 surface ocean CO_2 gridded products, derived by a variety of methods, many of them based on SOCAT.

Interior Ocean Carbon (SIC!-IOC)
Recent activities focused on analysing the carbon data from hydrographic surveys to determine change in the oceans' anthropogenic CO_2 content since the 1990s. The preliminary results from the first decade of GO-SHIP were presented in a review paper. The WG will finalize the results on the basis of GLODAPv2, the quality-controlled database released in January 2016 for CO_2-relevant biogeochemical and physical parameters from 724 scientific cruises covering the global ocean.

IOC also contributed to the joint GO-SHIP/Argo/IOCCP "Sustained ocean observing for the next decade" meeting in Galway, Ireland http://www.gaic2015.org. They continue to support the development and application of biogeochemical sensors on Argo floats. Recently, they contributed to the draft BGC-Argo Implementation Plan and reported on it to the Argo steering team in March 2016. IOC is likely to engage fully in the data synthesis and integration on a global/basin-scale.

SOLAS-IMBER Ocean Acidification (SIOA)
The SIOA working group coordinates international efforts and synthesis activities for ocean acidification research. Within a single decade ocean acidification has gone from a research area of limited interest to one that is now considered to be a priority for ecology and environmental sciences. This rapid expansion has made it difficult for experts to share information and train new scientists from different countries.

The SIOA was instrumental in the development of the OA International Coordination Centre (OA-ICC) and in co-design and co-production with a range of stakeholders. OA-ICC is mainly driven by the SIOA. The Centre aims to foster scientific collaboration at the international level, promote best practices, improve observational capacities and databases, and facilitate communication and outreach. The OA-ICC is supervised by a science coordinator (SIOA's current chair). The OA-ICC advisory board includes all SIOA members, the IMBER SSC Chair, and is chaired by a SIOA member.

The 4th Ocean in a High-CO_2 World Symposium was held in Hobart, Australia, on 3-6 May 2016. SIOA organised several side events at the IPCC Our Common Future Under Climate Change conference in Paris in July 2015, and produced a variety of outreach material.

Continental Margins Working Group (CMWG)
With the tragic death of past CMWG co-chair Kon-Kee (K.K.) Liu, and the re-organisation of LOICZ as Future Earth Coasts (FEC), the CMWG has been semi-quiescent this year. However, Karin Limburg has now been appointed as the IMBER CMWG co-Chair and Don Forbes her FEC counterpart. New activities are being planned to progress the ideas developed by the CMWG in the previous three years. The priority areas identified in Glavovic et al. (2015) map well onto the IMBER Grand Challenges. Because these are somewhat general, it is necessary to refine and test them with case studies. Accordingly, it is suggested that two good test areas would be: 1) a densely populated part of the world, where severe pollution/hypoxia/etc. is in conflict with fisheries, aquaculture, and other consumptive activities (e.g., southern Asia), and 2) a sparsely populated part of the world (e.g., the Arctic), where climate warming is driving an increase in economic activities and exploitation in fragile, largely pristine continental margins. New CMWG members are being selected according to expertise relevant to the case studies. **A proposal to fund a workshop to organize the first case study was submitted to the Asia Pacific Network (APN); however, it was rejected. The Arctic case study has yet to be developed and connections with the IMBER ESSAS programmes and ESA are being made. Both IMBER and FEC successfully applied for IGBP/ESA funds to support a workshop on the Arctic focus within the CMWG, and the planning for this is underway.**

Data Management Committee (DMC)
The current Data Management Committee (DMC) has achieved what it set out to do. If the group is to continue, new members with expertise in social science data, and maybe in animal tracking, GOOS, etc. need to be appointed and new Terms of Reference developed.

The Data Management Cookbook (http://imber.info/index.php/Science/Working-Groups/Data Management/Cookbook) remains an important and significant product of the DMC. Data

management workshops have been organised at the IMBIZOs and the OSC. At IMBIZO IV in October 2015 the DMC provided advice and guidance on all data-related issues.

Capacity Building Task Team (CBTT)
At the last IMBER SSC meeting it was agreed that the Capacity Building Task Team has done an excellent job, and has fulfilled its mandate. As capacity building is now included in all IMBER activities and events, once the IMBER capacity building legacy document is published, the members will be thanked and the Task Team disbanded. IMBER will ensure that the recommendations in the legacy document are properly considered/ fulfilled.

Human Dimensions Working Group (HDWG)
The group is finalising a book comprising 19 chapters related to I(MBER)-ADApT (Assessment based on Description, Responses and Appraisal for a Typology, http://www.imber.info/Science/Working-Groups/Human-Dimensions/I-MBER-ADApT) and has published a special issue (February 2016) of *Regional Environmental Change*. They will also convene a session at the World Fisheries Congress in Korea in May 2016 together with ICES and PICES. It is hoped this might lead to better linkages with natural and social sciences, including governance. The HDWG focuses on the interactions between human and ocean systems, and aims to create an integrated and interactive natural-social science marine research community within IMBER. One of its major achievements has been the development of the I(MBER)-ADApT decision support tool.

Four new members have agreed to join the HDWG next year, including van Putten, thus ensuring a continued HDWG-SSC link when Bundy and Chuenpagdee rotate off.
I-ADApT has been published and is now being tested with an increasing number of case studies. The goal is to include about 100 cases.

On a longer term, the intention is to develop a database of global case studies as an open-access web site to help decision makers, researchers and stakeholders decide how to respond when faced with difficult choices and trade-offs. There is an open invitation and template to supply case studies to the I-ADApt system. Because of the complex interactions and feedbacks between humans and the ocean, the case study template includes questions about the natural, social and governing systems, the stressors that affect them, their response and an appraisal of that response.

IMBER-CLIVAR Upwelling Working Group
There have been two major events on upwelling since the last IMBER SSC meeting in June 2015.

Enrique Curchitser, leader of the Research Focus (RF) group, organized a workshop in Ankara, Turkey, in October 2015 to further plan the work of the Upwelling WG. It was held following a CLIVAR summer school. A total of 18 participants were involved representing several disciplines: physical oceanography models and observations, atmospheric sciences, biogeochemistry, climate modelers, and fisheries scientists. Reuben Escribano was the IMBER representative, although several other IMBER scientists (such as Colleen Maloney) also attended. The discussion centered primarily on Eastern Boundary Upwelling Systems (EBUS).

Particular attention was paid to global climate model biases resulting from the lack of resolution in EBUS. Some of the major points of the discussion included:

- There is need to design proper metrics for climate models. Significant work is needed on the atmospheric and coupled atmosphere/ocean dynamics in EBUS.
- What observations are needed, e.g. glider lines, etc.? Oxygen Minimum Zones (OMZs) and their interaction within upwelling regions were discussed.
- More information is needed on the origin and destination of the upwelled waters.
- The definition of an EBUS needs to be refined and comparison between different systems need to be highlighted
- The role of the meso- and sub-mesoscale processes in determining characteristics of EBUS needs to be elucidated.
- Detailed resolution of coastal winds in upwelling zones is required.
- It was recognized that fisheries in upwelling areas need to be addressed and a plan was drafted regarding the use of models to understand the impacts of climate variability on EBUS. Schematics of EBUS processes in a coupled atmosphere/ocean system were drawn up.

The second major event was the Upwelling Workshop at IMBIZO IV in Trieste, Italy led by Francisco Chevez, Eddy Allen and Nina Bednarsek. The main objectives of the workshop were to:

1. Determine how integrated and coordinated projects can be developed so that the relative roles of natural climate variability, anthropogenic climate change, broader global change, and human responses can be elucidated and predicted.
2. Integrate perspectives from a broad range of disciplines, including oceanographers, ecologists, economists, political scientists, and others with interests in coastal systems and their dependent human populations.
3. Prepare a white paper/synthesis paper incorporating novel ideas generated during the sessions

E. Other IMBER activities

Development of the new IMBER Science Plan and Implementation Strategy (SPIS)
Developing the new SPIS (2016-2025) “IMBER into the Future” was a major task for the SSC Chair and the IPO. The SPIS includes a new vision and research goal for IMBER, and is developed around three Grand Challenges (GC) and four Innovation Challenges (IC). Specific research questions relating to the GCs and ICs are intended to provide the basis for implementation of research programs. The SPIS was submitted to SCOR and Future Earth (FE) in November 2015 for joint review, and about 10 reviewers (selected by SCOR and FE) have delivered their reviews. Based on this SCOR and FE are producing a joint document suggesting improvements/changes for IMBER to consider before making the final version openly available.

IMBER will maintain its focus on fundamental biogeochemistry and ecosystem research, but will expand to include aspects of sustainable oceans, human well-being, biodiversity conservation, and making science relevant to society. Another issue is to ensure that IMBER science is available in a form that can be used to influence decision-making that will safeguard marine ecosystems and their dependent human societies. Achieving this will require the involvement of a diverse science community that is drawn from a range of different disciplines, including quantitative global change social science, international relations, and ocean geopolitics. IMBER will also engage in activities that enhance integration among and between IMBER's regional programmes, working groups, and endorsed projects.

Preparing for the ClimEco5 Summer School

IMBER ClimEco Summer Schools are held every two years and are a successful capacity-building mechanism for engaging students and early-career scientists. The planning for the summer school to be held in August in Natal, Brazil is on schedule. The theme is "Towards more resilient oceans: Predicting and projecting future changes in the ocean and their impacts on human societies." We have had > 200 applicants, have approved about 90 from more than 30 different countries, and expect about 10% to drop out. There is some concern regarding the zika virus outbreak, and all approved candidates has been thoroughly notified and given links to important websites.

IMBIZO IV & V

The IMBIZO IV (held in Trieste, Italy 26-30 October 2015), co-convened by Xavier Arístegui and Ingrid van Putten, was very successful. There were four concurrent workshops instead of the usual three. Presentations during the workshops showed the state of the art of the science in the four themes, and there was discussion regarding the way forward and IMBER´s role.
Before the start of the IMBIZO, early-career workshops were held on how to write a good publication, and how to write a good grant proposal. Each workshop will produce a synthesis paper or special issue. An article on the IMBIZO was published in the April edition of the *OCB Newsletter*.

IMBIZO V will be held in 2017 in Woods Hole, probably at the beginning of October, and it was suggested that the next IMBER SSC meeting should be held in conjunction with IMBIZO V, to involve more SSC members.

Based on the IMBER SSC decision to use the workshops to specifically progress implementation of the SPIS, potential topics for IMBIZO V include the following:

IMBIZO V – Overall theme: Sustainable Oceans in the 21st Century

1. Metabolic diversity and adaptation (Herndl/Rynearson)
2. IMBER scenarios/projections and their applications (Bopp and FISHMip)
3. Putting human behaviour into models (MSE) (van Putten/Werner)

IMBER contributions to IGBP synthesis and celebration at AGU

The IMBER manuscript to the IGBP synthesis special issue of *Anthropocene* was accepted and published in late 2015 (see http://www.sciencedirect.com/science/article/pii/S2213305415300242).

A final IGBP celebration was held at the Fall Meeting of the American Geophysical Union in San Francisco, 14-18 December 2015. An IGBP-IMBER session was convened at the meeting, where Hofmann presented results from the four workshops of IMBIZO IV and a summary statement.

IMBER and Future Earth
IGBP ended in December 2015 and a transition document (TD) to Future Earth was developed (lead by Hofmann) being a formal request by IMBER to become a core project of Future Earth. Reviews of the TD have been very positive this far, so the process is essentially a formality. The signing of a FE-SCOR-IMBER Memorandum of Understanding (MoU), outlining how they will work together, will be the final step.

The IMBER chair and IPO is actively taking part in the development of Future Earth, in particular delivering inputs to several Knowledge Action Networks (KAN), with a focus on the Ocean KAN. We will participate in a Future Earth Core Project meeting in Bern in June 2016, and the IPO is involved in the Future Earth/IPBES fast track initiative.

Status of the International Project Office (IPO, Norway) and the Regional Project Office (RPO, China)

IPO
The present IPO funding from IMR and the Norwegian Research Council (NRC) runs out at the end of March 2017. Meetings have been held with the IMR leadergroup and several NRC directors, resulting in a "promise" for co-funding for another three years (until end of March 2020). An IPO project proposal has been sent to NRC on this, and the final decision is expected in mid-June 2016.

Since the present IPO director is getting close to retirement, a process is underway for his replacement. The IMR leader group decided this would happen via an internal advertisement process at IMR, and IMBER will have key IMBER people in the evaluation committee.
The IPO also planned and executed (in late November 2015) a Sweden-IMBER workshop in Stockholm on "Effects of ocean acidification on ecosystems and human societies", which recruited about 40 new "members" to the IMBER community. At the same time, the IPO took part and presented IMBER at the opening of the Stockholm Future Earth Hub.

The IPO organised the IMBER SSC meeting in New Orleans in February 2016 alongside the ASLO/AGU/TOS Ocean Science Meeting.

The IPO director is part of the Science and Technology Advisory Board for the European Copernicus Marine Environment Monitoring Service (CMEMS) having about two meetings per year. CMEMS is looking for more users of their services related to marine ecosystems, and this may be a source for IMBER to use.

In March 2016, the IPO attended the Future Earth/IPBES indicator workshop in Switzerland.
The IPO is struggling with getting the IMBER new web site up to a quality ready for release.

RPO
The present RPO funding from the East China Normal University in Shanghai ends in 2016. An active process is ongoing to renew the funding.

The leader of the RPO, Yi Xu represented IMBER at the successful 7th China/Japan/Korea (CJK) IMBER symposium at the KIOST Jeju centre. The results from the symposium will soon be presented in an IMBER newsletter.

Xu also participated in the IOC/WESTPAC-CorReCAP Workshop that was held at SKLEC, ECNU. Under the leadership of Dr. Jing Zhang, the RPO will produce a book synthesizing the anthropogenic impact on Coral Reefs in the West Pacific region, and they are applying for funds from IOC/WESTPAC to run a summer training course about the influence of ocean acidification on coral reefs.

F. **IMBER SSC member nominations**
Hofmann ended her term as SSC Chair at the end of 2015. There is no call for nominations with regard to the Chair. Rather, the Executive Committee identifies individuals who are/have been involved with IMBER. The Executive Committee suggested Carol Robinson (University of East Anglia, UK and former IMBER SSC member), and she took over from the beginning of 2016. Hofmann remains as ex officio Past Chair in 2016.

Three new SSC members are needed and a call for nominations went out in April 2016. In relation to the existing and outgoing expertise IMBER is searching for scientists with skills in:

- marine sustainability science
- marine policy/governance science
- integrated modelling of social and marine ecological systems
- biodiversity/adaptation science
- communication (ocean literacy)

Nominations are still being received with a deadline in late May 2016.

G. IMBER cooperation
IMBER has been closely collaborating for many years with SOLAS (see SIC!) and LOICZ (now Future Earth Coast, see CMWG above) and recently with CLIVAR, and with other projects and organizations.

a. Too Big To Ignore (TBTI)
IMBER is a partner of the TBTI project. TBTI has reached its midpoint and now includes over 200 scientists from 45 countries. TBTI is conducting a global analysis, based on information systems, to better understand small-scale fisheries (SSF). IMBER information that might relate to SSF can be added at www.issf.toobigtoignore.net, and this can be used for case studies for I-ADApT. There was collaboration at IMBIZO IV. A TBTI Fellowship (3-4 month placement or Postdoc) will soon be launched. Chuenpagdee

recommended that IMBER-relevant organisations with mutual interests should be encouraged to consider hosting a TBTI-IMBER Fellow

b. Ocean Carbon Biogeochemistry (OCB)

OCB continues to actively support IMBER by advertising its activities and events, and by providing financial support for activities. OCB provided travel support for five participants from the United States to attend IMBIZO IV. IMBER has always had a SSC member on the OCB SSC. Hofmann rotated off and is replaced by Mike Roman (IMBER Vice-Chair 2006-2012). In the interests of raising IMBER's profile in the United States, Hofmann has suggested a session proposal for the OCB summer workshop in 2017.

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c. WCRP

CLIVAR, a core project of WCRP and its Indian Ocean panel works closely with SIBER. CLIVAR will hold an OSC from 19 to 23 September 2016 in Qingdao, China and several IMBER-related sessions will be convened at this conference. A Joint Upwelling WG is established, now represented with Escribano from the IMBER SSC.

d. GOOS/Copernicus

SIBER has strong connections with IO-GOOS, and IMR is involved with EURO-GOOS through Copernicus (European Programme to establish European capacity for Earth Observation). Also the SOLAS-IMBER Carbon WG has good links to GOOS. Increased alignment with GOOS will help IMBER deal with the challenge of ocean data. Links have been established with Eric Lindstrom (co-chair of GOOS). IMBER responded to the recent GOOS Biology Panel survey for metadata.

e. ICES

The IMBER IPO had an information booth at the ICES Annual Science Conference in Copenhagen, Denmark in September 2015. In addition to having more than 100 WGs on IMBER-relevant science, ICES provides official management advice (for the north Atlantic), with strong interaction with stakeholders. The management advisory processes have very strict quality assurance procedures, which are beyond IMBER´s capacity. ICES is funded by member countries and has a secretariat of more than 50 people and arranges annual science conferences (ASC) with about 700 participants including several IMBER scientists. The next ASC will be in Riga, Latvia on 19-23 September 2016, and next year in Fort Lauderdale, USA on 18-21 September 2017.

f. IOC

IOC agreed to support two participants from developing countries to attend the Upwelling workshop at IMBIZO IV and to support participants for the CLIOTOP Symposium.

g. Hjort Centre

The Hjort Centre for Marine Ecosystem Dynamics is an active research cluster in Bergen with similar goals to IMBER. The Hjort Centre administration is co-located with the IMBER IPO at the Institute of Marine Research in Bergen with effective exchange of information between the two research communities.

h. PICES

IMBER and PICES continue to collaborate, with representatives from both communities attending and funding each other's activities, such as summer schools and science meetings. PICES will hold its 25th Annual Meeting in November 2016

H. Selected IMBER Publications

IMBER has produced more than 1,000 refereed research papers since its implementation; about 150 papers were published in 2015-2016.

Publications related to recent discoveries and highlights

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Communication and Outreach

IMBER's main communication tool is the project website (www.imber.info), which has an average of about 250 visitors each day. A new IMBER website is being developed and soon will be ready for release, hosted at IMR. Software changes by the Internet service provider in France were such that the existing IMBER website could no longer be supported. This transition has caused disruptions in availability of the IMBER website, and the transfer has taken much longer than anticipated. Once the new site at IMR is launched, it will have a new more regularly updated news section, and the community will be encouraged to regularly send news items and articles to be featured on the website. The new IMBER website will also be accessible from a range of devices, such as mobile phones and iPads.

The IMBER Update Newsletter, www.imber.info/index.php/News/Newsletters, is emailed to ~2,000 scientists three times a year, and re-directed through multiple channels to about 10,000 researchers:

- **Issue n°30** – April 2016. The IMBER IMBIZO IV that was held in Trieste, Italy last year provides the impetus for this issue of the IMBER Update. IMBIZOs are IMBER´s flagship 'gatherings' (this is the meaning the Zulu word 'IMBIZO'). They are held every second year and bring together about 120 mutlidisciplinary scientists to discuss and synthesise the current state of knowledge about marine and human systems and their linkages, and to consider key research questions for the IMBER community to address going forward. The overall theme of IMBIZO IV was Marine and human systems: Addressing multiple scales and multiple stressors.
- **Issue n°29** – December 2015, is dedicated mostly to articles pertaining to the CLImate Impacts On Top Oceanic Predators (CLIOTOP) Regional Programme. They held their 3rd Symposium, titled "Future of oceanic animals in a changing ocean", in Spain in September. In addition to highlighting some of the excellent work that CLIOTOP working groups and individual scientists have done in the years since the previous symposium in New Caledonia, this gathering also provided the opportunity to get community input about the direction that the programme should go in its next phase.
- **Issue n°28** - June 2015, included articles about a new ESSAS Arctic project, Canadian research in the North, a generic concept for the vertical behaviour of fish eggs in the world oceans, observing changes in the surface ocean carbon, and a worldwide evaluation of the use of ecosystem drivers of stock production in tactical fisheries management.

An electronic IMBER eNews Bulletin is published monthly, which provides information about IMBER and IMBER-relevant activities and events. Calls for funding proposals, job opportunities, workshops and conference announcements are also included.

The IMBER contact database is continually updated with information for about 2,300 marine researchers.

Finally, the IPO and RPO staff and several IMBER researchers presented more than a dozen IMBER poster and oral presentations at national and international meetings during 2015.

I. Support from SCOR

IMBER greatly appreciates the ongoing support received from SCOR, and the additional support for specific IMBER activities provided or managed by SCOR from other funding sources. In addition, IMBER welcomes the advice, assistance and information received from the SCOR President and secretariat, especially its Executive Director, Ed Urban, and Financial Officer, Liz Gross.

Funding request

We are requesting funding to support students and researchers from developing countries to attend the IMBIZO V that will be held in Woods Hole in early October 2017.

Amount requested: 10,000 USD

J. Strategic development

IMBER is entering into its second decade, based on the new IMBER SPIS and involving Future Earth instead of IGBP.

IMBER has a history of connecting natural and social sciences and promoting integration across disciplines and communities. Many of IMBER's coordination and networking activities match the integrated approaches desired by Future Earth. As a result, IMBER is well placed to take the lead in developing marine-focused efforts under Futuer Earth. The transition to a combined SCOR-Future Earth core project should not require modifications to IMBER science goals or implementation strategy.

As with SCOR, the new SPIS forms the basis for Future Earth's incorporation of IMBER as a core project. The transition document (TD) includes a description of what IMBER can bring to Future Earth in terms of science and as an international network of researchers. The TD also includes what IMBER expects from Future Earth, such as support for SSC meetings and integrated activities, funding at the same level as provided by SCOR, and specific assistance with fund raising, outreach, communication and engagement of stakeholders.

The IMBER SSC met in February 2016, and proposed the following strategic actions for IMBER:

1. Work towards better integration between the regional programmes and working groups, focusing particularly on the priority research areas.
2. Target IMBIZO workshops towards implementation of the SPIS.
3. Link to experts on governance, maintain social science expertise on the SSC
4. Delegate members of the SSC as "champions" to lead the progress of the different SPIS challenges
5. Create stronger links to organisations dealing with global observations

6. Implement an action plan to raise the profile of IMBER
7. Revamp the Data Management Committee to better deal with both natural and social science data,
8. Decide whether to change the name of IMBER and if so, create a strategy to communicate the new name
9. Make a strong contribution to the Future Earth Oceans KAN
10. Start preparing for the 2nd IMBER open science conference in 2019
11. Find ways to better measure success
12. Find more funding

K. Budget

The SCOR omnibus grant from the National Science Foundation, which provides support for IMBER, was last year funded for three years (1 Sept. 2015-30 Aug. 2018). Support for the 2016 SSC meeting was also obtained from Future Earth. In addition. leftover money from IGBP and IGBP/ESA were received, making 2016 a quite good financial year. However, if no extra funds are obtained for 2017, the IMBER program and WG activities must be reduced significantly. A proposal through SCOR was sent to NASA for a new grant that supports activities of the HDWG, ESSAS and the SIOA, plus extra support to the IMBER/CLIVAR Upwelling Group. There are signals that the NASA proposal will be approved. A European Cost Action proposal is planned to be submitted in 2016. Ideally, an additional 100K USD per annum sponsorship would enable IMBER to implement its new plans, as well as continuing the on-going work. There are currently no funds available to allow us to increase IMBER's visibility, so activities to raise the profile of IMBER have to be cost-neutral for the time being.

Some activities may be reduced in 2016, and related funds are requested to be transferred to 2017.

3.2 GEOTRACES Naqvi

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: Ed Boyle (USA) and Reiner Schlitzer (Germany)

Other Members: Eric Achterberg (Germany), Adrian Burd (USA), Zanna Chase (Australia), Luidmila Demina (Russia), Jordi Garcia-Orellana (Spain), Vanessa Hatje (Brazil), Tung-Yuan Ho (China-Taipei), Phoebe Lam (USA), Maeve Lohan (UK), Maria Maldonado (Canada), Oliver Marchal (USA), Hajime Obata (Japan), Katherina Pahnke (Germany), Micha Rijkenberg (Netherlands), Alakendra Roychoudhury (South Africa), Géraldine Sarthou (France), David Turner (Sweden), and Liping Zhou (China-Beijing)

Executive Committee Reporter: Wajih Naqvi

GEOTRACES SCIENTIFIC STEERING COMMITTEE ANNUAL REPORT TO SCOR 2015/2016

1 June 2015 to 30 April 2016

1. SCOR Scientific Steering Committee (SSC) for GEOTRACES

The SSC membership (listed above) includes representatives of 14 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 ocean; 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

GEOTRACES continues to work diligently and enthusiastically, enjoying a very successful implementation. Its cruise field programme has now 84 GEOTRACES cruises (including 11 International Polar Year cruises) with 946 section stations completed and about 678 peer-reviewed papers published.

2.1 Status of GEOTRACES field programme

During the past reporting year, GEOTRACES has successfully completed most of the expeditions of the international Arctic GEOTRACES Programme. This includes 4 section cruises (from Canada, USA and Germany). One more Arctic cruise (from Germany) will be undertaken in summer 2016. In addition, one German cruise in the southeastern Atlantic Ocean was successfully concluded. The Atlantic Ocean basin now has remarkable coverage.

In complement to the GEOTRACES Ocean sections cruises, 8 process study cruises have also been completed. The GEOTRACES field programme is progressing excellently.

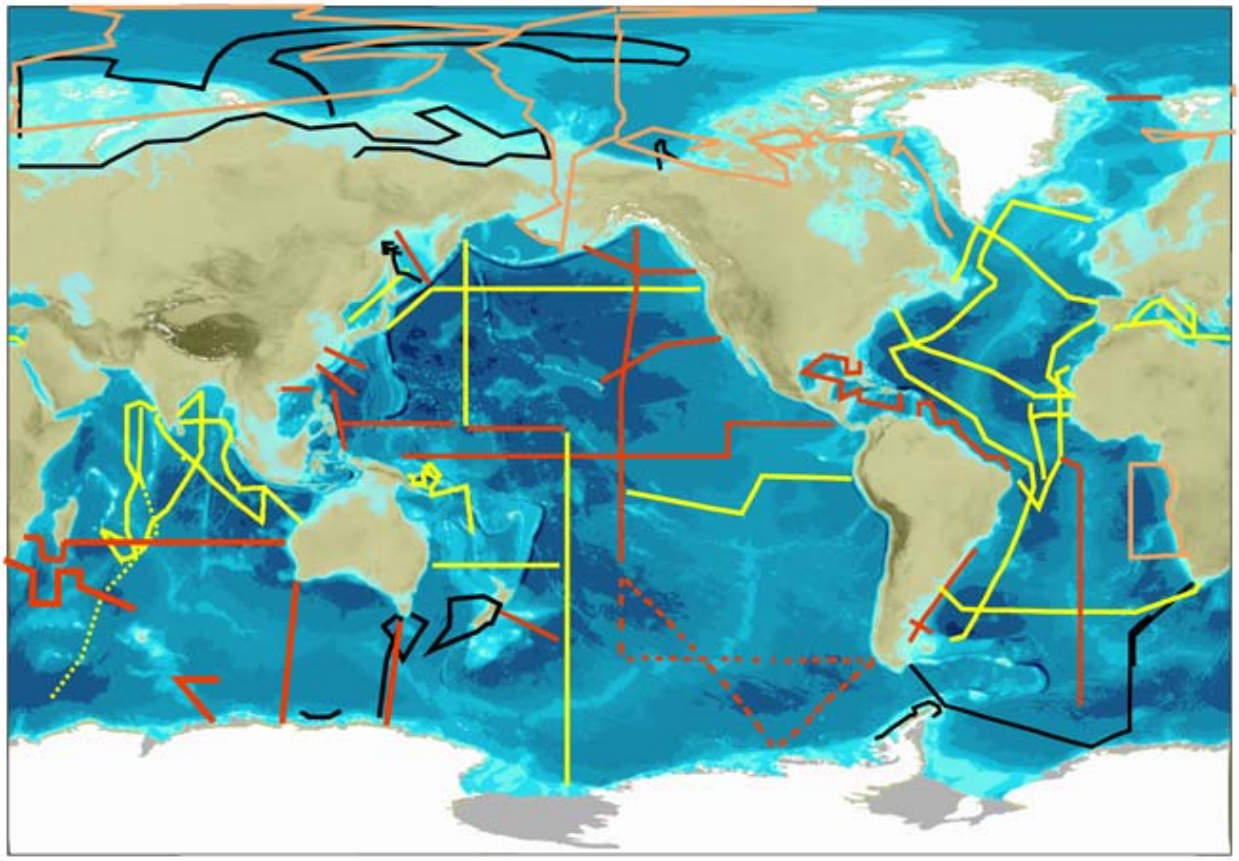

Figure 1: *Status of GEOTRACES global survey of trace elements and their isotopes. In black: Sections completed as the GEOTRACES contribution to the International Polar Year. In yellow: Sections completed as part of the primary GEOTRACES global survey. In orange: Sections completed during the past year.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

This year, one special field programme event merits to be highlighted. On the 7 September 2015, two cruises from the international Arctic GEOTRACES Programme, on the U.S. Coast Guard Cutter *Healy* and the German ship *RV Polarstern,* rendezvoused at the North Pole, having a memorable opportunity to occupy the same sampling station.

When the Standards and Intercalibration Committee created the idea of the crossover station—where two different GEOTRACES transect cruises occupy the same sampling station and subsequently compare their TEI data to facilitate intercalibration—they never imagined that two ships would be at the North Pole at the same time! They were both rafted up to the same ice floe and scientists could simply walk to visit each other's ships, labs, and share experiences and knowledge.

*Figure 2: USCGC Healy and RV Polarstern at the North Pole ©Stefan Hendricks. Source: **blogs.helmholtz.de**.*

2.2 GEOTRACES Intermediate Data Products

The GEOTRACES community is working hard to prepare the next Intermediate Data Product (IDP), which will be released at the 2017 Goldschmidt Meeting (13-18 August 2017, Paris, France). The Intermediate Data Product 2017 (IDP2017) is being built upon the feedback received from the IDP2014 survey that collected 262 answers (the results were described in last year's report to SCOR).

To ensure timely release of the IDP2017, a clear procedure and timelines for data submission and review were established and communicated broadly (see data management section in this report for further details).

Promoting the use of IDP2014 data
While working on the next IDP, GEOTRACES is continuing its efforts to publicise the IDP2014, promote its use and intensify collaboration of GEOTRACES with the broader ocean research community. To this end, a Town Hall was held at Ocean Sciences Meeting 2016 (21-26 February 2016, New Orleans, Louisiana). The Town Hall session on "**Opportunities to Strengthen Your Science (and Proposals) using GEOTRACES Data"** (1) informed the community about strategies to access, download and manipulate data from IDP2014 and provided preliminary information about IDP2017; (2) sought feedback from users of IDP2014 to improve IDP2017 and make it as user-friendly as possible; and (3) presented the outcome of the first Iron-Model Intercomparison Project (FeMIP), in which comparison to GEOTRACES data allowed an unprecedented assessment of model performance.

Figure 3: GEOTRACES Town Hall Meeting at Ocean Sciences 2016.

Furthermore, the IDP2014 was also presented at the booth that SCOR had at the Exhibition Hall of the Ocean Sciences Meeting. At the booth, a GEOTRACES banner introducing the IDP2014 was displayed; promotional postcards of eGEOTRACES Atlas 3D scenes were distributed; and SSC members and IPO staff were available to inform visitors about the IDP2014 and the GEOTRACES Programme.

Figure 4: SCOR booth at Ocean Sciences 2016.

2.3 GEOTRACES Publications

During the reporting period, 130 new papers have been added to the GEOTRACES peer-reviewed papers database (http://www.geotraces.org/library-88/scientific-publications/peer-reviewed-papers). In total the database includes 678 publications so far.

The following three special issues were published since the 2015 SCOR meeting, and two more are in preparation:

> Marine Chemistry (Volume 177, Part 1, Pages 1-202, December 2015)
> **Biogeochemistry of trace elements and their isotopes**
> Edited by Rob Middag, Claudine Stirling, Alessandro Tagliabue and Jingfeng Wu
> http://www.sciencedirect.com/science/journal/03044203/177/supp/P1
>
> Marine Chemistry (Volume 177, Part 3, Pages 409-582, December 2015)
> **Cycles of metals and carbon in the oceans - A tribute to the work stimulated by Hein de Baar**
> Edited by Loes J.A. Gerringa, Micha J.A. Rijkenberg, Patrick Laan and Klaas R. Timmermans
> http://www.sciencedirect.com/science/journal/03044203/177/part/P3
>
> Biogeosciences, special issue (Volumes 11 and 12)
> **KEOPS2: Kerguelen Ocean and Plateau Study 2**
> Edited by S. Blain, I. Obernosterer, B. Queguiner, T. Trull, and G. Herndl
> http://www.biogeosciences.net/special_issue164.html

Also, several publicity articles have been published in news magazines or journals in the past year. For example:

> Turner, D., & Urban, E. (2016). GEOTRACES: High-Quality Marine Analytical Chemistry on a Global Scale. Chemistry International, 38(1), 16–17. doi:10.1515/ci-2016-0108 (Open Access)

A complete list of the publicity articles is available here:
http://www.geotraces.org/outreach/publicity-documents

2.4 GEOTRACES Science highlights

The GEOTRACES International Project Office regularly edits highlights of published articles, which are posted in the website (http://www.geotraces.org/science/science-highlight) and in the electronic newsletter (http://www.geotraces.org/outreach/geotraces-enewsletter). Among the numerous highlights published since last year's report, we selected those which bring scientific messages related to the coupling (or not) of TEIs with nutrients: Zn and Si on the one hand, and the Cd and PO_4 paradigm on the other hand. High-resolution measurements conducted in the framework of GEOTRACES cruises are questioning well-established paradigms, such as the

famous Cd/PO_4 relationship classically used in paleoceanography. These high-resolution data are also confirming that a significant fraction of Al is released by sediments to the ocean.

Decoupling between dissolved zinc and silicon in the North Atlantic Ocean driven by mixing of end members

Roshan and Wu (2015, see reference below) reveal that the correlation between dissolved zinc (Zn) and silicon (Si) is relatively weak in the North Atlantic Ocean (GA03 US section). They use the results of an Optimum Multi-Parameter Water Mass Analysis to establish which parameter is mainly controlling the Zn distribution. Surprisingly, they present evidence that remineralization might have an insignificant effect on the zinc distribution in this region. They conclude that dissolved zinc in the North Atlantic Ocean is mainly controlled by water mass mixing, although some water mass end-members exhibit deviations in the Zn-Si correlation as, for example, the Mediterranean Outflow Waters. Unexpectedly large Zn inputs of hydrothermal origin are also perturbing the expected relationships.

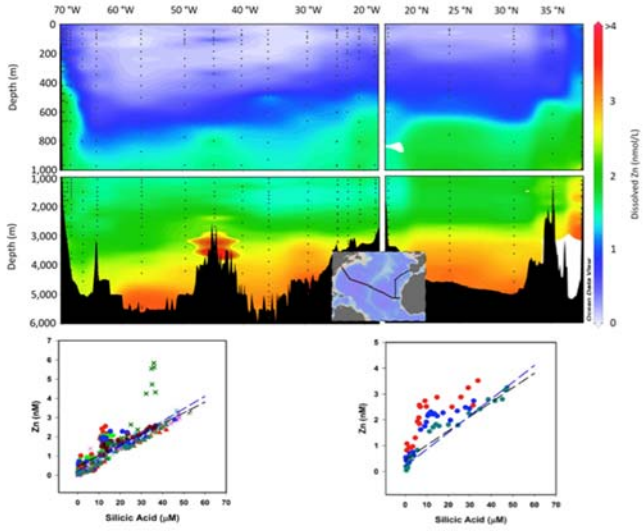

Figure 5: *The Top panel shows the distribution of dissolved Zn along the GA03. Bottom panel shows the Zn-Si relationship for the zonal (left) and meridional (right) transect. Disappearance of a linear correlation is evident, particularly for the meridional transect where the Mediterranean waters have a great influence.*

Reference:

Roshan, S., & Wu, J. (2015). Water mass mixing: The dominant control on the zinc distribution in the North Atlantic Ocean. Global Biogeochemical Cycles, 29(7), 1060–1074. doi:10.1002/2014GB005026

Changing the cadmium : phosphorus paradigm?

The well-established strong linear relationship linking dissolved cadmium (Cd) and phosphorus (P) concentrations in seawater is at the origin of the attraction of Cd as a proxy for PO_4 in the paleocean. However, exploring the dissolved Cd and PO_4 distributions in the ocean, Quay and co-workers (2015, see reference below) show that the Cd/P of particles exported from the surface ocean doubles in high-nutrient low chlorophyll (HNLC) regions. They also demonstrate that Cd/PO_4 variations in the surface ocean and deep sea depend on Cd/P of degraded particles. Using a box model, they present evidence that past changes in HNLC conditions would change the Cd-PO_4 relationship in deep sea, which has to be considered in paleo-reconstructions.

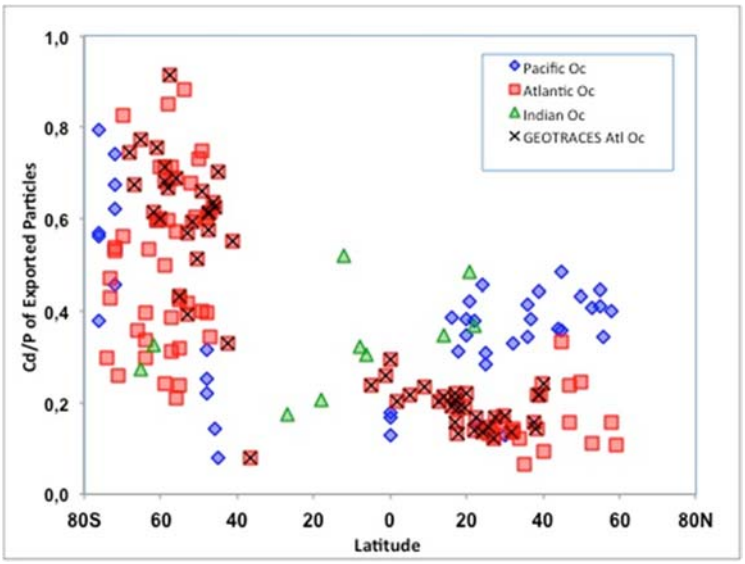

Figure 6: *The meridional and interbasin trends in the estimated Cd/P ratio of particles exported from the surface ocean. The Cd/P of exported particles is a primary factor controlling the spatial variations of dissolved Cd/P in the surface ocean and in the deep sea where particles are degraded.*

Reference:
Quay, P., Cullen, J., Landing, W., & Morton, P. (2015). Processes controlling the distributions of Cd and PO_4 in the ocean. Global Biogeochemical Cycles, 29(6), 830–841. doi:10.1002/2014GB004998

Impressive set of data reveal new features on the modern cadmium–phosphate relationship

Xie and co-authors (2015, see reference below) report vertical profiles of dissolved cadmium (Cd) in the western South Atlantic Ocean (GEOTRACES section GA02), which show nutrient-like distributions similar to those of the macronutrient phosphate (PO4). A close look at the data reveal

- In the surface ocean, preferential uptake of Cd over PO_4 by phytoplankton occurs along the transect, regardless of ambient iron (Fe) concentrations, suggesting Fe availability is not critical for biological Cd utilization in the southwest Atlantic;
- In addition, horizontal advection of Cd-depleted low-oxygen waters originating from the Angola Basin and brought across the Atlantic Ocean via the Benguela and Equatorial currents imparts a Cd-depleted signature to equatorial intermediate waters distinguishing them from southerly intermediate waters.
- This new dataset provides further evidence that Subantarctic Mode Water plays an important role in generating the non-linearity of the global Cd-PO_4 correlation.

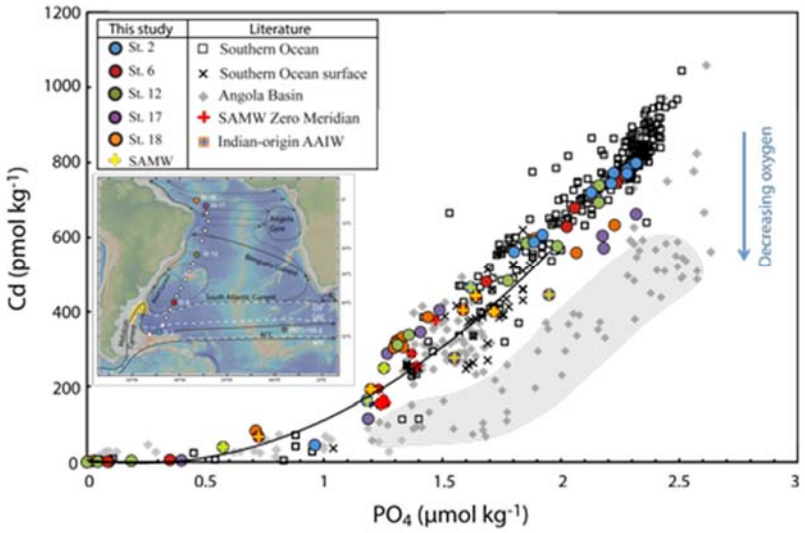

Figure 7: *Evaluation of Cd–PO_4 systematics using new data from GEOTRACES GA02 Leg 3 (colored circles; see inset for location) and literature data (Southern Ocean: Abouchami et al., 2014; Baars et al., 2014; Boyé et al., 2012; Xue et al., 2013; Indian Ocean: Vu and Sohrin, 2013; Angola Basin: Waeles et al., 2013) at the scale of the South Atlantic Basin. The Cd–PO_4 relationship for samples with PO_4 >1.3 µmol kg^{-1} in this study exhibits two parallel linear correlations. The influence of low-oxygen waters originating in the Angola Basin (grey shading) is noticeable in intermediate waters at the equatorial stations. The clear kink at PO_4 ~ 1.3 µmol kg^{-1} in the South Atlantic is attributed to northward flowing, nutrient-rich Subantarctic Mode Water.*

Reference:

Xie, R. C., Galer, S. J. G., Abouchami, W., Rijkenberg, M. J. A., De Jong, J., de Baar, H. J. W., & Andreae, M. O. (2015). The cadmium–phosphate relationship in the western South Atlantic — The importance of mode and intermediate waters on the global systematics. Marine Chemistry, 177, 110–123. doi:10.1016/j.marchem.2015.06.011

Large fluxes of dissolved aluminium exported from the coast to the ocean

In the Eastern China Sea (ECS), the continental shelf serves as an important source of dissolved aluminium (DAl) for the overlaying waters via resuspension of sediments and benthic fluxes. This was demonstrated by Ren et al. (2015, see reference below), who identified cross-shelf transport in the subsurface water over the ECS. The DAl export from the 100 m isobath is 1.67 x 10^{10} g yr.

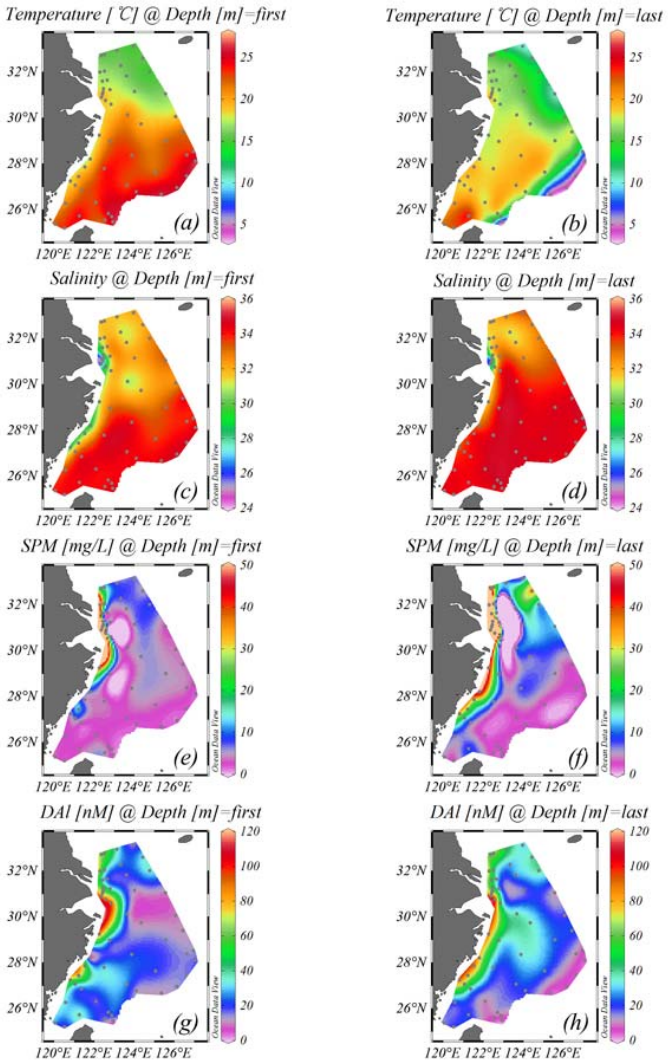

Figure 8: *Horizontal distributions of temperature, salinity, SPM (mg/L), and dissolved Al (nM) in the surface water (a, c, e, g) and bottom water (b, d, f, h, with water depth ranging from 13 m to 1200 m) of the East China Sea. Changjiang Diluted Water (CDW) expanded southeastward in the surface, and was restricted to the coastal area by the incursion of Kuroshio Waters (KW). The incursion of Kuroshio Subsurface Water (KSSW) in the bottom layer can reach 30°N near the Changjiang Estuary. The concentration of dissolved Al decreased gradually from the coastal area to the central shelf, and then decreased sharply at the shelf break. The bottom layer had higher concentrations of dissolved Al than in the surface layer in the coastal and middle shelf,*

consistent with their higher concentrations of SPM.

Thanks to the Kuroshio current, more than half of this Al is transported northward within the region enclosed by the 100 m and 200 m isobaths to the Japan Sea/East Sea. The remaining flux is transported out of the shelf across the 200 m isobath. This highlights the importance of coastal processes and subsurface cross-shelf transport as a source of dissolved trace elements to the open ocean.

Reference:

Ren, J.-L., Xuan, J.-L., Wang, Z.-W., Huang, D., & Zhang, J. (2015). Cross-shelf transport of terrestrial Al enhanced by the transition of northeasterly to southwesterly monsoon wind over the East China Sea. Journal of Geophysical Research: Oceans, 120(7), 5054–5073. doi:10.1002/2014JC010655

Multiple controls on the dissolved aluminium fate in the western Atlantic Ocean

Thanks to the most impressive set of dissolved aluminium (Al) and silicon (Si) data ever published in the Atlantic Ocean, Middag and co-workers (2015, see reference below) are thoroughly scanning the processes determining their oceanic distributions. They reveal that i) atmospheric inputs are affecting only the surface and subsurface waters; ii) there is an elusive but obvious coupling between Si-containing biogenic particles and Al; iii) scavenging is occurring faster than the horizontal advective transports, preventing the use of Al as quantitative water mass tracer; and iv) not observed at a basin-wide scale before, suspended sediments are a significant source for dissolved Al in the deep waters.

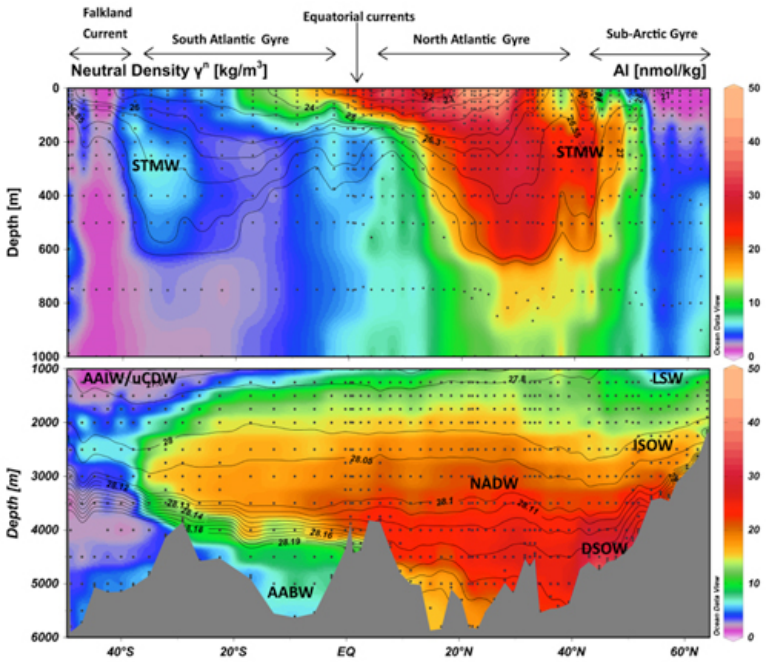

Figure 9: *The distribution of Aluminium (Al) is depicted in colour scale overlain with neutral density isopycnals and main water masses labelled for the upper 1000m and the deep ocean. The effects on the Al concentrations of sediment resuspension in the deep ocean and atmospheric deposition in the surface ocean are clearly visible.*

Reference:

Middag, R., van Hulten, M. M. P., Van Aken, H. M., Rijkenberg, M. J. A., Gerringa, L. J. A., Laan, P., & de Baar, H. J. W. (2015). Dissolved aluminium in the ocean conveyor of the West Atlantic Ocean: Effects of the biological cycle, scavenging, sediment resuspension and hydrography. Marine Chemistry. doi:10.1016/j.marchem.2015.02.015

3. Activities

3.1 GEOTRACES intercalibration activities

The Standards & Intercalibration (S&I) Committee is currently composed of Karen Casciotti, Peter Croot, Tina van de Flierdt, Walter Geibert, Lars-Eric Heimbürger, Maeve Lohan, and Hélène Planquette (who joined since the last reporting period). Greg Cutter has stepped down from the committee and we thank him for all his efforts. Walter Geibert is now a co-chair, together with Maeve Lohan. Since its meeting in Galway, Ireland in January 2015, a virtual meeting was held in January 2016, and a three-day in-person meeting took place at Stanford University from 27 to 29 April 2016. The committee is in constant communication via email and through a shared online resource.

The main task of the committee in the past year was preparing for IDP2017 and ensuring the submission of data to be intercalibrated well in advance of the completion of the data product. The improvements of the submission procedure from the last reporting period are working well and we are pleased with the response from the community. The committee has provided details on requirements for different types of cruises and parameters, which made the intercalibration process more transparent for data submitters. In addition, a new flowchart of the submission procedure was designed and put on the website (http://www.geotraces.org/dp/intermediate-data-product-2017/steps-to-ensure-that-your-data-are-in-idp2017). This better description of the process, combined with regular reminders, individual letters, and written instructions for specific parameters, all contributed to receiving a large number of S&I reports from the analysts from the Atlantic and Pacific oceans. The submission of data for approval has been split into three deadlines, of which the second has now passed. While the submission of reports for data intercalibration can take place at any time before the final deadline, early submission is encouraged so that the committee can resolve issues before the final meeting for approval.

The S&I Committee received approximately 200 datasets from the Atlantic, 50 from the Pacific, 2 from the Indian Ocean, 6 from past IPY cruises, 8 from process studies and 4 GEOTRACES-compliant datasets for the April deadline. During the April meeting of the S&I Committee, all datasets were introduced by the assigned committee members, and discussed by the full committee. Several intercalibration reports were of outstanding quality, providing excellent

detail on intercalibration procedures, which was seen as a clear improvement to submissions for the 2014 IDP. There are some remaining issues with some sections where no data have been submitted, or very little data. A particular issue has been the hydrography and nutrient datasets.

Some data in IDP2014 was not intercalibrated due to late submissions and lack of crossover stations. Because all data to appear in IDP2017 must be intercalibrated, we have therefore contacted all data generators whose data were not intercalibrated for IDP2014 and asked for a report to be submitted for IDP2017. We have received many of these reports, but some have not yet been submitted, and the S&I Committee will contact these analysts once more.
Elemental co-ordinators, who have been contributing substantially to GEOTRACES by producing reference materials, standards, and organising intercalibration studies, play a key role in ensuring good data quality and improving the abilities of the communities. The existing list of elemental co-ordinators on the web page has been re-assessed, and all elemental co-ordinators contacted to ask if they wished to continue in this role. The responses were overwhelmingly positive, and only a few changes are required. The committee points out in this context that it is critical to involve the S&I Committee in decisions that have a potential influence on the choice, the availability and the characterization of reference materials, as this is our main tool to ensure consistent data sets.

The S&I Committee also discussed how analyses of consensus materials should be archived and distributed in the future. This discussion is on-going and it includes defining committee interaction with elemental co-ordinators, defining how values should be published, the level of anonymity required, and how consensus values can be updated in a manner that is transparent to the community.

The committee is in the process of re-designing the web page and obtaining a dedicated email address (sic@geotraces.org) to make electronic interaction with the S&I Committee more transparent.

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; the GEOTRACES Data Manager (Abby Bull) is based at the BODC office in Southampton, UK. Regular communication is maintained between the two sites so that support and assistance can be offered to the GEOTRACES Data Manager when required.

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

- interaction between PIs and national data centres in order to encourage regular and timely data/metadata submissions
- maintaining and modifying GDAC web pages to include updated ocean basin maps (http://www.bodc.ac.uk/geotraces/cruises/section_maps/) and upcoming cruises on the programme page (http://www.bodc.ac.uk/geotraces/cruises/programme/)

- liaising with the Data Management Committee and Standards & Intercalibration Committee to ensure that 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
- Collation of data/ metadata for the IDP2017

BODC has recently assigned extra resources to the GEOTRACES Project in order to aid and provide support to Abby, focusing entirely on processing data to be included in the IDP2017. When the GEOTRACES Project expects to experience busy periods (i.e., from Summer 2016 – May 2017) this extra resource will be invaluable.

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

Working with the IPO
The IPO continues to offer support to GDAC when required. The IPO continues to help GDAC stay up to date with new cruises, as well as providing reminders of when certain people should be contacted in order to extract various information at relevant times.

Working with BCO-DMO
GDAC and BCO-DMO have worked closely together over the past year. GDAC has liaised with BCO-DMO about how they can offer support and decrease the data processing time from GDAC's point of view via the use of the GDAC metadata template/methodology form. Communication is regular and BCO-DMO informs GDAC when new U.S. GEOTRACES data are submitted, as well as providing an estimated data processing time. Working with BCO-DMO has also helped to streamline data submission and processing procedures.

GDAC website updates
The GDAC basic delivery mechanism has been removed from the GDAC website as it was not being used. GEOTRACES would like to see an interactive map re-established on the GDAC website rather than the static maps, however, this will consume resources and is therefore not a current priority. All basin maps have been updated and pre/post cruise metadata forms added to the information section about each cruise situated below the basin maps. Contact information of each Chief Scientist/GEOTRACES Scientist for each cruise have also been included on these pages.

DMC/SSC meeting – July 2015
The DMC/ SSC meeting in July 2015, Vancouver, was the first opportunity for Abby to meet most of the key GEOTRACES participants and country representatives. At the DMC meeting, Abby presented various data management areas. These included:

1. Summary of the GEOTRACES transition process from Ed Mawji to Abby Bull
2. A break-down of GEOTRACES data visits since being in position
3. Information and highlights on version 2 of the IDP2014
4. A GDAC website report
5. A process study update

6. A comparison/ interpretation of version 1 and version 2 IDP download statistics

The DMC meeting also focused on the agreement of IDP2017 data and S&I Committee submission deadlines. These are as follows:

S & I/ data deadlines	**S & I approval**	**Anticipated large amounts of data submitted to GDAC**	**Significance**
1 November 2015	January 2016	January – February 2016	Earliest deadline
1 April 2016	May 2016	April – June 2016	Data guaranteed to be in IDP2017
1 December 2016	March 2017	December 2016 – March 2017	Final deadline – data not guaranteed to be in IDP2017

All data for IDP2017 need to be submitted to Reiner Schlitzer by end of May 2017.

The 1 November deadline saw very little data submitted to GDAC and the S&I Committee (Nd and REE data from 4 cruises). This was expected, however, given the 3 deadlines. On the other hand, the guaranteed 1 April deadline experienced an increase in data/intercalibration report submission of around 50 GEOTRACES datasets. At this moment in time, GDAC has received 271 datasets, which are currently being processed and 93 which are completed and 'Reiner ready'. Abby is expecting a steady stream of data to be submitted over the course of the summer in the lead up to and after the DMC/SSC meeting in September 2016.

Maeve Lohan and Greg Cutter (as co-chairs of the S&I Committee) and Abby have put together a document which allows us to determine which analysts have sent both data and intercalibration reports, only sent data, or only intercalibration reports. In the latter 2 situations, communication is required in order to encourage data or intercalibration report submission. This document allows us to keep on top of what has been received and what still needs chasing for data to be successfully included in the IDP2017. This document will also detail approval so Abby is aware of what data have been intercalibrated and what data require further work. This, in turn, alerts Abby whether data values need to be changed in the GDAC database.

A flowchart, created as a joint effort of the S&I Committee, GDAC and the IPO, details how scientists can ensure that their GEOTRACES data are present in the IDP2017. The flowchart illustrates 2 parallel pathways – data submission to GDAC, and the intercalibration process for the dataset via the S&I Committee. Both pathways must be followed (*which can be done concurrently*) in order to have data included in the IDP2017. This flowchart can be accessed on the following GDAC web page :
http://www.bodc.ac.uk/geotraces/data/submission/intermediate_data_product/

BioGEOTRACES meeting – November 2015
BioGEOTRACES discussions at the SSC meeting highlighted the need for a BioGEOTRACES workshop involving GEOTRACES and BioGEOTRACES researchers, as well as GDAC, in order to decide how to prepare for the submission of biological parameters for inclusion in the IDP2017.

A BioGEOTRACES meeting was held in November 2015 at Woods Hole, Massachusetts. It was decided that in order for BioGEOTRACES data to be included in the IDP2017 the following procedure would be followed:

1. GDAC to provide a metadata form to BioGEOTRACES participants so that scientists are aware of what information is required.
2. BioGEOTRACES scientists to provide GDAC example datasets with accompanying metadata so GDAC can provide feedback.
3. Guaranteed IDP2017 submission deadline on 1 April 2016 for BioGEOTRACES data.
4. Maite Maldonado to provide recommendations for methodologies and intercalibration protocols/efforts for each BioGEOTRACES parameter that has been chosen to be included in the IDP2017.

GDAC has provided feedback on example BioGEOTRACES datasets that were submitted and used biological data management resources at BODC for support and expertise. Only ‘element quotas of individual phytoplankton cells’ were submitted by the guaranteed IDP2017 deadline. GEOTRACES datasets will still continue to be prioritised over BioGEOTRACES datasets.

GDAC data wiki page
One change to note since July 2015 is that there is now a wiki page which details the number of outstanding, received, and processed datasets (those ready for the IDP2017). This tool has proved to be invaluable in regard to tracking outstanding data and monitoring the throughput of data into the BODC system so priorities are more easily defined and work efforts/extra resource can be targeted as required. This wiki page (https://wiki.ceh.ac.uk/display/GDM/GEOTRACES+IDP17+Progress) is updated at the end of every month so changes can be easily identified, and pressure can be applied where needed. Through the use of this tool it is hoped we will see a steady stream of data submitted to GDAC rather than a large submission close to the final deadline (December 2016), therefore lifting a potential burden from the GDAC data manager. Through the use of the wiki page, updates can be discussed further with the DMC co-chairs.

Data overview
The data management of the GEOTRACES programme is a large undertaking, with a total of 84 associated cruises (including all cruise legs; this takes into account all section cruises, process studies and compliant data), and 64 sections/studies. More than 800 scientists have taken part in the GEOTRACES cruises, with 15 different nations having run a major GEOTRACES IPY/section/process study cruise.

The 2015/2016 period has witnessed the submission of outstanding data, with metadata becoming more forthcoming. It has been recognised that a way of encouraging PIs to submit their data to GDAC more readily is to use the IDP2017 as an incentive.

Summary of completed GEOTRACES cruises to date:

Section cruises	IPY cruises	Process studies	Compliant data
31 cruises (including all legs) with 23 sections	11	35 (including all legs) with 23 studies	5

Summary of GEOTRACES cruises which have taken place in 2015/2016:

This year the International GEOTRACES Arctic research programme was focused on field efforts from the United States, Canada and Germany. Four Arctic cruises were planned, funded, and took place between July and October 2015. The German **section** cruise (M121 (GA08)) focused on the SE Atlantic with cruise dates of 22 November-28 December 2015. Other cruises which took place were **Process Study** cruises, and are as follows:

- Japanese cruise (KH15-3 – GPpr12) in the East China Sea – October–November 2015
- Netherlands cruise (PE401 ViciFe – GApr05) in the Black Sea – August–September 2015
- German cruise (SO245 UltraPac– GPpr09) in the ultra-oligotrophic South Pacific – December 2015–January 2016
- Australian cruises (K-axis - GIpr06) and (HEOBI GIpr05) – both in the Indian sector of the Southern Ocean – January–March 2016
- Canadian cruise (LineP- 2015-10 - GPpr07) in the Pacific Ocean – August-September 2015
- UK cruise (Shelf Seas – DY033 - GApr04 leg 3) in the Celtic Sea – July–August 2015

Summary of GEOTRACES cruises to take place in 2016/2017:

Process Studies

- **ViciFe** – Netherlands - Arctic Pelagia – Summer 2016 – further information to be provided shortly.
- **SOSCEx II** – South Africa – (PI: Pedro Montero)
- **Peacetime** – France – (PI: Dr Guieu Cecile) – of which further information will be provided shortly.

Section cruises

- **GN05 – GRIFF** – Germany (PI: Torsten Kanzow) – Arctic Ocean – 19/07/2016 – 09/09/2016

In summary

The collection and processing of data to be included in the IDP2017 will be the focal point of GDAC's data activities over the coming year.

In summary, GDAC is receiving more and more data/metadata via the use of the metadata templates. Scientists are consulting the GDAC web pages before submitting, which is an indication that this part of the data submission process is improving. The methodology information is crucial when it comes to assigning BODC parameter codes, instrumentation, and writing documentation for the user.

3.3 GEOTRACES International Project Office

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

The IPO is responsible for:

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

Outreach
The following outreach activities merit to be reported:

- GEOTRACES Outreach web page
  The IPO has continued to compile and make available on the GEOTRACES Outreach web page educational and outreach materials. This year, a remarkable effort was invested in outreach for the GEOTRACES International Arctic Programme. This includes:

  - 17 cruise blogs
  - 58 videos
  - participation of a PolarTREC science teacher on board the U.S. expedition who posted over 65 blogs to the PolarTREC website (www.polartrec.com/expeditions/us-arctic-geotraces/journals)

- the "Float the Boat" programme (programme designed to involve students and public with an Arctic research on the U.S. *Healy* where over 1,300 boats on the ice were deployed as drifters to track the ice movement across the Arctic: http://floatboat.org
- radio interviews
- Educational outreach to U.S. Coast Guard personnel
- outreach to local populations who depend on the Arctic Ocean for their livelihood (U.S. researchers put together a package for presentation at Kawerak Conference (31 May-4 June, 2015, Alaska) and presented GEOTRACES at the meeting for rural natives.

- GEOTRACES eNewsletter Special Issue devoted to Outreach activities
  In order to provide visibility to the numerous GEOTRACES outreach activities, the IPO published a special issue of the e-Newsletter devoted to outreach. This issue was published and broadly distributed coincidently with the opening of the COP21 conference on climate change (30 November 2015), to reinforce the message that GEOTRACES research is closely linked to climate change. The special issue is available here: http://www.geotraces.org/index.php?option=com_acymailing&ctrl=archive&task=view&mailid=501&key=pEtJKupG&tmpl=component
  After the release of the special issue, the IPO sought feedback from the GEOTRACES SSC members, end users and experts in communication and outreach. Feedback received was positive and very encouraging.

- Booth at Ocean Sciences Meeting 2016
  The IPO helped SCOR in coordinating, setting and staffing the SCOR booth at Ocean Sciences Meeting (21-26 February 2016, New Orleans, LA, USA). This year SCOR invited GEOTRACES, SOLAS, IMBER and SOOS international projects. For this booth, the IPO prepared several ad-hoc materials, including:

  - A new roll-up banner introducing the GEOTRACES programme, the IDP2014 and a selected science highlight.
  - A set of 4 postcards showing 4 different eGEOTRACES Atlas 3D scenes. The aim of these postcards was to attract visitors at the booth at the same time as helping to promote and give visibility to the GEOTRACES products.
  - A video display documenting scientific activities of several SCOR-sponsored projects. This video is available here: https://youtu.be/lx1cnNx2dhY.

- Goldschmidt 2015
  A new poster introducing GEOTRACES and the Intermediate Data Product was presented at the Goldschmidt 2015 meeting (16 - 21 August 2015, Prague, Czech Republic).

In addition, this year we would like to highlight the following tasks:

- GEOTRACES website:
  After the major overhaul done last year, the IPO has continued to improve the GEOTRACES website (<http://www.geotraces.org>) and fix several bugs of the new template. In addition, three upgrades have been done. As an example of new features, the GDAC cruise programme is now embedded in the IPO website so that there exists one cruise programme in both websites, facilitating navigation through them.

- IDP2017 Flowchart
  As initiative of the IPO, a flowchart describing the process to follow in order to ensure that data are in IDP2017, has been created as a joint effort of the S&I Committee, GDAC and the IPO. This flowchart is available on both the GDAC and the IPO websites: http://www.geotraces.org/dp/intermediate-data-product-2017/steps-to-ensure-that-your-data-are-in-idp2017

- Meeting and Workshop organisation
  The IPO has been solicited to assist at a different level in the following meetings and workshops: 2016 SSC and DMC meetings; Goldschmidt 2016 Workshop "Exploring GEOTRACES Data with ODV"; Ocean Sciences Meeting Town Hall "Opportunities to Strengthen Your Science (and Proposals) using GEOTRACES Data"; Workshop "Biochemical cycling of trace elements within the ocean: A synthesis workshop", Workshop "Biogeochemical studies in the Siberian Shelf"; "GEOTRACES Royal Society coupled workshop and meeting". Please read section "GEOTRACES Workshops" for further information about these workshops.

- Funding
  A new agreement has been concluded within the sponsors of the GEOTRACES IPO. From now on, the University Paul Sabatier replaces the Centre National de la Recherche Scientifique (CNRS) in the financial management of the agreement. Attaining this new agreement has required a substantial time investment from both the IPO science director and the executive officer. In addition, since the IPO is hosting the 2016 SSC and DMC meetings, additional funding has been secured through the University Paul Sabatier.

- Some statistics
  25 new highlights published (105 in total)
  5 eNewsletter published (bimonthly newsletter, 20 in total)
  130 new peer-reviewed papers included in the GEOTRACES Publication Database (678 in total)
  179 new articles published on the GEOTRACES website (from them 35 jobs/student positions)
  140 announcements sent through the GEOTRACES mailing list
  110 new posts on Facebook and 281 likes (top post reach 1,556)
  70 new tweets and 211 followers
  81 new subscribers on the GEOTRACES website

3.4 GEOTRACES Workshops

Coupled meeting and workshop to discuss and synthesise findings from the GEOTRACES programme, 7–10 December 2015, UK.

This meeting was organised in two parts, with two different venues: the first part (#1 below, a Royal Society Scientific Discussion Meeting) was dedicated to a broad audience, the goal being to give an overview of the up-to-date research in marine biogeochemistry and the role of ocean trace-element cycling in Earth systems. The second part was a workshop (#2) occurring in Buckinghamshire (Chicheley Hall). Plenary sessions and small group meetings alternated. The different workshops discussed and synthesised the present knowledge of the fluxes of trace elements at the four ocean boundaries: from continents across the shelf; from marine sediments; from mid-ocean-ridges; and from the atmosphere. Poster sessions allowed discussions around the most recent results.

All the authors were requested to submit a paper in a dedicated issue of *Philosophical Transactions A* of the Royal Society.

1) The biological and climatic impacts of ocean trace-element chemistry, 7–8 December 2015, The Royal Society, London, UK.
For further information (recorded audio presentations are available):
https://royalsociety.org/events/2015/12/ocean-chemistry/

2) Quantifying fluxes and processes of trace-metal cycling at ocean boundaries, 9–10 December 2015, Chicheley Hall, Buckinghamshire, UK.
For further information:
https://royalsociety.org/events/2015/12/ocean-chemistry/

Biogeochemical studies in the Siberian Shelf Seas, 27–28 January, Kiel, Germany.

The aim of this workshop, supported by IASC, TRANSDRIFT (System Laptev Sea) and GEOTRACES, was to bring together various groups working on biogeochemical cycles in the Siberian shelf seas and explore possibilities of cooperation. As a result, two possibilities emerged for cooperation with Russia in the field of tracer studies: (1) the participation of a GEOTRACES scientist in the Russian 2017 Expedition to the Barents, Kara Laptev Seas; and (2) GEOTRACES scientists are encouraged to host a Russia student/scientist on a GEOTRACES cruise or lab, with support from SCOR.

Forthcoming:

Exploring GEOTRACES data with Ocean Data View (Goldschmidt 2016 Workshop), 26 June 2016, Yokohama, Japan.

This hands-on workshop will teach standard and advanced ODV methods for the exploration and scientific analysis of environmental data. The GEOTRACES Intermediate Data Product 2014

(IDP2014) will be used as example dataset. Participants will learn how to create publication-ready maps, property-property plots and sections, and how to apply simple or advanced station and sample filters. In addition, an overview over the wide range of derived variables available in ODV will be given and a number of variables often needed in geochemical research will be described and applied. This includes aggregation, interpolation, unit conversion, differentiation and integration. The workshop will start with presentations of general software concepts and capabilities, followed by hands-on sessions for the creation of specific plot types and scientific discussion rounds explaining the findings. Participants are encouraged to bring their own laptop computer with ODV (http://odv.awi.de/) and the IDP2014 dataset (http://www.bodc.ac.uk/geotraces/data/idp2014/) already installed. For further information: http://www.geotraces.org/meetings/geotraces-events/eventdetail/263/-/exploring-geotraces-data-with-ocean-data-view

Joint GEOTRACES/OCB Workshop: "Biogeochemical cycling of trace elements within the ocean: A synthesis workshop", 1–4 August 2016, Lamont-Doherty Earth Observatory, Palisades, New York, USA.

The workshop will launch a synthesis initiative on the biogeochemical cycling of trace elements and their isotopes within the ocean. The aim is to bring together expertise from GEOTRACES, OCB, and the broader oceanographic community of observationalists and modelers to explore the biological–chemical–physical underpinnings of trace element cycling, including (but not limited to) bioavailability, uptake, scavenging, and regeneration. The workshop will identify a small number of high-priority synthesis objectives that can be achieved over the next decade, exploiting the rapidly expanding set of data from GEOTRACES and related studies. The workshop will also outline strategies to reach those goals, which may include new modeling and observational initiatives. For further information: http://www.geotraces.org/meetings/geotraces-events/eventdetail/254/-/joint-geotraces-ocb-workshop-on-internal-cycling-of-trace-elements

3.5 Special sessions at international conferences featuring GEOTRACES findings

Several special sessions with relevance to GEOTRACES were featured in major international conferences including:

2016 Ocean Sciences Meeting, 21–26 February 2016, New Orleans, Louisiana, USA.
For further information: http://osm.agu.org/2016/

GEOTRACES Town Hall:

*****Town Hall "Opportunities to Strengthen Your Science (and Proposals) using GEOTRACES Data", **Thursday, February 25, 2016: 6:30 PM - 7:30 PM**

GEOTRACES Tutorial:

*****T014: What Controls the Distribution of Dissolved Iron in the Ocean?, **Tuesday, February 23, 2016, 03:30 PM - 04:00 PM**
Primary Chair: Alessandro Tagliabue, University of Liverpool.

GEOTRACES Sessions:

Atmospheric deposition and ocean biogeochemistry
Primary Chair: Ana M. Aguilar-Islas, University of Alaska Fairbanks, Fairbanks, AK, United States
Chairs: Clifton S Buck, Skidaway Institute of Oceanography, Savannah, GA, United States and Meredith Galanter Hastings, Brown Univ-Geological Sciences, Providence, RI, United States

*****The role of particles in the cycling of trace elements and their isotopes in the ocean
Primary Chair: Hélène Planquette, LEMAR, CNRS, Plouzané, France
Chairs: Phoebe J. Lam, University of California Santa Cruz, Department of Ocean Sciences, Santa Cruz, CA, United States and Benjamin S. Twining, Bigelow Lab for Ocean Sciences, East Boothbay, ME, United States

*Trace Elements and Isotopes at the Interfaces of the Atlantic Ocean
Primary Chair: Geraldine Sarthou, LEMAR UMR 6539 CNRS UBO IRD IFREMER, IUEM, Plouzané, France
Chairs: Edward A. Boyle, Massachusetts Institute of Technology, Earth Atmospheric and Planetary Sciences, Cambridge, MA, United States, Gideon Mark Henderson, University of Oxford, Earth Sciences, Oxford, United Kingdom and Micha J.A. Rijkenberg, Royal Netherlands Institute for Sea Research, Den Burg, Netherlands

*Trace Metal Bioavailability and Metal-Microorganism Interactions
Primary Chair: Julia M. Gauglitz, Woods Hole Oceanographic Institution, Marine Chemistry and Geochemistry, Woods Hole, MA, United States
Chairs: Randelle Bundy, Woods Hole Oceanographic Institution, Marine Chemistry and Geochemistry, Woods Hole, MA, United States and Jill N. Sutton, IUEM/UBO, Technopôle Brest-Iroise, Place Nicolas Copernic, Plouzané, France

*Trace metal speciation in seawater: measurements, modelling and impact on marine biogeochemistry
Primary Chair: David R. Turner, University of Gothenburg, Gothenburg, Sweden
Chairs: Stan M.G. van den Berg, University of Liverpool, Liverpool, L69, United Kingdom, Sylvia Gertrud Sander, University of Otago, Dunedin, New Zealand, Kristen N. Buck, University of South Florida Tampa, Tampa, FL, United States, Rachel Shelley, LEMAR/UBO, Brest, France, Peter L Morton, Florida State University, Department of Earth, Ocean, and Atmospheric Science, Tallahassee, FL, United States, Christian Schlosser, GEOMAR Helmholtz Centre for Ocean Research Kiel, Chemical Oceanography, Kiel, Germany and Eric P. Achterberg, GEOMAR Helmholtz Centre for Ocean Research Kiel

Goldschmidt 2015, 16–21 August 2015, Prague, Czech Republic.
For further information: http://goldschmidt.info/2015/index

** Theme 2: Ocean Geochemistry. Present Conditions and Past Variation: fluxes, reservoirs and processes
Co-coordinators: Geraldine Sarthou (Brest University, France) and Andrew Bowie (University of Tasmania).
Team members: Katherine Barbeau (Scripps, USA), Kristen Buck (Univ South Florida, USA), Zanna Chase (Institute for Marine and Antarctic Studies, Australia, Rob Middag (Univ Otago, New Zealand), James Moffett (Univ. South Carolina, USA)

*02a: Trace Metals in the Ocean: Distributions, Isotopic Variation and Speciation
Conveners: Katherine Barbeau (UC San Diego, Scripps Institution of Oceanography, USA), Andrew Bowie (University of Tasmania), Kristen Buck (University of South Florida, College of Marine Science, USA), Rob Middag (Univ Otago, New Zealand), Christopher Pearce (National Oceanography Centre), Phil Pogge von Strandmann (Earth Sciences, University College London, UK), Géraldine Sarthou (LEMAR CNRS, Brest, France).

*02b: Radionuclides in the Ocean
Session Conveners: Bob Anderson (Lamont-Doherty Earth Observatory, USA), Ken Buesseler (Woods Hole Oceanographic Institution, USA), Pere Masque (Universitat Autònoma de Barcelona)

*02c: Past Changes in Ocean Biogeochemistry and Circulation and their Interaction with Climate
Session Conveners: Zanna Chase (Institute for Marine and Antarctic Studies, Australia), Martin Frank (GEOMAR Helmholtz Centre for ocean research Kiel, Germany), Norbert Frank (University of Heidelberg, Germany), Katharina Pahnke (ICBM and MPI for Marine Microbiology, Germany), Laetitia Pichevin (University of Edinburgh, UK), Laura Robinson (University of Bristol, UK), Tina van de Flierdt (Imperial College London, UK), Kazuyo Tachikawa (Cerege, CNRS, France)

*02d: What are the unifying principles common to all three Oxygen Minimum Zones (OMZs)?
Session Conveners: Jim Moffett (Univ. Southern Carolina, USA), Aurélien Paulmier (LEGOS, France)

*02e: Air-Sea Exchange, the Biological Pump, and Ocean Acidification
Session Conveners: Steve Emerson (University of Washington, USA), Doug Wallace (Dalhousie University, Canada)

*02f: Biogeochemistry of Arctic and Antarctic sea ice systems
Session Conveners: Jun Nishioka (Univ. Hokkaido, Japan), Delphine Lannuzel (University of Tasmania, Australia)

*02g: Advances in marine N, P and Si biogeochemistry
Session Conveners: Damien Cardinal (University Pierre and Marie Curie, LOCEAN, Paris), Albert Colman (University of Chicago, USA), Masha Prokopenko (University of Southern California, USA), Christian März (Newcastle University, UK)

*02s: Goldschmidt 25th Anniversary
The 25th anniversary talk is an overview of the progress and breakthroughs made in this theme over the last 25 years. Invited speaker: Catherine Jeandel

22nd International Society for Environmental Biogeochemistry (ISEB) Symposium Dynamics of Biogeochemical Systems: Processes and Modeling, 28 September - 2 October 2015, Piran, Slovenia.
For further information: http://www.iseb22.ijs.si

*Marine and coastal environments – Special session: GMOS and GEOTRACES

American Geophysical Union Fall 2015 Meeting, 14–18 December 2015, San Francisco, California, USA.
For further information: http://fallmeeting.agu.org/2015/

*GC067: Trace Metal Cycling in the Environment – 40 Years of Advancements
Convenors: Priya Ganguli, Frank Black, Sergio Sanudo-Wilhelmy and Ed Boyle

Forthcoming:
2016 Goldschmidt Meeting, 26 June–1 July, 2016, Yokohama, Japan.
For further information: http://goldschmidt.info/2016/

*12d: Oceanic Cycling of Trace Elements Using Elemental, Isotopic, and Modeling Approaches: Geotracers and Beyond...
Convenors: Tim Conway, Tristan Horner, Jessica Fitzsimmons, Hajime Obata, Catherine Jeandel, Andrew Bowie, Phoebe Lam

*12f: Elemental and Isotopic Marine Biogeochemistry at a Range of Scales: The Global Ocean, Marginal Seas, and Polar Atmosphere–Sea Ice–ocean Systems
Convenors: Susan Little, Daiki Nomura, Gregory de Souza, Markus Frey, Delphine Lannuzel, Jun Nishioka, Patrick Rafter, Martin Vancoppenolle

*16d: Models of Life and Geochemistry: Integrating Large-Scale Datasets into Global Climate Models
Convenors: Seth John, Tatiana Ilyina, Andy Ridgwell

Challenger Society 2016 Conference - Oceans and Climate, 5–8 September 2016, Liverpool, UK.
For further information: https://www.liverpool.ac.uk/challenger-conference-2016/

***Trace element and isotope exchange at ocean boundaries**
Conveners: Will Homoky (Oxford), Torben Stichel (Southampton) & Susan Little (Imperial)

3.6 Capacity building

At-Sea Training GEOTRACES gratefully acknowledges support from SCOR to enable one scientist per year from a developing nation to participate in a GEOTRACES cruise. These opportunities are vital to the development of technical expertise in sampling and sample handling for contamination-prone elements aboard "dirty" ships.

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. A complementary goal is to establish a programme whereby scientists who have accrued experience in operating these systems can share that knowledge with scientists from nations that either are in the process of acquiring clean sampling systems.

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

Nation	Status	System/ Carousel	Bottles	Depth
Australia	Complete	Powder coated aluminium, autonomous 1018 intelligent rosette system	12 x 10-L Teflon-lined Niskin-1010X	6000 m; 6 mm Dynex rope
Australia	2nd system (complete)	Polyurethane powder-coated aluminium autonomous Seabird rosette with CTD and other sensors, auto-fire module, and all titanium housings and fittings	12 x 12-L Teflon-lined OTE external-spring Niskin-style bottles	1750 m 9mm Dyneema rope or 200 m 6 mm Dyneema rope 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	Towed fish	NA	Surface
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	CTD and bottles purchased, winch planned	Powder coated aluminium with titanium pressure housings and fittings	27 x 12-L OTE GO-Flo	8000 m; conducting Kevlar
India	Complete	Powder coated aluminium 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	10000 m; titanium armored cable
Netherlands	Complete	Titanium frame	24 X 12-liter GO-Flo	10000 m; conducting Kevlar
Netherlands	Complete	Titanium frame	24 X 27-liter ultraclean PVDF	10000 m; conducting Kevlar
New Zealand	Complete	Powder coated aluminium	13 X 5-L Teflon-lined Niskin-X; 13 X 5GO-Flo	4000 m; 8 mm Kevlar line

Norway	In development	Standard 12 positions CTD Rosette GO	5-L Niskin-X	
Poland	Complete* (although the steel cable)	Powder coated aluminum, SeaBird Rosette	8x 10L GoFlo	3000m, steel conducting cable
Poland	Complete	Single bottle	10l G-FLO X Teflon coated	300m Kevlar
Poland	Complete	Teflon pump on-line	Surface water pump	1.5m fixed
Poland	In development	Pump CTD	Teflon hose 10mm	Up to 200m
South Africa	Complete	Powder coated aluminium, titanium housing/fittings	24 X 12-liter GO-Flo	6500 m; Kevlar cable
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-19 plusV2 CTD unit. Powder coated aluminium with Ti parts and pressure housing. Fires at pre-programmable depths	12 X 5-L Teflon-lined Niskin-X	2000 m 0.5-inch Kevlar wire
USA – Polar Programs	Complete	Powder coated aluminium with titanium pressure housings and fittings	12 X12-L Niskin-X	3000 m; conducting Kevlar

4. Plans for coming year

While continuing to progress with the field programme, the top priority for next reporting year will be the release of the second **Intermediate Data Product at the Goldschmidt Meeting**

2017 (13-18 August 2017, Paris, France). This will require a huge effort from the GEOTRACES community, GDAC, and IPO and, thus, most of the GEOTRACES work will be centred in making the IDP2017 possible, with several meetings to be held.

In addition, GEOTRACES will continue to implement the **GEOTRACES synthesis of results strategy** with (1) a workshop focused on the internal cycling of TEIs within the ocean to be held in August 2016, organised by U.S. GEOTRACES, in collaboration with the Ocean Carbon and Biogeochemistry Programme (OCB) and (2) a workshop centred on geochemical tracers used as paleoceanographic proxies, proposed for 2018. A proposal has been submitted to the Past Global Changes project (PAGES) to explore partnership with them to host the workshop.

Acknowledgements

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Written and compiled by:
Ed Boyle and Reiner Schlitzer (Co-Chairs GEOTRACES SSC)
Maeve Lohan and Walter Geibert (Co-Chairs of the GEOTRACES S&I Committee)
Abby Bull (GEOTRACES Data Manager)
Catherine Jeandel (GEOTRACES IPO Science Director)
Elena Masferrer Dodas (GEOTRACES IPO Executive Officer)

May 2016

3.3 Surface Ocean–Lower Atmosphere Study (SOLAS) (joint with Future Earth, WCRP, and CACGP) **Turner**

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: Véronique Garçon

Other Members: Emmanuel Boss, Anja Engel, Cristina Facchini, Hui-wang Gao, Christophe Garbe, Michele Graco, Christophe Heinze, Ilan Koren, Lisa Miller, Yukihiro Nojiri, Alfonso Saiz-Lopez, VVSS Sarma, and Brian Ward
Executive Committee Reporter: John Turner

Executive Officer: Emily Breviere

SOLAS Annual Report to SCOR

Reporting period: September 2015- May 2016 Version of 13 May 2016 by Stefan Kontradowitz

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 Scientific Steering Committee

Since January 2015 Véronique Garçon from France serves as Scientific Steering Committee (SSC) chair, with her term ending in December 2017. Before becoming the SSC chair she spent two terms as an SSC member between 2007 and 2012.

SOLAS has an Executive Committee composed of the chair, Lisa Miller, Brian Ward and Cristina Faccini. Since the last report the following SSC members rotated off in December 2015:

- Cecile Guieu,
- Christoph Heinze, and
- Nojiri Yukihiro.

Ending his first term and being selected for a second term in the SSC was Ilan Koren. In January 2016 three new SSC members were appointed:

- Philip Boyd (M, Australia),
- Andrew Jessup (M, USA), and
- Parvadha Suntharalingam (F, UK).

The SOLAS SSC met in Hamburg, Germany, 11-13 September 2015 for its 15th SSC meeting following the SOLAS Open Science Conference 2015, which took place in Kiel, Germany. The next SSC meeting is currently scheduled to take place between 24 and 26 October 2016 in Qingdao, China. This meeting will be followed by a `SOLAS Symposium Day` where some SSC members and local researchers will be able to present their work. This will be the third time a SOLAS SSC meeting will be followed by a `Symposium Day` as it proved very successful in Japan in 2013 and in Israel in 2014. Because of the SOLAS Open Science Conference a Symposium Day was not organized in conjunction with the 2015 SSC meeting in Hamburg.

The current membership of the SOLAS SSC is listed below (16 members including the chair):

Last name	First name	Country of employm	Gender	Scientific expertise	Term end on 31 Dec
Boss	Emmanuel	USA	M	Ocean optics and biogeochemistry	2017
Boyd	Philip	Australia	M	Marine biogeochemistry	2018

Engel	Anja	Germany	F	Microbial biogeochemistry, sea surface microlayer	2017
Facchini	Cristina	Italy	F	Physical and chemical processes in multiphase atmos. systems	2017
Gao	Huiwang	China	M	Atmospheric deposition and ecological effect	2017
Garbe	Christoph	Germany	M	Air-sea physical interaction	2016
Garçon	Veronique	France	F	Marine biogeochemistry and ecosystems dynamics	2017
Graco	Michelle	Peru	F	Biogeochemical cycles in upwelling systems, OMZ	2017
Jessup	Andrew	USA	M	Air-sea interactions, remote sensing	2018
Koren	Ilan	Israel	M	Cloud Physics	2018
Levasseur	Maurice	Canada	M	Ocean biogeochemistry, dimethylsulfide, Arctic, ice algae	2017
Miller	Lisa	Canada	F	Sea-ice/CO_2 exchanges	2016
Saiz-Lopez	Alfonso	Spain	M	Atmospheric halogens/modelling	2016
Sarma	VVSS	India	M	Biogeochemical cycling of C and N in the ocean and estuaries, stable isotopic geochemistry/ocean acidification	2017
Suntharalingam	Parvadha	UK	F	Numerical modelling / C, N, S bgc cycles	2018
Ward	Brian	Ireland	M	Air-sea physical interaction	2016

The current gender and country balance of the SSC is as follows; for a total of 16 members including the chair:

- 6 female members and 10 male members
- 3 members from developing countries and 13 from developed countries

I.b. Development of the SOLAS Mid-term strategy

Since 2008, SOLAS has supported the development of the Mid-term strategy (MTS) themes, identified as areas where progress can be accelerated significantly with the support of an international programme such as SOLAS. A good summary/overview of the research of the MTS is available through the article

> Law C. *et al.* (2013) Evolving Research Directions in Surface Ocean - Lower Atmosphere (SOLAS) Science. Environmental Chemistry. Available on the SOLAS website and at

http://www.publish.csiro.au/view/journals/dsp_journals_pip_abstract_Scholar1.cfm?nid=188&pip=EN1215 9

Since the 2015 report, the new SOLAS science plan has been finished and provided to the sponsors. Because of new themes mentioned and described in detail in the science plan (see I.g) some topics of the Mid-term strategy have progressed less than in previous years.

- Sea-ice biogeochemistry and interactions with the atmosphere

Activities of the MTS on sea-ice are intrinsically linked to the **Biogeochemical Exchange Processes at the Sea-Ice Interfaces (BEPSII) SCOR WG 140**, chaired by Jacqueline Stefels and Nadja Steiner.

Because of the strong linkage to SOLAS and the conclusion of the SCOR support to this group in 2016, BEPSII is now co-sponsored by SOLAS and CliC (Climate and Cryosphere) since early 2016.

During the SOLAS Open Science Conference 2015 a discussion session on `**Towards joint SOLAS-CliC activities on sea-ice biogeochemistry**` took place which led to the co-sponsorship mentioned above. The session was convened by Lisa Miller and Martin Vancoppenolle. Below is a short summary provided by Lisa Miller:

Following on their successes, SCOR working group 140 on "Biogeochemical Exchange Processes at Sea-Ice Interfaces" (BEPSII) identified a need to sustain the community studying sea-ice biogeochemistry beyond the lifetime of the SCOR working group, in order to develop consistent methodologies, establish effective sea-ice data archiving approaches and databases, integrate observational and modelling efforts, and foster technological developments. While sea-ice biogeochemistry has been a mid-term strategy of SOLAS, which has endorsed BEPSII, the WCRP Climate and Cryosphere (CliC) project has Arctic and Antarctic sea ice working groups and a Sea Ice and Climate Modelling Forum that are also working towards similar goals from a more physical perspective. Therefore, we held a discussion at the SOLAS Open Science Conference to explore ways SOLAS and CliC can jointly promote activities in sea-ice biogeochemistry.

The goal of the discussion was to develop a draft proposal to the CliC and SOLAS steering committees for a joint framework to support continuing developments in sea-ice biogeochemical research. We were largely successful in achieving that goal, in that a CliC Forum application is being prepared for their November 15th deadline, and we will also submit a modified version of that proposal to SOLAS. However, the requirements for that application are very brief and general, and much of the discussion pursued more detailed ideas for long-term BEPSII activities. We started the session with a presentation by BEPSII co-chair Jacqueline Stefels on BEPSII history, starting with the SOLAS mid-term strategy and an initial COST-SOLAS workshop in Amsterdam in 2011, followed by provisional acceptance as a SCOR working group later that year and their first (unofficial) meeting at the 2012 SOLAS Open Science Conference. The final BEPSII meeting under the auspices of the SCOR working group will be held in Paris during March 2016.

The initial aim of BEPSII was ambitious: To improve our understanding of the role of sea ice in global biogeochemistry by bringing together sea-ice modelers and observationalists. This goal was approached through four activities:

1. *Standardisation of methods for data inter-comparison;*
2. *Summarizing existing knowledge in order to prioritise processes and model parameterizations;*
3. *Up-scaling of processes from 1D models to earth system models; and*
4. *Analysing the role of sea ice biogeochemistry in climate simulations. Despite substantial successes, much of this work still remains incomplete, and the need for additional activities has become apparent.*

Martin Vancoppenolle then presented the general goals and structure of CliC (www.climate-cryosphere.org), including their 'Fora' which provide a framework for long-term association of communities addressing specific issues in crysopheric science. Support provided for a forum includes 5000 CHF/year to support a workshop, travel bookings, and hosting a website. Lisa Miller then described the activity structures and resources available from SOLAS, noting that their structures are in no way incompatible with those of CliC.

The open discussion was then set up with a list of ideas for future BEPSII activities identified at the last BEPSII meeting (in Barga, Italy, March 2015) and through a survey of the BEPSII mailing list in late summer. The discussion was framed by 4 themes: networking mechanics and funding; scientific topics and issues; membership, including entraining more atmospheric scientists; and boundaries.

In March 2016, a three day **BEPSII meeting** took place in Paris to discuss about the future of the project. This was the last meeting under the SCOR umbrella, and dedicated to discuss the continuation of BEPSII. The SOLAS chair attended the meeting.

In addition to 1.5 days of interesting talks, the group had several discussion sessions and worked out a set of new and continued task groups with focused research covering: Methodologies and data collation, modeling and observational process studies, synthesis and outlook as well as outreach. A full list of tasks with requests for community participation will be accessible from the BEPSII website as well as communicated via BEPSII's new Twitter page. BEPSII's next meeting will be at Scripps Institution of Oceanography in San Diego, on April 3-5, 2017, with support from SOLAS and CLIC. A proposal for additional support from IASC has been submitted. Members of the BEPSII group also submitted a new SCOR proposal in support of method intercomparison studies.

An additional short outcome report of the meeting provided by Lisa Miller can be found below:

BEPSII's FUTURE: Discussion Paris meeting 18 March 2016

Goals and Objectives

- *Develop dedicated consistent methodologies for sea ice biogeochemical research*
- *Establish effective sea-ice biogeochemical data archiving approaches and databases*

- *Foster ecological process studies to determine their impact on biogeochemical cycles.*
- *Foster technological developments towards large-scale, autonomous and high-frequency sampling of sea ice biogeochemical parameters*
- *Improve the representation and evaluation of sea ice biogeochemistry in regional and Earth System numerical models*
- *Synthesize and integrate observational and modeling efforts*
- *Continually revise and renew scientific foci, teams, and objectives*

Task groups and Products
TG1 on Methodologies and data collation
(Leads: Lisa Miller Lisa.Miller@dfo-mpo.gc.ca and Klaus Meiners Klaus.meiners@aad.gov.au)

- *Intercalibration & intercomparison campaign (SCOR prop) (Francois Fripiat ffripiat@ulb.ac.be)*
- *In-situ platforms / sensor development & validation (Hauke Flores, Klaus Meiners)*
- *Remote-sensing tools and algorithms (who?)*
- *Designing time series process studies (inform MOSAIC) (Bruno Delille, Anya Waite anya.waite@awi.de , Martin Vancoppenolle)*
- *Guide of best Practice as life document (Lisa Miller, Bruno Delille, Klaus Meiners)*
- *Historical data collation and analysis; emphasis on Arctic (Ilka Peeken ilka.peeken@awi.de, Martin Vancoppenolle, Nix Geilfus nxgeilfus@gmail.com)*
- *Tools and protocols for genetic community assessments (Jeff Bowman bowmanjs@ldeo.columbia.edu , Katja Metfies Katja.Metfies@awi.de)*

TG2 on Modeling and observational process studies
(Leads: Nadja Steiner nadja.steiner@canada.ca and Hauke Flores Hauke.Flores@awi.de)

- *Ridges-associated processes (Giulia Castellani Giulia.Castellani@awi.de)*
- *Impact of micro plastics on sea-ice ecosystems (Ilka Peeken, Gunnar Gerdts: ilka.peeken@awi.de , Gunnar.Gerdts@awi.de*
- *Time variability of algal wax and wane (Nadja Steiner, Maria van Leuuwe m.a.van.leeuwe@rug.nl)*
- *Interactions of snow and sea ice (James France J.France@uea.ac.uk, Jennie Thomas Jennie.Thomas@latmos.ipsl.fr, Thorsten Bartels-Rausch thorsten.bartels-rausch@psi.ca , Bruno Delille)*
- *Impact of biochemistry on physical ice properties (Elena Golubeva elen@ommfao.sscc.ru, Nadja Steiner)*
- *Upscaling (Hauke Flores, Klaus Meiners, Nadja Steiner)*
- *Intercomparison of 1D models (Letizia Tedesco, Martin Vancoppenolle)*
- *Intercomparison of 3D models (Nadja Steiner, Clara Deal deal@iarc.uaf.edu)*
- *Analysis of regional and global climate models (CMIP 5 / 6; FAMOS) (Martin Vancoppenolle, Nadja Steiner)*

TG3 on Synthesis and outlook
(Leads: Martin Vancoppenolle martin.vancoppenolle@locean-ipsl.upmc.fr and Delphine Lannuzel Delphine.Lannuzel@utas.edu.au)

- *Conceptual model development: ice-pelagic-benthic coupling and OA (Sebastian Moreau Sebastien.Moreau@hotmail.com, Jacqueline Stefels, Nadja Steiner, Letizia Tedesco)*
- *Conceptual model development: DMS(P) cycle and connection to paleoclimatology (DMS in sea ice review) (Jacqueline Stefels, Gauthier Carnat gauthier.carnat@gmail.com , Nadja Steiner)*
- *Conceptual model development: sea ice - paleoclimatology connection (Celia C.J.Sapart@uu.nl , Gauthier Carnat, Jacqueline Stefels)*
- *Functional interactions across trophic levels (Hauke Flores, Maria van Leuuwe, Janne Rintala, Letizia Tedesco)*
- *Methane-in-sea ice synthesis (Celia Sapart, Ellen Damm, ellen.damm@awi.de*
- *Review papers on major biochemical processes (Elementa special issue – in progress – contact Nadja Steiner)*

TG4 on Outreach
(Leads: Bruno Delille Bruno.Delille@ulg.ac.be , Letizia Tedesco Letizia.Tedesco@ymparisto.fi)

- *Stakeholder links (Nadja Steiner)*
- *Outreach to general public: Facebook (Bruno Delille),*
- *Outreach to stakeholders: Twitter (Letizia Tedesco)*
- *Outreach to science: website (Bruno Delille)*
- *Capacity building: Summer school (Letizia Tedesco)*
- *Logo*

Following is a short overview provided by the task groups of BEPSII:

Task Group 1 on Methodologies and Intercomparisons (Leads: Lisa Miller and Lynn Russell): Task Group 1 on Methodologies was not very active over the last year except preparing the new SCOR working group proposal, which was submitted to SCOR in April 2016. There was at least one small-scale intercalibration experiment in Hokkaido this winter, but the outcome is not yet known.

Task Group 2 on Data (Leads: Klaus Meiners and Martin Vancoppenolle, information provided by K. Meiners):
The BEPSII Task Group 2 on Data has progressed several historical data collation efforts over the last 12 months. New data collations contributing to, or conducted through BEPSII, include: i) a circum-Antarctic fast ice core chlorophyll a data set from a total of >900 ice cores collected over the last three decades, ii) an Antarctic sea ice core (particulate and dissolved) iron data set, and an iii) Antarctic sea ice macro-nutrient data set. European teams have progressed the collation of Antarctic sea ice dissolved inorganic carbon/total alkalinity data sets and a bi-polar ice algal biodiversity data set. The task group recommends further collation and analysis of existing/historical data, in particular particulate organic carbon (POC) and dissolved organic carbon (DOC) data from Antarctica. The group is also looking for colleagues to lead and champion the collation of various Arctic data sets (e.g., macro-nutrients, POC and DOC). The BEPSII data team has also developed a variety of new MATLAB scripts to read information from standardised data-entry forms (ASPEct-Excel sheets), and these will be made available through

the BEPSII home page in the near future. Discussion within this task group and the BEPSII research community also identified the need for simultaneous long-term observation of physical/biological/biogeochemical sea ice parameters and recommends the development of automated sampling platforms and in-situ sensors.
Task Group 3 on Modeling (Leads: Nadja Steiner and Clara Deal, information provide by N. Steiner): Task 1- The paper "What sea-ice biogeochemical modellers need from observationalists" is now published in *Elementa* (BEPSII SF)[1] and the task completed
Task 2-Review papers on major biogeochemical processes – This task is still in progress, more than 10 papers are submitted or published and a similar amount is in preparation. Submission deadline for the *Elementa* SF has been extended to June 30, 2016. A summary of all BEPSII papers is attached.

Task 3 - 1-D model intercomparison. Ice-algae comparison has been delayed due to issues with the Antarctic data set. It was decided to continue with the intercomparison with the Arctic (Resolute) data set only. A publication comparing parameterisations of mixed layer processes is in preparation. A DMS intercomparison has not yet been done, due to a lack of models, but will be pursued in the future. Despite limited progress in 1-D model intercomparisons, lots of progress has been made in 1-D model development.

Task 4 – Application and evaluation of regional and global models. Several intercomparsions of Arctic biogeochemistry have been performed and published; however, so far hardly any of the models included sea-ice biogeochemistry and evaluation was restricted to the pelagic environment. Progress is being made with respect to the implementation of sea ice algae in regional and global models and an intercomparisons will be pursued in the near future within the framework of FAMOS. The link to FAMOS will be strengthened in the next phase of BEPSII due to enhanced focus on ice -pelagic and benthic coupling.

- Air-sea gas fluxes at Eastern Boundary upwelling systems

During the SOLAS Open Science Conference 2015 a discussion session on this topic titled `**Priorities and integrated programs for the study of eastern boundary upwelling systems**` took place. A report about the session can be found below:

Introductory talk EBUS by F. Chavez (F.C.)
The main biogeochemical features which are common to all EBUS result from the occurrence of coastal upwelling. In these systems cold, nutrient and CO2-rich waters transported to the surface not only result in enhanced gas exchange with the atmosphere, but also in fertilization of the upper layers of the ocean which in turn stimulates biological production at all trophic levels. In addition, the creation of low oxygen (O2) environments is a typical characteristic of EBUS, due to the enhanced rain of organic material from the surface.

Understanding long-term physical and biogeochemical variability in EBUS is important considering their potential socio-economic impact for activities such as fisheries. EBUS are susceptible to climatic variability due to their close association with atmospheric circulation. Hence, large-scale climatic changes (e.g. ongoing global warming) might have significant effects,

[1] http://www.elementascience.org/articles/84

although the individual responses of different EBUS can be markedly different. Nevertheless, EBUS are poorly represented in global models and more work is needed to elucidate their potential responses to future climate change.

Given the fact that EBUS are sites of intense ocean-atmosphere coupling, and because their study requires a multidisciplinary approach with cooperative efforts from different areas of expertise, EBUS are suggested to be one of the focal points of SOLAS.

Introduction to cross-topics: Veronique Garcon (V.G.)
Due to the upcoming transition from IGBP to Future Earth, a call for more integrated efforts from the various scientific, socio-economic and political sectors is in order, with the main purpose being the improvement of the current regional coupled models considering ocean-atmosphere interactions. In order to achieve this goal it is suggested to coordinate international multi-model experiments with enhanced observations both in atmosphere and ocean, and which also include socio-economic impacts. The development of a monitoring system for near-coastal areas is particularly relevant considering the current observational limitations as well as the bias between in situ and modeled data. Recent studies showed that, for example, there is a clear trend towards higher biases between in situ and global climate models-derived SST in EBUS. Some possible reasons for this are underestimation of stratocumulus clouds, errors in surface wind stress, as well as unresolved offshore transport by ocean eddies.

Discussion:
The discussion was centered on the identification of key questions which could lead to set priorities for the study of EBUS. As a start, the following points were presented:

- *Changing climate*
- *Declining/varying oxygen, fisheries*
- *Changing fluxes of critical elements*
- *Integration with other scientific and social programs*
- *Define observational and experimental programs*
- *Define how to improve model forecasts*
- *Define technology development efforts*

As a result of the discussion, a list of general questions/needs based upon which it would be easy to achieve a synergy between scientists of different expertise was produced:

- *Quantification of upwelling (e.g. volume transport, depth of upwelling)*
- *Are the respiration rates in OMZ's oxygen-dependent? (direct measurements of rates are needed)*
- *What is the extent of vertical transport and decay of organic matter? (in situ export profiles are needed)*
- *More information about remineralization rates is required*
- *Higher resolution view of oxygen vertical distribution in OMZ's*
- *What is the role of sedimentary rates of N-cycling?*
- *What is the role of iron in sediments underlying EBUS?*
- *How to include upper trophic levels?*

- *How primary productivity will change with global change and what is the impact for the local economies of the bordering countries?*
- *Detect trends and variability? Develop and implement an observational system: where to observe, how to observe, what to observe and how often?*

SCOR WG 144 workshop

The SCOR WG 144 on `Microbial Community Responses to Ocean Deoxygenation` organized a workshop between 30 August and 3 September 2015 in Warnemunde, Germany. The final workshop report was not finished at the time of this report.

Another meeting is currently planned to take place in Goa, India in December 2016, with a book or special issue in a journal planned following the meeting. An additional workshop in Chile after the Goa meeting is also planned.

A workshop took place at the IMBER IMBIZO in October 2015 titled `Eastern Boundary Upwelling Systems (EBUS) and Oxygen Minimum Zones (OMZ): A natural Future Earth priority`. An abridged report is below. Original report was written by Paulmier A., Dewitte B., Illig S., and V. Garçon:

The tropical and subtropical systems at eastern oceanic boundaries are characterized by upwelling-induced high primary production and export that, in combination with weak ventilation, causes oxygen depletion and the development of oxygen minimum zones (OMZs) in intermediate waters. Associated with strong physical-biogeochemical gradients, OMZs affect nearly all aspects of ecosystem structure and function in the water and on the seabed. The economies of countries neighbouring upwelling zones are largely reliant on marine resources for food and employment. There is an urgent need for increased capacity to predict changes in ecosystem structures and coastal water quality as a result of deoxygenation and acidification to define sustainable management strategies of their marine resources. The OMZs also play critical roles in atmospheric chemistry and climate through emission of active trace gases. These regions also feature extensive stratocumulus cloud decks that play a pivotal role on the Earth's radiation budget and thus, in the response of the climate system to greenhouse gas forcing. IPCC coupled global circulation models (CGCM) have great difficulties simulating eastern boundary regions, and exhibit severe biases in Sea Surface Temperature (SST; Richter et al., 2015) and OMZs structures (Cabré et al., 2015). Since 2009, the Surface Ocean - Lower Atmosphere Study (SOLAS) project has produced an Eastern Boundary Upwelling System (EBUS) and OMZs Strategy Initiative and has held three international workshops (Peru, November 2010 and 2012; EUR-OCEANS Conference, Toulouse, October 2011). An integrative approach for future EBUS research should join the efforts of various Future Earth core projects to combine atmosphere, ocean, continents and socio-economic dimensions. Some major scientific findings regarding EBUS are presented here.

Work is currently being undertaken to determine the cause of the warm SST bias in CGCMs (e.g.: VOCALS program, EU Preface project). Because the low-resolution global coupled models tend to underestimate the upwelled waters and are not able to simulate a well-defined upwelling cell at the coast, they have difficulties in accounting for the strong air-sea contrast in the EBUS. For instance, they usually represent more diffuse air temperature inversion zones located at lower altitudes than observed in forced atmospheric models (see Wyant et al. (2010) for the Humboldt

system). This bias in particular prevents the formation of low-level clouds, which in turn significantly alters the radiative heat budget at the air-sea interface and results in SST bias ~+3°C (Richter et al., 2015). Other possible mechanisms of air-sea interaction at work in the EBUS include wind-upwelling-SST gradients, SST-low clouds, wind-SST-low clouds, wind-evaporation-SST and SST-PBL (Planetary Boundary layer) turbulence-wind. However, the temporal and space scales at which they operate have yet to be elucidated. Therefore, a better understanding of these air-sea coupled processes and their relative contribution is required, all the more so because the radiative budget in the upwelling regions may involve zonal heat transfer from the coast to the inner ocean by offshore propagating eddies. Conflicting model results on the role of eddies in the heat budget in the South Eastern Pacific (Colas et al., 2012; Zheng et al., 2010; Toniazzo et al. 2010) calls for further observational analysis (Holte et al., 2013) and for better understanding of the control of eddy activity by equatorial variability (Dewitte et al, 2012; Combes et al., 2015).

The main biogeochemical issue is to determine the net effect of the upwelled OMZ on the Earth system, as a result of the many feedback mechanisms involved (Law et al., 2013). Particularly important are the interactions between the remineralization processes in subsurface waters associated with chemical anomalies and bacterial activity, and primary production at the surface. In addition, EBUS and OMZ do not match exactly, suggesting a sensitivity of the oxygen budget to some aspects of the global circulation, as well as basin-scale and interhemispheric differences. According to the World Ocean Atlas (WOA) 2013 database, the lowest oxygen concentrations in the Atlantic, the most oxygenated ocean, go down to 23µM and 14µM in the Canary and Benguela EBUS, respectively, whereas in the Pacific, the least oxygenated ocean, the minimum oxygen concentrations are close to the detection limit. Future challenges to understanding the EBUS-OMZ systems lie with identifying relevant domains and documenting relevant parameters of the appropriate space and time scales. All the EBUSs are linked to the equatorial dynamics, in particular showing an extreme sensitivity of the OMZ extension to the mean equatorial circulation (e.g. Montes et al., 2014). In terms of variability, the EBUSs are also very connected to the equatorial system through trapped coastal Kelvin waves controlling the interannual variability, particularly during El Niño and the Benguela El Niño events (Dewitte et al., 2012; Bachèlery et al., 2015). Another important domain for the EBUS-OMZ are mid-latitude anti-cyclonic gyres. These control the intra-annual variability as their sea level pressure is highly correlated to the coastal alongshore winds off both Peru and Namibia, (Dewitte et al., 2011). Relevant space scales include sub-regional domains, and three or four sub-components (or biomes and ecosystems) of the EBUS-OMZs are usually described (Fréon et al., 2009). In particular, the intense cross-shore gradient between the shelf and the open ocean sub-systems in terms of physical forcing and the biogeochemical activity and ecosystem communities must be correctly represented. For instance, simulations from the ROMS-BIOEBUS model in the Benguela system (Gutknecht et al., 2013) indicate off-shore O2 fluxes (production and aerobic processes) twice as often as near the coast. By contrast, the highest microbiological rates appear close to the coast of Peru, with a local ammonium release fueling the nitrogen loss in the nitrogen cycle through denitrification and anammox processes. The signature of this biogeochemical activity (relative nitrite maxima and nitrogen deficit) is advected off-shore in a second stage (Kalvelage et al., 2013).

EBUS-OMZs are also typically subjected to mesoscale and submesoscale variability and are populated by eddies. As evidenced from a modelling lagrangian study off Peru (Fig. 1), the paths (corridors) of mesoscale structures maintain the boundaries of the OMZ, whereas higher frequency submesoscale fluctuations ventilate the OMZ through eddy fluxes and local mixing (Bettencourt et al., 2015). This fine-scale pattern not only impacts the OMZ structure but also impacts the air-sea fluxes of greenhouse gases, illustrated for example in the extreme variability of CO2 and N2O between the coast and the open ocean, inducing complex coupled and decoupled source/sink situations (e.g. Paulmier et al., 2008; Kock et al., 2016).

In terms of relevant time scales, the EBUS-OMZ are subjected to interannual (with a thermocline and oxycline deepening during the El Niño events: e.g. Morales et al., 1999) and longer scales. The annual/seasonal cycle is also well marked (Vergara et al., 2016). In particular off Peru and Namibia, the annual O2 cycle presents a possible de-phasing between the Humboldt and Benguela systems, but also within the same system (Fig. 2; note especially the differences between 12°S off Peru and 21°S off Chile). The winds as a main physical forcing may also show seasonal latitudinal shifts off Chile (e.g. Monteiro et al., 2011). Sub-seasonal to intra-seasonal timescales have been reported from SST observations, an activity that is modulated seasonally by changes in stratification for the Peru (See Dewitte et al., 2011; Illig et al., 2014) and Benguela (Goubanova et al., 2013) systems. Data collected during recent cruises and a mooring off Peru (cf AMOP project: http://www.legos.obs-mip.fr/recherches/projets-en-cours/amop) also revealed large variability in dissolved oxygen at higher frequency, which could be partly associated with internal waves (such as a tide).

Modifications in physics and biogeochemistry impact the biological processes and ecosystems (e.g. habitats), and ecosystem services and ocean-related human activities. EBUS-OMZ systems exhibit high gradients and variability, including extreme events. They are the richest ecosystems in the ocean with strong ocean-atmosphere coupling. Consequently, they can be considered as natural laboratories in terms of multiple drivers and new technology challenges. There is a pressing need to improve the predictive capacities of regional coupled models, considering the breath of interactive processes between atmosphere, ocean, biogeochemistry and land at regional scales, and the limitations of global climate models for these regions. Coordinated multi-model experiments are crucial to achieve this, as are enhanced ocean and atmosphere observations of the eastern boundary regions. Future plans and actions need to include the EBUS-OMZ systems as a Future Earth priority, supporting international initiatives like the IOC UNESCO Global Oxygen Network (GO2NE).

Global Ocean Oxygen Network

Listening to the calls demanding increased cooperation and communication around low oxygen concentration in the marine environment, IOC-UNESCO initiated an ad hoc network of scientists focused on oxygen in both the open ocean and coastal areas – the Global Ocean Oxygen Network (GO2NE).

The GO2NE expert meeting took place on 12-13 December 2015 to develop terms of reference and a plan for the continuation of this interdisciplinary IOC-UNESCO network. The plan will be presented to the IOC Executive Council in June 2016 for possible adoption.

http://www.unesco.org/new/en/natural-sciences/ioc-oceans/sections-and-programmes/ocean-sciences/global-ocean-oxygen-network/

SOLAS joined the CLIVAR Focus on EBU´s in March 2016. More information about the existing research focus on upwelling between CLIVAR and IMBER can be found on the CLIVAR website at: http://www.clivar.org/research-foci/upwelling. The full `Prospectus for CLIVAR Research on Eastern Boundary Upwelling Systems` is available in an Addendum to this report as it would be too detailed to be included here.

SCOR WG proposals
A proposal has been submitted to SCOR for a working group called cOCtEAU (Ocean Atmosphere Upwelling) and is aimed at increasing the scientific understanding of the interactive processes between land, ocean, and atmosphere and their impacts on the marine biogeochemistry and ecosystems at the regional scale. Another proposal for a working group called EBUE (Eastern Boundary Upwelling Ecosystems: inter-comparisons, variability and forecasting responses to climate and global change) has also been submitted.

- Ship plumes: impacts on atmospheric chemistry climate and nutrient supply to the oceans
  As the interest in this topic has increased over the last years it was an important topic during the SOLAS Open Science Conference 2015 in Kiel, Germany. During the plenary session on `SOLAS science and society` a talk was given by David Turner on ship plumes. Also an entire discussion session on this topic was convened by D. Turner. A short report of the discussion session is provided below (by D. Turner):

Ship Plumes have been suggested as a SOLAS research topic for some time. The first SOLAS Ship Plumes discussion session was held in Barcelona in 2009. That session focused to a very large extent on the atmospheric science questions associated with Ship Plumes, with only limited interest from the marine science community. As a result, the Barcelona initiative did not gain momentum as an integrated SOLAS activity. In contrast, at the Kiel SOLAS Ship Plumes discussion session we had a fairly even division of research interests between atmospheric and marine sciences among the 30 participants.

Ship plumes are an important part of the environmental footprint of shipping. Emission regulations, which are most advanced for sulphur and nitrogen oxides, SOX and NOX, have been entirely driven by concerns about air quality and human health but are still very lax in comparison with the regulation of terrestrial emissions of these gases.

The meeting first reviewed the composition of ship plumes. In addition to CO2 this includes SOX and NOX, NHX, CO, metals, organic compounds, and particulates. Almost all these materials have a limited residence time in the atmosphere, and are therefore deposited relatively close to the source, usually within some hundreds of kilometres. Among the metals, Fe is of particular interest since it acts as a micronutrient in the marine environment: a recent study has suggested that shipping may become the major source of Fe to surface ocean waters by the end of the century. Organic compounds and particulate materials are mainly of concern for human health: PAH emissions are a concern, and also small (< 2.5 μm) particles that penetrate deep into the lungs. The emission of black carbon may have significant effects at high latitudes, where it

reduces albedo following deposition to ice surfaces. This implies that the anticipated opening of Arctic shipping routes as the sea ice retreats may lead to a positive feedback through black carbon deposition on the ice

The fate of the materials discharged in Ship Plumes depends on both transport processes in the atmosphere, and also transformation reactions. These, together with information on the emission sources (i.e. ships) determine the extent to which these materials are deposited to the sea surface, or transported to the terrestrial atmosphere. Marine and coastal atmospheric circulation systems will have a strong impact on the deposition, atmospheric dispersion and transport. Specific features of the marine atmosphere need to be considered.

A closely related topic, that should be included in a Ship Plumes study, is the use of wet scrubbers that remove SOX in a stream of seawater: in the simplest (open-loop) scrubbers, the effluent is discharged back to the surface water. These scrubbers are currently being installed within sulphur emission control areas (SECA), which encompass some northern hemisphere coastal waters. In these areas, the maximum allowed sulphur content of marine fuel was reduced from 1% to 0.1% in January 2015. Since this change results in a doubling of fuel costs, it has become attractive to use scrubbers so that cheap, high-sulphur fuel can be used without breaching the limits on SOX emission. However, little is known about the chemical composition of the effluent and its consequences for the marine environment.

During the meeting, all participants introduced themselves and provided a short summary of their research interests, which covered a broad range of atmospheric and marine science. A list of participants, together with email addresses and research interests, has been compiled. There was broad agreement that development of an integrated research programme on Ship Plumes would not only be scientifically exciting, but would also have significant societal implications: SOLAS science can play an important role in providing the scientific basis for future regulations. This led to a discussion of the need to develop collaboration with researchers in areas such as economics, law and social sciences, and also of the need to engage the attention of the public at large, approaches that fit well within the Future Earth concept.

However, it was concluded that the first priority is to identify the scientific questions and challenges, as a basis for developing wider collaborations.

Possible specific regions of interest were also considered. It was pointed out that the Arctic could be an important study area. Climate change is expected to lead to an opening of Arctic shipping routes, bringing a significant change in the distribution of Ship Plumes. The retreat of sea ice is already changing the Arctic environment: understanding the consequences of adding Ship Plumes with their cocktail of nutrients such as N and Fe, together with toxicants and black carbon, presents both an exciting scientific challenge and a question of substantial societal relevance. Other regions of relevance are shipping hot-spots regions (strongly trafficked regions in the vicinity of large harbours) and the protection regions (SECA…), where changes in the emission patterns are expected.

On a show of hands, 23 participants expressed strong interest in attending a workshop to further develop the basis for an integrated programme on Ship Plumes within SOLAS. Such a workshop

would need additional invited participants to cover areas of expertise not represented at the meeting (e.g. ship traffic analysis, marine engineering).

During a planned **SOLAS workshop** (26-27 October, Brussels, Belgium) on `SOLAS and society` one of three topics to be discussed will be `The shipping industry and air-sea interactions`.

Also a **separate workshop** on ship plumes is currently planned to take place in Sweden, but no firm date has been set at this time.

I.c. SOLAS- IMBER Carbon Group

Much of the science of SOLAS Focus 3 overlaps with IMBER and thus a joint SOLAS/IMBER Carbon Group (SIC) was formed during a meeting held in Colorado in Oct. 2005. This group is working in close collaboration with International Ocean Carbon Coordination Project (IOCCP). The SIC group is currently subdivided into three working groups:

***WG1-Surface Ocean Systems.** Chair: Andrew Lenton (Australia)

The Surface Ocean CO_2 Atlas (SOCAT) is a largely volunteer, international activity by the marine carbon community, with more than 100 contributors to assemble surface ocean carbon dioxide (CO_2) data in a uniform, quality-controlled format. Version 1 was made public in 2011, version 2 in 2013 and the latest version (version 3) was released at the SOLAS Open Science Conference 2015.

A one-day workshop on SOCAT and SOCOM (Surface Ocean pCO_2 Mapping Intercomparison) took place at the SOLAS Open Science Conference 2015. A report of this meeting is attached below (provided by Dorothee Bakker):

The Surface Ocean CO_2 Atlas (SOCAT) and the Surface Ocean pCO_2 Mapping Intercomparison (SOCOM) held a joint event in Kiel on 7 September 2015, in conjunction with the SOLAS (Surface Ocean - Lower Atmosphere Study) Open Science Conference. The 54 participants from 18 countries included SOCAT data providers, data managers, quality controllers, users, SOCOM contributors and science programme managers.

The Surface Ocean CO_2 Atlas provides quality controlled and documented, synthesis fCO_2 (fugacity of carbon dioxide) data products for the global oceans and coastal seas. SOCAT was initiated in 2007, as the need for a publicly available, surface ocean CO_2 data synthesis product was recognized.

SOCAT Version 3 was released at the Kiel event. Version 3 has 14.5 million surface water fCO_2 values collected between 1958 and 2014. New features include 4.4 million additional fCO_2 values, extension of the data set, inclusion of fCO_2 data from well calibrated sensors and alternative platforms, a new data set flag of E, accuracy criteria for all fCO_2 values, automated data checks, and powerful visualisation tools in the interactive Cruise Data Viewer.

A system for automated data upload to SOCAT was formally launched. This automation system integrates data upload, data submission and quality control on a single platform, thereby

enabling annual SOCAT releases from Version 4 onwards. Version 4 deadlines for data submission and quality control are 31 January and 31 March 2016, respectively. Version 4 will be released on 30 June 2016.

SOCAT data products enable detection of changes in the ocean carbon sink, quantification of ocean acidification and model validation. Numerous research publications and scientific reports have used and cited SOCAT, as listed on the website (http://www.socat.info/publications.html). These include high-impact reports and over 100 peer-reviewed, scientific publications. The SOCAT and SOCOM Event included discussion of additional surface water parameters, data set flags, collaboration with the Global Carbon Project and the data usage policy. The long-term sustainability and funding of SOCAT were discussed, as well as the need to strengthen SOCAT impact at policy level.

The Surface Ocean pCO_2 Mapping Intercomparison (http://www.bgc-jena.mpg.de/SOCOM/) is a comparison of data-based air-sea CO_2 flux estimates, many of them using SOCAT. Different methods are applied for interpolating sparse pCO_2 (partial pressure of CO_2) data in time and space. Approaches include interpolation, regression and model-based regression or tuning. The SOCOM initiative aims to quantify uncertainties and to identify common features in the surface ocean pCO_2 mapping methods. The event enabled presentation of SOCOM science and discussion on SOCOM progress.

Members of the SOCAT and SOCOM communities expressed a strong wish to continue the collaboration between both projects, to mutual advantage.

Dorothee Bakker, Chair of the SOCAT global group, was recognised for her outstanding contribution to the SOCAT community with an award presented at the SOLAS Open Science Conference.

A full report of the SOCAT and SOCOM Event will be posted on the SOCAT and SOCOM websites.

***WG2-Interior Ocean.** Chair: Nicolas Gruber (Switzerland)
WG2's recent activities focused on analysing the carbon data from hydrographic surveys to determine change in the oceans' anthropogenic CO_2 content since the 1990s. The preliminary results from the first decade of GO-SHIP were presented in a review paper. The WG will finalize the results on the basis of GLODAPv2, the quality-controlled database released in January 2016 for CO_2-relevant biogeochemical and physical parameters from 724 scientific cruises covering the global ocean.

WG2 also contributed to the joint GO-SHIP/Argo/IOCCP "Sustained ocean observing for the next decade" meeting in Galway, Ireland http://www.gaic2015.org.

They continue to support the development and application of biogeochemical sensors on Argo floats. Recently, they contributed to the draft BGC-Argo Implementation Plan and will report on it to the Argo steering team in March 2016. WG2 is likely to engage fully in the data synthesis and integration on a global/basin-scale.

***WG3-Ocean Acidification.** Chair: Jim Orr (France)
The last annual meeting of the SIOA working group took place in May 2016 in conjunction with the symposium on The Ocean in a High-CO_2 World (Hobart, Australia, 3-6 May 2016). The meeting was supported financially by SOLAS and IMBER. The chair of the SIOA working group is Jim Orr.

Following is a short update on changes in SIOA membership (provided by Jim Orr):
Five SIOA members are rotating off and 4 new members are rotating on (lists below). For a smooth transition, they are striving for a bit of overlap. For instance, Fred Gazeau (new) has been working with Jean-Pierre Gattuso for some months in order to take over leadership on the international database for ocean acidification data. Furthermore, all members, new and old, have been invited to attend the Hobart meeting.

Former Members (rotating OFF):

- Jim Barry (USA), served 2009-2016
- Jelle Bijma (Germany), served 2009-2016
- Jean-Pierre Gattuso (France), served 2009-2016
- Yukihiro Nojiri (Japan), served 2009-2016
- Ulf Riebesell (Germany), served 2009-2016

New Members (rotating ON):

- Frédéric Gazeau, started late 2015 Laboratoire d'Océanographie de Villefranche CNRS-UPMC, France
- Hans Pörtner, started late 2015 Alfred Wegener Institute, Germany
- Kim Currie <kim.currie@niwa.co.nz>, starts in 2016 (Hobart) Research Centre for Oceanography University of Otago, New Zealand
- Kristy Kroeker, starts in 2016 (Hobart meeting) Ecology and Evolutionary Biology University of California, Santa Cruz, USA

SIOA Members are all Members of the Advisory Board of the OA-ICC (Ocean Acidification International Coordination Centre), based at the IAEA Environment Laboratories in Monaco. There is an OA-ICC web site (https://www.iaea.org/ocean-acidification/page.php?page=2181) and a news stream (https://news-oceanacidification-icc.org/). The activities of the OA-ICC are to promote 1) the development of a global observation network; 2) use of joint platforms and facilities; 3) collaboration between natural and social sciences; 4) intercomparison exercises; 5) joint ocean acidification experiments; 6) best practices in OA research; 7) online bibliographic database; 8) data management; 9) capacity building and 10) information sharing and communication.

A training course on `Best practices in ocean acidification research` took place on 19-23 October 2015 in Xiamen, China. The training course was organized by the OA-ICC and the State Key Laboratory of Marine Environmental Science, Xiamen University, Xiamen, China. The training course sought to train early-career scientists and researchers from IAEA Asian Member States

entering the ocean acidification field. The end goal was to assist them to be able to set up pertinent experiments to avoid typical pitfalls and ensure comparability with other studies. Twenty eight scientists from 10 IAEA Asian Member States participated in the course, which aimed to provide an introduction to both monitoring and experimental ocean acidification studies, with special focus on methods and potential pitfalls. It also looked to encourage networking and familiarize participants with existing international cooperation opportunities and resources in the field of ocean acidification.

Another training course on `Studying ocean acidification and its effects on marine ecosystems` took place on 2-6 November 2015 in Cape Town, South Africa. The training course was organized by the OA-ICC with the support of the University of Cape Town and the Council for Scientific and Industrial Research (CSIR). The course was open to 26 trainees from IAEA Member States in Africa. Priority was given to early-career scientists beginning to work in the field of ocean acidification.

The purpose of the course was to train early-career scientists and researchers from IAEA African Member States entering the ocean acidification field, with the goal to assist them in becoming able to measure ocean acidification and to set up pertinent experiments, avoiding typical pitfalls and ensuring comparability with other studies. It also sought to increase networking among scientists working on ocean acidification in Africa.

The 3rd Global Ocean Acidification Observing Network (GOA-ON) Science Workshop was held in Hobart, Australia, following the 4th International Symposium on the Oceans in a High-CO_2 World. GOA-ON is guiding the development of an integrated network for the detection and attribution of ocean acidification and ecosystem response, and has engaged with over one hundred participants from 30 nations to formulate its Requirements and Governance Plan. GOA-ON has also served to focus funding bodies and international research programs to integrate within a shared vision that extends from the coastal to open ocean domains.

OA-ICC provided travel grants for four participants from developing countries to the SOLAS Open Science Conference 2015.

I.d. SOLAS metadata portal

The SOLAS metadata portal was set up by the SOLAS project integration initiative (2007-2013) with the intention to help SOLAS scientists identify what data exist, the data originator and where the data are currently stored. The portal is hosted by NASA and the metadata files are stored on the international standard Global Change Master Directory (GCMD). The resource is freely available to the entire community.

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 email it to solas@geomar.de.

I.e. Task teams

SOLAS/IGAC Task Team: Halogens in the Troposphere (HitT)
The primary objective of the SOLAS/IGAC Halogens in the Troposphere task team (HitT) is to determine and quantify the importance of reactive halogen compounds in tropospheric chemistry and climate forcing. The goal of HitT is to facilitate international collaboration between laboratory, field, and model activities regarding tropospheric halogen chemistry especially in the following domains: polar regions, salt lakes, marine boundary layer (both remote and coastal), volcanoes, free troposphere, and urban areas.The SOLAS community was deeply saddened by the unexpected death of the co-leader of the team Roland von Glasow in September 2015.
SOLAS SSC member Alfonso Saiz-Lopez and Lucy Carpenter are currently working on a proposal for a new "Activity" that will build from the HitT task team. The proposal writing has taken longer than expected, but it is hoped to be completed this summer.

During the EGU meeting in 2016 a `Halogens in the Troposphere` session took place. This session had a total of 20 presentations (6 orals + 14 posters) comprising a good mix of laboratory, field, and modelling results and expanding from the tropics to the polar regions. The session was well attended, by about 90 people, and everyone suggested to continue having the session in next year´s EGU.

Task Team: Asian Dust and Ocean EcoSystems (ADOES)
The goal of ADOES is to quantitatively understand the deposition flux and bioavailability of Asian dust, and its impact on biogeochemical processes and ocean ecosystem in order to provide scientific bases for the mechanism of eolian dust-ocean ecosystem-radiative gases-climate change.

The co-chairs are Huiwang Gao (Ocean University of China, China), Guangyu Shi (Chinese Academy of Sciences, China) and Mitsuo Uematsu (University of Tokyo, Japan).

SOLAS-Japan or ADOES-Japan do not have its own grant at present. Most of the members are now working for IMBER, GEOTRACES and a new big program called OMIX (Ocean Mixing Processes; see http://omix.aori.u-tokyo.ac.jp/en/).

Fortunately, many researchers are continuing SOLAS science under their projects. ADOES would like to discuss to collaborate with the IOC/WESTPAC and Future Earth in the near future.

In 2015, the ADOES China and Japan team had several cruises and some symposia jointly with other projects in China and Japan.

- A West Pacific cruise was conducted from 21 March to April 26, 2016 by R/V *Dongfanghong-2* for air-sea interaction studies, including on-board incubation experiments on the influences of dust and haze addition on the surface ocean primary production.
- The KS-15-6 cruise: 25 June–6 July 2015, East China Sea, the Okinawa Trough and Philippine Sea for seawater and aerosol samplings collaborated with GEOTRACES-Japan.
- The KH-15-3 cruise: 14 October–4 November 2015, East China Sea for seawater and aerosol sampling and iron dissolution experiment collaborated with GEOTRACES-Japan

- The KH-15-4 cruise: 6-26 November 2015, upstream of Kuroshio region for aerosol sampling and a bubble bursting experiment collaborated with IMBER-Japan
- An international symposium was hosted by Ocean University of China on 26-28 July 2015 at Qingdao, China for aerosol pollution, deposition and impacts in land and ocean environment.
- Two national symposia were organized in collaboration with IMBER-Japan at AORI (Atmosphere and Ocean Research Institute), at the University of Tokyo on 18-19 February 2016 and with GEOTRACES-Japan on 28-29 March.

SOLAS/IGAC Task Team: Air-Ice Chemical Interactions (AICI)
The IGAC/SOLAS Air-Ice Chemical Interactions Task Team (AICI) was created in 2003. The goal of AICI is to assess the significance of the processes observed in the polar regions at the air-ice interface at local, regional, and global scales by bringing together the laboratory, field, and modeling communities. The co-chairs are V. Faye McNeill (Columbia University, USA) and Thorsten Bartels-Rausch (Paul Scherrer Institut, Switzerland).

In late 2015, IGAC withdrew its sponsorship of AICI/OASIS with instructions to review the needs of the community, regroup, and propose a new activity.

The Ocean–Atmosphere–Sea Ice–Snowpack (OASIS) program was created in 2002 to bring together an international group of multidisciplinary field researchers, laboratory scientists, and modelers to study chemical and physical interactions and exchange processes between the title reservoirs, with a primary focus on the impact on tropospheric chemistry and climate feedbacks.

Efforts by the group have now been focused on regrouping and will probably continue in this vein for the next year. The first phase of the current plan is to solicit feedback from the AICI/OASIS community regarding research priorities and needs. To this end, the group will hold town hall meetings at the IGAC, Goldschmidt, and AGU meetings, and issue an online survey. After this, a science committee will be formed to create a new proposal based on the community feedback and the successes and lessons learned from AICI/OASIS. Meanwhile, the group is also planning an interdisciplinary polar science meeting in Switzerland for 2017.

I.f. SOLAS Open Science Conference 2015
The SOLAS Open Science Conference 2015 was held in Kiel, Germany on 7-11 September at the Christian-Albrechts-Universität zu Kiel bringing together over 260 scientists from 35 countries to learn and discuss about the latest developments on biogeochemical-physical air-sea interactions and processes. During plenary talks, discussion sessions and poster presentations participants were able to learn and exchange about cutting-edge research in the field and present their own findings. On Monday 7 September special site events took place as part of the conference:

- An all-day meeting of the Surface Ocean CO_2 Atlas (SOCAT) and the Surface Ocean pCO_2 Mapping Intercomparison (SOCOM) community was attended by around 50 scientists with the highlight of launching SOCAT version 3. For her dedicated work with SOCAT, Dorothee Bakker received a reward during the conference banquet.
- The German contribution to SOLAS, the Surface Ocean Processes in the Anthropocene (SOPRAN) project also held its final meeting and published a brochure containing

important scientific highlights of the last 9 years.

- To strengthen the SOLAS commitment towards capacity building the workshop `The ABC of presenting: Audience-friendly, Brief and Clear` for early-career scientists was organized. This workshop was held over two days and helped early-career scientists to further develop their presentations skills.
- On the last day of the conference, a small `Nordic SOLAS` meeting took place to introduce the visions of Swedish SOLAS and discuss an expansion of the network to include scientists from all Nordic countries.

Poster sessions turned out to be particularly popular and successful during the OSC. Even the already extended time slot in the late afternoon seemed not to provide enough time. In all, 9 students won student poster awards (Panassa Essowe, Leonie Esters, Margaux Gourdal, Sinnika Lennartz, Mingshuang Sun, Precious Mongwe, Camille Richon, Tianfeng Guo and Alex Zavarsky).

The local organising committee (LOC) was composed of Hermann Bange (GEOMAR), Gernot Friedrichs (Univ. Kiel), Christa Marandino (GEOMAR), Birgit Schneider (Univ. Kiel), Emanuel Soeding (Future Ocean Cluster of Excellence Kiel) and a young post-doc Jonathan Durgadoo (GEOMAR).

Structurally, the SOLAS OSC15 took place in conjunction with two major events 1) the SOPRAN final meeting and 2) the Future Ocean Cluster of Excellence semester theme on "Processes at Ocean Interfaces: from science to society' of the summer 2015. The Scientific Organising Committee was composed of the SSC and one member of the LOC. SCOR kindly provided a travel grant for scientists from developing countries to attend the conference; the grant was distributed to 10 scientists. The Ocean Acidification-International Coordination Centre also provided a travel grant that allowed 4 scientists from developing countries to attend.

The layout of the conference was slightly changed from previous conferences as SOLAS invited 9 keynote speakers and selected 22 other speakers from the poster abstracts pool. Among the 22 speakers, 6 were from developing countries and 11 were early-career scientists. Here is a detailed overlook of the plenary session, discussion session and poster session topics and speakers etc.:

Tuesday 8

Plenary Session theme: Air-sea interface and fluxes of mass and energy
This session is dedicated to oceanic and atmospheric processes, driven for instance by waves, bubbles or surfactants, which act upon the air-sea interface and serve to regulate the fluxes of mass and energy between the coupled ocean-atmosphere system.

Overview keynote speaker: *Bernd Jähne* (University of Heidelberg, Germany) Talk title: Physics of the air-sea interface and fluxes of mass and energy
Speakers:

- *Ruo-Shan Tseng* (China - Taipei): Air-sea momentum transfer and near-surface currents under high winds and tropical cyclones
- *Tom Bell* (UK): Quantifying the effect of bubbles upon air-sea gas exchange
- *David Ho* (USA): Air-sea gas exchange in the North Atlantic: GasEx-98 revisited

Plenary Session theme: Interconnections between aerosols, clouds and ecosystems
This session is dedicated to the interconnections between aerosols, clouds, and marine ecosystems and the understanding of the system they form as a whole, in which change in one component is manifested in another.

Overview keynote speaker: *Karine Sellegri* (University Blaise Pascal, France)
Talk title: Marine aerosol emissions related to the seawater biogeochemical composition
Speakers:

- *Avirup Sen* (India): Chemical characterization of ambient atmospheric aerosols over different environments of India and the adjoining oceans during the winter and summer monsoons - 2014: Implications of a Coordinated Campaign
- *Poonam Tyagi* (Japan): Soil microorganisms and terrestrial plant metabolites in marine aerosols from the western North Pacific Rim: one-year observation of hydroxy fatty acids over Gosan site, Jeju Island)
- *Rafel Simo* (Spain): Highlights of the Pegaso cruise: plankton-emission of trace gases and aerosols in the Southern Ocean

Discussion Sessions
I: Towards joint SOLAS-CliC activities on sea-ice biogeochemistry Convener: *Lisa Miller*
II: Microbial life at the air-sea interface Convener: *Christian Stolle*
III: Differences between marginal areas and open ocean- Baltic Sea example Convener: *Jacek Piskozub*

Poster Session
Atmospheric deposition and ocean biogeochemistry Integrated topics
Ocean biogeochemistry control on atmospheric chemistry

Wednesday 9

Plenary Session theme: SOLAS science and society

This session is dedicated to SOLAS research with socially relevance and to activities, which have a direct impact on society, such as air quality, human health, marine resources and climate regulation.

Speakers:

- *Hans Joachim Schellnhuber* (Germany): Sustaining the Seven Seas
- *Philip Boyd* (Australia): Geoengineering the planet: from geochemistry to geopolitics
- *Lucia M. Fanning* (Canada): Assessing science-policy linkages in regional and global ocean governance arrangements for fisheries, pollution and biodiversity
- *David Turner* (Sweden): Ship plumes

Plenary Session theme: Integrated topics

This session is dedicated to oceanic systems where integrated studies are required and urgent. They are regional, high sensitivity and high-priority systems, such as for instance the upwelling systems, sea ice and coastal waters.

Speakers:

- *Anna Rutgersson* (Sweden): The role of upwelling systems for air-sea exchange in marginal seas
- *Andrew Reed* (USA): Vertical Spatial Variability of Denitrification in the Eastern Tropical North Pacific Oxygen Minimum Zone
- *Leticia Cotrim da Cunha* (Brazil): Acidification through eutrophication- an example from an urban coastal ecosystem in SE Brazil)
- - *Sebastien Moreau* (Belgium): The role of sea ice in the carbon cycle of polar seas: 1D to 3D modelling)

Discussion Sessions

I: Atmospheric deposition, ocean biogeochemistry and climate change
Convener: *Zongbo Shi*
II: Relationship between wind speed and gas exchange over the ocean: which parameterization should I use?
Convener: *Rik Wanninkhof*
III: Priorities and integrated programs for the study of eastern boundary upwelling systems
Convener: *Francisco Chavez*

Poster Session

Greenhouse gases and the oceans
Interconnections between aerosols, clouds & ecosystems

Thursday 10

Plenary Session theme: Greenhouse gases and the oceans

This session is dedicated to the most significant long-lived greenhouse gases, such as CO_2, CH_4 and N_2O and their natural cycles in the oceans and troposphere, which interact with anthropogenic inputs and lead to climatic feedback and environmental impacts.

Overview keynote speaker: *Ute Schuster* (University of Exeter, UK) Talk title: Greenhouse gases and the oceans

Speakers:

- *Chao Zhang* (China): Diagnosing CO_2 fluxes in a River-dominated Ocean Margin (RiOMar): the East China Sea off the Changjiang estuary
- *Damian Arévalo-Martínez* (Germany): Nitrous oxide emissions from eastern boundary ecosystems: Case studies from Peru and Benguela upwelling regions
- *Sayaka Yasunaka* (Japan): Mapping of the air-sea CO_2 flux in the Arctic: basin-wide distribution and seasonal to interannual variability

Plenary Session theme: Ocean biogeochemical control on atmospheric chemistry

This session is dedicated to the ocean emissions of aerosols and reactive gases, such as organic and oxygenated organic compounds, and sulphur-, nitrogen- and halogen-containing compounds and their impacts on atmospheric photochemistry, air quality and stratospheric ozone.

Overview keynote speaker: *Elliot Atlas* (University of Miami, USA) Talk title: Ocean Biogeochemical Controls on Atmospheric Chemistry

Speakers:

- *Sarah Lawson* (Australia): Unexplained organic trace gases over temperate Southern hemisphere oceans
- *Liselotte Tinel* (France): Shining light on the air-sea interface: investigating the photochemical production of functionalized VOC
- *Susann Tegtmeier* (Germany): The future role of oceanic halogen compounds for the stratosphere

Discussion Sessions

I: Future air-sea gas transfer laboratory experiments
Convener: *Bernd Jähne*
II: Nutrients supply to Southern Ocean surface
Convener: *Remi Losno*
III: SOLAS research into the effects of potential geoengineering
Convener: *Cliff Law*

IV: Ship Plumes Convener: *David Turner*

Poster Session
Air-sea exchange and fluxes of mass and energy Outside of the box ideas
SOLAS science and society

Friday 11

Plenary Session theme: 'Outside the box' ideas
This session is dedicated to ideas, initiatives, and experiments that are not yet part of SOLAS. This can be a new perspective on continuing projects, a promising new technique, a pressing societal need or a completely new direction in SOLAS science. Surprise the programme committee with the unexpected!

Speakers:

- *Doug Wallace* (Canada): Dorado/Dolphin: a unique semi-submersible autonomous vehicle for SOLAS science
- *Miriam Gonzalez* (Germany): Comparing the effects of different climate engineering techniques on ocean acidification
- *Marcelo Santini* (Brazil): Using oceanographic data collected by southern elephant seals (*Mirounga leonina*) to infer the sea-ice formation rate on the vicinity of the Wilkins Ice Shelf in 2008

Plenary Session theme: Atmospheric deposition and ocean biogeochemistry
This session is dedicated to the broad range of particles of continental origin the ocean receives from the atmosphere. Atmospheric deposition impacts vast regions of the oceans and result from both natural processes and human activities.

Overview keynote speaker: *Keith Moore* (University of California, USA) Talk title: Atmospheric Deposition and Ocean Biogeochemistry

Speakers:

- *Kamana Yadav* (India): Variations in source and chemical composition of dust during 2010 and 2012 winter in the west coast of India
- *Kathrin Wuttig* (Australia): Bioavailability of iron to N_2 fixers under the Saharian dust plume)
- *Bärbel Langmann* (Germany): On the long-time fertilisation of the surface ocean by volcanic ash)

Reports of the discussion sessions and other events can be found on the SOLAS website at http://www.solas-int.org/solas-events.html

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

As mentioned in previous reports, SOLAS celebrated its 10-year anniversary in 2014. In 2013, SOLAS began an effort to define research themes of importance for SOLAS research over the next decade and prepared a new science plan for the next phase of the project until 2025. Reviewer comments were taken into account and addressed in the second half of 2015 and early 2016 with the revised version of the science plan and a letter to the referees addressing all comments were submitted to the sponsors by mid-March 2016.

The full title of the document is: SOLAS 2015-2025: Science plan and Organisation Linking ocean-atmosphere interactions with climate and people

Table of contents:

For further details of the procedure followed to produce the new science plan please refer to the report of last year. The revised version of the Science Plan is available on the SOLAS website at http://www.solas-int.org/about/future_solas.html. As a next step an implementation document will be produced by the SOLAS SSC and IPO.

I.h.Engagement with Future Earth: Research for Global Sustainability

In October 2015, SOLAS signed a `Memorandum of Understanding` with Future Earth. Since the Future Earth Global Hubs are in place, SOLAS has regular communication with the officers on various topics and is following webinars on all kind of Future Earth-related topics.

SOLAS has shown great interest and support to establish a Future Earth Knowledge Action Network (KAN) on the Ocean. Future Earth's Knowledge-Action Networks are hoped to be prime mechanism for delivering the future Earth research strategy. Knowledge-Action Networks are collaborative frameworks that facilitate highly integrative sustainability research. Their aim is to generate the multifaceted knowledge needed to inform solutions for complex societal issues. Knowledge-Action Networks build on the broad range and diversity of specialist expertise represented in the large community of researchers and practitioners associated with Future Earth, for example, in Research Projects, Fast-Tack Initiatives and Clusters, and endorsed and associated organisations, projects, and individuals that are part of the Future Earth Open Network.

The objectives of the Knowledge-Action Networks are to:

- identify and respond to society's needs for scientific knowledge to successfully undertake the transformation to sustainability
- generate integrated knowledge that is relevant to decision-makers
- develop and cultivate research that is solution-driven, inter- and trans-disciplinary
- add value to research that is or has been carried out already

Currently, the process of establishing the Ocean KAN has not been laid out entirely by Future Earth to interested core projects. SOLAS is involved in all communications regarding the issue and the SOLAS SSC chair is part of the development team of the Ocean KAN. In early May, Peter Liss was named co-leader of the Ocean KAN.

During a Future Earth core project meeting in Bern in late June 2016 an extra day of meeting has been allocated for further establishing the Ocean KAN.

I.i. Possible topics across projects/programmes with a marine component for co-design and co-production of knowledge in marine sciences

Following the momentum of a meeting that took place in March 2015, co-organised by SCOR in Kiel, Germany, SOLAS has started an effort to develop cross-projects topics. During the SOLAS open Science Conference some representatives of involved programmes met for an afternoon discussion on this subject. Different views on how to proceed on this issue were mentioned. Some key extracts of the meeting minutes are below:

Cross projects/programmes topics of marine sciences
Véronique Garçon gave a brief introduction providing background information and describing the non-exhaustive list of cross-project topics identified over the last 6 months by various projects, on which a Knowledge Action Network (KAN) Oceans could focus. Véronique stressed that not all the topics presented neatly fit into the Future Earth vision as they emphasise fundamental science rather than stakeholders' involvement but that a KAN could provide a pathway for merging competencies and resources to achieve both fundamental science and the Future Earth vision. She concluded that core projects and KAN-Oceans need to co-exist and mutually benefit each other. Her presentation included some slides provided by ecoSERVICES and GEOTRACES. David Turner added that GEOTRACES, besides proposing the topic on deep-sea mining, is also

interested in the topics of Extreme events in Eastern Boundary Upwelling systems and Changes in the Arctic: threat or opportunity?

Bob Duce, then briefly presented GESAMP (Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection), its WG38 on 'The Atmospheric Input of Chemicals to the Ocean' and the two new topics to be developed in the coming years:

- *Impact of Ocean Acidification on Fluxes of Atmospheric non-CO_2 Climate-Active Species;*
- *Changing Atmospheric Nutrient Solubility.*

The discussion started.

Martin Visbeck and David Carlson reminded that WCRP is already doing co-design and co-production, for instance with climate services and IPCC. It was suggested that questions for KAN-Oceans should be limited to those that are too complex and/or broad for a single project to address. It was also suggested that 'upstream' stakeholders be consulted for the research that interests them, and/or they can provide the questions KAN-Oceans should be addressing, e.g. IPCC, who identify the issues and uncertainties that prevent better climate predictions. Currently, the discussion is internal to the academic research sector, which decides what are the 'most interesting' questions for the global community. This idea that KAN-Oceans needs to focus on upstream research are shared by WCRP and CLIVAR.

Peter Liss mentioned that IGBP has been functioning differently from WCRP and is now ending. Future Earth offers a home for the core projects in a new way, with the additional angle of looking into what society needs scientifically, as well as fundamental sciences. KAN-Oceans offers the opportunity to work on big societal issues in addition to what the core projects are doing, to deliver on their existing science plans. He also reminded the group that there are practical funding possibilities too. Future Earth provides a framework, and a dialogue needs to take place between scientific groups and Future Earth about what they wish to do together. Martin Visbeck commented that core projects currently have very little, if any, visibility or participation in some of the big current endeavours, such as the World Ocean Assessment about to be released, and this needs to change. Martin gave examples of 3 dialogues that should take place and develop beyond the first contact and that should be listed in the cross-projects topics of marine sciences:

- *interaction with the World Ocean Assessment;*
- *interaction with UNEP;*
- *interaction with the Seabed Authority.*

Martin Visbeck noted the rationale and outcome of the meeting of some ocean related core projects that took place in March 2015, in Kiel, Germany and added that according to Future Earth, the KAN-Oceans could include all ocean-related projects, not only Future Earth core projects, if that is what the ocean community wishes. Returning to the modus operandi for KAN-Oceans, Peter Liss noted it was important to start with the question and determine a structure appropriate to answer the question and not the other way round. It was noted that scientists are so good at dividing themselves, it is not difficult for the relevance of science to be lost in the

bigger schemes. There are many acronyms [projects] with an oceans interest/focus, but what have they actually contributed in a co-design mode? Limiting factors are a lack of enthusiasm from some and funding to embrace new challenges. Challenges need to be framed in a way that is not sector specific, e.g., "How to get enough protein to feed 10 billion people?" is a question to which all disciplines could contribute, A central theme is to lift ideas beyond the normal science rhetoric.

Peter Liss re-emphasised that however the question is framed, it should be the science question that leads and looks beyond existing science. An additional benefit is that such an approach is going to position KAN-Oceans to be able to access different (new) sources of funding. This led to a discussion about how KAN-Oceans could be organised to draw scientists together. Phil Boyd thought it would be useful to know what are the Grand Challenges.

Martin Le Tissier replied that all big bodies have some. Although IGBP did overall very good research, an area identified with hindsight where more efficient work could have been done was the interaction/collaboration between projects, both internal to IGBP, as well as with other GEC projects.

Martin Le Tissier shared Peter's proposition that instead of thinking of how to operationalise things, we should concentrate on identifying which topics we can work on together.

Martin Visbeck noted the few large topics proposed at the meeting in March in Kiel, suggesting that they could be the topics of the KAN-Oceans:

- *Ocean discovery*
- *Ocean solutions*
- *Ocean 2100*
- *Ocean extremes*
- *Ocean pollution*
- *Ocean governance*

Bob Duce expressed the view that he is unsure if the network concept including the 6 large topics mentioned by Martin Visbeck are fitting what Future Earth is offering with the KAN-Oceans. A round table solicited everyone's views on how to move forward. Phil Boyd summarised that the KAN-Oceans should capture scientific excellence and enthusiasm, the ability to act on grand challenges, and delivery of science to society, and that the sum should be greater than the parts. What is still needed is how to jump through hoops to get to the big questions?

Lisa Miller thought that it would be beneficial to have workshops, preferably with the appropriate stakeholders involved in the workshop agenda and planning.

A document providing a summary of the efforts led by SOLAS trying to come up with a list of possible topics across core projects inside and outside ex-IGBP that could fit Future Earth agenda (easily associated for co-design with stakeholders) has been written. The ultimate intention of this document is to foster interactions between international projects on co-designed and co-produced knowledge in marine sciences.

The idea behind this approach is to start with a couple of topics, learn how to do the co-design and co-production of knowledge with the help of Future Earth.

The topics listed are:

- Extreme events in EBUS
- Atmospheric chemistry services
- Changes in the Arctic: threat or opportunity
- Environmental consequence of resource exploitation in the deep-sea
- Conservation of reef fishes and sustainable co-management of inshore small-scale fisheries

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

II.a. SOLAS visit to NASA and NSF in Washington D.C.

A SOLAS delegation composed of Brian Ward and Emmanuel Boss travelled to Washington D.C. in January 2016 to visit representatives of the National Science Foundation (NSF) and National Aeronautics and Space Administration (NASA) to present and discuss SOLAS research priorities and goals in view of funding requests by SOLAS to NSF and NASA.

At NSF, a SOLAS presentation was given to about 15 NSF programme managers and some additional meetings were arranged with:

- Henrietta Edmonds, who will take over as the new Chemical Oceanography Programme manager from Don Rice. Don is the programme manager who has supported SOLAS through SCOR.
- Kelly Falkner, who is the Geosciences Division Director.
- Don Rice and Sylvia Edgerton (Atmospheric Chemistry).

At NASA, a meeting with Paula Bontempi and Barry Leifer took place and a SOLAS presentation was given. Another meeting with Jack Kaye (Associate Director for Research of the Earth Science Division (ESD) and Hal Marring (Radiation Sciences Program Manager) was also arranged.

II.b. SOLAS @ Ocean Sciences Meeting

Through the support of SCOR, SOLAS was presented at a shared booth at the Ocean Sciences Meeting 2016 in New Orleans in February 2016. The new SOLAS flyer was presented to the public for the first time. Also a banner summarizing the SOLAS project was placed at the booth.

II.c. Collaboration with ESA

After the completion of the OceanFlux project, ESA mentioned that it is very high interested in continuing the collaboration with SOLAS, though additional funding depending on its interest. As an outcome of the topical conference on "Earth Observation for Ocean-Atmosphere Interactions Science 2014 - Responding to the new scientific challenges of SOLAS" a detailed report has been written and was revised by SOLAS. This report served as a basis for a synthesis

document `ESA-SOLAS Earth Observations and SOLAS science priorities`. This document provided to ESA will be submitted to their programmatic review.

Also a SOLAS/ESA workshop will take place in late June 2016 (see II.e.).

II.d. Collaboration with PICES

The North Pacific Marine Science Organization (PICES; http://www.pices.int) is an intergovernmental scientific organization with the mandate to promote and coordinate marine research in the northern North Pacific and adjacent seas. The present members are Canada, Japan, People's Republic of China, Republic of Korea, the Russian Federation, and the United States of America.

The 24th PICES Annual Meeting (PICES-2015) was held from October 14 to 25, 2015, in Qingdao, China, under the theme `Change and Sustainability of the North Pacific`. Unfortunately, the budget of SOLAS did not allow SOLAS to send a representative at the meeting.

II.e. SOLAS workshops on Remote Sensing and SOLAS and Society

SOLAS is funding two important workshops in June and October 2016. The first workshop will be a SOLAS/ESA workshop on `concurrent remote-sensing inversions of ocean and atmosphere` to take place at the ESA facilities in Frascati, Italy on 13-15 June. Three main questions will be addressed during the workshop:

- What are the benefits and drawbacks of having sensors focused on the ocean and atmosphere (or both) on the same platform/constellation?
- Holistic inversion* – is it time to invert ocean, atmosphere and clouds together? What is the advantage of doing so? Polar orbiting vs. Geostationary satellites. Use of ancillary data in inversions.
- Data accessibility – How can we maximize the availability of data and inversion products to the community?

Workshop conveners are SOLAS SSC members Ilan Koren and Emmanuel Boss.

A second workshop to take place in Brussels, Belgium in late October on `SOLAS and society` will concentrate on the following three issues:

- Carbon valuation
- Law/policy across the air-sea interface
- Shipping and emissions/effluents

Workshop conveners are Christa Marandino (GEOMAR) and Erik van Doorn (University of Kiel).

II.f. SOLAS communication
SOLAS website: http://www.solas-int.org/

SOLASNews newsletter (NL): emailed to ~2,400 scientists and airmailed to ~100 scientists, mainly from developing countries. Copies are held by the SOLAS IPO for distribution at SOLAS-relevant conferences and meetings. The NL is also available from the website. The SOLAS News is printed and airmailed from China courtesy of State Key Laboratory of Marine Environment Science, Xiamen University. Since issue 11, SOLAS also implemented an on-screen reader pdf version. Issue 18 is currently planned for publication in late summer 2016.

E-bulletins: sent to over 2,400 SOLAS scientists roughly 5-8 times per year; previous issues are archived on the website at http://www.solas-int.org/archive.html. The bulletins contain news from SOLAS, opportunities for meetings, abstract submission deadlines, recent publications, vacancies and news from relevant partner project and collaborators.

Flyers; The IPO has created an A5 flyer that informs on the outline of the new science plan.

Twitter account; The IPO created a SOLAS Twitter account. Posting regular SOLAS updates is planned to begin in the second half of 2016.

II.g. SOLAS national networks
Twenty-nine nations are part of the SOLAS network. Each has a representative (see list below).

Australia: Sarah Lawson and Andrew Bowie
Belgium: Nathalie Gypens
Brazil: Leticia Cotrim Da Cunha
Canada: Maurice Levasseur
Chile: Laura Farias
China (Beijing): Minhan Dai
China (Taipei): Gwo-Ching Gong
Denmark: Lise Lotte Soerensen and Mikael Sejr
France: Remi Losno
Germany: Christa Marandino and Hartmut Herrmann (NEW)
India: VVSS Sarma
Ireland: Brian Ward
Italy: Chiara Santinelli
Finland: Gerrit de Leeuw
Japan: Mitsuo Uematsu
Korea: Kitack Lee
Mexico: Jose Martin Hernandez Ayon
Netherlands: Jacqueline Stefels
New Zealand: Cliff Law
Norway: Siv Lauvset
Peru: Michelle Graco
Poland: Timo Zielinski
Russia: Sergey Gulev
Spain: Alfonso Saiz-Lopez
Southern Africa: Carl Palmer
Sweden: Katarina Abrahamsson
Turkey: Baris Saglihoglu and Mustafa Koçak
UK: Tom Bell
USA: Rachel Stanley (NEW)

Implemented in Jan. 2009, the national representatives of the SOLAS nations are asked to report annually about the SOLAS activities in their country. To facilitate the reporting effort, a template form is provided. In April 2016, 23 reports were received and will soon be posted on the SOLAS website. The information contained in the reports has been/are a great source of information for the IPO to report to sponsors, but also to facilitate the coordination job and to redistribute the results and progress from some nations to the rest of the SOLAS community via the Newsletters

and the website. This year the information provided through the reports will also be used to create an implementation plan for the new SOLAS science plan.

(All the reports received during the reporting period are available in an Addendum to this report; see http://www.scor-int.org/Annual%20Meetings/2016GM/2016_SOLAS_National_Reports.pdf)

II.h. ***Endorsed projects***

Over the reporting period, SOLAS endorsed the project NAAMES - North Atlantic Aerosols and Marine Ecosystems Study and the International Carbon Dioxide Conference to be held summer 2017 in Interlaken.

Information about support letter and endorsement are accessible on the website, along with the endorsement submission form.

II.i. SOLAS article on `Scientific synthesis and contribution to Earth system science`

A SOLAS article titled `SOLAS: Scientific synthesis and contribution to Earth system science` by Emilie Brévière et al., was published in *Anthropocene* in December 2015.
The article is available at: http://www.sciencedirect.com/science/article/pii/S2213305415300187

Abstract:
The domain of the surface ocean and lower atmosphere is a complex, highly dynamic component of the Earth system. Better understanding of the physics and biogeochemistry of the air–sea interface and the processes that control the exchange of mass and energy across that boundary define the scope of the Surface Ocean-Lower Atmosphere Study (SOLAS) project. The scientific questions driving SOLAS research, as laid out in the SOLAS Science Plan and Implementation Strategy for the period 2004–2014, are highly challenging, inherently multidisciplinary and broad. During that decade, SOLAS has significantly advanced our knowledge. Discoveries related to the physics of exchange, global trace gas budgets and atmospheric chemistry, the CLAW hypothesis (named after its authors, Charlson, Lovelock, Andreae and Warren), and the influence of nutrients and ocean productivity on important biogeochemical cycles, have substantially changed our views of how the Earth system works and revealed knowledge gaps in our understanding. As such SOLAS has been instrumental in contributing to the International Geosphere–Biosphere Programme (IGBP) mission of identification and assessment of risks posed to society and ecosystems by major changes in the Earth's biological, chemical and physical cycles and processes during the Anthropocene epoch. SOLAS is a bottom-up organization, whose scientific priorities evolve in response to scientific developments and community needs, which has led to the launch of a new 10-year phase. SOLAS (2015–2025) will focus on five core science themes that will provide a scientific basis for understanding and projecting future environmental change and for developing tools to inform societal decision-making.

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

III.a. SOLAS International Project Office, Kiel

The SOLAS IPO is hosted at the GEOMAR Helmholtz-Centre for Ocean Research Kiel in Kiel, Germany. The office is currently staffed with the interim executive officer, Stefan Kontradowitz (substituting for Emilie Brévière during her maternity leave). The funding for a second staff position (project officer) ended in January 2016. Emilie Brévière will be back as executive officer by 1 October. Due to some leftover funds provided by IGBP it will be possible to keep Stefan Kontradowitz in the IPO until December 2016 or January 2017.

GEOMAR provides office space and funds the executive officer salary since 1 February 2011 until December 2020. As per today unfortunately, no other funding opportunity for securing the second position could be found.

3.4 International Quiet Ocean Experiment **Shapovalov**

2016 Annual Report
International Quiet Ocean Experiment

Since publication of the Science Plan of the International Quiet Ocean Experiment (IQOE) in 2015, the following actions have taken:

- An IQOE Science Committee was approved by SCOR and the Partnership for Observation of the Global Oceans (POGO)
- The Science Committee met in London, UK in March 2016
- IQOE Co-chairs and Sponsors met in Woods Hole, Massachusetts, USA on 22 July.
- The Science Committee formed 6 working groups to begin implementing the activities of the project
- An IQOE Web site was developed

IQOE Science Committee

The IQOE Science Committee has the major responsibility to direct the science of the project and implement the IQOE Science Plan. The inaugural committee has two co-chairs, one an acoustician and the other bioacoustician. The members include the following:

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

Other Members: Olaf Boebel (Germany), Bishwajit Chakraborty (India), Christ de Jong (The Netherlands), Anthony Hawkins (UK), Jennifer Miksis-Olds (USA), Hanne Sagen (Norway), Jakob Tougaard (Denmark), and Alexander Vedenev (Russia).

Other scientists will be involved in IQOE through working groups (see below) and through endorsement of national scientific activities.

March 2016 IQOE SC Meeting

The IQOE SC held its first meeting in London, UK on 29-31 March to begin its work. The meeting agenda included presentations of all portions of the IQOE Science Plan to ensure that all SC members were familiar with the document. An important part of the meeting was to hear from potential stakeholder organizations based in London, such as the Institute of Marine Engineering, Science & Technology (IMarEST), International Chamber of Shipping, U.S. Office of Naval Research-Global, International Association of Oil & Gas Producers (IOGP), and from Geneva, the Comprehensive Test Ban Treaty Organisation (CTBTO). The meeting also began to make plans for the initial IQOE implementation activities. Six working groups were proposed and the terms of reference and working group membership are being developed (see below).

Meeting of IQOE Co-chairs and Sponsors

The chairs and sponsors of IQOE will meet in Woods Hole, Massachusetts, USA on 22 July 2016. Several co-chairs are in Woods Hole during the summer months, making it a convenient

location to meet. The meeting reviews the status of IQOE implementation and discusses fund-raising for the project. [modify after the meeting]

IQOE Working Groups

1. Standards and Intercalibration: Any project that involves more than one investigator, laboratory, or observing system must agree to standard techniques and/or perform intercalibrations among techniques or observations to make it possible to later compare their results. The IQOE will form a subcommittee responsible to recommend best practices for experimentation and observation or, where this is considered undesirable, will determine other means to ensure that results are comparable.
2. Data Management and Data Access: One of the goals of the IQOE will be to create time series of acoustic data in key locations of the global ocean, to provide to policymakers documentation of how sound in the ocean has changed over time. The IQOE will seek to make as many acoustic observations and experimental results as openly available as possible, and will develop a data management and data access policy for scientists and data centers involved in the project.
3. Arctic Science: The Arctic Ocean is still relatively pristine acoustically. However, with the continuing decrease in ice cover of this basin, oil and gas exploration, shipping, tourism, and other noise-producing activities are increasing. The IQOE will seek to produce an acoustic baseline against which future sound increases can be compared.
4. Measurement of Biodiversity on Coral Reefs with Acoustics: Coral reefs are some of the most biodiverse areas of the global ocean, are important to human society, and are in danger from global change. The biodiversity of reef habitats can be difficult to assess because it requires observations by human divers. However, many reef organisms make sounds that can be measured continuously. This working group will explore the potential to monitor sound on coral reefs continuously to characterize one measure of reef biodiversity.
5. Using Acoustics to Locate Spawning Aggregations of Fish: Many species of fish vocalize. Some vocal species also form dense spawning aggregations in areas that have not always been identified. This working group will assess the potential to use passive acoustics to locate and monitor aggregations of fish such as cod and haddock.
6. Stakeholder Relations: Diverse stakeholder groups have an interest in sounind in the ocean, because their activities produce sound incidentally or produce sound purposely, or because they are concerned about the effects of sound on marine organisms. Other stakeholders collect and archive acoustic data. This working group will help the IQOE Science Committee interact with the various stakeholders to keep them informed, make sure their concerns are addressed, and entrain them as partners in the IQOE.

In addition, the Partnership for Observation of the Global Oceans (POGO) set up a Working Group to Implement IQOE Science Recommendations on Noise Exposure and Broad-Scale Acoustic Monitoring to contribute to IQOE goals. This working group will implement specific elements of the IQOE Science Plan related to (1) approaches to assess the impact of noise exposure and acoustic monitoring methods, (2) means to implement and improve these approaches, and (3) better understanding broad-scale issues related to ocean noise and human influences.

IQOE Web Site

An IQOE Web site has been developed with basic information about the project (see www.iqoe.org). The site includes information about the development of the project, products that have resulted, people who have been involved, and resources for the community, such as links to relevant programs, scientific meetings, and publications. Information about IQOE working groups will be added when available.

Funding

SCOR budgeted US$10,000 for IQOE implementation activities in 2016 and an additional $10,000 from the Monmouth University-Rockefeller University consortium was carried over from 2015. These funds were used primarily to support the March 2016 SSC meeting.

Submitted by Ed Urban, SCOR Executive Director

3.5 Second International Indian Ocean Expedition **Burkill**

Second International Indian Ocean Expedition

Launch of IIOE-2

SCOR, the Intergovernmental Oceanographic Commission (IOC) of UNESCO, and the Indian Ocean Global Ocean Observing System (IO-GOOS) launched the Second International Indian Ocean Expedition (IIOE-2) on 4 December 2015. The launch included distribution of the IIOE-2 Science Plan and Implementation Strategy documents (see http://www.iioe-2.incois.gov.in/IIOE-2/Reports.jsp). On the same day, the first cruise of the IIOE-2 left from Goa, India for Mauritius (see http://www.iioe-2.incois.gov.in/IIOE-2/Expedition1.jsp), on ORV *Sagar Nidhi*. The cruise included significant participation of non-Indian scientists demonstrating strong international collaborative leadership.

IIOE-2 Steering Committee

A request for nominations of scientific theme and operational working group chairs was issued through SCOR, IOC, and IO-GOOS. The chairs will comprise the IIOE-2 Steering Committee. The co-sponsors are considering nominations and hope to appoint the committee by the time of the SCOR meeting. Co-sponsors are still discussing how to resource meetings of the Science Committee.

Joint Project Office (JPO)

Two project offices have been set up for IIOE-2; one in Perth, Australia at the IOC regional office, and the other in INCOIS in Hyderabad, India. The two offices are being referred to as the Joint Project Office. Staffing and other costs are provided by national governments and IOC. Ed Urban from SCOR continues to provide support to the project also.

National IIOE-2 Committees

SCOR with the other co-sponsors are encouraging the formation of national IIOE-2 committees, to foster and coordinate national research in the Indian Ocean and promote increased funding for such work. National contributions will provide a strong foundation for the IIOE-2 and national committees have been formed in Australia, Germany, India, South Africa, the UK, and the USA. The U.S. IIOE-2 Committee held a Town Hall session at the Feb. 2016 Ocean Sciences Meeting to provide an update about IIOE-2 progress.

Endorsement Process

The IIOE-2 co-chairs have created an endorsement process to create a process to engage national projects in IIOE-2.

Early-career Scientist Activities

A workshop was held by early-career scientists at the Goa symposium in December. There is a paper underway to report on the recommendations of the workshop. A Facebook page (IIOE 2 Early Careers) as a networking tool.

Communication

An IIOE-2 Web site is available at http://www.iioe-2.incois.gov.in/IIOE-2/index.jsp# and the Indian Ocean Bubble-2 provides updates about the project (see http://www.iioe-2.incois.gov.in/IIOE-2/Bubble.jsp).

Funding

The 2016 SCOR budget approved in at the Goa meeting included US$20,000 for IIOE-2 activities. Australia and India are supporting at least two FTEs for the JPO. IOC and IO-GOOS have yet confirmed their financial support.