SOLAS 2015-2025

Implementation Strategy 2016-2018

Linking Ocean-Atmosphere Interactions with Climate and People

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1 Introduction

In 2004, the Surface Ocean-Lower Atmosphere Study (SOLAS) project was established to provide international science coordination and capacity building whose objective was:

> *To achieve quantitative understanding of the key biogeochemical-physical interactions and feedbacks between the ocean and the atmosphere, and of how this coupled system affects and is affected by climate and environmental change.*

SOLAS is unique in connecting the oceanic and atmospheric scientific communities. Thanks to this innovative collaboration over the past decade, the SOLAS community has made important scientific discoveries, while also coming to understand the critical role of SOLAS science in many aspects of the human realm. Now, the need for continued coordination remains compelling, both to address new problems and to develop new approaches to persistent questions.

Progress in SOLAS science is needed to assess the impact of anthropogenic emissions on future climate and ecosystem services, as well as the environmental consequences of policy options. These include various climate intervention strategies that propose manipulation of the surface ocean-lower atmosphere environment to mitigate future climate change. SOLAS is the only project in place to facilitate integrated ocean-atmosphere research, across disciplinary and national boundaries. Important services provided by SOLAS to the research community include coordination of international field programmes; exchange of data, analytical techniques, and ideas; optimal utilisation of research platforms; and the development of the next generation of SOLAS researchers.

The new *SOLAS 2015-2025 Science Plan and Organisation* (SPO)[1], subtitled 'Linking Ocean-Atmosphere Interactions with Climate and People', is a strategy to maintain international SOLAS for the next decade under the sponsorship of the Scientific Committee on Oceanic Research (SCOR), Future Earth, the World Climate Research Programme (WCRP), and the International Commission on Atmospheric Chemistry and Global Pollution (iCACGP). The human biogeochemical footprint on the planet is now so large that future quality and sustainability of environmental resources will be determined by societal choices, as well as natural variability. There is an enormous benefit to society in understanding the wide-ranging environmental consequences of societal trends and policies. For the SOLAS realm, providing the critical knowledge for competent decision making will require improved process-level understanding of biogeochemistry, and an enhanced observational capacity, particularly for remote regions of the atmosphere and ocean. Significant investment will be required in order to maintain existing observing systems, develop and deploy new sensors for in situ and remote observations, and improve infrastructure for the archiving and distribution of large datasets for both research and operational products.

The SOLAS science mission is organized around five Core Themes:

Core Theme 1: Greenhouse gases and the oceans

Core Theme 2: Air-sea interface and fluxes of mass and energy

Core Theme 3: Atmospheric deposition and ocean biogeochemistry

Core Theme 4: Interconnections between aerosols, clouds, and marine ecosystems

Core Theme 5: Ocean biogeochemical control on atmospheric chemistry.

[1] = Brévière, E. and the SOLAS Scientific Steering Committee (eds.) (2016): SOLAS 2015-2025: Science Plan and Organisation. SOLAS International Project Office, GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel.

In addition, several examples of oceanic systems have been identified where integrated studies of these five themes are particularly urgent and need to be either initiated or expanded (Fig. 1). Examples include upwelling systems, the polar oceans and sea ice, and coastal waters. In addition, SOLAS has a unique role in evaluating the environmental efficacy and impacts of geo-engineering proposals and other policy decisions and societal developments.

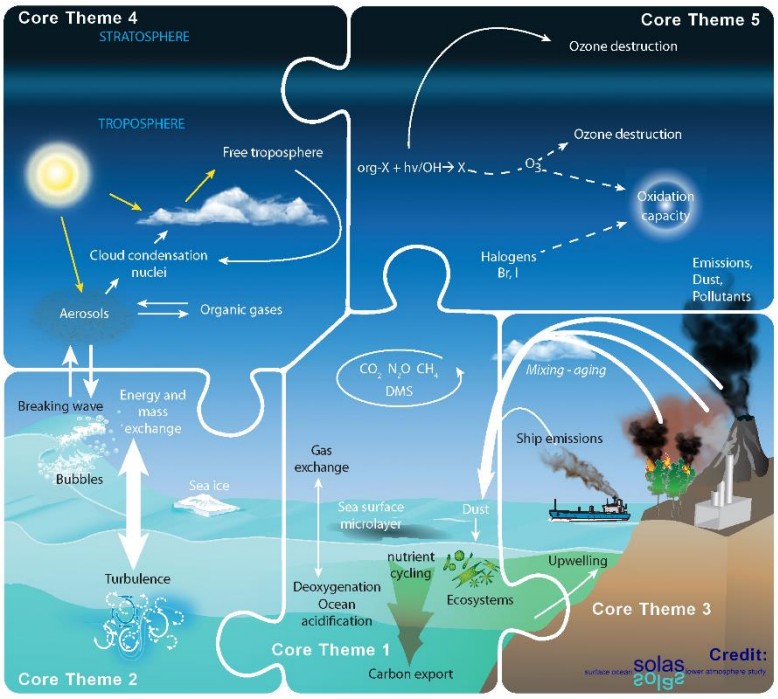

Fig. 1: Interactions between the five SOLAS Core Themes

SOLAS 2015-2025 will develop a leadership structure based on the scientific themes, with each group responsible for developing research goals, workshops, and synthesis activities. At the same time, SOLAS will also develop new approaches to facilitate capacity building interactions with partner organisations, and co-design targeted projects to meet societal needs with regards to geoengineering, air quality, marine resources, and other issues.

SOLAS does not have the financial capacity to fund research. SOLAS research is funded at the national level, and in order to stay informed of relevant activities worldwide, SOLAS has national representatives in thirty countries that provide the SOLAS Scientific Steering Committee (SSC) and International Project Office (IPO) with compilations of their meetings, funded and planned field campaigns and research projects, and future plans. For example, Fig. 2 was designed on the basis of the information provided in the 2015 annual national reports. All these efforts taking place at the national level constitute an essential part of the implementation of the SOLAS SPO. In this *Implementation Plan*, SOLAS is adopting a pragmatic approach: some of the information reported in the following pages has been provided by the 2015 annual national reports, and some is derived from efforts that are being encouraged, led by the SOLAS SSC and the IPO, to generate progress on specific topics related to the SOLAS Core Themes or Cross-cutting Themes. This document is being structured around three major sections: (1) events; (2) established working groups (WG) and their activities; and 3) working groups under development. All items listed have an international dimension and are reported regardless of their source of

information and funding.

Fig. 2: Map showing countries that have funded or planned cruises/flights linked to SOLAS research 2016 and 2018, as well as their locations. Numbers adjacent to the flags indicate the SOLAS Core Theme number, IT stands for Integrated Topics. Please note that the exact location of the flag does not necessarily reflect the precise cruise tracks or study location.

2 Events

This section details a set of workshops and symposia that directly address SOLAS Core Themes and Cross-cutting Themes of SOLAS 2015-2025, or respond to capacity-building and networking needs.

ESA-SOLAS Workshop on 'Harnessing remote sensing to address critical science questions at the ocean-atmosphere interface' on 13-15 June 2016 in Frascati, Italy

During this workshop, a mixed group of SOLAS and remote-sensing scientists discussed how existing and novel remote sensing tools can bring new perspectives to SOLAS questions, specifically those associated with SOLAS Core Themes 2, 4, and 5. The meeting took place at the European Space Research Institute of the European Space Agency (ESA).

On the first day, introductory talks covered particular SOLAS challenges and the state of the art in ocean and atmosphere remote sensing. In the morning of the second day, three team leaders introduced the SOLAS Core Themes 2, 4, and 5, focusing on problems related to fluxes of material and energy across the ocean-atmosphere interface, links between aerosols and ocean ecosystems, and ocean biogeochemical controls on atmospheric chemistry. Each team leader provided several questions on which the group could focus as case studies highlighting the utility of remote sensing.

The three questions ultimately chosen were the following:

1) How can turbulence be quantified in the global ocean?
2) What is the relationship between phytoplankton bloom dynamics and aerosol loading?
3) How do the characteristics of surface ocean organic matter influence the properties of primary aerosols?

A commentary manuscript is being prepared for the journal *Elementa: Science of the Anthropocene* to present the ideas generated, including ways existing remote sensing tools could be used better, as well as ideas for new satellite missions.

A workshop report is available at: http://tinyurl.com/zws7an5.

The outcomes of this event contribute to **Core Theme 2: Air-sea interface and fluxes of mass and energy** (see 2.1.2 of the SPO), **Core Theme 4: Interconnections between aerosols, clouds, and marine ecosystems** (see 2.1.4 of the SPO), and **Core Theme 5: Ocean biogeochemical control on atmospheric chemistry** (see 2.1.5 of the SPO).

SOLAS Science and Society Workshop on 26/27 October 2016 in Brussels, Belgium

One of the goals of Future Earth, the newest SOLAS sponsor, is to more tightly couple science and societal needs. To date, the most direct coupling between SOLAS scientists and society has been on the topic of geoengineering. To jump-start new interactions, a discussion session was held during the SOLAS Open Science Conference in September 2015 in Kiel, Germany, with the aim of identifying SOLAS scientists interested in pursuing this integrating effort and generating ideas for topics and procedures. The main outcome was that there is clear interest within the SOLAS community to participate in joint scientific research with social scientists. In order to facilitate this process, a two-day workshop was held in October 2016 in Brussels, Belgium, focusing on three distinct topics: (1) Blue carbon; (2) Incorporating air-sea interaction

science into policy and public relations; and (3) Shipping industry and air-sea interactions. The workshop brought together ocean-atmosphere interaction researchers, economists, lawyers, and sociologists.

Each topical session was led by a social scientist and a natural scientist, with the intention to work toward a concrete outcome. Some examples of such possibilities are the formation of an EU Innovative Training Network, a nation-specific or multilateral research proposal (e.g., through the France-Stanford Center for Interdisciplinary Studies), a peer-reviewed publication, or as a long-term plan, the creation of a new institution (e.g., a Fraunhofer Institute). Each group proposed first writing a review paper on their topic in order to identify gaps in the existing knowledge. A first document reporting on the workshop highlights is being written for the journal *Ambio*.

The outcomes of this event contribute to **Cross-Cutting Theme 'Science and Society'** (see 2.2.3 of the SPO).

SOLAS in Asia: A Future SOLAS Symposium on 26-28 October 2016 in Qingdao, China

Challenges remain when we look at the future of SOLAS, not only for the coordination of cross-disciplinary basic research, but also in better understanding climate and ecosystem services. Asian countries have made widespread contributions to SOLAS in the context of international collaborations, especially in the fields of the oceanic carbon cycle, air-sea exchange, and atmospheric deposition to the ocean. The Furure SOLAS Symposium fostered the exchange of ideas and knowledge among Asian scientists via presentations and discussions to encourage collaborations within Asian countries for SOLAS research and activities over the next decade.

The symposium programme is available at: http://tinyurl.com/gpbru68

NETCARE-SOLAS Workshop on 'The impacts of Arctic DMS emissions on future climate' on 17/18 January 2017 in Sidney, Canada

One of the goals of the Network on Climate Aerosols: Addressing Key Uncertainties in Remote Canadian Environments (NETCARE) is to better connect oceanic processes to the climatic role played by sulfur-containing aerosols in the Arctic. This work has proceeded through measurements of dimethyl sulfide (DMS) in the seawater, sea ice, and the atmosphere, and related modelling via an ocean-atmosphere coupled biogeochemical model, two chemical transport models, and the Canadian Earth system model. The main objectives of the workshop are to review our current understanding of DMS dynamics in today's and tomorrow's Arctic. The workshop will gather oceanographers and atmospheric scientists, field researchers and modellers. It will be an opportunity to thoroughly evaluate our level of understanding of the strength of the DMS-climate connection in the Arctic and to orient future research. The NETCARE-SOLAS network generated new observations of this connection. Our intention is to explore how these new findings can be used to improve our ability to predict future DMS emissions in the Arctic. A community paper to which all attendees will be invited to contribute is planned as an outcome of this workshop.

Information about NETCARE is available at: http://www.netcare-project.ca

The outcomes of this event contribute to **Core Theme 3: Atmospheric deposition and ocean biogeochemistry** (see 2.1.3 of the SPO) and **Cross-Cutting Theme 'Integrated Topics'** (i.e., polar oceans and sea ice) (see 2.2.1 of the SPO).

Future Earth Coasts/SOLAS/IMBER/IAEA Ocean Acidification Training and Networking Activity on 13-16 February 2017 in Dakar, Senegal

The knowledge base on ocean acidification remains inadequate, but this global change is now recognized as a threat for the environment with potentially severe social and economic consequences. Areas where upwelling is prevalent, such as West Africa, lead to coastal and estuarine waters becoming natural “hot spots” of special concern for ocean acidification.

Two pathways have been identified to help build local, national, and regional capacity to measure and study ocean acidification, as well as to advance discussions around the operationalisation of the Africa Network for Ocean Acidification Science (OA-AFRICA). OA-AFRICA was launched by the International Atomic Energy Agency (IAEA) Ocean Acidification International Coordination Centre (OA-ICC) in November 2015 in Cape Town. OA-Senegal is specifically designed to promote (1) capacity building; (2) regional and inter-regional networking; and (3) collaboration and data sharing and will contribute towards effective monitoring of ocean acidification.

The two pathways to success are:

- Practical and theoretical training in the study of ocean acidification. Participants will have the opportunity to be involved in practical demonstrations of instrumentation for ocean acidification monitoring and experiments.
- A networking activity, which aims to provide a mechanism for knowledge exchange between OA scientists across Africa and to build on the newly launched OA-Africa Network. Participants will help identify future needs, collaboration opportunities, and potential funding avenues to maintain and expand OA research throughout Africa.

Future Earth Coasts and OA-ICC have secured some funding to run these two events in Senegal. SOLAS and IMBER through their joint working group (WG) on Ocean Acidification are co-designing and co-organising these activities.

Information about OA-Senegal is available at: https://oasenegalconference.wordpress.com/

This event contributes to **Core Theme 1: Greenhouse gases and the oceans** (see 2.1.1 of the SPO) and **Capacity-Building Efforts** (see 3.2 of the SPO).

Workshop on ‘Frontiers in ocean-atmosphere exchange: Air sea interface and fluxes of mass and energy’ on 15-19 May 2017 in Cargèse, France

The uncertainty in the air-sea exchanges of heat, greenhouse gases (GHG), momentum, freshwater and aerosols constrains our ability to understand and model our changing climate. Accurate quantification of air-sea fluxes is required for forcing ocean models, understanding ocean dynamics, investigating the effects of atmospheric and oceanic variability, understanding the ocean’s role in climate variability and change, and assessing the realism of models used for predictions from weather to climate time scales.

The main topic of this workshop is air-sea fluxes, with three sub-themes: waves, turbulence, and surfactants. There will be plenary presentations interspersed with smaller groups focussing on each of the three sub-themes, as well as air-sea fluxes, in general. Each of the first four days will focus on one of the themes, with the final day reserved for summaries. The agenda for the workshop is interdisciplinary, and the objective is to allow for exchange of ideas between disparate communities who have similar scientific challenges. The major output from this workshop will be a publication in a peer-reviewed journal.

Information about the workshop is available at: http://www.solas-int.org/solas-events.html.

The outcomes of this event contribute to **Core Theme 2: Air-sea interface and fluxes of mass and energy** (see 2.1.2 of the SPO).

SOLAS/ESA Workshop on 'Novel remote sensing approaches tuned to address challenges at the ocean-atmosphere interface' in fall 2017, USA

Our current level of understanding of exchange fluxes of material, heat, and momentum between the atmosphere and the ocean is limited by lack of sufficient measurements of the governing processes that are often highly nonlinear. The characteristic scale of the air-sea flux exchange lies between two relatively narrow boundary layers, which vary on different time and space scales. Problems of momentum exchange are dependent on processes occurring on the scales of waves, from capillary waves of millimetres scale to swells of 10s of meters. In contrast, heat exchange occurs on scales of micrometres. Challenges in studying air-sea exchange include decoupling and understanding interactions between complex processes that are related to many different scientific disciplines such as marine ecology and biology, marine and atmospheric chemistry, dynamics, microphysics and radiation transfer.

Such a narrow vertical layer that contains a sharp discontinuity in the optical properties poses challenges and limitations on how we can remotely sense these interface processes. To expose remote sensing experts more to the importance and challenges of SOLAS, we have started to conduct a series of meetings dedicated to bring together experts who use remote sensing to study the atmosphere and those who study the ocean together with SOLAS scientists, to brainstorm on how to use current technologies and what future technologies are needed to better understand the interface processes.

The outcomes of a previous workshop on remote sensing organized by SOLAS and ESA in June 2016 in Frascati, Italy (see previous page) produced new and promising applications of sun-glint analysis to extract information on the mixed-layer turbulence and micro-layer, as well as active remote sensing ideas to define better the state of marine ecosystems. In this workshop, we aim to expand the range of the retrieved properties and to try to develop new approaches to evaluate the fluxes of gases and aerosols across the air-sea interface, as well as gas concentrations in the mixed layer.

The outcomes of this event contribute to **Core Theme 2: Air-sea interface and fluxes of mass and energy** (see 2.1.2 of the SPO), **Core Theme 4: Interconnections between aerosols, clouds, and marine ecosystems** (see 2.1.4 of the SPO)**,** and **Core Theme 5: Ocean biogeochemical control on atmospheric chemistry** (see 2.1.5 of the SPO).

3 Established Working Groups

From the beginning, SOLAS has had a strong tradition of supporting productive working groups (WG), sometimes alone but often in collaboration with other large-scale international projects, programmes, and organisations. The efficiency of these groups allows SOLAS to make significant progress towards the implementation of the *SOLAS 2015-2025 SPO*. This section reports some active WGs with major SOLAS involvement.

Global Ocean Oxygen Network (GO_2NE)

The ocean, from its coastal waters to its open seas, is challenged by the future. Changes in climate affect the physical, chemical, and biological characteristics of the marine environment. Oxygen is essential since 'if you cannot breathe, nothing else matters'. Altering oxygen concentrations therefore greatly impacts marine ecosystems and the provision of their goods and services. During recent decades researchers have detected decreasing oxygen content (deoxygenation) in coastal and oceanic waters worldwide. The main causes of deoxygenation are climate change (for example, warmer water dissolves less oxygen and becomes more strongly stratified, which reduces ventilation, i.e., oxygen replenishment of the ocean interior and estuaries is decreased), and measurably higher anthropogenic nutrient loads in coastal areas (eutrophication).

GO_2NE, initiated by IOC-UNESCO as a sustained interdisciplinary network, focuses on oceanic oxygen distributions and the risks related to its changing condition. By connecting scientists investigating the open ocean and coastal areas, GO_2NE will help to improve communication and cooperation among experts and decision-makers.

A workshop on 6-7 September 2016 in Paris, France, was devoted to highlighting new findings and developments in the scientific community, and to designing an efficient communication strategy and actions to improve the international recognition of deoxygenation and the related threats to ocean health. A technical brief on ocean deoxygenation for policy makers is being finalized by the group and should be released in early 2017. The workshop agenda is available at http://tinyurl.com/h4sw9yx. A follow-on workshop will take place in September 2017 in Moss Landing, USA.

The group has existed since 2016. Website: http://tinyurl.com/zsxwta6.

The outcomes of this group contribute to **Core Theme 1: Greenhouse gases and the oceans** (see 2.1.1 of the SPO) and **Cross-Cutting Theme 'Integrated Topics'** (i.e., upwelling systems, coastal waters) (see 2.2.1 of the SPO).

OceanFlux Greenhouse Gases Evolution

The atmosphere-ocean exchange of climate active gases, such as CO_2, N_2O, CH_4, DMS, and CH_3Br, is a critical part of the climate system and a major factor in the biogeochemical function of the ocean. More accurate and higher resolution calculations of these gas fluxes are required if we are to fully understand and predict the chemistry of our atmosphere and hence future climate. This endeavour requires the maintenance of major observing systems (shipboard, satellite-borne and land-based) and a deep understanding of the transfer processes. It is a challenging task that needs interdisciplinary collaboration and cost-effective solutions.

The European Space Agency (ESA) and the SOLAS community came together in 2010 to

support a new initiative in this area, leading to the OceanFlux greenhouse gas project. At the same time, there have been colossal efforts internationally to collect and collate data, strengthening and organising the measurement of dissolved gases (e.g., by the Lamont-Doherty Earth Observatory, the Surface Ocean CO_2 Atlas (SOCAT), and GLODAPv2) and explore new methods of measuring and modelling gas transfer processes and exchange coefficients.

The first OceanFlux workshop was held in 2013, and a second international workshop took place on 6-9 September 2016 in Brest, France. Recent advances on all aspects of air-sea gas transfer of climatically important gases, including reactive gases, were presented with foci on Arctic and marginal ice zones, extreme winds, atmospheric modelling and inversion techniques, and heat fluxes. Specific aims of the workshop were to identify key challenges and opportunities facing the air-sea gas flux community, and to set priorities. Workshop posters and presentations are available at http://tinyurl.com/guwtyd2. A final meeting took place on 8-9 December 2016 in Noordwijk, Netherlands.

The group has existed since 2011. Website: http://www.oceanflux-ghg.org/.

The outcomes of this group contribute to **Core Theme 1: Greenhouse gases and the oceans** (see 2.1.1 of the SPO) and **Core Theme 2: Air-sea interface and fluxes of mass and energy** (see 2.1.2 of the SPO).

Latin-American Ocean Acidification Network (LAOCA)

On 15 December 2015, in the city of Concepción, Chile, the Latin-American Ocean Acidification Network (LAOCA) was officially launched. A group of 24 scientists from seven Latin-American countries, including Argentina, Brazil, Colombia, Ecuador, Peru, Mexico, and Chile, worked together on a regional workshop, funded by the Intergovernmental Oceanographic Commission (IOC) of UNESCO , Ocean Acidification International Coordination Centre (OA-ICC), Center for the Study of Multiple-Drivers on Marine Socio-Ecological Systems (MUSELS), and the Millennium Institute of Oceanography (IMO) in Chile. During two days, participants discussed the strengths and weaknesses of each country with regard to research on ocean acidification. Along with this analysis, the missions and goals of LAOCA were defined.

The network has ten main objectives:

i) Synthesize the information about ocean acidification impacts in Latin-American
ii) Encourage the implementation, maintenance, and calibration of long-term data-set of carbonate chemistry in Latin-America
iii) Train LAOCA members in the different action lines (e.g., observation, experimentation, and modelling)
iv) Standardize chemical analytical techniques and protocols for experimentation in order to enhance data quality
v) Establish a regional node for the articulation and communication between local, regional, and global research programmes (e.g., GOA-ON and IOCCP)
vi) Determine and evaluate local and regional scenarios of ocean acidification for different types of marine ecosystems (e.g., estuaries, coastal area, open ocean, among others)
vii) Enhance student exchange and facilitate access to infrastructure and equipment among institutions and LAOCA member countries
viii) Design an outreach strategy to communicate the problematic of ocean acidification to society
ix) Promote the development of cooperation projects between member countries of LAOCA
x) Promote the inclusion of the problematic of ocean acidification on the political agenda of member countries, and even through the pursuit of cooperation agreements among LAOCA members.

The group has existed since 2015. A video is available at: https://vimeo.com/196494563

The outcomes of this group contribute to **Core Theme 1: Greenhouse gases and the oceans** (see 2.1.1 of the SPO) and **Cross-Cutting Theme 'Integrated Topics'** (i.e., upwelling systems, coastal waters, polar oceans and sea ice) (see 2.2.1 of the SPO).

SCOR WG 143 on 'Dissolved N_2O and CH_4 measurements: Working towards a global network of ocean time series measurements of N_2O and CH_4'

In the Earth's atmosphere, nitrous oxide (N_2O) and methane (CH_4) account for 24% of the total radiative forcing associated with GHG. Whilst CO_2 is the most abundant greenhouse gas, N_2O and CH_4 are more potent, respectively exerting ~300 and 25 times more radiative forcing than CO_2 over a period of 100 years. The atmospheric burdens of N_2O and CH_4 are increasing at an annual rate of 0.4% and 0.25%, respectively, and there is an ever increasing need to better constrain and understand the sources and sinks of both gases at the Earth's surface. The global ocean represents a source of both N_2O and CH_4 to the overlying atmosphere. It is estimated that oceanic CH_4 emissions range from 4-15 Tg CH_4 yr^{-1} and the rate of oceanic N_2O emissions to range from 1.8-5.8 Tg N yr^{-1}, although it should be noted that this is considered an underestimation by at least a factor of 2. The biogeochemical cycling of both gases in the environment is sensitive to temperature and redox conditions. Thus potential feedbacks to anthropogenic perturbations such as global warming, eutrophication, and spreading anoxia represent challenges for future marine scientific research.

This WG aims to improve and consolidate measurements of the greenhouse gases N_2O and CH_4 dissolved in seawater by conducting, firstly, an intercalibration exercise amongst the group's members targeting discrete N_2O and CH_4 measurements. Recommendations and protocols for calibration, quantification, and data reporting will be published following this exercise. This part of the project will also provide a review of existing and near-future methods for quantifying N_2O and CH_4 in seawater including spectroscopy measurements. The second part of the project will be to conduct an overall assessment on the status of dissolved N_2O and CH_4 measurements in the global ocean. Key regions and recommendations on the necessary temporal and spatial scale for sampling will be identified.

This group has existed since 2014. Website: https://portal.geomar.de/web/scor-wg-143/home

The outcomes of this group contribute to **Core Theme 1: Greenhouse gases and the oceans** (see 2.1.1 of the SPO).

SCOR WG 144 on 'Microbial community responses to ocean deoxygenation'

Marine waters deficient in oxygen affect biogeochemical processes and fisheries of importance to humans. They are important sites of denitrification and anammox, the two key processes associated with the loss of fixed nitrogen from the global ocean. Oxygen-deficient pelagic regimes also may be significant global sources of N_2O. Thus, these regions affect Earth's radiative budget and stratospheric chemistry. In a broader sense, ocean deoxygenation directly impacts marine ecosystem functions and services through changes in food web structure and biodiversity. Additionally, climate change-induced water column stratification and anthropogenic discharges are believed to increase deoxygenation throughout the ocean. As oxygen levels decline, energy is increasingly diverted away from higher trophic levels into microbial community metabolism, resulting in significant environmental changes to food-web dynamics, and impacts on fixed nitrogen losses, possible accumulation of hydrogen sulphide, and production of climate-active trace gases.

To advance knowledge of oxygen-deficient marine waters, SCOR WG 144 convened an international symposium on 3-5 December 2016 at the National Institute of Oceanography in Goa, India. At this symposium, renowned global experts on marine microbial ecology and biogeochemistry of oxygen-depleted water columns presented their work. Papers from the conference will be compiled into a peer-reviewed monograph and the open-access journals *Frontiers* or *PLoS* to ensure high visibility and free access. Collectively, these documents will synthesize available information on coastal and open-ocean waters to provide a unified conceptual microbial and biogeochemical model, and will direct future research through recommendations for the standardization of experimental approaches, data collection, and dissemination.

The group was established in 2014. Website: http://omz.microbiology.ubc.ca/index.html

The outcomes of this group contribute to **Core Theme 1: Greenhouse gases and the oceans** (see 2.1.1 of the SPO) and **Cross-Cutting Theme 'Integrated Topics'** (i.e., upwelling systems, coastal waters) (see 2.2.1 of the SPO).

SCOR WG 149 on 'Changing ocean biological systems (COBS): how will biota respond to a changing ocean?'

Climate models all project concurrent alterations to multiple oceanic properties, due to the effects of anthropogenic climate change. These projections are supported by a growing body of ocean observations demonstrating simultaneous shifts in life-sustaining properties such as temperature, CO_2, O_2, and nutrients. Hence, a major challenge for marine sciences is to determine the cumulative effects of such interactive and widespread alterations of oceanic conditions on organisms, communities and ecosystems. This challenge is multi-faceted, and research must advance in parallel to tackle three major themes: effects of multiple environmental drivers on the performance of individual organisms; community and food web responses to complex ocean change; and timescales of biological responses to climate change. Consequently, there is an urgent need to develop a new generation of studies based on methodology that will allow to progress from

- Single to multiple environmental drivers
- Organismal- to community- and ecosystem-level responses
- Transient acclimation physiology to long-term adaptation and evolution.

This group builds strong transdisciplinary links to facilitate the design and development of a framework of experiments, observations, and conceptual/mathematical models to evolve each of these themes. This multi-thematic approach provides a platform for the next generation of scientists to conduct rigorous inter-related research and to further refine this approach as new technologies emerge. The group targets how to develop powerful tools to convey the major research findings of this complex topic as directly and simply as possible to decision-makers.

The group had its first meeting on 15-17 July 2016 in Waterville, New Hampshire, USA.

The outcomes of this group contribute to **Core Theme 3: Atmospheric deposition and ocean biogeochemistry** (see 2.2.3 of the SPO).

SCOR WG 151 on 'Iron Model Intercomparison Project' (FeMIP)

The micronutrient iron is at the heart of biological activity in the ocean, shaping marine resources and the global carbon cycle. The iron model intercomparison project (FeMIP), SCOR WG 151, proposes to bring together a diverse set of scientists to deliver new insight into the

functioning of the ocean iron cycle, using observations and, in particular, to improve its representation in ocean models. This is important, as the multi-disciplinary work being proposed will improve confidence in the projections of how environmental change will affect ocean productivity in iron-limited areas and facilitate the use of numerical models to test hypotheses within a community-driven context of model skill. The aim is to produce guidelines for how models can best represent the iron cycle and develop tools for objective interpretations of model skill relative to observations. The impact of underlying inter-model differences in iron cycling will be evaluated and consensus input fields will be produced. Importantly, how models can take the next important steps and represent the complexity of biological interactions within the iron cycle will also be reviewed.

This group will start its work in 2017.

The outcomes of this group contribute to **Core Theme 1: Greenhouse gases and the oceans** (see 2.1.1 of the SPO) and **Core Theme 3: Atmospheric deposition and ocean biogeochemistry** (see 2.2.3 of the SPO).

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

Observations over recent decades suggest that sea ice plays a significant role in global biogeochemical cycles, providing an active biogeochemical interface at the ocean-atmosphere boundary. A pressing need exists to perform methodological intercalibration experiments in sea ice in order to obtain reliable measurements of basic biogeochemical properties including many of the essential climate variables (ECV) of the global climate observing system.

With newly emerging techniques, and pressed by the rapid changes in sea ice, the time has come to evaluate and improve our approach to studying sea-ice systems. An international WG is required to synthesize past intercalibration exercises and to design and coordinate new experiments. The ultimate goal of this WG is to provide the international community with standardized protocols for processing sea-ice samples and collecting data for key variables, including partial pressure of CO_2, nutrients, algal biomass and production, and gas exchange. The effectiveness of new techniques to deal with the great heterogeneity (often referred to as "patchiness") found in sea ice also will be established. These tasks will directly serve a long-term community goal of understanding variations in polar marine environments severely affected by ongoing global change.

This group will start its work in 2017. The first meeting will be held on 3-5 April 2017 in La Jolla, USA.

The outcomes of this group contribute to **Cross-Cutting Theme 'Integrated Topics'** (i.e., polar oceans and sea ice) (see 2.2.1 of the SPO).

The Global Ocean Observing System and OceanObs Research Coordination Network

The OceanObs'09 conference highlighted the need for the ocean observing community to improve coordination and collaboration amongst physical, biogeochemical, and biology/ecosystem disciplines. Since 2012, significant progress has been made through the introduction of the Framework for Ocean Observing and more recently through the creation and refinement of the disciplinary Essential Ocean Variables (EOVs) that capture the societal and scientific requirements for sustained observations. With advances in observing technology, and the definition of EOVs, clear opportunities exist to further improve the coordinated planning and implementation of observing activities measuring EOVs across the three disciplines.

A workshop will take place on 8-10 February 2017 in Miami, USA. This workshop will identify priorities for improving the coordinated planning and implementation of multi-disciplinary observing activities by bringing together experts in physical, biogeochemical and biological/ecosystems ocean observations and modelling, users of established observing networks, and communities of practice. Based on expert evaluation of feasibility and impact of a multi-disciplinary, EOV-based observing system, the Global Ocean Observing System (GOOS) Expert Panels for Physics, Biogeochemistry, and Biology & Ecosystems set the following objectives for the workshop:

- Building on the established societal and scientific requirements expressed in EOVs, identify the key applications and phenomena that will benefit from co-located and/or complementary multi-disciplinary sustained observations
- Identify near-term innovation priorities for observing platforms and instrumentation to enable multi-disciplinary observations and modelling
- Identify programmatic and professional connections between existing and emerging observing networks that will increase multi-disciplinary observations.

Outcomes from the workshop – focused around three preselected demonstration themes (Plankton community changes (including ocean colour); Oxygen minimum zones; and Open ocean/shelf interactions (including boundary currents) – will be a clear series of actions with related milestones and metrics for efforts of collaboration across disciplines and observing platforms. The identified actions will fall within currently funded activities or will have clear sources of resources.

The outcomes of this event contribute to **Cross-Cutting Theme 'Integrated Topics'** (i.e., upwelling systems, coastal waters) (see 2.2.1 of the SPO).

Biogeochemical Exchange Processes at Sea-Ice Interfaces (BEPSII)

At the end of 2015, SOLAS, jointly with the Climate and Cryosphere (CliC) project, approved BEPSII as an Activity on biogeochemical exchange processes at sea-ice interfaces. Following on the success of SCOR WG 140 of the same name, BEPSII focuses on polar oceans, and its work is articulated within four task groups: (1) Methodologies and data collation; (2) Modelling and observational process studies; (3) Syntheses and outlook; and (4) Outreach. Some specific goals and objectives include the following:

- Developing dedicated consistent methodologies for sea ice biogeochemical research
- Establishing effective sea-ice biogeochemical data archiving approaches and databases
- Fostering ecological process studies to determine sea-ice impacts on biogeochemical cycles
- Fostering technological developments towards large-scale, autonomous and high-frequency sampling of sea ice biogeochemical parameters
- Improving the representation and evaluation of sea ice biogeochemistry in regional and Earth System numerical models
- Synthesizing and integrating observational and modelling efforts
- Continually revising and renewing scientific foci, teams, and objectives.

In addition to funding from SOLAS and CliC, BEPSII receives support from the International Arctic Science Committee (IASC) and the Scientific Committee on Antarctic Research (SCAR), and a COST action proposal is being prepared for submission in 2017. The group is also liaising with IGAC and its activity on Cryospheric Atmospheric Chemistry (CATCH). The final meeting of SCOR WG 140 and inaugural meeting of the SOLAS/CliC activity took place on 17-18 March 2016 in Paris, France. A special feature in *Elementa* is being published with 16 papers from

SCOR WG 140. One WG of BEPSII is leading SCOR WG 152 on 'Measuring Essential Climate Variables in Sea Ice (ECV-Ice)'. The 2017 annual meeting of BEPSII will take place on 3-5 April 2017 in La Jolla, USA.

This group was established in 2016. Website: https://sites.google.com/site/bepsiiwg140

The outcomes of this group contribute to **Cross-Cutting Theme 'Integrated Topics'** (i.e., polar oceans and sea ice) (see 2.2.1 of the SPO).

GESAMP WG 38 on 'Atmospheric input of chemicals to the ocean'

The Joint Group of Experts on the Scientific Aspects of Marine Environment Protection (GESAMP) is an advisory body to the United Nations system organized in working groups. In 2015, WG 38 launched two new initiatives, which will be addressed with two parallel workshops on 27 February–2 March 2017 in Norwich, UK.

The workshop on 'Impact of ocean acidification on fluxes of non-CO_2 climate-active species' will focus on the impacts of ocean acidification on the oceanic sources of a range of non-CO_2 gaseous species, as well as aerosol precursors, that are influential in regulating radiative forcing, atmospheric oxidizing capacity, and atmospheric chemistry. The aims are to

- Review and synthesize the current knowledge on the direct impacts of ocean acidification on marine production and emissions to the atmosphere of key species important for climate and atmospheric chemistry;
- Identify the primary needs for new research to improve process understanding and to quantify the impact of ocean acidification on these marine fluxes (i.e., provide recommendations on the specific laboratory process studies, field measurements, and model analyses needed to support targeted research activities and improved understanding on this topic); and
- Publish the results of this activity in the open peer-reviewed scientific literature.

The workshop on 'Changing atmospheric acidity and the oceanic solubility of nutrients' will focus on how changing atmospheric acidity will affect the solubility, and thus bioavailability, of such aerosol derived nutrients as iron and phosphorus when they are deposited in the ocean from the atmosphere. The aims are to

- Review and synthesize the current scientific information on the solubility of aerosol associated key biogeochemical elements, the biogeochemical controls on aerosol solubility, and the pH sensitivity of those controls;
- Consider the likely changes in solubility of key species into the future and the potential biogeochemical consequences of such changes;
- Identify the key future research needs to reduce uncertainties in predictive capability in this area; and
- Publish the results of this activity in the open peer-reviewed scientific literature.

This group was founded in 2008. Website: http://tinyurl.com/hurk96q

The outcomes of this group contribute to **Core Theme 1: Greenhouse gases and the oceans** (see 2.1.1 of the SPO) and **Core Theme 3: Atmospheric deposition and ocean biogeochemistry** (see 2.2.3 of the SPO).

GESAMP WG 41 on 'Marine geoengineering'

The objectives of this group are to better understand the potential impacts of marine geoengineering approaches on the marine environment. Scientists have been identified with a wide range expertise in marine science and engineering, marine ecology, oceanography, atmospheric chemistry, marine science, social sciences, and environmental economics. One of the main objectives is to provide information to decision-makers considering the regulation of marine geoengineering activities under the London Protocol. An inception meeting took place on 23-24 May 2016 in London, UK. A summary report is currently being written. The next meeting will take place in North America in April/May 2017 to provide a detailed focused review of a limited number of proposed marine geoengineering techniques that are likely to have some potential for climate mitigation purposes addressing five criteria.

This group has existed since 2016. Website: http://tinyurl.com/gl82uz8

The outcomes of this group contribute to **Cross-Cutting Theme 'Research on environmental impacts of geoengineering'** (see 2.2.2 of the SPO).

4 Working Groups under Development

Global environmental research is progressing and evolving rapidly, and SOLAS has important contributions to make in providing insight and information on the role of air-sea exchange processes in the Earth system. Therefore, over the coming years, SOLAS will continue to hone the cutting edge of Earth system science research, identifying new challenges, developing new collaborations, and designing new research programmes. To facilitate this, SOLAS is continuously striving to establish a stable financial platform, hoping that in the future, the IPO will be able to issue competitive yearly calls for new initiatives and activities dedicated to specific themes. This section includes some selected activities currently under development.

Future Earth Oceans Knowledge-Action Network

The oceans form a globally connected ecosystem and highly dynamic environment of physical, chemical, and biological interaction. They maintain a great diversity of life, exchange mass and heat with the atmosphere, and modulate our climate. Oceans, including coastal and nearshore areas, thus provide services essential for life on earth and to the history, culture and livelihoods of people across the globe. However, oceans are also facing multiple challenges from climate change, overfishing, acidification, deoxygenation, and pollution. Accordingly, the United Nations referred to the importance of healthy oceans in several of their Sustainable Development Goals.

The Future Earth Oceans Knowledge-Action Network (KAN) seeks to address these challenges through solutions-oriented research, by engaging with stakeholders from diverse sectors and regions, and by drawing on the strong fundamental research and innovative agendas of the international marine projects and communities in Future Earth and beyond.

Generating the knowledge that decision-makers need to preserve and enhance the health and value of the ocean will require defining the problems facing the ocean and their interfaces with the adjacent land and overlying atmosphere, understanding associated mechanisms, impacts, and consequences, and directing research towards their solutions. Key questions include the following:

- How do human activities, combined with natural variability, affect the health of the ocean, coasts, and their environmental and socio-economic services?
- How can detrimental effects on ocean health be avoided?
- How can ocean health and services to people be preserved or restored?

Engagement of a broad range of researchers and societal partners is central to the work of the Oceans KAN. As such, Future Earth will facilitate transdisciplinary research that can be used by policy-makers, businesses, and communities to achieve sustainable interactions of humans with the oceans at large. We will also work to build scientific capacity to empower researchers and societal partners worldwide to assess the state of the oceanic and coastal domains and improve their management and governance.

Future Earth marine projects and other large-scale international organisations have started to define the key issues where sustainability research can help support healthy oceans and coastal regions at various meetings since 2015. In June 2016 in Bern, Switzerland, a document was drafted to inform the Belmont Forum Collaborative Research Actions (CRAs). The Belmont Forum will likely issue a call for CRAs proposals in 2018. The topics listed in the document are

Sustainable and equitable use of the oceans

Link environmental, social, and economic consequences of living (e.g., fisheries resources) and non-living (e.g., energy, minerals) resource extraction, non-extractive industries (e.g., shipping, transportation, tourism, coastal development), and the development and implementation of models, scenarios, and strategies for the sustainable use of marine resources.

Predict and reduce negative impacts of global change in the oceans

Better quantify, understand, and communicate the additive, antagonistic, and synergistic effects of multiple drivers of change (e.g., circulation, temperature, sea level, population growth, migration) and stressors (e.g., ocean acidification, deoxygenation) on marine ecosystems and human activities and wellbeing.

Reduce pollution and its effect on marine ecosystems

Define the importance, now and in the future, of a wide range of pollutants and their impacts on marine ecosystems and human activities and wellbeing. Innovate solutions to reduce the inputs and the impact of marine pollutants by, for example, inducing behaviour change of individuals, regulators, and industry.

A follow-up meeting took place on 4-5 December 2016 in Kiel, Germany. A report is currently being written. Website: http://futureearth.org/future-earth-oceans

This group contributes to **Cross-Cutting Theme 'Science and Society'** (see 2.2.3 of the SPO).

Horizon 2020 European Training Network 'Variability of oxygen in marine ecosystems and climate change' (VOYaGE)

The VOYaGE European Training Network (ETN) will aim to train young investigators to make significant advances in the field of regional climate-related marine ecosystems prediction, an emerging discipline spurred by societal demand for mitigation and adaptation strategies. Unequivocal indirect effects of climate change on the ocean due to increased stratification on ocean circulation include deoxygenation. VOYaGE will focus on oxygen-sensitive marine ecosystems over margins adjacent to populous regions, that is, the Black Sea, Benguela, and Humboldt upwelling systems. It will adopt an integrative modelling approach considering the breadth of interactive processes between land, atmosphere, ocean, sediments, marine resources, and society to address these main questions:

- What are the key processes driving the marine ecosystem state and variability in these regions?
- How will they be modified by future reduced oxygen conditions?
- How will deoxygenation affect these marine ecosystems and alter sources of protein (fisheries) they provide to society?

Given the transnational and global nature of deoxygenation, and its scale and complexity, activities are carried out at the European Union (EU) level and beyond. The ETN thus will gather seven academic research teams and two non-academic beneficiaries together with ten partner organisations from across the EU, EU-associated, and other countries. VOYaGE will provide to a generation of young scientists a crucible for designing innovative approaches for achieving the societal transition towards the Sustainable Development Goals approved by the United Nations.

The proposal will be submitted in January 2017.

This group contributes to **Cross-Cutting Theme 'Integrated Topics'** (i.e., upwelling systems) (see 2.2.1 of the SPO) and **'Science and Society'** (see 2.2.3 of the SPO), as well as **Capacity-Building Efforts** (see 3.2 of the SPO).

Cryospheric Atmospheric Chemistry Activity (CATCH)

The CATCH mission is to facilitate atmospheric chemistry research within the international community, with a focus on natural processes specific to cold regions of the Earth. Cold regions include areas which are seasonally or permanently covered by snow and ice, from the high mountains to the polar ice sheets and sea ice zones, as well as regions where ice clouds are found. CATCH scientists will aim to answer the following questions:

- How are aerosols formed and processed in cold regions?
- How do cold-region aerosols act as cloud precursors and impact cloud properties?
- What are the feedbacks between climate change and atmospheric chemistry that are determined by changes in the cryosphere?
- How can the ice core record be used to understanding global environmental change?
- How do physical, chemical, biological, and ecological changes in sea ice and snow impact atmospheric chemistry?
- What are the background composition of trace gases and aerosols in cold regions that are undergoing industrialisation, as well as being impacted by climate change.

This activity is supported by IGAC and SOLAS. A community workshop is scheduled to take place on 19-21 April 2017 in Paris, France (http://www.igacproject.org/2017CATCHWS). Website: http://igacproject.org/CATCH

This group contributes to **Core Theme 4: Interconnections between aerosols, clouds, and marine ecosystems** (see 2.2.4 of the SPO) and **Cross-Cutting Theme 'Integrated Topics'** (i.e., polar oceans and sea ice) (see 2.2.1 of the SPO).

Halogens Initiative

Naturally emitted halogens are important contributors to ozone loss and methane oxidation. Recent climate simulations suggest that halogens may also impact radiative forcing. Understanding the mechanisms leading to their production and emission to the atmosphere, along with climate impacts, requires cross-disciplinary research that includes experimental and theoretical work across several compartments of the Earth system. Traditionally, halogen research has been only focused on their atmospheric or ocean/ice facet. In the initiative on halogens under development, it is proposed to have a holistic approach to halogen research that involves different components of the Earth system and their interlinkages.

This initiative is developed by SOLAS and will build on the successful SOLAS/IGAC joint task team on 'Halogens in the Troposphere' (HitT). The new initiative will be established in collaboration with the activity on Cryosphere and Atmospheric Chemistry (CATCH).

This group contributes to **Core Theme 4: Interconnections between aerosols, clouds, and marine ecosystems** (see 2.2.4 of the SPO) and **Core Theme 5: Ocean biogeochemistry control on atmospheric chemistry** (see 2.2.5 of the SPO).

Carbon Group

In the first SOLAS decade, the joint SOLAS/IMBER Carbon Group (SIC) was divided in three working groups dealing with Surface Ocean Systems, Interior Ocean, and Ocean Acidification. Two significant structural outcomes of these working groups were the establishment of the Ocean Acidification International Coordination Centre (OA-ICC) and the Surface Ocean CO_2 Atlas (SOCAT).

As SOLAS, IMBER, and CLIVAR are at the dawn of a new decade of research coordination, this carbon group is being revisited, in collaboration with IOCCP.

This group contributes to **Core Theme 1: Greenhouse gases and the oceans** (see 2.1.1 of the SPO) and **Cross-Cutting Theme 'Integrated Topics'** (i.e., upwelling systems, coastal waters, polar oceans and sea ice) (see 2.2.1 of the SPO).

5 Outlook: A creative and flexible Future

Table 1 provides an overview of the various actions, up to today, led and/or co-led by SOLAS for 2016 and 2017. Although concurrent development of all other aspects of the SPO is also necessary, it is anticipated that the Implementation Strategy 2017-2018 will have a particular emphasis on polar oceans and the atmosphere, driven by funding priorities. However, it is difficult at this stage to provide a detailed list of events that will take place in 2018, what steps the established working groups will take, and/or predictions of what new working groups will be launched. SOLAS has a long tradition of responding to the evolving needs of its scientific community, and that is not changing as SOLAS enters its second decade. This document reflects our current priorities, but new ideas, many of which have not yet even been conceived, are guaranteed to surface in the coming years. The SOLAS structure and organisation has the flexibility to respond to those new ideas, to help the community build the new collaborations necessary to execute those ideas, and foster the integration of the resulting new knowledge into our understanding of the Earth system. This is why this document is a living, web-based document, which will be updated every year.

In its first decade, the IPO coordinated and organized six international SOLAS Summer Schools (which trained more than 420 young scientists) and six highly successful international Open Science Conferences (OSCs) (Damp, Germany; Halifax, Canada; Xiamen, China; Barcelona, Spain; Cle Elum, USA; Kiel, Germany). Despite some difficulties encountered in 2015/16 to maintain the needed level of staffing in the IPO, a 7th SOLAS Summer School will be take place on 23 July-3 August 2018 in Cargèse, France, and a 7th SOLAS Open Science Conference in early 2019, likely in the Southern Hemisphere.

In order to maintain the high level of productive activities that have become the hallmark of the international SOLAS project, it will be necessary to explore innovative new ways to fund and staff the IPO.

	Activity / Time	2016												2017											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Core Themes	1: Greenhouse gases and the oceans									WG			WG		EV	WG						WG			
	2: Air-sea interface and fluxes of mass and energy						EV			WG			WG				EV	EV							
	3: Atmospheric deposition and ocean biogeochemistry							WG						EV		WG									
	4: Interconnections between aerosols, clouds, and marine ecosystems						EV										EV, UD								
	5: Ocean biogeochemical control on atmospheric chemistry						EV										EV								
Cross-Cutting Themes	IT: Polar oceans, sea ice			WG										EV			WG, UD								
	IT: Upwelling systems									WG			WG	UD	WG							WG			
	IT: Coastal waters									WG			WG		WG							WG			
	Research on environmental impacts of geoengineering					WG												WG							
	Science and society						UD				EV		UD	UD											
Others	Capacity building										EV			UD	EV										
	Symposia, Meetings										SSC								SSC						

Table 1: Time frame of SOLAS Events (EV), established Working Groups (WG), Working Groups under Development (UD), Scientific Steering Committee meetings (SSC), SOLAS Summer School (SSS), and SOLAS Open Science Conference (OSC) as described in this document.

6 Acronyms

BEPSII	Biogeochemical Exchange Processes at Sea-Ice Interfaces
CATCH	Cryospheric Atmospheric Chemistry
CliC	Climate and Cryosphere
CLIVAR	Climate Variability and Predictability
COBS	Changing Ocean Biological Systems
CRAs	Collaborative Research Actions
DMS	Dimethyl sulfide
ECV	Essential Climate Variables
EOVs	Essential Ocean Variables
ESA	European Space Agency
ETN	European Training Network
EU	European Union
FeMIP	Iron Model Intercomparison Project
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
GHG	Greenhouse gases
GLODAPv2	Global Ocean Data Analysis Project Version 2
GOA-ON	Global Ocean Acidification Observing Network
GO_2NE	Global Ocean Oxygen Network
GOOS	Global Ocean Observing System
HitT	Halogens in the Troposphere
IAEA	International Atomic Energy Agency
IASC	International Arctic Science Committee
iCACGP	International Commission on Atmospheric Chemistry and Global Pollution
IGAC	International Global Atmospheric Chemistry
IMBER	Integrated Marine Biogeochemistry and Ecosystem Research
IMO	Millennium Institute of Oceanography Chile
IOC	Intergovernmental Oceanographic Commission of UNESCO
IOCCP	International Ocean Carbon Coordination Project
IPCC	Intergovernmental Panel on Climate Change
IPO	International Project Office
KAN	Knowledge-Action Network
LAOCA	Latin-American Ocean Acidification Network
MUSELS	Center for the Study of Multiple-Drivers on Marine Socio-Ecological Systems
NETCARE	Network on Climate Aerosols: Addressing Key Uncertainties in Remote Canadian Environments
OA-ICC	Ocean Acidification International Coordination Centre
OSC	Open Science Conference
SCAR	Scientific Committee on Antarctic Research
SCOR	Scientific Committee on Oceanic Research
SIC	SOLAS/IMBER Carbon Group
SOCAT	Surface Ocean CO_2 Atlas
SPO	SOLAS 2015-2025 Science Plan and Organisation
SSC	Scientific Steering Committee
UNESCO	United Nations Educational, Scientific and Cultural Organization
VOYaGE	Variability of Oxygen in Marine Ecosystems and Climate Change
WCRP	World Climate Research Programme
WDAC	World Climate Research Programme Data Advisory Council
WG	Working Group