Title:

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

Acronym: EBUS

Summary/Abstract

Eastern Boundary Upwelling Systems (EBUS) (California, Humboldt, Benguela and Canary Current System) are characterized by complex dynamical processes spanning a wide range of spatio-temporal variability due to the strong coupling between the ocean and atmosphere. They are among the most productive marine ecosystems in the world supporting some of the world's major fisheries, yet occupying only 0.1% of the global surface. Trade winds drive coastal upwelling, which brings cold and nutrient-rich waters to the surface, where favorable light conditions sustain high phytoplankton growth. Below the surface, Oxygen Minimum Zones develop due to high organic matter export. When these waters upwell, they release CO_2 and N_2O, potent greenhouse gases, to the atmosphere. Locally, the mesoscale low-level atmospheric circulation is affected by air-sea-land interactions, which impact the upwelling and productivity, while remote forcing can modulate upwelling at timescales from intraseasonal (*e.g.* Kelvin waves) to interdecadal (*e.g.* gyre circulation) and longer. EBUS are natural laboratories for studying the breadth of interactive processes between land, ocean and atmosphere at the regional scale. This SCOR WG will focus on the integration of existing knowledge on EBUS to formulate a strategic recommendation white paper for setting up regional observational systems and climate modeling approaches to monitor and understand physical and biogeochemical ocean-atmosphere interactions. These observational systems will be instrumental in improving the performance and reliability of climate models in these socio-economically relevant regions of the world ocean. This WG will also review and critically evaluate the different "hard science" approaches that are pursued with respect to the socio-economic benefits they could bring.

Scientific Background and Rationale

The Eastern Boundary Upwelling Systems (EBUS) are the most productive areas of the world's oceans (Pauly and Christensen, 1995), supporting large populations of commercially important fish species (Bakun et al., 2015). In these regions the equatorward alongshore winds drive offshore Ekman transport of the surface layers of the ocean and, cold, nutrient-rich deeper waters outcrop to re-establish the geostrophic equilibrium in eastern boundaries, developing the so-called Coastal Upwelling Systems. These areas (California, Peru-Chile, Benguela and Canary Current, Sumatra-Java Systems) are characterized by equatorward alongshore boundary currents, poleward undercurrents, filaments, squirts, mesoscale eddies and internal waves, also driven, triggered and modulated by the local-to-regional wind field (e.g., Chelton et al., 2007). These processes interact at different timescales influencing a wide variety of processes including marine fishery production (e.g., Mbaye et al., 2015), phytoplankton cell size (e.g. Van der Lingen et al., 2009), plankton and fish community structure (e.g. Van der Lingen et al., 2006) and

biogeochemical cycling (e.g. Woodson and Litvin, 2015). High biological productivity in the surface layer drives elevated rates of downward vertical flux of organic matter that in combination with sluggish circulation results in the development of the Oxygen Minimum Zones (OMZs). The four EBUS display varying levels of OMZ development from the shallow, anoxic Peru-Chile system to the deeper hypoxic California system (Chavez and Messié, 2009). Low-oxygen areas strongly influence the distribution of macroorganisms that are displaced by oxygen-poor conditions. Deoxygenation may also modify plankton regimes that can have profound consequences on ecosystem structure (e.g. Gomes et al., 2014). Extreme anoxic events can reduce habitat (for instance in Peru-Chile by creating a shallow habitat leading to increased catchability) or increase mortality (rock-lobster walkouts in the Benguela are well documented). Specific biogeochemical processes (denitrification, anammox, methanogenesis) which only occur at low oxygen concentrations influence global ocean nutrient cycles as well as production of greenhouse gases (e.g. Stramma et al., 2010). The impact of oceanic trace gases on atmospheric chemistry is also yet to be determined (e.g. Rees et al., 2011).

The basic forcing mechanisms are similar across the different EBUS and establish similarities in physical dynamics and ecosystem structure, and progress has been achieved in understanding the EBUS dynamics from an integrative and comparative perspective (e.g., Pegliasco et al., 2015; Capet et al., 2014; Lachkar and Gruber, 2012; Gruber et al. 2011; Chavez and Messié, 2009; Capet et al., 2008; Carr and Kearns, 2003). However, owing to differences in the relative strength of the potential stressors (e.g. the strength of the equatorial oceanic teleconnection or subtropical pressure system), a unified view is yet to be established and challenges to understanding the sensitivity of individual EBUS to climate variability and change remain (e.g. Wang et al., 2015; Bakun et al., 2015; Mackas et al., 2006). From a global climate perspective, some EBUS are also thought to influence large-scale climate modes. For instance, the EBUS in the Indian Ocean, the Sumatra-Java upwelling system, is relatively less studied, although it plays an important role in the development of the Indian Ocean Dipole (Saji et al., 1999). The difference in their latitudinal positions implies that some EBUS or EBUS sub-components are more wind-driven (those at high-latitudes) while others experience more tropical oceanic teleconnections, although the Benguela EBUS is also influenced by the Agulhas leakage. Therefore while commonalities in the nature of the forcing have suggested that a common theory of the circulation and its role on biogeochemical properties (e.g. OMZs) could be drawn, the characteristics of the forcing (amplitude, frequency, persistence, asymmetry) linked to inherent non-linearities of the systems call for a revision of this paradigm. In addition, progress in regional modeling has shed light on potentially important processes that were only inferred until recently (e.g. effect of the wind-drop off on upwelling dynamics (Capet et al., 2004; Renault et al., 2015, 2016); current-wind coupling (Chelton et al., 2007); eddy-induced transport (Bettencourt et al., 2015; Vergara et al., 2016; Gruber et al., 2011; Rossi et al., 2008) and that are, so far, difficult to tackle only with observations or from global models. The latter in particular still suffer persistent warm biases (Richter, 2015; Zuidema et al., 2016) that have limited our predictive capability of the EBUS evolution at various timescales (intraseasonal to climatic timescales) (Cabré et al., 2015; Stramma et al., 2012). While most regional modeling studies have been process-oriented, some long-term regional hindcast simulations are becoming available (Dewitte et al., 2012; Franks et al., 2013; Combes et al., 2015) and regional model simulations with data

assimilation are becoming available (Neveu et al., 2016). Although not yet including all relevant processes (e.g. air-sea coupling at the mesoscale) and mostly limited to the physical component of the system, they however allow the investigation of processes at low-frequency time scales and within a climate framework, overcoming some of the limitations of the observational studies and modeling studies based on low-resolution global models. So far the focus has been on the four major EBUS (California, Canary, Humboldt, Benguela). However it is also of interest to contrast the EBUS with the weak upwelling/less productive eastern boundary current systems such as the Iberian Current and Leeuwin Current systems, so as to better understand transient processes in the context of global warming.

The challenge for better understanding EBUS dynamics as a whole has spurred, in recent years, a number of joint efforts from an observational and modeling perspective, e.g., the international CLIVAR program VOCALS (VAMOS Ocean-Cloud-Atmosphere-Land Study) was implemented to develop and promote scientific activities leading to an improved understanding of the South Eastern Pacific coupled ocean-atmosphere-land system on diurnal to interannual timescales (Mechoso et al., 2014). VOCALS also motivated research on the Benguela upwelling system (e.g. European projects MEECE and PREFACE). The transdisciplinary AMOP (*Activities of research dedicated to the Minimum of Oxygen in the eastern Pacific)* project was launched to investigate the mechanisms leading to the formation of the OMZ off Peru and its variability from hourly to centennial timescales. The German initiative SFB754 '*Climate-Biogeochemistry Interactions in the tropical Ocean*' addressed the relatively newly recognized threat of ocean deoxygenation, its possible impact on tropical OMZs and implications for the global climate biogeochemistry system. The recently initiated TPOS 2020 project (http://tpos2020.org/) aims at designing a future tropical Pacific observing system including monitoring the Eastern boundary and addressing coastal upwelling dynamics (Takahashi et al., 2014). A CLIVAR/SOLAS/IMBER Research Focus on upwelling systems has also been initiated recently that is aimed at making progress in our understanding of EBUS dynamics from physics to fisheries.

These observing programs along with recent progress in regional coupled modeling offer a new perspective for understanding EBUS and can revitalize the intercomparison approach. In particular, the perspective of long-term regional simulations (not just climatological) is an asset for addressing temporal and spatial scale interactions (upscaling, rectification processes) and their sensitivity to low-frequency changes in the environmental conditions, providing material for revisiting the interpretation of historical data. The on-going international effort for intensifying the ocean observing systems (e.g. Argo, IOCCP, SWOT mission, Sentinel missions) in order to address small spatial scales of variability also sets favorable conditions for documenting quantitatively the continuum of small scales (from mesoscale to submesocale) and its impact on the ecosystem dynamics. In that sense the context is favorable for launching a working group on related issues. Its aims will be in particular to stimulate the interactions between the modelers and experts in observations interested in EBUS.

There are a number of regional processes in EBUS that modeling studies suggest to be key but that have been undocumented by observations (e.g. impacts of coastal mesoscale atmospheric jets, transports of water properties by eddies, deep zonal oceanic jets, air-sea

interactions at mesoscales, etc). This calls first for more quantitative evaluations of the role of such processes in EBUS dynamics from integrated modeling platforms, i.e., that take into account the complexity of feedbacks and scale interactions, and within a climate perspective, i.e., from long-term (multidecadal) simulations. Second, it motivates the design of dedicated observing programs in order to document these processes in nature and in return evaluate the realism of the coupled models. The socio-economic importance of EBUS (0.1% of global ocean area that sustains 20% of the world's fish catch) further urges the investigation of the role of these regional processes in the biogeochemistry of the OMZs. This is a prerequisite for improving our predictive capabilities of the evolution of marine ecosystems in these key economic regions and for anticipating changes in the nature of extreme events (e.g. hypoxia). This will require the design and implementation of efficient and cost effective observing systems, which are motivated by adequate scientific objectives. The activities that will be carried out within this proposed working group are thus also oriented towards providing guidance for the design of such observation systems based on modeling and process studies and synthesis of existing knowledge. It will build upon current initiatives both at national and international levels (e.g. TPOS2020, GOOS IMSOO (Implementation of Multi-Disciplinary Sustained Ocean Observations) panel on Oxygen Minimum Zones) while providing a synthetic view through looking at all upwelling systems.

The EBUS WG will address the knowledge gaps outlined above by making recommendations as to how better and more cost-effectively observe these regions in both the ocean and atmosphere simultaneously. It will first provide a comprehensive evaluation of current knowledge regarding control mechanisms, impacts on biogeochemical cycles and feedbacks derived from all published observational and modeling approaches, and will then develop a strategic recommendation white paper to fill these gaps. This WG will thus have material for conducting a socio-economic exercise to review and critically evaluate the different "hard science" approaches that are pursued with respect to the socio-economic benefits they could bring (at what scales, what level of complexity on the physics, what level of complexity on the ecosystem, what precise applications, what are the enduring challenges, inter alia)**.** While the latter is not in the main scope of the WG, the objective is to take advantage of the rich networks of collaboration of the WG participants to identify relevant experts during the course of the project, and invite them to collaborate on a recommendation paper. As well this will be coordinated with relevant programs (CLIVAR RF on EBUS, GEF (Global Environment Facility), Future Earth Oceans KAN, etc).

To achieve these goals, a unique group of early career scientists and more senior scientists, all experts in different EBUS of the world ocean and involved in relevant national and international programs, has been invited to participate in this working group. This group is composed so as to cover issues of both observations and modeling, and gather scientists originating from a range of developed and developing countries and disciplines, which shall ensure communication of the outcomes to the wider research community, and alignment with national and global research platforms.

Terms of Reference

1. **Synthesize existing knowledge** on the different physical mechanisms occurring over different time scales (i.e., diurnal, intraseasonal, interannual, decadal, multidecadal) and their implications on water column properties, biogeochemical cycles, biodiversity/ecosystem structure and functioning and the regional climate, to identify the key feedback processes, establish similarities, differences and the knowledge gaps.

2. **Conduct a regional database initiative** to hold a web-based platform for graphically querying integrated information of observational systems (e.g. including data access, available timescale, papers published, associated databases) and numerical outputs (e.g. including configuration details as well as associated scientific production and responsible scientists together with their contact details) as well as protocols for measuring key properties and indicators in EBUS. Such a database will be used in particular to explore the processes that are difficult to tackle with just observational datasets (e.g. submesocale processes and their role in structuring the biological environment)

3. **Produce a** comparative analysis from modeling validated/published results, presented as a **high impact factor review paper**. While such an analysis will have mostly a regional focus, it will also attempt to address subregional scales building upon past and on-going research programs on specific upwelling centers (e.g. Bay of Hann near Dakar (Senegal), Bay of Monterey (USA), Bay of Concepcion (Chile)), which will help linking to the socio-economic exercise (see Term of Reference 5).

4. **Provide a strategic recommendation brief** for setting up regional observational systems to monitor and understand physical and biogeochemical ocean-atmosphere interactions. These observational systems will be designed so as to be instrumental in improving the performance and reliability of climate models in these socio-economically relevant regions of the world ocean. Such a recommendation brief will also address needs for fostering interactions between the observational and modeling communities (e.g. coordinated experiments with common forcing; recommendations on resolution of specific processes or a specific scale, etc).

5. **Conduct a socio-economic exercise** to review and critically evaluate the different hard science approaches that are pursued with respect to the socio-economic benefits they could bring, that will provide useful information about scales, level of complexity on the physics and on the ecosystem, precise applications, among others. This document, prepared as a report (printed and online) for diverse target audiences including the scientific community, policy-makers and stakeholders, will present the basis on which to assess changes across EBUS and will be useful for governance activities.

Working plan

Year 1 (2018)

The first year will be focused on organizing the working group and assembling the information needed to achieve terms of references 1, 2 and 3. This will be discussed initially via email and coordinated at **a first meeting** where full and associate members will attend together with their PhD students, postdocs or early career scientists (at least one each). The meeting will be developed in two parts, the first where full and associate members will (1) agree on a clear plan of the strategies required to achieve the goals and (2) organize the structure of the **peer-reviewed publication** that will be submitted and published in an open-access journal at the end of the first year (Deliverable 1). The second part will be devoted to capacity building and activities in which early career scientists will be involved, and would look for to be linked with the IMBER early career Network of socio-ecologists and CLIVAR and SOLAS initiatives. The first meeting will be organized four months after the SCOR WG is implemented.

Year 2 (2019)

The second year will be dedicated to organizing the **regional database initiative** and **summer school**. This will be developed in a **second meeting**/workshop where full and associate members will attend together with some invited stakeholders from the scientific community and decision-makers. Following the second meeting, **a summer school** will be organized either in Senegal and/or Peru involving PhD students and early career scientists mostly from Africa and South America, having the objective to 'Provide an overview of the main processes occurring in EBUS (including physical, biogeochemical, biological, fish and fisheries processes and trends), in order to understand ocean-atmosphere interactions, combining lectures and hands-on sessions, and practical lessons' as well as 'to identify potential students to integrate the capacity building strategy' (i.e., create an early career network from alumni of the summer school). All experts and younger scientists will participate giving lectures and tutorials. The WG will request funding from SCOR and other sources to facilitate the participation of students and early-career scientists. Classes given during the summer school will be recorded and available from the SCOR WG EBUS webpage that will be provided and supported by the Computational Geophysical Fluid Dynamic Laboratory at IGP (Geophysical Institute of Peru).

The **regional database initiative** (Deliverable 2) will be developed in close collaboration with the early career scientists, with the aim to involve graduate students from different developing countries and disciplines (some of them identified in the summer school) to prepare a web based graphical platform where the compilation of regional observational systems and numerical simulations will be available for the scientific community and stakeholders. Also, it will serve as material for preparing and submitting a **high impact factor review paper** (Deliverable 3) compiling modeling results**,** addressing the comparison between EBUS, and establishing the strengths and weaknesses of regional coupled models, and directions for the future.

Year 3 (2020)

The third year will be oriented towards organizing the **Open Science Conference** composed of three parts:

- *Day 1*: Objective 'Organize the strategic recommendation brief to be presented as a short paper to the Executive Panel (i.e. defined as a representative group of decision makers, stakeholders and scientific experts from different areas)', where only full and associated members will participate.
- *Days 2-3*: Objective 'Bring together all interdisciplinary and multidisciplinary ocean and atmospheric science communities involving modelers and observationalists studying EBUS and related topics'.
- *Day 4*: Executive Panel. Objective 'Bring together decision makers, stakeholders and the scientific community to present and highlight the main findings, suggest first priority topics, offer suitable and cost-effective alternatives to approach solutions to further understand EBUS dynamics'. It will be developed just after the Open Science Conference.

During this year **a strategic recommendation brief** (Deliverable 4) on how to best set up regional observational systems to monitor and understand physical and biogeochemical ocean-atmosphere interactions in the EBUS will be presented. Note that the Executive Panel discussion will feed the strategic recommendation brief.

Year 4 (2021)

The fourth year will be focused on **preparing the report** of the socio-economic exercise (Deliverable 5) which will be developed in a meeting where full and associate members will attend, together with some invited stakeholders from the scientific community and decision-makers. In addition, the **final report** of the SCOR WG will be delivered.

Deliverables

Deliverable 1. **A multidisciplinary synthesis peer-reviewed publication**, with the existing knowledge about the different physical and biogeochemical mechanisms developed over different time scales on EBUS as well establishing similarities and differences**.**

Deliverable 2. **A web-based platform,** where graphically the EBUS databases will be queried and useful information about measurements and protocols

Deliverable 3. **A high impact factor review paper** (e.g., Nature Geoscience)**,** wherein a comparative analysis based on modeling results from both the ocean and atmosphere is presented

Deliverable 4. **A short recommendation paper for stakeholders and policy makers** where a strategic recommendation on how to more cost effectively design and improve regional observational systems with the overarching goal to improve the performance and reliability of global climate models.

Deliverable 5. **A report** where a socio-economic exercise for EBUS is conducted.

Capacity Building (How will this WG build long-lasting capacity for practicing and understanding this area of marine science globally)

The WG is planning to hold an international summer school focused on PhD students and young post-docs mainly (but not exclusively) from Africa and South America and other developing countries. The objective will be to provide the young scientists with an integrative view of the land-atmosphere-ocean continuum in their modeling coupled physical/biogeochemical approach. The basics of atmospheric physics and chemistry and associated coupled and modeling platforms will be presented. An introduction to regional weather and climate systems off the EBUS will be given, as well as basic concepts in physical oceanography and biogeochemistry and hands-on practicals with the ROMS-BIOEBUS[1] modeling platform. Statistics applied to climatology and challenges of regional climate downscaling for performing regional climatic projections will be taught. We will try to explore a new, innovative capacity-building concept: the Network of Early Career Scientists (NECS). This will combine traditional capacity-building of individual early career scientists with a new level of institutional networking. The ultimate goal is to build long lasting capacity through training and by interconnecting the next generation of scientists, and to develop enduring institutional interactions that will help address the scientific challenges facing the EBUS. We will also encourage and facilitate other training and professional development workshops and programs, such as those funded by the Marie Skłodowska Curie Innovative Training Network. Funding for sustaining our NECS will be sought from a range of sources and stakeholders supporting training and networking measures worldwide. We will collaborate with START, IAI, POGO and APN, so that their fellowship schemes and other mechanisms can be used for capacity development.

Several of the scientists involved in the consortium are dedicated to supervise students from southern countries, therefore this WG proposal will also serve as a platform for networking and increasing the critical mass of young researchers hence reinforcing capacity in oceanic sciences in these developing countries. The co-chair of the Working Group is a female early career scientist originating from a developing country, thus guaranteeing the attention given to capacity building and to gender equity.

Additionally, the web-based platform will be the key element to build a young multidisciplinary team from different disciplines and countries to work on EBUS to provide synthetic material for students and local researchers from the developing countries, as well as for decision-makers around the world. In this sense, since the database will provide comprehensive information including observational and numerical data as well as their respective owners and associated scientific production, students and local researchers would be in direct contact with the ocean science community reinforcing their capacity building in these topics and at the same time initiating and expanding their international collaborations.

1 This model is chosen for its relative versatility and simplicity, which is convenient for capacity building

Working Group composition

Full Members

Name	Gender	Place of work	Expertise relevant to proposal
1. Francisco Chavez (United States of America)	Male	Monterey Bay Aquarium Research Institute, USA	Biological Oceanography/ California, Peru
2. Enrique Curchitser (United States of America)	Male	Institute of Marine and Coastal Sciences, Rutgers University, USA	Physical oceanography Modeling / CLIVAR
3. Boris Dewitte (France)	Male	IRD-LEGOS, CEAZA-Chile	Physical Oceanographer, EBUS Dynamics, Air-sea interactions, ENSO dynamics
4. Ruben Escribano (Chile) **Co-chair**	Male	Department of Oceanography, Universidad de Concepción, Chile	Biological Oceanography, Chile/ IMBeR/CLIVAR
5. Sara Fawcett (South Africa)	Female	Department of Oceanography, University of Cape Town, South Africa	Biogeochemical Oceanographer
6. Salvador Lluch-Cota (Mexico)	Male	Programa de Ecología Pesquera. CIBNOR-CONACYT, México	Fishery/Socio-economist ecology
7. Baye Cheikh Mbaye (Senegal)	Male	Laboratoire de Physique de l'Atmosphère et de l'Océan Simeon Fongang (LPAOSF), University Cheikh Anta Diop of Dakar (UCAD), Senegal	Physical/biological Oceanography - Senegalese- Mauritanian coastal upwelling within the Canary upwelling system off North-West Africa
8. Ivonne Montes (Peru) **Co-chair**	Female	Instituto Geofísico del Perú (IGP)	Physical Oceanographer, biogeochemical coupled modeling and dynamics of the Peru/Chile System
9. Andreas Oschlies (Germany)	Male	Helmholtz-Zentrum für Ozeanforschung Kiel (GEOMAR)	Physical Oceanography, Marine Biogeochemical Modeling
10. Parv Suntharalingam (UK)	Female	University of East Anglia (UEA)	Oceanographer, biogeochemical modeling/SOLAS

Associate Member

Name	Gender	Place of work	Expertise relevant to proposal
1. Edward Allison (United States of America)	Male	School of Marine & Environmental Affairs, University of Washington, USA	Interdisciplinary marine scientist focus on climate, social science and resource management
2. Javier Aristegui (Spain)	Male	Instituto de Oceanografía y Cambio Global (IOCAG) at the University of Las Palmas de Gran Canaria (ULPGC)	Biological Oceanography/ Canary Current EBUE
3. Xavier Capet (France)	Male	CNRS-LOCEAN, Paris	Physical Oceanographer - modeler
4. Iris Kriest (Germany)	Female	Helmholtz-Zentrum für Ozeanforschung Kiel (GEOMAR)	Biogeochemical modeller
5. Eric Machu (France)	Male	IRD – LPAO-SF, ESP, Université Cheikh Anta Diop, Dakar Sénégal	Oceanographer, structuration of plankton communities from coupled approaches (observation & modeling)
6. Beatriz Yanicelli (Chile)	Female	Centro de Estudios Avanzados de Zonas Aridas (CEAZA)	Oceanographer, Chile Coastal Upwelling System
7. Damodar Shenoy (India)	Male	National Institute of Oceanography, Goa, India	Biogeochemistry/Bay of Bengal/Arabian Sea
8. Ryan Rykaczewski (USA)	Male	University of Southern California	Biological Oceanography of EBUS – California System/CLIVAR
9. Lynne Shannon (South Africa)	Female	Marine Research Institute, University of Cape Town	Fishery/Socio-economist ecosystem EBUE
10. Ming Feng (Australia)	Male	CSIRO Marine and Atmospheric Research	Physical oceanographer specialized in the Leeuwin Current dynamics

Working Group contributions

The full and associated members involved in this SCOR WG have been invited due to their field of expertise and past works, coming from various countries and disciplines; these are:

Dr. Francisco Chavez has published extensively on climate variability and EBUS, worked for many decades on the California and Humboldt EBUE, and has broad interests in

oceanography, biogeochemistry, ecology, modeling, and new technology. He has led several synthesis efforts, edited multiple special issues and is active in national and international programs.

Dr. Enrique Curchitser is a physical oceanographer with interests in the dynamics of eastern boundary currents and shelf circulation and coupled bio-physical and numeric modeling. He is leading the CLIVAR Eastern Boundary Upwelling Research Focus that is trying to better understand the very large biases that climate models have in EBUS.

Dr. Boris Dewitte is a physical oceanographer involved in numerous projects dedicated to the study of Humboldt Current System; with wide experience on ENSO events and their impacts. He is currently a member of the CLIVAR Scientific Steering Group and of the Task Team "Eastern Boundary" of the international program TPOS2020. He was an associate member of the SCOR group 128 on Natural and Human-Induced Hypoxia and Consequences for Coastal Areas (2006-2008).

Dr. Ruben Escribano is a biological oceanographer who specializes in zooplankton, was active in the GLOBEC program and is presently on the IMBeR Scientific Steering Committee, working extensively on the Humboldt.

Dr. Sara Fawcett is dedicated to understanding the complex relationships between biogeochemical fluxes (particularly nitrogen) and primary productivity in the ocean, with implications for past and future climate, ecosystem structure and function, ocean fertility, and global biogeochemical cycles.

Dr. Salvador Lluch-Cota has interests in climate variability and change and its effects on living marine resources; he was one of the six lead authors of the IPCC chapter on Ocean Systems. He has worked extensively in the California Current System particularly off Baja California, Mexico and has led synthesis efforts to uncover and better understand the variability of small pelagic fish in Atlantic and Pacific EBUS.

Dr. Baye Cheikh Mbaye is specializing in the Senegalese-Mauritanian coastal upwelling within the Canary upwelling system off North-West Africa. His main focus is to analyze how both physical and biological factors affect the survival of fish early life stage (eggs and larvae), and how this ecological understanding could help improve policies for marine conservation and fisheries management of eastern boundary upwelling systems; his approach integrates both modeling and observation (remote sensing).

Dr. Ivonne Montes is specialized on coupled physical-biogeochemical modeling applied to Eastern boundary current system (Guinea Gulf, Mexico and Peru/Chile) to study the role of the ocean in climate, the investigation of processes maintaining the Oxygen Minimum Zone off Peru, and the impact of remote and local air-sea interactions over the upwelling systems.

Dr. Andreas Oschlies is an expert on marine biogeochemical Modeling dedicated to study the physical, biogeochemical, and ecological constraints on the oceanic carbon uptake and its climate sensitivity as well as interested on mixing processes and their representation in numerical models.

Dr. Parv Suntharalingam is focused on biogeochemical cycles of climatically important species in the atmosphere and ocean.

Relationship to other international programs and SCOR Working groups

This EBUS theme is an integral part of the integrated topics in the new SOLAS Science Plan 2015-2025 [2]. Moreover, CLIVAR (Climate and Ocean: Variability, Predictability and Change), IMBeR (Integrated Marine Biosphere Research) and SOLAS have a joint Research Focus on Upwelling systems. In addition, there is a strong link between this SCOR WG proposal and the new initiative from IOC-UNESCO called GO_2NE (Global Ocean Oxygen NETwork), an interdisciplinary network concerned about the low oxygen concentrations in both the open ocean and coastal areas, which will be involved in the regional database initiative. This working group is also timely since it fits with the concerns of the program TPOS2020 that is aimed at designing the future of the observing system in the Pacific (http://tpos2020.org/). Interactions with the Task Team "Eastern Pacific" of the TPOS2020 program will be encouraged during the course of the SCOR group. It will also link with the GOOS IMSOO (Implementation of Multi-Disciplinary Sustained Ocean Observations) panel on Oxygen Minimum Zones. This SCOR WG will also have the opportunity to start with standards, datasets and comparative analysis of the oxygen deficient systems being generated by the SCOR Working Group 144 on Microbial Community Responses to Ocean Deoxygenation, developed for the world ocean to the wider oceanographic and Earth system science communities and the public.

This SCOR WG will also strive to integrate in its synthesis outcomes of relevant regional modeling and observational projects (e.g. CORDEX) through collaborations of its members.

Key References

Bakun, A., et al. (2015) Anticipated Effects of Climate Change on Coastal Upwelling Ecosystems, *Curr. Clim. Change Rep.*, 1, 85–93.

Bettencourt, J.H., et al. (2015) Boundaries of the Peruvian Oxygen Minimum Zone shaped by coherent mesoscale dynamics, *Nature Geosci.,* 8, 937–940.

Cabré, A., et al. (2015) OMZs in the tropical Pacific across CMIP5 models: mean state differences and climate change trends, *Biogeosciences*, 12, 6525-6587.

Capet, A., et al. (2014), Implications of refined altimetry on estimates of meso-scale activity and eddy-driven offshore transport in the Eastern Boundary Upwelling Systems, *Geophys. Res. Lett.*, 41, 7602–7610.

Capet, X., et al. (2008) Mesoscale to Submesoscale Transition in the California Current System. Part I: Flow Structure, Eddy Flux, and Observational Tests, *J. Phys. Oceanogr.,* 38, 29–43.

Capet, X.J., et al. (2004) Upwelling response to coastal wind profiles, *Geophys. Res. Lett*.,31, L13311.

Carr, M.-E., and E. J. Kearns (2003) Production regimes in four Eastern Boundary Current systems,

[2] http://www.solas-int.org/files/solas-int/content/downloads/About/Future%20SOLAS/Revised_SOLAS%20Science%20Plan.pdf *By inversions we mean inversions to obtain information on the properties of materials in the ocean and the atmosphere (gas, particles, dissolved materials, drops etc') as well as at the interface (waves, bubbles). By properties we mean concentration, composition, size and shape, lifetime, optical properties.

Deep Sea Res. PartII, 50(22–26), 3199–3221.
Chavez, F.P., and M. Messie (2009) A comparison of Eastern Boundary Upwelling Ecosystems, *Prog. Oceanogr.,* 83(1–4), 80–96.
Chelton, D.B., et al. (2007) Summertime coupling between sea surface temperature and wind stress in the California Current System, *J.Phys.Oceanogr.,* 37, 495–517.
Combes, V., et al. (2015) Interannual variability of the subsurface eddy field in the Southeast Pacific, *J. Geophys. Res. Oceans*, 120, 4907–4924, doi:10.1002/2014JC010265.
Dewitte B., et al. (2012) Change in El Niño flavours over 1958-2008: Implications for the long-term trend of the upwelling off Peru, *Deep Sea Research II,* doi:10.1016/j.dsr2.2012.04.011.
Franks, P.J.S., et al. (2013), Modeling Physical-Biological Responses to Climate Change in the California Current System, *Oceanography*, 26(3), 26-33.
Gomes, H.D.R., et al. (2014) Massive outbreaks of Noctiluca scintillans blooms in the Arabian Sea due to spread of hypoxia, *Nature communications,* 5, 4862, doi:10.1038/ncomms5862.
Gruber, N., et al. (2011) Eddy-induced reduction of biological production in eastern boundary upwelling systems, *Nature Geosci.,* 4, 787–792.
Lachkar, Z., and N. Gruber (2012) A comparative study of biological production in eastern boundary upwelling systems using an artificial neural network, *Biogeoscience*s, 9, 293-308.
Mbaye, et al. (2015) Do Sardinella aurita spawning seasons match local retention patterns in the Senegalese–Mauritanian upwelling region?, *Fisheries Oceanography*, 24(1), 69-89.
Mackas, D.L., et al. (2006) Eastern ocean boundaries – pan regional overview. In*: The Global Coastal Ocean: Interdisciplinary Regional Studies and Syntheses – PanRegional Syntheses and the Coasts of North and South America and Asia*, The Sea, vol 14A. Robinson, A. R., and K. H. Brink (eds.), Harvard University Press., 2, 21-60.
Mechoso, C.R., et al. (2014) Ocean–Cloud–Atmosphere–Land Interactions in the Southeastern Pacific: The VOCALS Program, *Bull. Amer. Meteor. Soc.,* 95, 357–375, doi: 10.1175/BAMS-D-11-00246.1.
Neveu, E., et al. (2016), An historical analysis of the California Current circulation using ROMS 4D-Var: System configuration and diagnostics, *Ocean Modelling*, 99, 133-151.
Pauly, D., and V. Christensen (1995) Primary production required to sustain global fisheries, *Nature*, 374, 255-257.
Pegliasco, C., et al. (2015) Main eddy vertical structures observed in the four major Eastern Boundary Upwelling Systems, *J. Geophys. Res.*, 120, 6008-6033.
Rees, A.P., et al. (2011**)** The Lagrangian progression of nitrous oxide within filaments formed in the Mauritanian upwelling, *Geophys. Res. Lett.*, 38, L21606, doi:10.1029/2011GL049322.
Renault, L., et al. (2016). Partial decoupling of primary productivity from upwelling in the California Current system, *Nature Geosci.*, 9, 505–508 doi:10.1038/ngeo2722
Renault, L., et al. (2015) Orographic shaping of US West Coast wind profiles during the upwelling season, *Clim Dyn*, 46(1-2), pp.273-289.
Richter, I. (2015), Climate model biases in the eastern tropical oceans: causes, impacts and ways forward, *WIREs Clim Change*, 6, 345–358.
Rossi, V., et al. (2008) Comparative study of mixing and biological activity of the Benguela and Canary upwelling systems, *Geophys. Res. Let.*, 35, L11602.
Saji, N.H., et al. (1999) A dipole mode in the tropical Indian Ocean, *Nature*, 401, 360-363
Stramma, L., et al. (2010) Ocean oxygen minima expansions and their biological impacts, *Deep-Sea Res.PartI-Oceanographic Res. Papers*, 57, 587-595.
Stramma, L., et al. (2012) Mistmatch between observed and modeled trends in dissolved upper-ocean oxygen over the last 50 yr, *Biogeosciences*, 9(10), 4045–4057, doi:10.5194/bg-9–4045-2012.
Takahashi K., et al. (2014) TPOS White Paper #8a – Regional applications of observations in the eastern Pacific: White Paper #8a- Report of the Tropical Pacific Observing System 2020 Workshop (TPOS 2020) GCOS-184, 2, 171–205, http://www.wmo.int/pages/prog/gcos/Publications/gcos-184_II.pdf.

Van der Lingen, C.D., et al. (2009) Chapter 8: Trophic dynamics of small pelagic fish. *In: Checkley DM Jr, Roy C, Alheit J, Oozeki Y (Eds) Climate Change and Small Pelagic Fish*. Cambridge University Press, 112-157.

Van der Lingen, C.D., et al. (2006) Comparative trophodynamics of anchovy *Engraulis encrasicolus* and sardine *Sardinops sagax* in the southern Benguela: are species alternations between small pelagic fish trophodynamically mediated?, *African Journal Of Marine Science*, 28 (3-4), 465-477, http://dx.doi.org/10.2989/18142320609504199.

Vergara, O., et al. (2016) Seasonal Variability of the Oxygen Minimum Zone off Peru in a high-resolution regional coupled, *Biogeosciences*, 13, 4389-4410, doi:10.5194/bg-13-4389-2016.

Woodson, C.B. and S.Y. Litvin (2015) Ocean fronts drive marine fishery production and biogeochemical cycling, *PNAS*, 112 (6), 1710–1715, doi:10.1073/pnas.1417143112.

Wang, D., et al. (2015) Intensification and spatial homogenization of coastal upwelling under climate change, *Nature*, 518(7539), 390-394.

Zuidema et al. (2016) Challenges and Prospects for Reducing Coupled Climate Model SST Biases in the Eastern Tropical Atlantic and Pacific Oceans: The U.S. CLIVAR Eastern Tropical Oceans Synthesis Working Group. Bull, *Amer. Meteor. Soc.*, 97, 2305–2328, doi:10.1175/BAMS-D-15-00274.1.

Appendix (For each Full Member, indicate 5 publications related to proposal)

Dr. Francisco Chavez

Chavez, F.P., J.P. Ryan, S. Lluch-Cota, and M. Ñiquen (2003) From anchovies to sardines and back-Multidecadal change in the Pacific Ocean, *Science,* 299, 217-221.

Chavez, F.P., A. Bertrand, R. Guevara, P. Soler, and J. Csirke (2008) The northern Humboldt Current System: brief history, present status and a view towards the future, *Progress in Oceanography*, 79, 95-105.

Chavez, F.P. and M. Messie (2009) A comparison of eastern boundary upwelling ecosystems, *Progress in Oceanography*, doi: 10.1016/j.pocean.2009.07.032.

Chavez, F.P. , M. Messié, and J.T. Pennington (2011) Marine primary production in relation to climate variability and change, *Annual Review of Marine Science*, 3, 227–60, doi:10.1146/annurev.marine.010908.163917.

Chavez, F. P. (2012) Climate Change and Marine Ecosystems, *Proceedings of the National Academy of Sciences*, 47, 19045-19046, doi: 10.1073/pnas.1217112109.

Dr. Enrique Curchitser

Small, R.J., **E.N. Curchitser**, K.S. Hedstrom, B. Kaufman, and W. Large (2015) The Benguela Upwelling System: Quantifying the Sensitivity to Resolution and Coastal Wind Representation in a Global Climate Mode, *Journal of Climate*, 28, 9409-9432, doi: 10.1175/JCLI-D-15-0192.1.

Curchitser, E.N., K.A. Rose, S-I. Ito, M.A. Peck, and M.J. Kishi (2015) Combining modeling and observations to better understand marine ecosystem dynamics, *Progress in Oceanography*, 138, PartB, 327-330, http://dx.doi.org/10.1016/j.pocean.2015.11.001.

Fiechter, J., K.A. Rose, **E.N. Curchitser** and K.S. Hedstrom (2015) The role of environmental controls in determining sardine and anchovy population cycles in the California Current: Analysis of an end-to-end model, *Progress in Oceanography*, 138, Part B, 381-398, http://dx.doi.org/10.1016/j.pocean.2014.11.013.

Rose, K.A., J. Fiechter, **E.N. Curchitser**, K. Hedstrom, M. Bernal, S. Creekmore, A. Haynie, S-I. Ito, S. Lluch-Cota, B.A. Megrey, C.A. Edwards, D. Checkley, T. Koslow, S. McClatchie, F. Werner, A. MacCall, and V. Agostini (2015) Demonstration of a fully-coupled end-to-end

model for small pelagic fish using sardine and anchovy in the California Current, *Progress in Oceanography*, 138, PartB, 348-380, http://dx.doi.org/10.1016/j.pocean.2015.01.012.

Fiechter, J., **E.N. Curchitser**, C.A. Edwards, F. Chai, N.L. Goebel, and F.P. Chavez (2014) Air-sea CO2 fluxes in the California Current: Impacts of model resolution and coastal topography, *Global Biogeochem. Cycles*, 28, 371–385, doi:10.1002/2013GB004683.

Dr. Boris Dewitte

Vergara, O., **B. Dewitte**, I. Montes, V. Garçon, M. Ramos, A. Paulmier, and O. Pizarro (2016) Seasonal Variability of the Oxygen Minimum Zone off Peru in a high-resolution regional coupled, *Biogeosciences*, 13, 4389-4410, doi:10.5194/bg-13-4389-2016.

Bettencourt J., C. López, E. Hernández-García, I. Montes, J. Sudre, **B. Dewitte**, A. Paulmier, and V. Garçon (2015) Boundaries of the Peruvian oxygen minimum zone shaped by coherent mesoscale dynamics, *Nature Geoscience*, 8 (12), 937-940.

Dewitte B., J. Vazquez-Cuervo, K. Goubanova, S. Illig, K. Takahashi, G. Cambon, S. Purca, D. Correa, D. Gutierrez, A. Sifeddine and L. Ortlieb (2012) Change in El Nino flavours over 1958-2008: Implications for the long-term trend of the upwelling off Peru, *Deep Sea Research II*, doi:10.1016/j.dsr2.2012.04.011.

Monteiro P. M. S., **B. Dewitte**, M.I. Scranton, A. Paulmier and A. van der Plas (2011) The role of open ocean boundary forcing on seasonal to decadal-scale variability and long-term change of natural shelf hypoxia, *Environ. Res. Lett.*, 6, 025002, doi:10.1088/1748-9326/6/2/025002.

Dewitte B., S. Illig, L. Renault, K. Goubanova, K. Takahashi, D. Gushchina, K. Mosquera, and S. Purca (2011) Modes of covariability between sea surface temperature and wind stress intraseasonal anomalies along the coast of Peru from satellite observations (2000-2008), *J. Geophys. Research*, 116, C04028, doi:10.1029/2010JC006495.

Dr. Ruben Escribano

Riquelme-Bugueño, R., M. Correa-Ramírez, **R. Escribano**, S. Nuñez, and S. Hormazabal (2015) Mesoscale variability in the habitat of the Humboldt Current krill, spring 2007, *Journal of Geophysical Research*, 120, 2769–2783.

Escribano, R., and C.E Morales (2012) Spatial and temporal scales of variability in the coastal upwelling and coastal transition zone off central-southern Chile (35-40°S), *Progress in Oceanography,* 92-95, 1-7.

Escribano, R., and W. Schneider (2007) The Sructure and Functioning of the Coastal Upwelling System off Central/south of Chile, *Progress in Oceanography*, 75, 343-346.

Escribano, R., P. Hidalgo, H.E. González, R. Giesecke, R. Riquelme-Bugueño, and K. Manríquez (2007) Interannual and seasonal variability of metazooplankton in the Central/south upwelling region off Chile, *Progress in Oceanography*, 75, 470-485.

Escribano, R., D. Daneri, L. Farías, V.A. Gallardo, and H.E. González, D. Gutierrez, C. Lange, C.E. Morales, O. Pizarro, O. Ulloa, and M. Braun (2004) Biological and chemical consequences of the 1997-98 el niño in the Chilean coastal upwelling system: a synthesis, *Deep-Sea Research Part II*, 51, 20-21, 2389-2411.

Dr. Sarah Fawcett

Altieri, K.E., **S.E. Fawcett,** A.J. Peters, D.M. Sigman, M.G. Hastings (2016) Marine biogenic source of atmospheric organic nitrogen in the subtropical North Atlantic, *Proceedings of the National Academy of Sciences,* 113, 925-930, doi/10.1073/pnas.1516847113.

Knapp, A.N., **S.E. Fawcett**, A. Martínez-Garcia, N. Leblond, T. Moutin, and S. Bonnet (2015) Nitrogen isotopic evidence for a shift from nitrate- to diazotroph-fueled export production in

VAHINE mesocosm experiments, *Biogeosciences Discussions,* 12, 19901-19939 (www.biogeosciences- discuss.net/12/19901/2015/bgd-12-19901-2015.html).

Van Oostende, N., J.P. Dunne, **S.E. Fawcett,** and B.B. Ward (2015) Phytoplankton succession and acclimation explains nitrate uptake following an upwelling event. *Journal of Marine Systems,* 148, 14-25.

Fripiat, F., D.M. Sigman, **S.E. Fawcett,** P.,Rafter, M. Weigand, and J.L. Tison (2014) New insights on sea ice nitrogen biogeochemical dynamics and paleoceanography implications from nitrogen isotopes, *Global Biogeochemical Cycles,* 28, 115-13

Fawcett, S.E., and B.B. Ward (2011) Phytoplankton succession and nitrogen utilization during the development of an upwelling bloom, *Marine Ecology Progress Series,* 428, 13-31, http://www.int-res.com/abstracts/meps/v428/p13-31/.

Dr. Salvador Lluch-Cota

Chavez, F.P., J. Ryan, **S.E. Lluch-Cota**, and M. Ñiquen (2003) From Anchovies to Sardines and Back: Multidecadal Change in the Pacific Ocean, *Science*, 299 (5604), 217-221.

Schwartzlose, R.A., J. Alheit, A. Bakun, TR Baumgartner, R Cloete, R.J.M. Crawford, WJ Fletcher, Y. Green-Ruiz, E. Hagen, T. Kawasaki, D. Lluch-Belda, **SE Lluch-Cota**, AD MacCall, Y. Matsuura, MO Nevárez-Martínez, R.H. Parrish, C. Roy, R. Serra, K.V. Shust, M.N. Ward, and J.Z. Zuzunaga (1999) Worldwide large-scale fluctuations of sardine and anchovy populations, *South African Journal of Marine Science*, 21 (1), 289-347.

Lluch-Cota, SE (2000) Coastal upwelling in the eastern Gulf of California, *Oceanologica Acta*, 23 (6), 731-740

Pörtner, H.O., D.M. Karl, P.W. Boyd, W. Cheung, **SE Lluch-Cota**, Y Nojiri, D.N. Schmidt, P.O. Zavialov (2014) Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 411-484, Cambridge University Press.

Bakun, A., C. Roy, and **SE Lluch-Cota (**1998) Coastal upwelling and other processes regulating ecosystem productivity and fish production in the Western Indian ocean. In: Sherman K. (ed.), Okemwa EN (ed.), Ntiba MJ (ed.) Large marine ecosystems of the Indian ocean: assessment, sustainability and management (103-141). Blackwell

Dr. Baye Cheikh Mbaye

Mbaye, B.C., T. Brochier, V. Echevin, A. Lazar, M. Levy, E. Mason, and E. Machu (2015) Do Sardinella aurita spawning seasons match local retention patterns in the Senegalese–Mauritanian upwelling region?, *Fisheries Oceanography*, 24(1), 69-89.

Brochier T., P.A. Auger, L. Pecquerie, M. Thiaw, E, Machu, B.C. **Mbaye**, C.B. Braham, O. Ettahiri, N. Charouki, P. Brehmer (2015) Virtual monitoring of small pelagic fish spatial structure dynamics: the case of *Sardinella aurita* in the Canary Upwelling System, *Fish and Fisheries* (submitted, ID is FaF-15-Dec-OA-229)

Mbaye B. C., E. Machu, V. Echevin, and T. Brochier. Modelling *Sardinella aurita* spawning habitat and larvae dynamic off Senegalese-Mauritanian upwelling. *In prep.*

Dr. Ivonne Montes

Vergara, O., B. Dewitte, **I. Montes**, V. Garçon, M. Ramos, A. Paulmier, and O. Pizarro (2016) Seasonal Variability of the Oxygen Minimum Zone off Peru in a high-resolution regional coupled, *Biogeosciences*, 13, 4389-4410, doi:10.5194/bg-13-4389-2016.

Bettencourt J., C. López, E. Hernández-García, **I. Montes**, J. Sudre, B. Dewitte, A. Paulmier, and V. Garçon (2015) Boundaries of the Peruvian oxygen minimum zone shaped by coherent mesoscale dynamics, *Nature Geoscience*, 8 (12), 937-940

Montes, I., B. Dewitte, E. Gutknecht, A. Paulmier, I. Dadou, A. Oschlies, and V. Garçon, (2014) High-resolution modeling of the Eastern Tropical Pacific oxygen minimum zone: Sensitivity to the tropical oceanic circulation, *J. Geophys. Res.-Oc.,* 119 (8), 5515-5532.

Montes I., W. Schneider, F. Colas and B. Blanke (2011) Subsurface connections in the Eastern Tropical Pacific during La Niña 1999-2001 and El Niño 2002-2003, *J. Geophys. Res.*, 116 (C12022), doi:10.1029/2011JC007624.

Montes I., F. Colas, X. Capet, and W. Schneider (2010) On the pathways of the Equatorial Subsurface Currents in the Eastern equatorial Pacific and their contributions to the Peru-Chile Undercurrent, *J. Geophys. Res.*, 115 (C09003), doi:10.1029/2009JC005710.

Dr. Andreas Oschlies

Getzlaff, J., H. Dietze, and **A. Oschlies** (2016) Simulated effects of southern hemispheric wind changes on the Pacific oxygen minimum zone, *Geophys. Res. Lett.*, 43, 728–734, doi:10.1002/2015GL066841.

Kriest, I. and **A. Oschlies** (2015) MOPS-1.0: modelling the regulation of the global oceanic nitrogen budget by marine biogeochemical processes, *Geoscientific Model Development*, 8, 2929-2957, doi:10.5194/gmd-8-2929-2015.

Su, B., M. Pahlow, H. Wagner, and **A. Oschlies** (2015) What prevents nitrogen depletion in the oxygen minimum zone of the eastern tropical South Pacific?, *Biogeosciences*, 12, 1113-1130, doi:10.5194/bg-12-1113-2015.

Duteil, O., F.U. Schwarzkopf, C.W. Böning, and A. **Oschlies** (2014) Major role of the equatorial current system in setting oxygen levels in the eastern tropical Atlantic Ocean: a high-resolution model study, *Geophysical Research Letters*, 41, 2033-2040. doi:10.1002/2013GL058888.

Getzlaff, J., G. Nurser, and A. **Oschlies** (2012) Diagnostics of diapycnal diffusion in z-level ocean models, *Part II: 3-Dimensional OGCM Ocean Modelling*, 45-46, 27-36, doi:10.1016/j.ocemod.2011.11.006.

Dr. Parv Suntharalingam

Suntharalingam, P., Buitenhuis, E., Le Quere, C., Dentener, F., Nevison, C., Butler, J., Bange, H., and Forster, G. (2012) Quantifying the Impact of Anthropogenic Nitrogen Deposition on Oceanic Nitrous Oxide, *Geophysical Research Letters,* 39, L07605, doi:10.1029/2011GL050778

Thomas, M., **P. Suntharalingam**, L. Pozzoli, A. Devasthale, S. Kloster, S. Rast, J. Feichter, and T. Lenton (2011) Non-linearity in DMS aerosol-cloud-climate interactions, *Atmospheric Chemistry and Physics Discussions*, 11, 15227-15253.

Thomas, M., P. **Suntharalingam,** L. Pozzoli, S. Rast, S., Devasthale, A., Kloster, S., J. Feichter, and T. Lenton (2010) Quantification of DMS aerosol-cloud-climate interactions using ECHAM5-HAMMOZ model in current climate scenario, *Atmospheric Chemistry and Physics Discussions*, 10, 3087-3187.

Suntharalingam, P., Sarmiento, and J. (2000) Factors governing the oceanic nitrous oxide distribution: Simulations with an ocean general circulation model, *Global Biogeochemical Cycles*, 14, 429-454.

Memorandum to:
Dr Ed Urban
Executive Director
Scientific Committee on Oceanic Research
College of Earth, Ocean, and Environment
Robinson Hall
University of Delaware
Newark, DE 19716 USA

Kiel, 11 April 2017

Subject: SOLAS support for SCOR Working Group on 'Eastern boundary upwelling systems (EBUS): diversity, coupled dynamics and sensitivity to climate change'

Dear Ed,

With this letter SOLAS expresses strong support for the proposal to establish a SCOR Working Group on 'Eastern boundary upwelling systems (EBUS): diversity, coupled dynamics and sensitivity to climate change', submitted by Ivonne Montes, Ruben Escribano and others. The proposal is a response to the need for integrating existing knowledge on EBUS to formulate a strategic recommendation white paper for setting up regional observational systems to monitor and understand physical and biogeochemical ocean-atmosphere interactions. This is a frontier issue scientifically and one of the scientific priorities for SOLAS as detailed in the SOLAS 2015-2015 Science Plan and Organisation. Observational systems will be instrumental in improving the performance and reliability of climate models in these socio-economically relevant regions of the world ocean.

The SOLAS International Project Office (IPO), as you know, has limited financial resources with which it must support activities across the full scope of the SOLAS science plan. As a result, there are insufficient resources available for SOLAS to fund the proposed activity. SOLAS will support the group to the best of its ability, ensure access to the communications and organisational capabilities of the IPO, and help link the Working Group's activities to other ongoing SOLAS planning activities and scientific meetings. We expect that regular communiqués on the group's activities can be published via the SOLAS report series and E-news.

The international team assembled for this Working Group is well qualified to carry out its mission and we hope that SCOR will be able to support the proposal. We look forward to this becoming one more area in which SOLAS and SCOR can continue our productive cooperation.

With very best regards,

Dr. Véronique Garçon
Chair, SOLAS Scientific Committee Steering

Dr. Emilie Brévière
Executive Director,
SOLAS International Project Office

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IMBeR

Integrated Marine Biosphere Research

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15 April 2017

Dr. Ed Urban
Executive Director
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Robinson Hall, University of Delaware
Newark, DE 19716 USA

Dear Ed,

I am writing to confirm that IMBeR strongly supports the proposal for a SCOR Working Group on ‘*’Eastern boundary upwelling systems (EBUS): diversity, coupled dynamics and sensitivity to climate change*”, which would be co-chaired by Ivonne Montes, a physical oceanographer working at the Instituto Geofisico del Perú, and Rubén Escribano, a biological oceanographer at the University of Concepción, Chile.

The objectives of EBUS, to synthesise, compare, make accessible and recommend future observational and modelling approaches to monitor and understand the physical and biogeochemical feedbacks occurring in eastern boundary upwelling systems align well with the IMBeR research goal as outlined in the Science Plan and Implementation Strategy (2016-2025). In particular, this includes the IMBeR objectives to improve the quantitative understanding of ocean variability and change in order to provide the basis for scenarios, projections and predictions of the future, and to enable the acquisition and provision of evidence-based advice for marine managers, policy makers and other end-users for sustainable marine governance. IMBeR also has a commitment to supporting early career researchers, so we would be particularly pleased to link the EBUS summer school participants with our Early Career Network of socio-ecologists, which developed from our own series of biennial ClimEco summer schools.

If funded, IMBeR will support the SCOR working group in terms of ensuring networking opportunities within the IMBeR community, for example through collaboration with the CLIVAR/SOLAS/IMBeR upwelling Working Group, and access to the logistical and organizational expertise of the IMBeR International and Regional Project Offices in Bergen and Shanghai. The interdisciplinary activities of the IMBeR Human Dimensions and Continental Margins Working Groups would be a particular source of expertise for the EBUS socio-economic exercise.

We look forward to the opportunity to work closely with this potential new SCOR Working Group.

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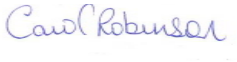
Yours sincerely,



Dr. Carol Robinson
Chair, IMBeR Scientific Steering Committee