

Project	AtlantOS – 633211
Deliverable number	D5.1
Deliverable title	Status of regional climate and ecosystems observing Report
Description	Report on the current observing status in the North Atlantic subpolar gyre and the South Atlantic subtropical gyre, containing the results of the investigation on regional observing activities, systems, and connectivity in relation to climate and ecosystems
Work Package number	5
Work Package title	Integrated regional observing systems
Lead beneficiary	CNRS
Lead authors	CNRS [Sabrina Speich] and GEOMAR [Johannes Karstensen]
Contributors	NOCS (Elaine McDonagh), OSNAP, SAMOC, and collaborators from Angola, Argentina, Brazil, Canada, Cape Verde, Morocco, Namibia, Nigeria, South Africa, Uruguay, USA.
Submission data	25/03/2019
Due date	36PM
Comments	We wanted to extend as long as possible the possibility to network and connect with pan-Atlantic Stakeholders



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n° 633211.

Stakeholder engagement relating to this task*

<p>WHO are your most important stakeholders?</p>	<p><input type="checkbox"/> Private company If yes, is it an SME <input type="checkbox"/> or a large company <input type="checkbox"/>? <input checked="" type="checkbox"/> National governmental body <input type="checkbox"/> International organization <input type="checkbox"/> NGO <input type="checkbox"/> others Please give the name(s) of the stakeholder(s): ...</p>
<p>WHERE is/are the company(ies) or organization(s) from?</p>	<p><input checked="" type="checkbox"/> Your own country <input checked="" type="checkbox"/> Another country in the EU <input checked="" type="checkbox"/> Another country outside the EU Please name the country(ies): ...</p>
<p>Is this deliverable a success story? If yes, why? If not, why?</p>	<p><input checked="" type="checkbox"/> Yes, because we have been capable to meet the task objectives of assessing the observing capabilities for the two regions (and beyond them) we targeted and, may be even more important, we have build a solid observing pan-Atlantic stakeholder network for the ocean observing. <input type="checkbox"/> No, because</p>
<p>Will this deliverable be used? If yes, who will use it? If not, why will it not be used?</p>	<p><input checked="" type="checkbox"/> Yes, by AtlantOS partners involved in other WPs as well as by the pan-Atlantic community network that we have established. <input type="checkbox"/> No, because</p>

Status of regional climate and ecosystems observing Report

Executive Summary

To establish an assessment of the regional observing and the connected societal requirements, we followed a twofold approach: we organized a sequence of meetings in conjunction with other international events related to climate, fisheries, and Atlantic observing (including AtlantOS GA) and in connection with the GOOS and GCOS panels as well as within the Galway and Belem accords communities to connect the various Atlantic stakeholders from east to west and from south to north.

In total we have organized 11 meetings/workshops that revealed that integration of climate and ecosystem observations and fisheries is relatively well advanced in many of the Atlantic bordering countries that may also reflect the close linkage with the economically important fishery industry. However, when it comes to observing the Atlantic open ocean, current in-situ activities came out as sparse and not well interconnected.

We synthesized the various societal and observing requirements but also observed the different processes which may be required to better connect ocean observing to stakeholder needs.

This synthesis has been declined according to different societal requirements in 11 community white papers that the meetings we organized and the discussions that followed such events have incited and to which we thoroughly contributed. These papers also include the users and stakeholders requirements and objectives for an Atlantic Observing System that goes beyond the state-of-the-art, and leaves a legacy of sustainability.

Objective

Taking the opportunity of the work and teams that participates as partners or collaborators in the H2020 AtlantOS project but also within the communities gathered in the framework of the GOOS and GCOS panels as well as within the Galway and Belem accords, we have organized a set of meetings and workshops intended to collect as broadly and completely as possible, the users and stakeholders requirements and objectives for an Atlantic Observing System that goes beyond the state-of-the-art, and leaves a legacy of sustainability.

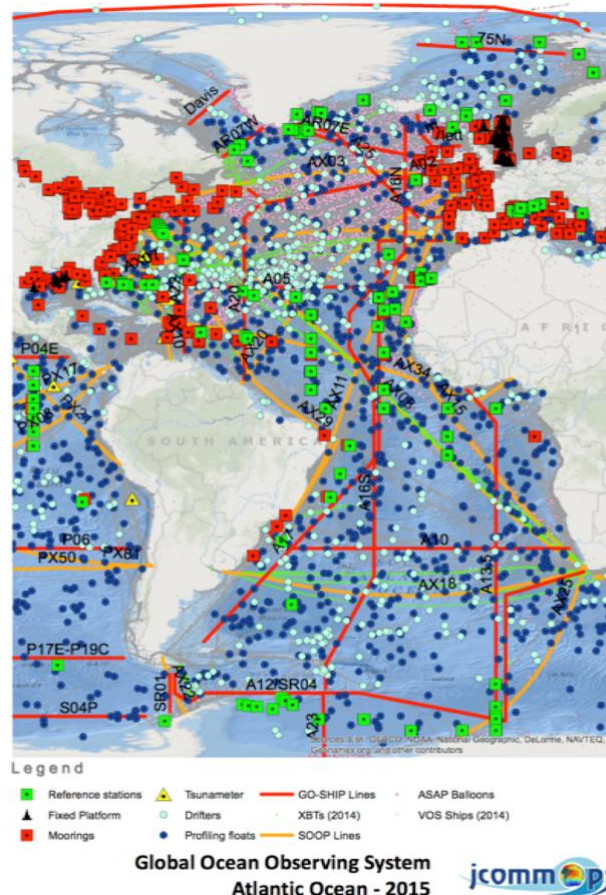


Figure 1: A synoptic image of the 2015 Atlantic observing system. Such system is constituted by a number of different platforms deployed within different scientific projects undertaken to answer very different societal requirements.

The Atlantic in-situ observing is a conglomerate of basin-wide and local/regional sampling (Figure 1). Basin scale sampling include systems like Argo, surface drifter, moorings, oceanographic research ship cruises, voluntary ship observing, coastal surveys and multiple satellite remotely sensed platforms which are designed around large-scale scientific objectives and targeted to be operational for at least decades long. The local/regional sampling is often designed by specific science objectives that may have large-scale implications (e.g., the basin-scale ocean circulation, the strength of the ocean meridional overturning) but the systems are often operational only through a project lifetime of a few years only (e.g. RAPID, SAMOC, OSNAP).

With the objective to achieve a transition from a loosely-coordinated and fragmented set of existing activities, into a system that is sustained and sustainable, efficient, and fit-for-purpose we needed to assess the current and emerging status of observational programs and projects in the context of climate and ecosystems for the Atlantic and this by identify a common understanding of requirements across the stakeholders of an Atlantic sustained ocean observing.

In particular we aimed to pragmatically evaluate the potential to connect the ocean observing across projects (from physical oceanography to ecosystems and fisheries), observing systems (e.g. Oceanographic cruises, GO-SHIP, Argo, moored arrays) and across agencies (WRCP, FAO, ICES, NAFOS, OSPAR).

To start an efficient process toward this objective we proposed to use different general conferences and meetings organized within the lifetime of the H2020 AtlantOS project to convene the largest group of sustained Atlantic Observing System stakeholders linked with one or more observing objectives (climate, ecosystem and fisheries). We thought that this was the best way to enable us building on and consolidating the existing networks in order to create a pan-hemispheric coordinated Atlantic Ocean observing.

We initially thought to undertake the task by organizing side meetings during only two years and by tackling four major international workshops or conferences. However, during the first two years we thought that, to reach our scope and build a more consolidated Atlantic Ocean observing community, we needed to extend our task. Hence, we have dedicated much more effort to our enterprise by extending in time the organization of dedicated meetings. This effort has been just recently achieved.

Actions

We focussed our effort by establishing regional contacts in two regions of the North and South Atlantic Ocean, the subpolar North Atlantic and the Subtropical South Atlantic, with a particular emphasis on the latter, in order to have the most general view on national programmes of ocean observations (open ocean and coastal projects) and the appropriate stakeholders on climate and fisheries to connect with.

During the first year of the project, we started to enhance and map the regional contacts in order to have the most general view on national programmes of ocean observations (open ocean and coastal projects) and the appropriate stakeholders to connect with. In order to complete the baseline study on ocean observing we started networking during the IUGG Meeting in Prague (Czech Republic, July 2015), and again at Ocean Sciences 2016 (New Orleans, USA, February 2016).

By taking the opportunity of the many international conferences and workshops on ocean sciences that took place during the period 2016-2019, we organized seven international meetings and participated in additional two by bringing our aims to provoke interest and adherence from the pan-Atlantic ocean observing community. During these meetings we engaged discussions, collected information and initiated concrete actions with many pan-Atlantic stakeholders and users, all this by taking in account their connection to societal requirements for a sustained Atlantic Observing. The final outcomes, apart the networking engaging different communities itself, is the production of four community white papers published in peer-review international journals. In particular, these white papers show how the many discussions engaged with North and South Atlantic open-ocean observing programmes and national/local researchers have issued in partnership commitments for observations strategy, observing platform deployments, capacity building in observing, data analysis and modelling.

Moreover, in order to reinforce the regional integration, we also established a capacity-building programme by proposing in 2016 two dedicated cruises (the “MyScience” cruises) to South Atlantic undergraduate, master and PhD students. During these cruises, the international Atlantic students received a formation on ocean observations, oceanography-climate topics (including aspects in physics, biology and biogeochemistry) and work on South Atlantic/pan Atlantic research topics.

Finally, within our Atlantic observing integration action, we invited South Atlantic partner countries to participate to the first GO-SHIP SAMBA-SAMOC cruise that took place in January 2017 along the 34.5°S parallel between Cape Town and Brazil. The cruise and scientific analyses were achieved by the whole Pan-Atlantic group.

The various meetings organized in the framework of WP5 of AtlantOS are more precisely described in the following sections as well as the four community white papers and the oceanographic cruises.

Meeting 1 – “Assessing requirements for a regional Atlantic Observing system: Focus on the subpolar North Atlantic and Subtropical South Atlantic”. Side meeting during the 1st AtlantOS GA. June 29 2016, GEOMAR, Kiel, Germany.

We invited to this meeting the AtlantOS European partners and representatives of non-European countries bordering the Atlantic Ocean. We gathered stakeholders from Angola, Argentina, Brazil, Canada, Cape Verde, Morocco, Namibia, Nigeria, South Africa, United States of America and the European members of AtlantOS (Figure 2).

The discussions started with the description of national coordination and strategies. This segment of the meeting provided a panorama of the very diverse national observing approaches and requirements. In particular, while some countries with important observing capabilities are investing in open-ocean monitoring of the physical and biogeochemical state of the ocean, in addition to more coastal monitoring programs of ecosystems and fish-stocks, others are investing or would like to invest more in operational programs linked with fisheries and coastal management. These discussions also revealed important gaps in the regional Atlantic observing and in national capabilities (poorly sampled regions, not public release of data, poor or non existent biogeochemistry and biology sampling). We also discussed the application of the Framework of Ocean Observing (FOO) and of the Essential Ocean Variables (EOVs) the existence and benefits of which was not well known by many stakeholders.

The second part of the meeting was devoted to discuss a short-term program (starting in 2016 and be effective – and growing in its applications – during the AtlantOS project period) to sharing knowledge and best practices, observing platforms, and implement new coordinated observing strategies.

The implementation of this short-term program started the same year with the design of the “MyScience” oceanographic cruises dedicated to the at-sea training of 20 Phd and Master students coming from South and North Atlantic bordering countries. We decided also the implementation, for the first time, of a GO-SHIP cruise along the SAMOC-SAMBA line located on the 34.5°S parallel, connecting the SAMBA East and West moorings arrays that actually happened in January 2017, with on board many teams that participated to the Kiel meeting. It was also decided a collaboration on the RV James Cook 24°S transect that took place at the end of 2017.



Figure 2: The international pan-Atlantic community that gathered in Kiel, Germany from June 28 to July 1 2016 around the two Meetings (1 and 2) that we organized to start assessing the regional Atlantic observing system and the regional societal requirements that need to be taken into account by a future fit-for-purpose Atlantic observing system.

Meeting 2 – “Essential Ocean Variables for monitoring and assessment of marine biodiversity and ecosystem health” Workshop from 30. June – 1. July 2016 at, Steigenberger Conti Hansa, Schloßgarten 7, Kiel, Germany.

During this workshop, that happened the two days following our Meeting 1, always in Kiel, we discussed the opportunity of ocean observing integration across disciplines and platforms. This was motivated by the goal to better rationalize the operability of Atlantic ocean observations and proceeding to build a fit-for-purpose observing system for climate, ecosystems and fisheries.

This workshop was organized also to contribute to the IOC-UN Global Ocean Observing System (GOOS) effort to develop a framework of ocean observing to address operational needs on ocean physical, biogeochemical, and biological information. The GOOS framework has been modeled after the Framework for Ocean Observing (the FOO: Lindstrom et al., 2012), and it is meant to be nimble in addressing the needs of the ocean observing community. The potential of the GOOS framework is that information made available through it is required by industries (e.g., fisheries, shipping trade, mining), defense, and environmental agencies around the world. Partners in the process to develop the GOOS framework have included national observing programs, the World Meteorological Organization, the UN Environment Programme, and the International Council for Science. Increasingly, the GOOS framework is the basis for assessing ocean health. Until recently, GOOS provided advice mostly in the disciplines of physics, climate, and biogeochemistry (Miloslavich et al., 2015). The GOOS Physics Panel, formed in 1995, was built on the expertise and advice of the Ocean Observations Panel for Climate, while the GOOS Biogeochemistry Panel was built on the International Ocean Carbon Coordination Project. These groups defined their EOVs based on specific scientific and societal requirements driven mostly by climate change and the need for weather forecasts (Lorenzoni and Benway, 2013; Bauer et al., 2015) as well as in support of the requirements of the Global Climate Observing System in meeting the needs of the United Nations Framework Convention on Climate Change (Houghton et al., 2012; Bojinski et al., 2014).

The two-day workshop gathered a group of 60 experts, including AtlantOS partners and extra-European countries bordering the Atlantic. The participants brainstormed on the current state of defining the EOVs for the monitoring and the assessment of marine biodiversity and ecosystem health. Discussions brought up the main gaps in knowledge and the future needs in observing biodiversity, also in terms of fisheries management during a joint session on “Biodiversity and Fisheries”. The outcomes of the workshop fed into the GOOS Biology Panel and in the related EOVs that have been (at least partially) finalized during 2018 (Miloslavitch et al., 2018). The group felt that further discussions with a wider group were needed to progress in bridging climate, ecosystems, biodiversity and fisheries. We therefore decided to organize an *ad hoc* workshop on “Connecting climate, ocean and ecosystem observations” during the ICES/PICES/IOC Symposium on Climate Change and Impacts on the World’s Oceans, that effectively took place in July 2018 in Washington DC (USA).

Meeting 3 – Side event at the IAPSO Conference, Cape Town, Sept. 2017:

An ad-hoc meeting facilitated via the University of Cape Town and with a focus on climate and ecosystems was organized as a side event of the IAPSO Conference (27 August to 1 September 2017), in Cape Town, South Africa. This side event was meant to bring a first brainstorming on common observing objectives, phenomena, and the related observing variables for the subtropical South Atlantic and the subpolar North Atlantic. The side event raised a large interest from ocean stakeholders and in particular from those, from South Atlantic bordering nations, interested in marine ecosystem and fisheries management that usually do not participate to conferences on open ocean or climate sciences. We exchanged on the rationale behind the need of the FOO and GOOS framework implementation, on the rationalization of the ocean observing across scopes and objectives, on more concrete cooperative actions (and our South Atlantic colleagues, discussed the example of the benefits of the “MyScience” cruises and the collaborative achievement of the SAMBA-SAMOC 34.4°S GO-SHIP cruise), and on the interest of implementing robust best practices on ocean observations.

Meeting 4: Belem side-event “Connecting to better observe the Atlantic Ocean”; Location & Organizers: Altis Belem Hotel, Doca do Bom Sucesso, 1400-038 Lisboa, Portugal; Sabrina Speich (LMD/IPSL-ENS, Paris, France); Johannes Karstensen (GEOMAR, Kiel, Germany) with support from AtlantOS, AORA-CSA, 12. July 2017.

We have organized a very successful day-long side event during the High-Level Ministerial and Scientific Event “A New Era of Blue Enlightenment” in Lisbon, July 12, 2017 that has crowned the last couple of years of discussions and collaborations with southern and northern hemisphere colleagues and stakeholders. This meeting enabled to share a common vision, from the Northern to the Southern end of the Atlantic, of an Atlantic Observing System in the framework of Climate and Marine Ecosystems. These efforts also strongly contributed in the last months to achieve the signature of the Belem Statement in Lisbon, on July 13, 2017, by the European Commission, South Africa and Brazil. This agreement mirrors the North Atlantic Galway statement for the South Atlantic and it gives a well-framed setting for research and operational collaborations on the Atlantic Ocean Observing.

Meeting Objective:

To achieve a transition from a loosely-coordinated and fragmented set of existing ocean observing activities, into a system that is sustained and sustainable, efficient, and fit-for-purpose the current and emerging status of observational programs and projects in the context of climate and ecosystems for the Atlantic needs to be assessed.

In particular, a common understanding of requirements across the stakeholders of an Atlantic sustained ocean observing is required. Through a number of meetings in liaison with international conferences we aim to convene a large group of sustained Atlantic Observing System stakeholders with interest in climate, ecosystem and fisheries observing products in order to discuss their expectations and needs.

Outcomes of this event:

- We provided an introduction to, and examples for, a “*Framework for Ocean Observing (FOO)* – thinking” and showed how it links to real ocean observing problems
- We obtained an overview on expectations, current thinking, strategies from individual, countries & stakeholders
- We assembled the information that we successively used in various community white papers (actually in press on *Frontiers of Marine Science*): from the one on the Tropical Atlantic Observing System to that on “Connecting for better observing process” North and South Atlantic, on climate, ecosystem and fisheries.

Meeting 5 – AtlantOS GA Gran Canary Friday, 24th of September 2017 (09:00-15:00), PLOCAN, Gran Canary (AtlantOS GA facilities)

This has been a dedicated meeting with related groups in AtlantOS: WP1 – for capacities and gaps & requirement discussion and WP2 & WP3 – task leader/network representatives for input and discussion on network view about the *scientific objectives*, the *phenomena* and the *EOVs*.

AtlantOS has sponsored the ocean-observing enhancement in the South Atlantic via dedicated activities linked to deliverables (e.g. SOOP extension [UEXETER]; surface drifter deployments [EUMET]; Tuna modelling [CLS]; CPR surveys [SAFOS]; Animal telemetry [IMAR]; Sea Level catalogue [NERC]; South Atlantic EOV based product development [IFREMER]; and POGO fellowships [AWI]). At the PLOCAN AtlantOS GA Nov. 2017 workshop (“Mid-term project review of integrated regional observing”) organized by WP5 we reviewed these activities in the regional context.

Indeed, in the North Atlantic subpolar gyre, the observing activities on climate and ecosystems are strong and supported by a series of national and international projects. Not only is the region well covered by all sorts of Argo floats (standard, deep Argo, biogeochemical Argo) but also by long-term

moored installations such as the US Ocean Observation Initiative (OOI) global node “Irminger Sea”, the German “53°N array” and the “K1” in Labrador Sea, the long term observing system at the Greenland Scotland Ridges by the Faroese, Icelandic, German, and Norwegian moorings. Likewise, the region is surveyed by ship based long-term observation and by gliders e.g. in the framework of the UK Extended Ellett Line [UK/NERC] or the French OVIDE program [CNRS]. For the climate topic various aspects are routinely monitored as well as process studies being executed, such as the warm to cold water transformation and the various science questions associated with it: carbon sequestration, air/sea gas exchange, Spring bloom onset and duration, heat and freshwater transport, and of course the connection with/export to the Arctic (e.g. via the Nordic Seas/Barents Sea link) as well as the import across the Greenland Scotland Ridges and the Baffin Bay.

Linkages between all these observing efforts still have room for improvement, for example the link with the sustained ecosystem observations performed in the context of the Intergovernmental Organization ICES, one of the leading ecosystem management/fisheries organizations, is not as well developed as it could. Communication with ICES, via WP5 initiated meetings but also in the context of WP2 (plankton acoustic surveys) and WP1 (requirements) exists and we further built on this during 2018 and 2019.

Meeting 6 – The first Tropical Atlantic Observing System Review Workshop, Hilton Hotel, 8 -9 February 2018, Portland USA

Among the various regions of the Atlantic Ocean, the Tropical Atlantic observing system was, to our end, the longest coordinated effort among different nations for a fit-for-purpose observing system, especially (but not only) because of the long-lasting effort of PIRATA (Prediction and Research Moored Array in the Tropical Atlantic), the achievement of the FP7 EU project Enhancing Prediction of Tropical Atlantic Climate and its Impacts (PREFACE) and the synergy with AtlantOS. PIRATA in 20 years has also expanded to new sites and has enhanced its measurement suite with higher vertical resolution in the mixed layer, and new CO₂ and O₂ measurements.

It was therefore timely to systematically review the requirements for sustained observations in the tropical Atlantic, and to critically review the design of the sustained observing system in order to take advantage of what has been learned to date, to collectively identify new opportunities to build on past accomplishments, and to explore the possibility for expanded interdisciplinary initiatives with other communities, e.g. in biogeochemistry. To that end, a Tropical Atlantic Observing System (TAOS) review was proposed by the CLIVAR Atlantic Region Panel (ARP) and H2020 AtlantOS partners are participating actively in it, seeking involvement of the large Tropical Atlantic Ocean community as well as other multidisciplinary programs such as the International Ocean Carbon Coordination Project (IOCCP), the Integrated Marine Biosphere Research Program (IMBeR) and Surface Ocean - Lower Atmosphere Study (SOLAS), among others, as key partners in the review process.

We hoped that the results of the TAOS review could feed into the AtlantOS design strategy that is currently being formulated in advance of the OceanObs'19 conference. We decided that the TAOS review should be forward looking and strategic, and focus on possible changes to the observing system in the next decade. It should consider new observing technologies, observing system requirements from the user community (e.g. weather and climate forecasts), and observational products that will be delivered. The review should be guided by the FOO and make recommendations toward an adequate governing mechanism. The review should be comprehensive across all relevant observing system networks, including satellite observations, but with the focus primarily on the in situ observing system, and should consider atmospheric parameters (e.g. winds, surface fluxes) as well as aerosols, biogeochemistry and biology within the framework of a single integrated observing system.

We organized the kickoff workshop of the TAOS Review committee and community in parallel to the 2018 Ocean Sciences conference (February 2018, Portland, OR, USA). The workshop was organized into four main sessions on the following topics:

Session 1: Requirements for the Tropical Atlantic Observing System (co-chairs: S. Speich, M. Balmaseda)

Session 2: Tropical Atlantic Observing System Networks: Current Status and plans to 2030 (chair: B. Johns)

Session 3. Data Flow and Information Products (chair: N. Smith)

Session 4. Governance, Review, and Resourcing (chair: K. Hill)

Most of the time during the workshop was devoted to topics 1 and 2, with the goal of accomplishing at this first workshop a thorough review of:

(1) the state of knowledge of the tropical Atlantic regarding key science and operational drivers relevant to societal applications, and

(2) the present state of the tropical Atlantic observing system and its capabilities for delivering the necessary data and information products toward these applications.

In the ensuing discussions the participants were asked to consider the question: What is the key information that is being (a) successfully provided and (b) missing from the Tropical Atlantic observing system for these science/societal drivers?

Presentations were given on a wide range of topics covering the modes of tropical Atlantic variability and their known climate consequences, issues related to operational weather and extreme event forecasting, data assimilation, climate projection, and biogeochemical and biological/fisheries applications. The various elements of the present TAOS including mooring arrays, autonomous devices, satellite observations, and vessel-based observations were also thoroughly reviewed. On the second day of the workshop the mechanisms and effectiveness of data delivery from the existing tropical Atlantic observing system, and considerations on possible future governance and resourcing for the TAOS, were also briefly discussed.

Session summaries prepared by the session chairs outlining the main outcomes and recommendations from the workshop as well as the extended abstracts from each of the presenters in sessions 1 and 2 are included in the Workshop Report available from the CLIVAR website:

<http://www.clivar.org/sites/default/files/documents/1st%20TAOS%20Review%20Workshop%20Report%20final.pdf>

The workshop was a successful first step in evaluating the present TAOS and considering possible future enhancements or modifications to the TAOS. The general conclusion from this workshop was that the observational community in the Tropical Atlantic is a relatively tightly knit group that currently enjoys a high degree of collaboration and effective leveraging of its resources, but that the TAOS as a whole could benefit from further integration across its various data platforms and efforts to enhance and streamline data delivery.

The following two meetings:

Meeting 7 – Ocean Sciences 11-16 February 2018 Portland OR, USA: “Connecting climate, ocean and ecosystem observation” – Ocean observation futures: Ocean Sciences Meeting, Portland USA, Thursday February 15, 2018 10:00 AM to 01:00PM (Oregon Convention Center - C120-C121)

Meeting 8 – 4th ICES/PICES/IOC Symposium on Climate Change and Impacts on the World’s Oceans Washington DC : W8 Workshop, Connecting climate, ocean and ecosystem observation – Ocean observation futures, Jun 03, 2018, 08:30am – 06:00pm

were organized to strengthen the link with stakeholders, including biodiversity and fisheries. Indeed, Fisheries provides more than 500 million people with food and income, and thus supports their livelihoods. Sustainable management of fisheries is a means to sustain these livelihoods. The basis for

management is an understanding of the system and thorough monitoring of its state and changes in light of multiple pressures. To provide the basis for this understanding, as well as identifying and monitoring relevant ecosystem components, many countries and organizations plan and conduct observations. Ocean observation is also conducted for other purposes like understanding ocean state and processes, today increasingly in light of climate variability and change. However, the different ocean observation communities rarely communicate and thus synergies of identifying objectives and planning observing frameworks rarely happen. These meetings further explored the outcomes of the Kiel 2016 Workshop. Namely they explored options for a future observing system for marine ecosystems by i) identifying needs for different user groups, ii) describing available large datasets and existing technologies, and iii) recommending observational approaches for Ecosystem Based Management.

The outcomes of the two workshops that were very well attended (more than 50 participants each) have been concretized in a peer-reviewed paper that will soon be published by *Frontiers in Marine Sciences* (Schmidt et al., 2019). This article also presents regional case studies and explains how process studies can be linked to long-term monitoring. It concludes by describing capacity development needs and the vision for ocean observing in support of the Ecosystem Based Fisheries Management.

Meeting 9 – AtlantOS at the Belém All-Atlantic Research Forum, Salvador (Brazil) from the 23-24th of July 2018.

The Belém All-Atlantic Research Forum took place in Salvador (Brazil) from the 23-24th of July 2018. The objective of this meeting was to advance in the implementation of the “Belém Statement”, continuing the progress made since its signing in July 2017, in Lisbon, Portugal, and strengthening the successful partnership with the European Commission (DG- RTD) and the Department of Science and Technology of Brazil and South Africa. Just before the formal start of the Forum, on July 22nd afternoon, two more informal meetings took place: The South-South dialogue organized by Brazil and South Africa to extend the cooperation to other countries of the South Atlantic. To be noted the official participation of the delegation of the Ministers of Science and Technology from Argentina and Uruguay; In parallel, the European groups gathered together to discuss the status of the implementation of the Belém Statement and its way forward.

The Forum was officially opened on July 23rd by the local authorities and the main representatives from EU John Bell, the European Commission DG RTD Director of Bioeconomy, Thomas Auf der Heyde, Department of Science and Technology of South Africa and Andrei Polejack Ministry of Science, Technology, Innovation and Communications of Brazil.

This meeting sought to reaffirm the importance of ocean research informing the research partnership between Brazil, South Africa and Atlantic neighboring countries and the European Union after the signing of the Belém statement in July 2017 in Lisbon (Portugal). AtlantOS contributed by demonstrating the socioeconomic and political need for the Belém Partnership.

Meeting 10 – The second Tropical Atlantic Observing System Review workshop, October 2018, Marseille, France.

During this meeting we reviewed the "Key Science and Operational Drivers for the TAOS" by emphasizing the (a) gaps in observing system and recommendations, (b) EOV's, and (c) what parts of present TAOS are most essentially contributing to each topic, and how). We summarized the enhancements/modifications and we rationalized them by trying to frame the key enhancements that should be recommended for the TAOS, and what elements of the present TAOS are "least critical/least essential", i.e. where could savings potentially be made to allow room for enhancements. This meeting led to long discussions leading to an action of rationalizing the TAOS through an assessment of observing requirements within a FOO and EOVs framework. This work that has been assigned to the TAOS Review committee together with various stakeholders and end users identified during the

AtlantOS WP5.1 task and the TAOS meetings should deliver a first TAOS Review Report to stakeholders for review.

Meeting 11 – the 20 POGO Ocean Science Centre Mindelo (OSCM) and Instituto Nacional de Desenvolvimento das Pescas (INDP), Cabo Verde 19-25 January 2019.

AtlantOS actively participated to the 20th POGO Annual Meeting (POGO-20). The meeting was held from 21-25 January 2019, hosted by the Instituto Nacional de Desenvolvimento das Pescas (INDP) and the GEOMAR Helmholtz Centre for Ocean Research Kiel, at their newly inaugurated joint research venue, the Ocean Science Centre Mindelo (OSCM) on the island of Sao Vicente, Cabo Verde. The participants were welcomed by the meeting hosts, Dr. Osvaldina Silva, Director of INDP, and Prof. Peter Herzig, Director of GEOMAR, and the meeting was officially inaugurated by H.E. the Minister of Maritime Economy of Cabo Verde.

The POGO-20 Meeting was extremely well attended, bringing together 86 delegates from 25 countries. The meeting location was strategically chosen to bring in African countries to contribute to the global ocean observing agenda, and to become members of POGO. Thus, representatives of institutions and universities in Benin, Côte d’Ivoire, Ghana, Nigeria, Senegal and Tunisia were present and provided valuable insights into the needs and priorities of northern and western African countries.

We organized a topical sessions focused on “Sustained observing in the South Atlantic Ocean and beyond”, “Ocean observing technology and sensor development”, and a lunch Side Event on Capacity Development. The large pan-Atlantic participation led to include new countries requirements and enlarge the pan-Atlantic observing network we have established so far. The network included also the Colombian *Instituto de Investigaciones Marinas y Costeras* (INVEMAR). Sabrina Speich will be actively work during 2019 in Colombia (nominated by the Colombia Presidency in a group of *Savios*) to help the government to build a new strategy on ocean research and innovation.

AtlantOS “MyScience” cruises

Knowledge transfer and capacity development is key in the process in connecting ocean observing with society. In order to reinforce the regional integration activities capacity-development activities were executed. In the western and eastern South Atlantic three cruises (“MyScience cruises” March 2016 M124, Dec 2017 M133; Coastal upwelling cruise RV Meteor M148) were made with a focus on capacity development and mainly with undergraduate, master and PhD students on board. During these cruises, the international Atlantic students studied and worked on ocean observations, oceanography-climate topics (including aspects in physics, biology and biogeochemistry) and on South Atlantic/pan Atlantic research topics. The first “MyScience” cruise (M124) took place in February/March 2016 on the German RV Meteor (chief scientist J. Karstensen (GEOMAR, Germany), senior scientist S. Speich (CNRS-ENS, France). The second “MyScience” cruise was conducted in December 2017, again on board the German RV Meteor (chief scientist M. Visbeck (GEOMAR, Germany)). Both “MyScience” cruises crossed the South Atlantic, leaving from Cape Town (South Africa) while M133 arrived in the Malvinas/Falkland Islands and M124 in Rio de Janeiro (Brazil). Both cruises took on board 15 students from as much as 11 different Atlantic bordering countries. The concept behind “MyScience” cruises is that the students work up their own science projects during the cruise also including the “own” data collected at sea. Moreover, the students participate in the standard watch system of the cruise.

The RV Meteor M145 (chief scientist M. Dengler (GEOMAR, Germany)) concentrated on the eastern boundary upwelling system of the South Atlantic. Again the “MyScience” cruise concept was applied but the students stayed also for a period of time in an institution (GEOMAR) working up the data from the cruise.

AtlantOS knowledge transfer cruises

Within the various observing activities undertaken under AtlantOS the first GO-SHIP cruise along the SAMBA-SAMOC zonal section between Cape Town and Brazil, along the 34.5°S was conducted. The science crew came primarily from South Atlantic AtlantOS partner countries. RV Maria S Merian cruise MSM60 (chief scientist J. Karstensen (GEOMAR, Germany) took place in January 2017 from Cape Town (South Africa) to Montevideo (Uruguay). The full suite of GO-SHIP cruise requirements was targeted for the cruise.

Within the North Atlantic the two Maria S Merian cruises MSM54 (May 2016) and MSM74 (May/June 2018) brought together scientists from Europe, Canada and the US to exchange science and technology knowledge of high latitude observing. Activities were embedded in the truly international, basin wide observing array OSNAP (*Overturning in the Subpolar North Atlantic Program*).

Discussion and Conclusions

For the analysis of the regional observing and the connected societal requirements, we followed a twofold approach: we organized a sequence of meetings in conjunction with other international events related to climate, fisheries, and Atlantic observing (including AtlantOS GA) to connect the various stakeholders from east/west and north/south. We synthesized requirements but also observed the different processes that may be required to better connect ocean observing to stakeholder needs.

The meetings we have organized revealed that integration of climate and ecosystem observations (resp. fisheries) is well advanced in many of the South Atlantic bordering countries (east and west) that may also reflect the close linkage with the economically important fishery industry. Along the West African coastline, the observing activities are in many cases closely linked to the FAO fisheries program, and in particular to the FV FRITJOF NANSEN project. The NANSEN can be considered a key observing element for research and monitoring in coastal/open ocean transition region for the whole West African coast. In addition, substantial national investments in observing is seen e.g. the new Angolan Fisheries Research Vessel or the moored systems off Senegal and Namibia. Recent R & D activities within the EU FP7 PREFACE project, national collaborative programs (French IRD), and other efforts such as the Eastern Boundary Upwelling Systems multidisciplinary observing initiative "Variability in the Oxycline and its Impacts on the Ecosystem (VOICE)" all contribute to improvement and optimization of climate and fisheries/ecosystem ocean observing in these regions. However, when it comes to observing the South Atlantic open ocean, current in-situ activities are sparse.

The collection of a review of the actual observing under different societal needs and the requirements for a fit-for-purpose observing system addressing such needs are fully described in the following 11 manuscripts that these meetings have incited and to which we thoroughly contributed:

Community Whitepapers produced:

Benveniste, Jérôme, Anny Cazenave, Stefano Vignudelli, Luciana Fenoglio-Marc, Rashmi Shah, Rafael Almar, Ole Baltazar Andersen, Florence Birol, Pascal Bonnefond, Jérôme Bouffard, Francisco Mir Calafat, Estel Cardellach, Paolo Cipollini, Gonéri Le Cozannet, Claire Dufau, M.Joana Fernandes, Frédéric Frappart, James Garrison, Christine Gommenginger, Guoqi Han, Jacob L Høyer, Villy Kourafalou, Eric Leuliette, Zhijin Li, Hubert Loisel, Kristine Skovgaard Madsen, Marta Marcos, Angélique Melet, Benoit Meyssignac, Ananda Pascual, Marcello Passaro, Serni Ribó, Remko Scharroo, Y.Tony Song, Sabrina Speich, John Wilkin, Philipp Woodworth and Guy Woppelman: **Requirements for a Coastal Zone Observing System**, 2019. *Frontiers in Marine Sciences*. Under Review.

Foltz, Gregory R., Peter Brandt, Ingo Richter, Belen Rodriguez-fonseca, Fabrice Hernandez, Marcus Dengler, Regina R. Rodrigues, Jörn Oliver Schmidt, Lisan Yu, Nathalie Lefevre, Leticia Cotrim Da Cunha, Michael James McPhaden, Moacyr Cunha de Araujo Filho, Johannes Karstensen, Johannes Hahn, Marta Martín-Rey, Christina M. Patricola, Paul Poli, Paquita Zuidema, Rebecca Hummels, Renellys C. Perez, Vanessa Hatje, Joke Luebbecke, Irene Polo, Rick Lumpkin, Bernard Bourlès, Francis E.

Asuquo, Patrick Lehodey, Anna Conchon, Ping Chang, Philippe Dandin, Claudia Schmid, Adrienne J Sutton, Herve Giordani, Yan Xue, Serena Illig, Teresa Losada, Semyon Grodsky*, Florent Gasparin, Tong Lee, Elsa Mohino, Paulo Nobre, Rik Wanninkhof, Noel S Keenlyside, Veronique Garcon, Emilia Sanchez-Gomez, Hyacinth C. Nnamchi, Marie Drevillon, Andrea Storto, Elisabeth Remy, Alban Lazar, Sabrina Speich, Marlos Pereira Goes, Tarquin Dorrington, William E. Johns, James N. Moum, Carol Robinson, Coralie Perruche, Ronald Buss de Souza, Amadou Gaye, Maria Lopez-Parages, Paul-Arthur Monerie, Paola Castellanos, Nsikak U. Benson, Mahouton Norbert Hounkonnou and Janice Trotte Duha: **The Tropical Atlantic Observing System**, 2019. *Frontiers in Marine Sciences*. Under Review.

Frajka-Williams, Eleanor, Isabelle J. Anson, Johanna Baehr, Harry L. Bryden, Maria Paz Chidichimo, Stuart A. Cunningham, Gokhan Danabasoglu, Shenfu Dong, Kathleen A. Donohue, Shane Elipot, N. Penny Holliday, Rebecca Hummels, Laura C. Jackson, Johannes Karstensen, Matthias Lankhorst, Isabela A. Le Bras, M. Susan Lozier, Elaine L. McDonagh, Christopher S. Meinen, Herlé Mercier, Bengamin I. Moat, Renellys C. Perez, Christopher G. Piecuch, Monika Rhein, Meric Srokosz, Kevin E. Trenberth, Sheldon Bacon, Gael Forget, Gustavo Goni, Patrick Heimbach, Dagmar Kieke, Jannes Koelling, Tarron Lamont, Gerard D. McCarthy, Christian Mertens, Uwe Send, David Smeed, Sabrina Speich, Marcel van den Berg, Denis Volkov, Chris Wilson. **Atlantic Meridional Overturning Circulation: Observed transport and variability**, 2019. *Frontiers in Marine Sciences*. Under Review.

Garcon, Veronique C., Johannes Karstensen, Artur Palacz, Maciej Telszewski, Tony Aparco Lara, Denise Breitburg, Francisco Chavez, Paulo Coelho, Marcela Cornejo, Carmen Dos Santos, Bjoern Fiedler, Natalya Gallo, Marilaure Gregoire, Dimitri Gutierrez, Jose M. Hernandez-Ayon, Kirsten Isensee, Tony Koslow, Lisa A. Levin, Francis Marsac, Helmut Maske, Baye C. Mbaye, Ivonne Montes, Syed Wajih A. Naqvi, Jay S. Pearlman, Edwin Pinto, Grant C. Pitcher, Oscar Pizarro, Kenneth Rose, Damodar Shenoy, Anja K. Van Der Plas, Melo R. Vito, Kevin Weng, **Multidisciplinary Observing in the World Ocean's Oxygen Minimum Zone regions: from climate to fish- the VOICE initiative**, 2019. *Frontiers in Marine Sciences*. Under Review.

Meysignac, Benoit, Tim Boyer, Zhongxiang Zhao, Maria Z Hakuba, Felix W Landerer, Detlef Stammer, Armin Köhl, Seiji Kato, Tristan L'Ecuyer, Michael Ablain, John Patrick Abraham, Alejandro Blazquez, Anny Cazenave, John A Church, Rebecca Cowley, Lijing Cheng, Catia Domingues, Donata Giglio, Viktor Gouretski, Masayoshi Ishii, Gregory C Johnson, Rachel E Killick, David Legler, William Llovel, John Lyman, Matthew Dudley Palmer, Steve Piotrowicz, Sarah Purkey, Dean Roemmich, Rémy Roca, Abhishek Savita, Karina von Schuckmann, Sabrina Speich, Graeme Stephens, Gongjie G Wang, Susan Elisabeth Wijffels and Nathalie Zilberman: **Measuring Global Ocean Heat Content to estimate the Earth Energy Imbalance**, 2019. *Frontiers in Marine Sciences*. Under Review.

Palmer, Matthew Dudley, Paul Durack, Maria Paz Chidichimo, John Church, Sophie E Cravatte, Katherine Louise Hill, Johnny Johannessen, Johannes Karstensen, Tong Lee, David Legler, Matthew Mazloff, Eitarou Oka, Sarah Purkey, Ben Rabe, Jean-Baptiste Sallée, Bernadette Marie Sloyan, Sabrina Speich, Karina von Schuckmann, Josh Willis and Susan Elisabeth Wijffels: **Adequacy of the ocean observation system for quantifying regional heat and freshwater storage and change**, 2019. *Frontiers in Marine Sciences*. Under Review.

Jay S. Pearlman, Mark Bushnell, Laurent Coppola, Pier Luigi Buttigieg, Françoise Pearlman, Pauline Simpson, Michele Barbier, Johannes Karstensen, Frank E. Muller-Karger, Christian Munoz-Mas, Peter Pissierssens, Cynthia L. Chandler, Juliet Hermes, Emma Heslop, Reyna Jenkyns, Eric 'Achterberg, Manuel Bensi, Henry Bittig, Jerome Blandin, Julie A. Bosch, Bernard Bourlès, Roberto Bozzano, Justin J. Buck, Eugene F. Burger, Daniel Cano, Vanesa Cardin, Miguel Charcos Llorens, Andres Cianca, Chen Hua, Caroline Cusack, Eric Delory, Rene Garello, Gabriele Giovanetti, Valerie Harscoat, Robert Heitsenrether, Simon Jirka, Ana Lara-Lopez, Nadine Lanteri, Adam M. Leadbetter, Giuseppe M. Manzella, Joan Masó, Andrea Mccurdy, Eric Moussat, Manolis Ntoumas, Sara Pensieri, George Petihakis, Nadia Pinardi, Sylvie Pouliquen, Rachel Przeslawski, Nicholas Roden, Joe Silke, Mario Tamburri, Hairong Tang, Toste Tanhua, Pierre Testor, Julianna O. Thomas, Christoph Waldmann, Fred Whoriskey. **Evolving and Sustaining Ocean Best Practices and Standards for the Next Decade**. 2019. *Frontiers in Marine Sciences*. Under Review.

Schmidt, Jörn Oliver, Steven J. Bograd, Haritz Arrizabalaga, Steven J. Barbeaux, John A Barth, Tim Boyer, Stephanie Brodie, Scott Cross, Jean-Noel Druon, Agneta Fransson, Jason Hartog, Elliott Hazen, Johannes Karstensen, Alistair James Hobday, Michael Jacox, Sven Kupschus, Jon Lopez, Lauro A. S.-P. Madureira, José Eduardo Martinelli Filho, Patricia Miloslavich, Cristina Pereira Santos, KYlie Scales, Sabrina Speich, Matthew B. Sullivan, Amber Szoboszlai, Desiree Tommasi, Douglas Wallace

and Stephani Zador, **Future ocean observations to connect climate, fisheries and marine ecosystems**, 2019. *Frontiers in Marine Sciences*. Under Review.

Sloyan, Bernadette Marie, John Wilkin, Katherine Louise Hill, Maria Paz Chidichimo, Meghan F. Cronin, Johnny A. Johannessen, Johannes Karstensen, Marjolaine Krug, Tong Lee, Eitarou Oka, Matthew Dudley Palmer, Benjamin Rabe, Sabrina Speich, Robert Andrew Weller and Weidong Yu: **Towards a global ocean observing system for research and applications (from operational services to climate)**, 2019. *Frontiers in Marine Sciences*. Under Review.

Stammer, Detlef, Annalisa Bracco, Krishna AchutaRao, Lisa Beal, Nathan Bindoff, Pascale Braconnot, Wenju Cai, Dake Chen, Matthew Collins, Gokhan Danabasoglu, Boris Dewitte, Riccardo Farneti, Baylor Fox-Kemper, John Fyfe, Stephen Griffies, Steven Robert Jayne, Alban Lazar, Matthieu Lengaigne, Xiaopei Lin, Simon Marsland, Shoshiro Minobe, Pedro Monteiro, Walter Robinson, Roxy Mathew Koll, Ryan Rykaczewski, Sabrina Speich, Inga Smith, Amy Solomon, Andrea Storto, Ken Takahashi, Thomas Tonazzo and Jerome Vialard: **Ocean climate observing requirements in support of Climate Research and Climate Information**, 2019. *Frontiers in Marine Sciences*. Under Review.

Among these manuscripts, two address the integration of the observing across climate, ecosystem and fisheries societal requirements. In Schmidt et al. (2019), for example, a vision for ocean observing in support of ecosystem-based fisheries management (EBFM) is given. EBFM is a general approach (not only Atlantic) agreed on by the Food and Agriculture Organization (FAO) of the United Nations (UN) and individual countries to lead fisheries management and thus closely connected with the WP5 objectives. It is a certain realization of the ocean observing value chain (Figure 3). One big challenge in EBFM is that it requires observing across a vast range of scales and disciplines from short-term environmental variability to long-term climate influence and indirect impacts of other anthropogenic activities which alter habitat and ecosystem alike. EBFM is a prime case to clearly spell out the value of observations and link it to society and funding by taxpayers. Depending on the local/national/international implementation the value chain added a “Feedback loop” that is foreseen to enable a co-design element to all components of the value chain (Figure 3).

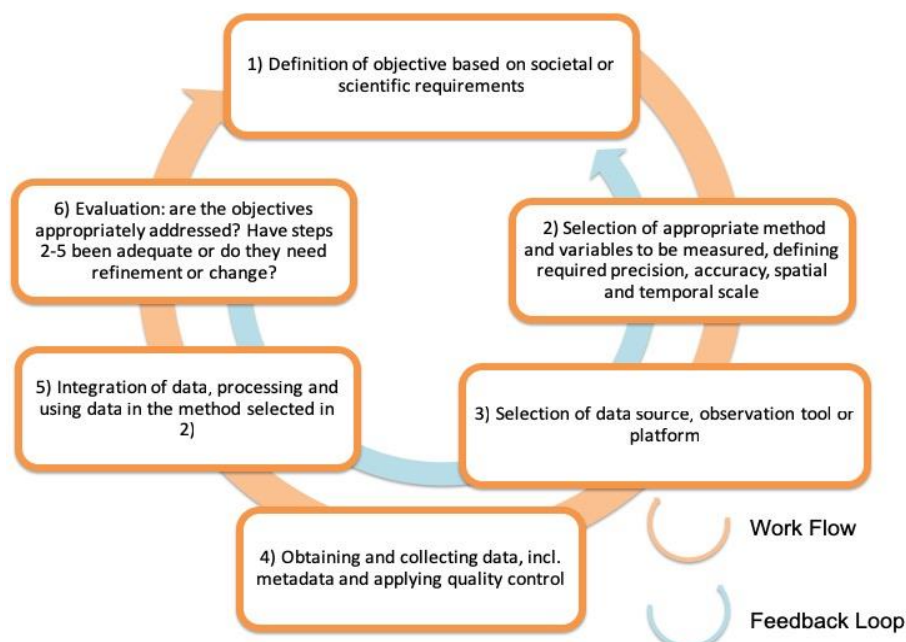


Figure 3: The Ocean observing value Chain for with a “feedback loop” that shall enable a stakeholder dialogue and appropriate interaction between ocean data users and observers. (Schmidt et al. submitted).

However, Schmidt et al. (2019) identify:

- A need for “tools” such as ecosystem services analyses, that relate specific observations to societal needs to enable advice on the observing that is needed and which is ultimately a societal decision based on costs, risk, and benefits.
- One important gap in the current ocean observing, not only for EBFM, is the inability to allow a thorough evaluation of the data flow, from generation to end use observing. Observational data is not traceable. The consequences are: (a) the value of observational data cannot be explicitly exposed or even measured; (b) the feedback mechanisms along the ocean observing value chain is missing and the different communities (observation, assessment, modelling) are not able to understand their needs and to evaluate and co-design.
- Another important issue in the context of EBFM, but also evident during the course of AtlantOS in many application areas, is the fragmentation on governance between national and international organizations and programs with different disciplinary communities and institutions leading to a clear lack of harmonization of needs.

Another manuscript integrating across requirements is Garcon et al. (2019). In this paper ocean observing related to deoxygenation in connection with oxygen minimum zones is considering societal relevant issues such as the impact on fisheries. The VOICE (Variability of the oxycline and impact on the ecosystems) demonstrates how societal benefits drive the need for integration and optimization of physical, biogeochemical and biological components of regional ocean observing. Building on the FOO, VOICE initiated readiness level (RL) assessments for ocean observing of the oxycline in highly productive and economically important OMZ waters. VOICE determines ocean observing design based on scientific and monitoring activities in selected OMZs including the AtlantOS ones. Regional champions aided in assessing FOO design elements for the respective OMZ, namely: requirements processes, coordination of observational elements, and data management and information products. The RL for FOO elements is derived for each region and points at system bottlenecks which prevent delivering information and products for end users with a goal of motivating consistency across regions. We found that fisheries and ecosystem management are a societal requirement for all regions, but maturity levels of observational elements and data management and information products differ.

During the project period we also implemented concrete and diverse actions to engage and cross fertilize Atlantic ocean observers through knowledge transfer and capacity development. Capacity development by introducing the “MyScience” cruise concept at the selected cruise in the South Atlantic, addressed undergraduate, master and PhD students from North/South/East/West. Knowledge transfer was addressed during two cruise in the subpolar North Atlantic and with the first GO-SHIP cruise along 34.5°S. Each cruise will prevail as an H2020 “AtlantOS” project legacy.

References

- Bauer, P., Thorpe, A., and Brunet, G. (2015). The quiet revolution of numerical weather prediction. *Nature* 525, 47–55. doi: 10.1038/nature14956
- Bojinski, S., Verstraete, M., Peterson, T. C., Richter, C., Simmons, A., and Zemp, M. (2014). The concept of essential climate variables in support of climate research, applications, and policy. *Bull. Amer. Met. Soc.* 95, 1431–1443. doi: 10.1175/BAMS-D-13-00047.1
- Houghton, J., Townshend, J., Dawson, K., Mason, P., Zillman, J., and Simmons, A. (2012). The GCOS at 20 years: the origin, achievement and future development of the global climate observing system. *Weather* 67, 227–235. doi: 10.1002/wea.1964
- Lorenzoni, L., and Benway, H. M. (2013). *Global Intercomparability in a Changing Ocean: An International Time-Series Methods Workshop*. Bermuda: Bermuda Institute of Ocean Sciences

- Lindstrom, E., Gunn, J., Fischer, A., McCurdy, A., & Glover, L. K. (2012). A framework for ocean observing. By the task team for an Integrated Framework for Sustained Ocean Observing. Paris, France: UNESCO.
- Miloslavich, P., Appeltans, W., Bax, N., Fischer, A., Gunn, J., Marsac, F., et al. (2015). GOOS: a platform to observe essential ecological and biological variables. *Interciencia* 40, 510.
- Miloslavich, P, Bax, NJ, Simmons, SE, et al. (2018) Essential ocean variables for global sustained observations of biodiversity and ecosystem changes. *Glob Change Biol.* 2018; 24: 2416–2433. <https://doi.org/10.1111/gcb.14108>

Annexe 1: Atlantic Ocean regional observing integration. Meetings and Workshop programs

Meeting 2 :“Essential Ocean Variables for monitoring and assessment of marine biodiversity and ecosystem health” Workshop from 30. June – 1. July 2016 at, Steigenberger Conti Hansa, Schloßgarten 7, Kiel, Germany

Meeting Program:

Thursday, 30th June (joint sessions at AtlantOS GA)

10:30 – 11:40	Expert session <ul style="list-style-type: none"> • Biodiversity Monitoring: observations, challenges, and the Marine Biodiversity Observation Network (MBON) - Gary Geller (GEO) • A brief introduction to the challenges in ecosystem and fisheries observations - Mark Dickey-Collas (ICES) • Technology of bio & fish instrumentation and survey - Matt Mowlen (NOC) • The ATLAS project: a trans-Atlantic assessment and deep-water ecosystem-based spatial management plan for Europe - Murray Roberts & the ATLAS consortium (HWU) • Deep-sea Sponge Grounds Ecosystems of the North Atlantic: an integrated approach towards their preservation and sustainable exploitation - Ute Hentschel Humeida (GEOMAR)
11:40 – 12:30	Panel discussion on “Biodiversity & Fishery”
12:30 – 13:30	Lunch
13:30 – 15:30	Break-out groups “Biodiversity & Fishery within ocean observation” - a reflection regarding AtlantOS <ul style="list-style-type: none"> • Observation (e.g. strategies and instruments) • Requirements (EBDV = EOY) • Products (communication/feedback/societal benefit) • Coordination of South Atlantic Activities (follow-up from 2015 workshop)
15:30 – 16:00	Coffee break
16:00 – 17:00	Presentation of the workshop results
17:00 – 18:00	Final discussion, open question, synergies with associated Blue Growth projects - Next steps
18:00 – 18:30	Break with drinks
18:30 – 19:00	Short welcome to the workshop (detached from AtlantOS GA) Inspirational talk on Science Communication and Stakeholder Dialogue - Ulrike Wolpers (science stories)
19:00 – 19:30	Poster espresso
19:30 – 22:00	Poster presentation, dinner & icebreaker

Friday, 1st July

8:30 – 9:00	Welcome Introduction of participants and objectives of workshop - Isabel Sousa Pinto (University of Porto) Report from Expert session AtlantOS - Jörn Schmidt (Kiel University)
9:00 – 10:15	Review global requirements for biodiversity and ecosystem observations <ul style="list-style-type: none"> • Biodiversity Policy and Response: GEO BON's Marine Biodiversity Observation Network (MBON) - Gary Geller (GEO) • EU regulatory framework: Common Fisheries Policy, MSFD and MSP - Mark Dickey-Collas (ICES)

	<ul style="list-style-type: none"> Existing data frameworks (Extended Darwin Core) - Klaas Deneudt (VLIZ) Long-term biodiversity data for research and monitoring trends through time- Amanda E. Bates (University of Southampton) 15 minutes discussion
10:15 – 11:00	How to define a minimal set of Variables? <ul style="list-style-type: none"> Identifying priorities for global monitoring of marine biology and ecosystems - Patricia Miloslavich et al. (AIMS) GEO BON proposed EBV and related proposals - Mark Costello (University of Auckland) 15 minutes discussion
11:00 – 11:30	Coffee break
11:30 – 13:00	Observing methods (survey – targeted versus opportunistic; integration in GOOS platforms; drifters, gliders) <ul style="list-style-type: none"> Marine Biodiversity Observation Networks (MBON) - Francisco Chavez & the MBON team (MBARI) ICES experience in fishing monitoring in Atlantic - Heino Fock (Thünen-Institute of Sea Fisheries) EAF Nansen Survey Project - fish and ecosystem surveys in the South Atlantic - Marek Ostrowski (IMR) ??? - (???) Opportunities for a global animal tracking and telemetry system - Fred Whoriskey (Dalhousie University) 15 minute discussion - synthesis of lessons in field and theoretical proposals
13:00 – 14:00	Lunch
14:00 – 16:00	Break-out groups Summarizing e.g.: <ul style="list-style-type: none"> Policy needs (Capabilities versus reality) Data management structures (Data acquisition) Proposed variables and field experiences (EOVs – spec sheets) Prioritizing observations or variables (What to measure first?)
16:00 – 16:30	Coffee break (Summary compiled by rapporteurs)
16:30 – 18:00	Summary of Working groups Recommendations regarding the way to move forward in developing “EOV for biodiversity and ecosystem health” Preparations for white paper, final discussions, closing remarks

Meeting 5 – Belem side-event “Connecting to better observe the Atlantic Ocean”; Location & Organizers: Altis Belem Hotel, Doca do Bom Sucesso, 1400-038 Lisboa, Portugal; Sabrina Speich (LMD/IPSL-ENS, Paris, France); Johannes Karstensen (GEOMAR, Kiel, Germany) with support from AtlantOS, AORA-CSA, 12. July 2017; 09:30am-07:30pm

Meeting agenda:

Fit-for-purpose multidisciplinary ocean observing from a strategic point of view		
<i>General introduction to on-going international efforts and strategies for better framing the challenges in multidisciplinary ocean observing</i>		
09:30-10:00	Introduction to Workshop & Tour de table incl. AtlantOS??	Speich/Karstensen
10:00-10:30	How to organize observations? An introduction to the <i>Framework for Ocean Observing</i>	T. Tanhua
10:30-11:00	Ocean Observing from a system design viewpoint: What can we expect from observing networks such as Argo, GO-SHIP, SOT, OceanSITES etc.?	J. Karstensen
11:00-11:30	Coffee break	
11:30-12:00	A Blue Print for Atlantic Ocean observing – an introduction	B. deYoung
12:00-12:30	Round table discussion (30')	
12:30-13:45 (1h15')	Networking lunch (across the three parallel sessions on „Building an Atlantic Community“)	

Atlantic observing challenges and approaches: An incomplete overview		
<i>Presentations of on-going observing efforts in the Atlantic Ocean as a whole. Topics relate to scientific approaches for societal relevant topics. The focus is on Climate and Ecosystems. Questions to be answered by the talks could include:</i>		
<ul style="list-style-type: none"> • Which societal problem(s) are addressed? • What are the scientific approach(es) that have been taken? • Is there a specific observing design underlying the observing effort? Is it a “proven” design? by which means? • Is the system sufficient for the questions that are asked? • Is it sustained into the future? • What do you think are the bottle necks in the current observing effort to generate the 		
13:45-14:00	<i>Climate and the Atlantic Meridional Overturning from North to South</i>	<i>Brian King UK</i>
14:00-14:15	<i>Tropical Atlantic: PIRATA/TAV</i>	<i>M. Araujo (tbc) BRA</i>
14:15-14:30	<i>North and South Atlantic Surface ocean fluxes and ocean acidification, carbon budget</i>	<i>P. Monteiro RZA</i>
14:30-14:45	<i>Eastern Boundary upwelling systems – from physics to fish PREFACE</i>	<i>P. Brandt DE</i>
14:45-15:00	<i>The open-ocean / coastal ocean transition zone – does the open ocean matter?</i>	<i>M. Paz (tbc) ARG</i>
15:00-15:15	<i>North Atlantic ICES area – a century of comprehensive Ocean Observing in the North Atlantic</i>	<i>J. Schmidt ICES</i>

15:15-15:30	<i>Sensor issues</i>	<i>Doug Connelly/ R. Lampitt</i>
15:30-16:15	Round table discussion (30')	
16:15-16:30	Coffee Break (across the three parallel sessions on „Building an Atlantic Community“)	

Nations and Stakeholders expectation on Atlantic Observing		
<i>In this part of the workshop we aim to exchange expectations and national initiatives linked to the Atlantic Ocean. We encourage representatives of countries to outline specific expectations. National activities, ships, infrastructure, capacity building, ...</i>		
	Possible presentation from: Brazil, South Africa, Argentina, Namibia, Angola, Nigeria, Cape Verde, Brazil, Uruguay	
18:30-19:00	Final Round table discussion (30')	
19:00-19:15	Concluding remarks and future activities	Speich/Karstensen

19:30	Networking cocktail (across the three parallel sessions on “Building an Atlantic Community“)	
-------	--	--

Meeting 7 The first Tropical Atlantic Observing System Review Workshop

Meeting 8 - 4th ICES/PICES/IOC Symposium on Climate Change and Impacts on the World's Oceans Washington DC : W8 Workshop, Connecting climate, ocean and ecosystem observation – Ocean observation futures, Jun 03, 2018, 08:30am – 06:00pm

W8 Workshop Connecting climate, ocean and ecosystem observation Ocean observation futures Jun 03, 2018		
08:30	Introduction by Convenors	
09:00	Short Introduction/Tour around the table	Jörn Schmidt
09:30	Multidisciplinary Ocean Time Series: for researcher aggregation and the generation of surprises and knowledge	Douglas Wallace (invited)
10:00	Implementation of biological Essential Ocean Variables in the global observing system	Patricia Miloslavich (invited)
10:30	Coffee/Tea Break	
11:00	Tara Oceans: Eco-Systems Biology at the Planetary Scale	Matthew B. Sullivan (Cont-1)
11:15	Monitoring marine climate change and closing the gaps in nearshore data availability	Karsten A. Shein (Cont-2)
11:30	The World Ocean Database – Conjoining research observations and observing systems across disciplines, across time.	Tim Boyer (Cont-3)
11:45	OBSERVA.PT - Observations on board national commercial ships to support the conservation of marine biodiversity in the Portuguese Seas	A. Miguel P. Santos
11:50	The Great Lakes: A Visual Description Of The Changes In Weather Patterns From 1979 To 2002, And Water Quality From 2002 To 2015	Varis Ransibrahmanakul
11:55	Widespread microplastic distribution at a microtidal Amazon sandy beach.	José E. Martinelli Filho
12:00	Short wrap up of talks and drafting the afternoon session	
12:30	Lunch	
14:00	World Cafe OR break out groups	
15:30	Coffee/Tea Break	
16:00	Reporting on World Cafe OR break out groups result	Rapporteurs
16:45	Final Discussion	Conveners
17:30	Wrap up and discussion on further actions	Coveners
18:00	Close of the Workshop	

Meeting 9– AtlantOS participated at the Belém All-Atlantic Research Forum, Salvador (Brazil)
from the 23-24th of July 2018.

Draft Detailed Programme

Sunday, 22 July 2018 Hotel Vila Galé Salvador	
During the day	Arrival of delegations and participants
19h00	Welcome reception and refreshments
Monday, 23 July 2018 Hotel Vila Galé Salvador	
08h30	Registration
09h00	Video - Promoting the values of the Atlantic Ocean
09h15	Welcome speeches Rodrigo Hita, Bahia's Secretary for Science, Technology and Innovation Jailson de Andrade, President of the Bahia Science Academy
09h30	Opening remarks John Bell, Director of Bioeconomy, Directorate-General for Research and Innovation, European Commission, Belgium Thomas Auf der Heyde, Deputy Director-General, Department of Science and Technology, South Africa Andrei Polejack, General Coordinator for Oceans, Geosciences and Antarctica, Ministry of Science, Technology, Innovation and Communications, Brazil
10h00 to 12h00	THEMATIC SESSION #1 Demonstrating the scope of the Belém Partnership: an overview of existing and planned cooperative research and innovation activities Moderator: Mauricio Mata (BR) Rapporteur: John Hanus, JPI Oceans (EU) Atlantic International Research Centre (AIR Centre) Antonio Sarmiento (PT) Benguela Current Commission Dr Ashley Naidoo (SA Department of Environmental Affairs) EU Earth Observation and Monitoring Programme – Copernicus Fabrice Hernandez, Mercator Ocean South-South Atlantic cooperation Mariano Jórdan (Argentina) Dr Thulani Makalahanye (South Africa) Samuel Mafwila (Sustainable regional marine and fisheries) (Namibia) Eduardo Manta (Uruguay) (TBC)
11:00	Coffee break

<p>12h00 to 13h00</p>	<p>Round table discussions Moderator: Mauricio Mata (BR) Rapporteur: John Hanus, JPI Oceans (EU)</p> <p>Sigi Gruber, European Commission – Support from the Horizon 2020 Programme Moacyr Araujo, Universidade Federal de Pernambuco Pedro Monteiro, CSIR, South Africa</p>
<p>13h00 - 1400</p>	<p>Lunch</p>
<p>14h00 to 17h00</p>	<p style="text-align: center;">THEMATIC SESSION #2</p> <p>Demonstrating the need for the Belém Partnership: expected socio-economic and policy impacts Moderator: Sigi Gruber (EU) Rapporteur: Thato Mtshali (SA)</p> <p>Socio economic and policy impacts from cooperative projects Pedro Monteiro (SA) – Ocean Modelling Paulo Nobre (BR) – PIRATA Sabrina Speich (EU) - AtlantOS Tarron Lamont (SA) – SAMOC</p> <p>Talking to citizens Ana Noronha, Ciência Viva, Portugal Kogi Govender (SA) – Ocean Science Engagement Danilo Calazans (BR) Sveinn Margeirsson, Matís</p> <p>Food from the Atlantic Ocean Mafaniso Hara (PLAAS, SA) – food security Andre Frainer, ClimeFish Wagner Valenti (BR) Isabel Sousa Pinto (EU)</p> <p>Coastal zone management Diego Oliveira (BR) (TBC) Martin Zimmer/Werner Ekau, Leibniz-Zentrum für Marine Tropenforschung (ZMT) GmbH Arnaud Bertrand, IRD</p>
<p>17h00 to 17h40</p>	<p>Round table discussions Moderator: Sigi Gruber (EU) Rapporteur: Thato Mtshali (SA) Ashley Naidoo (DEA, South Africa) Janice Trotte (BR) Gilles Lericolais, IFREMER (FR) Thomas Schröder, Embassy of the Federal Republic of Germany, Brasília</p>
<p>16h00</p>	<p>Coffee break</p>
<p>17h40 to 18h00</p>	<p>Wrap up day 1 Rapporteurs to present outcomes Brief discussions</p>
<p>19h00</p>	<p>Cocktail and refreshments</p>

Tuesday, 24 July 2018 Hotel Vila Galé Salvador	
09h00 to 12h30	<p style="text-align: center;">THEMATIC SESSION #3</p> <p>Building the Belém Partnership: a reflection on the way forward, intervention activities, priorities and most pressing needs. Moderator: Thomas Auf der Heyde (SA) Rapporteur: Andrea Cruz (BR)</p> <p>Horizon 2020 project proposals from the 2018 calls for an All Atlantic Ocean Research Alliance Flagship Horizon 2020 Project Proposals invited to 2nd stage:</p> <p style="padding-left: 40px;">Murray Roberts Jose Joaquin Hernandez Brito Noel Keenlyside Daniele Iudicone André Frainer</p> <p style="padding-left: 40px;">Coordination and Support Action Project Proposal: Sofia Cordeiro, Fundação para a Ciência e a Tecnologia (PT)</p> <p>Sharing of infrastructure and technology Janice Trotte (BR) Ilaria Nardello, EMBRC ERIC Nuno Lourenco EMSO ERIC João Sousa, EUMarineRobots Tommy Bornman (SA) – Coastal research infrastructure</p> <p>Training, mobility and human capacity building initiatives Juliet Hermes (SA) – SEAMester as a training intervention Lelio Fellows (BR) (TBC) Priscila Lelis Cagni (BR)</p> <p>Student showcase next generation in ocean sciences Daniele Miranda</p>
10h30	Coffee Break
12h30 – 13h30	Lunch
13h30 to 16h00	<p style="text-align: center;">THEMATIC SESSION #4</p> <p>Supporting the Belém Partnership: dialogue with funders, marine institutes, networks and industry Moderator: Andrew Kaniki (NRF, SA) Rapporteur: Laura McDonagh (EU)</p> <p style="padding-left: 40px;">Yonah Seleti (SA) – Oceans economy stimulated through Operation Phakisa Lelio Fellows CNPq (BR) Isabel Sousa Pinto (EU) Euromarine Elisa Natola (CONFAP BR) John Hanus and Anders Brudevoll, JPI Oceans</p>

	<p>Sheila Heymans, European Marine Board Roberto Marcondes - Belmont Forum (FAPESP) (BR) André Abreu, Tara Expeditions Patrick Lavens, EATIP Flavio Andrade, OceanPact</p>
16h00	Networking coffee break
16h30	<p>Wrap up day 2 Rapporteurs to present outcomes Brief discussions</p>
17h00	<p>Key messages and concluding remarks: John Bell, Director of Bioeconomy, Directorate-General for Research and Innovation, European Commission Thomas Auf der Heyde, Deputy Director-General, Department of Science and Technology, South Africa Andrei Polejack, General Coordinator for Oceans, Geosciences and Antarctica, Ministry of Science, Technology, Innovation and Communications, Brazil</p>
17h30	Closure

Meeting 10: The second Tropical Atlantic Observing System Review workshop, October 2018, Marseille, France.

Agenda for the 2nd TAOS Workshop.

Day 1: Thursday 10/25

9:00	Welcome and workshop goals/organization (Bill/Sabrina)
9:30	Review of "Key Science and Operational Drivers for the TAOS" (15 min summary +15 min questions/discussion for each topic. Summarize (a) gaps in observing system and recommendations, (b) EOV's, and (c) what parts of present TAOS are most essentially contributing to each topic, and how)
9:30	Dynamics of Tropical Atlantic Variability (Moacyr Araujo/Ping Chang)
10:00	Climate Impacts of Tropical Atlantic Variability (Jeff Knight, Yochanon Kushnir)
10:30	Break
11:00	The AMOC in the Tropical Atlantic (Bill Johns/Sabrina Speich)
11:30	The Carbon System in the Tropical Atlantic (Toste Tanhua, Carol Robinson)
12:00	Biogeochemical Processes in the Tropical Atlantic (Carol Robinson, Martin Visbeck)
12:30	Lunch
2:00	Ecosystem Dynamics and Fisheries (Jörn Schmidt, Brian Mudumbi)
2:30	Sea Level Rise and Ocean Heat Content (MikeMcPhaden, Abderrahim Bentamy)
3:00	Improved predictions on subseasonal to decadal time scales (10 min +10 min ea.)
3:00-3:20	(a) Weather forecasts (M. Balmaseda/A. Simmons, Philippe Dandin)
3:20-3:50	Break
3:50-4:10	(b) Tropical Cyclones and Extreme events (Scott Stripling, Ping Chang)
4:10-4:30	(c) Longer-time scale predictions (Noel Keenlyside, Ingo Richter)
4:30	Long-term climate change and impacts (Yochanon Kushnir, Noel Keenlyside)
5:00	Summary of proposed enhancements/modifications (Bill) (to be collected from each RC member prior to workshop, after drafts of each "driver" topic have been circulated; each member to submit to Jing - who will collate "anonymously" - their answers to two questions: (a) What are the key enhancements that should be recommended for the TAOS, and (b) What elements of the present TAOS are "least critical/least essential", i.e. where could savings potentially be made to allow room for enhancements? This will be used to help guide the discussions on the morning of day 2.)
6:00	Adjourn for day
7:30	Reception

Day 2: Friday 10/26

9:00	Discussion of recommended enhancements and prioritization
10:30	Break
11:00	Discussion of priorities for maintenance of existing observing system elements (proposals for re-configuration of buoy/drifter/Argo networks?)
12:30	Lunch

2:00 Governance/Review/Resourcing
Summaries of current governance structure for (10 min ea): (a) PIRATA (Bernard Bourles) (b) Argo (Steve Jayne) (c) SVP/drifters (Rick Lumpkin)
2:30 Recommendations for TAOS governance/resourcing (Mike McPhaden, Sabrina)
3:00 Recommendations for periodic TAOS Review ((Sabrina, Bill)
3:30 Break
4:00 Summary and open discussion of all recommendations; timeline for completion of TAOS Review report; writing assignments
5:30 Meeting Adjourned

Meeting 11: the 20th POGO workshop, 2019, Mindelo, Cape Verde.

POGO Open Meeting (POGO-20) 22nd – 23rd January 2019

Venue: OSCM, Instituto Nacional de Desenvolvimento das Pescas, Cova de Inglesa, C.P. 132, Mindelo, Island of São Vicente, Republic of Cabo Verde

Monday 21st January

19:00 – 21:00 Welcome reception for all delegates (*Venue: Terra Lodge*)

Tuesday 22nd January

Venue: OSCM Hangar

9:00 – 9:30 Opening session (Chair: Peter Herzig)

- Host welcome: Osvaldina Silva (President of INDP) and Peter Herzig (Director of GEOMAR)
- Remarks from Karen Wiltshire (Outgoing Chair) and handover to Incoming Chair
- Remarks from Nick Owens (Incoming Chair)
- Opening speech by H.E. the Minister of Maritime Economy of Cabo Verde, Dr. José da Silva Gonçalves
- Closure of formal opening session by the Hosts and Chair

9:30 – 9:40 Meeting logistics (Hosts and Secretariat)

9:40 – 11:00 Showcase of oceanography and ocean observing in Cabo Verde and West Africa (Chair: Arne Körtzinger)

- 9:40 Oceanographic observations in Cabo Verde: *Vito Ramos (OSCM, Cabo Verde)*
- 9:55 Recent evidences and possible shifts in the marine biome of the Cabo Verde archipelago in the tropical eastern Atlantic Ocean: *Rui Freitas (UniCV, Cabo Verde)*
- 10:10 Biogeochemistry of oxygen-depleted mesoscale eddies off West Africa: *Björn Fiedler (GEOMAR, Germany)*
- 10:25 Equatorial surface enrichment within the Gulf of Guinea Basin as inferred from in-situ measurements: *Olubunmi Ayoola Nubi (NIOMR, Nigeria)*
- 10:40 Showcase of ocean observations in Senegal and impact of regional warming on small pelagic fish distribution in West Africa: *Abdoulaye Sarré (CRODT, Senegal)*

10:55 Q&A

11:00 – 11:30 Group photo and Coffee break

11:30 – 13:00 Updates on POGO activities (Chair: Tony Worby)

- 11:30 Highlights: *Nick Owens*
- 11:50 progress Report: *Sophie Seeyave/Fiona Beckman*
- 12:10 Address by the Nippon Foundation: *Takehiro Umemura* 12:15 Update on POGO/NANO Global Project: *Houssem Smeti*
- 12:20 Updates on POGO Working Groups

☐ Planning the implementation of a global long-term observing and data sharing strategy for macroalgal communities: *Richard Coleman*

☐ EO for water-related diseases: *Icarus Allen*

12:30 – 13:30 Lunch & Poster Session Postgraduate Students and NANO alumni

(Venue: OSCM Foyer)

13:30 – 14:00 Update on POGO activities –cont'd (Chair: Tony Worby)

13:30 Report on POGO Biological Observations: Margaret Leinen and Eric Orenstein (**remote**)

14:00 – 15:15 Presentations by new/selected members (Chair: Edgar Pavia)

14:00 Introduction of new member -*INDP: Albertino Martins* (TBC)

14:15 Introduction of new member –*ZMT: Hildegard Westphal*

14:30 Introduction of new member –*INVEMAR: Francisco Arias*

14:45 Update from Qingdao National Laboratory for Marine Science and Technology:
Gongke Tan 15:00 The new era for FIO's deep ocean observation: **Tiegang Li**

15:15 – 15:45 Coffee break

15:45 – 16:45 Partner organisations and projects (Chair: Hildegard Westphal TBC)

- OceanoScientific Southern Expeditions: *Gérard Eldin* (CNRS)
- Sailing meets science – Ocean observation on sailing vessels: *Stefan Raimund*
- (SubCTech) Regional/European coordination of Arctic observing: *Kim Holmen* (Norwegian Polar Institute)
- Implementing the JPI Oceans Initiative – achievements and new actions: *Jacky Wood* (JPI Secretariat)

16:45 – 17:30 Closed session (POGO members only):

Financial Reports from fiscal year 2018

Discussion of dues for 2020 and 2021

Invitation of offers to host POGO-22 (to be discussed on Thursday **24th**)

19:00 – 21:30 Dinner (Venue: Restaurant U Sabor)

Wednesday 23rd January

Venue: OSC M Hangar

09:00 – 12:00 Workshop 1: Mineral-dust fertilisation of the marine environment and its consequences for the carbon cycle (Co-Chairs: Henk Brinkhuis & Jan-Berend Stuut)

9:00 – 9:05 Session introduction: Henk Brinkhuis & Jan-Berend Stuut

Keynote presentations:

9:05 The marine-environmental impact of Saharan dust: *Jan-Berend Stuut* (NIOZ, the Netherlands)

9:30 The lithogenic carbon pump: *Cécile Guieu* (LOV, France)





9:55 Upper ocean ecosystem responses to dust borne nutrient inputs in the context of system feedbacks: *Mark Moore (NOC, UK)*

10:20 – 10:45 Q&A/panel discussion

10:45 – 11:00 Coffee break

11:00 – 11:40

Other contributions:

-  *Khanneh Wadinga Fomba (TROPOS)*
-  *Björn Fiedler (GEOMAR)*
-  *Rui Freitas (Uni-CV)*
-  *Joao Cardoso (Uni-CV)*

11:40 – 11:55 General discussion Wrap-up by Session Chairs

11:55 – 13:55 Lunch and Side Event on Capacity Building in West Africa (Chair *Sophie Seeyave*)

Venue: INDP Auditorium/Foyer

12:05 POGO: Lessons learnt from almost two decades of capacity development: *Karen Wiltshire (AWI)/ Sophie Seeyave (POGO)*

12:15 Joint German-Cape Verdian WASCAL and GAME programmes: *Corrine Almeida (University of Cabo Verde)*

12:25 Gulbenkian Institute PGCD programme: *Joana Gonçalves-Sá (Graduate Program Science for Development)*

12:35 ICPMA Master Programme in Benin: *Zacharie Sohoun (IRHOB)/Norbert Houkonnou (ICPMA)* 12:45 Summer School in Ghana: *Brian Arbic (University of Michigan)/ Sam Addo (University of Ghana)* 12:55 Discussion

13:15 Lunch and informal discussions in Foyer

14:00 – 15:30 Session on Sustained Observing in the South Atlantic Ocean and Beyond (Chair: **Martin Visbeck)**

Presentations:

14:00 Decade of Ocean Science for Sustainable Development: *Martin Visbeck (GEOMAR, Germany)* 14:15 GOOS 2030 strategy and the relevance for POGO and its role in realizing that vision strategy: *Albert Fischer (IOC/GOOS)*

14:30 Successful implementation of integrated observation tools for the South Atlantic and experiences gained: *Sabrina Speich (ENS, France)*

14:45 Deep Ocean Observing Strategy: Opportunities for Capacity Development: *Andrea McCurdy (DOOS Secretariat)*

15:00 Argo2020 - a unified design for multidisciplinary global ocean observing: *Susan Wijffels (WHOI)* 15:15 Q&A/Discussion

15:30 – 16:00 Coffee break

16:00 – 17:00 Session on ocean observing technology and sensor development (Chair: *Margaret Leinen*)

- 16:00 Developing low-cost sensors –Update on the *OpenMODs project*: Alessandro Crise 16:15
Developing low-cost sensors –Update on the *NANO-SAGITTA project*: Kirill Kivva 16:30
Presentation from NF-GEBCO XPrize *finalist team*: Ivan Rhyzov (remote)
- 16:45 Ocean observing technology development at Rutgers University: Oscar Schofield 17:00
Q&A/Discussion
- 17:10 – 17:15 Plenary Meeting Closure (Nick Owens) 19:00 – 21:30 Dinner (Venue: Restaurant Gout de Grills)**

Annexe 2: Community White Papers produced

White paper 1: Requirements for a Coastal Zone Observing System

Benveniste, Jérôme, Anny Cazenave, Stefano Vignudelli, Luciana Fenoglio-Marc, Rashmi Shah, Rafael Almar, Ole Baltazar Andersen, Florence Birol, Pascal Bonnefond, Jérôme Bouffard, Francisco Mir Calafat, Estel Cardellach, Paolo Cipollini, Gonéri Le Cozannet, Claire Dufau, M.Joana Fernandes, Frédéric Frappart, James Garrison, Christine Gommenginger, Guoqi Han, Jacob L Høyer, Villy Kourafalou, Eric Leuliette, Zhijin Li, Hubert Loisel, Kristine Skovgaard Madsen, Marta Marcos, Angélique Melet, Benoit Meyssignac, Ananda Pascual, Marcello Passaro, Serni Ribó, Remko Scharroo, Y.Tony Song, Sabrina Speich, John Wilkin, Philipp Woodworth and Guy Woppelman. 2019. *Frontiers in Marine Sciences*. Under Review.

Abstract

Coastal zones are highly dynamical systems affected by a variety of natural and anthropogenic forcing factors, that include sea level rise, extreme events, local oceanic and atmospheric processes, ground subsidence, etc. However so far, they remain poorly monitored on a global scale. To better understand changes affecting world coastal zones and to provide crucial information to decision-makers involved in adaptation to and mitigation of environmental risks, coastal observations of various types need to be collected and analyzed. In this white paper, we first discuss the main forcing agents acting on coastal regions (e.g., sea level, winds, waves and currents, river runoff, sediment supply and transport, vertical land motions, land use) and the induced coastal response (e.g., shoreline position, estuaries morphology, land topography at the land-sea interface and coastal bathymetry). We identify a number of space-based observational needs that have to be addressed in the near future to understand coastal zone evolution. Among these, improved monitoring of coastal sea level by satellite altimetry techniques is recognized as high priority. Classical altimeter data in the coastal zone are adversely affected by land contamination with degraded range and geophysical corrections. However, recent progress in coastal altimetry data processing and multi-sensor data synergy, offers new perspective to measure sea level change very close to the coast. This issue is discussed in much detail in this paper, including the development of a global coastal sea-level and sea state climate record with mission consistent coastal processing and products dedicated to coastal regimes. Finally, we present a new promising technology based on the use of Signals of Opportunity (SoOps), i.e., communication satellite transmissions that are reutilized as illumination sources in a bistatic radar configuration, for measuring coastal sea level. Since SoOp technology requires only receiver technology to be placed in orbit, small satellite platforms could be used, enabling a constellation to achieve high spatio-temporal resolutions of sea level in coastal zones.

White paper 2: The Tropical Atlantic Observing System

Foltz, Gregory R., Peter Brandt, Ingo Richter, Belen Rodriguez-fonseca, Fabrice Hernandez, Marcus Dengler, Regina R. Rodrigues, Jörn Oliver Schmidt, Lisan Yu, Nathalie Lefevre, Leticia Cotrim Da Cunha, Michael James McPhaden, Moacyr Cunha de Araujo Filho, Johannes Karstensen, Johannes Hahn, Marta Martín-Rey, Christina M. Patricola, Paul Poli, Paqueta Zuidema, Rebecca Hummels, Renellys C. Perez, Vanessa Hatje, Joke Luebbecke, Irene Polo, Rick Lumpkin, Bernard Bourlès, Francis E. Asuquo, Patrick Lehodey, Anna Conchon, Ping Chang, Philippe Dandin, Claudia Schmid, Adrienne J Sutton, Herve Giordani, Yan Xue, Serena Illig, Teresa Losada, Semyon Grodsky*, Florent Gasparin, Tong Lee, Elsa Mohino, Paulo Nobre, Rik Wanninkhof, Noel S Keenlyside, Veronique Garcon, Emilia Sanchez-Gomez, Hyacinth C. Nnamchi, Marie Drevillon, Andrea Storto, Elisabeth Remy, Alban Lazar, Sabrina Speich, Marlos Pereira Goes, Tarquin Dorrington, William E. Johns, James N. Moum, Carol Robinson, Coralie Perruche, Ronald Buss de Souza, Amadou Gaye, Maria Lopez-Parages, Paul-Arthur Monerie, Paola Castellanos, Nsikak U. Benson, Mahouton Norbert Hounkonnou and Janice Trotte Duha. 2019. *Frontiers in Marine Sciences*. Under Review.

Abstract

The tropical Atlantic is home to multiple coupled climate variations covering a wide range of timescales and impacting societally relevant phenomena such as continental rainfall, Atlantic hurricane activity, oceanic biological productivity, and atmospheric circulation in the equatorial Pacific. The tropical Atlantic also connects the southern and northern branches of the Atlantic meridional overturning circulation and receives freshwater input from some of the world's largest rivers. To address these diverse, unique, and interconnected research challenges, a rich network of

ocean observations has developed, building on the backbone of the Prediction and Research Moored Array in the Tropical Atlantic (PIRATA). This network has evolved naturally over time and out of necessity in order to address the most important outstanding scientific questions and to improve predictions of tropical Atlantic severe weather and global climate variability and change. The tropical Atlantic observing system is motivated by goals to understand and better predict phenomena such as tropical Atlantic interannual to decadal variability and climate change; multidecadal variability and its links to the meridional overturning circulation; air-sea fluxes of CO₂ and their implications for the fate of anthropogenic CO₂; the Amazon River plume and its interactions with biogeochemistry, vertical mixing, and hurricanes; the highly productive eastern boundary and equatorial upwelling systems; and oceanic oxygen minimum zones, their impacts on biogeochemical cycles and marine ecosystems, and their feedbacks to climate. Past success of the tropical Atlantic observing system is the result of an international commitment to sustained observations and scientific cooperation, a willingness to evolve with changing research and monitoring needs, and a desire to share data openly with the scientific community and operational centers. The observing system must continue to evolve in order to meet an expanding set of research priorities and operational challenges. This paper discusses the tropical Atlantic observing system, including emerging scientific questions that demand sustained ocean observations, the potential for further integration of the observing system, and the requirements for sustaining and enhancing the tropical Atlantic observing system.

White paper 3: Atlantic Meridional Overturning Circulation: Observed transport and variability

Frajka-Williams, Eleanor, Isabelle J. Ansorge, Johanna Baehr, Harry L. Bryden, Maria Paz Chidichimo, Stuart A. Cunningham, Gokhan Danabasoglu, Shenfu Dong, Kathleen A. Donohue, Shane Elipot, N. Penny Holliday, Rebecca Hummels, Laura C. Jackson, Johannes Karstensen, Matthias Lankhorst, Isabel A. Le Bras, M. Susan Lozier, Elaine L. McDonagh, Christopher S. Meinen, Herlé Mercier, Bengamin I. Moat, Renellys C. Perez, Christopher G. Piecuch, Monika Rhein, Meric Srokosz, Kevin E. Trenberth, Sheldon Bacon, Gael Forget, Gustavo Goni, Patrick Heimbach, Dagmar Kieke, Jannes Koelling, Tarron Lamont, Gerard D. McCarthy, Christian Mertens, Uwe Send, David Smeed, Sabrina Speich, Marcel van den Berg, Denis Volkov, Chris Wilson. 2019. *Frontiers in Marine Sciences*. Under Review.

Abstract

The Atlantic Meridional Overturning Circulation (AMOC) extends from the Southern Ocean to the northern North Atlantic, transporting heat northwards throughout the South and North Atlantic, and sinking carbon and nutrients into the deep ocean. Climate models indicate that changes to the AMOC both herald and drive climate shifts. Intensive trans-basin AMOC observational systems have been put in place to continuously monitor meridional volume transport variability, and in some cases, heat, freshwater and carbon transport. These observational programs have been used to diagnose the magnitude and origins of transport variability, and to investigate impacts of variability on essential climate variables such as sea surface temperature, ocean heat content and coastal sea level. AMOC observing approaches vary between the different systems, ranging from trans-basin arrays (OSNAP, RAPID 26°N, 11°S, SAMBA 34.5°N) to arrays concentrating on western boundaries (e.g., RAPID WAVE, MOVE 16°N). In this paper, we outline the different approaches (aims, strengths and limitations) and summarize the key results to date. We also discuss alternate approaches for capturing AMOC variability including direct estimates (e.g., using sea level, bottom pressure, and hydrography from Lagrangian floats), indirect estimates applying budgetary approaches, state estimates or ocean reanalyses, and proxies. Based on the existing observations and their results, and the potential of new observational and formal synthesis approaches, we make suggestions as to how to evaluate a comprehensive, future-proof observational network of the AMOC to deepen our understanding of the AMOC and its role in global climate.

White paper 4: Multidisciplinary Observing in the World Ocean's Oxygen Minimum Zone regions: from climate to fish- the VOICE initiative

Garcon, Veronique C., Johannes Karstensen, Artur Palacz, Maciej Telszewski, Tony Aparco Lara, Denise Breitburg, Francisco Chavez, Paulo Coelho, Marcela Cornejo, Carmen Dos Santos, Bjoern Fiedler, Natalya Gallo, Marilaure Gregoire, Dimitri Gutierrez, Jose M. Hernandez-Ayon, Kirsten Isensee, Tony Koslow, Lisa A. Levin, Francis

Marsac, Helmut Maske, Baye C. Mbaye, Ivonne Montes, Syed Wajih A. Naqvi, Jay S. Pearlman, Edwin Pinto, Grant C. Pitcher, Oscar Pizarro, Kenneth Rose, Damodar Shenoy, Anja K. Van Der Plas, Melo R. Vito, Kevin Weng. 2019. *Frontiers in Marine Sciences*. Under Review.

Abstract

Multidisciplinary ocean observing activities provide critical ocean information to satisfy ever-changing socio-economic needs, and require coordinated implementation. The upper oxycline (transition between high and low oxygenated waters) is fundamentally important for the ecosystem structure and can be a useful proxy for multiple observing objectives connected to Oxygen Minimum Zones (OMZs). The VOICE (Variability of the Oxycline and its ImpaCt on the Ecosystem) initiative demonstrates how societal benefits drive the need for integration and optimization of physical, biogeochemical and biological components of regional ocean observing. In liaison with the Global Ocean Oxygen Network, VOICE creates a roadmap towards observation-model syntheses for a comprehensive understanding of selected oxycline dependent objectives. Local to global effects, such as habitat compression or deoxygenation trends, prompt for comprehensive observing of the oxycline on various space and time scales, and for an increased awareness of its impact on ecosystem services. Building on the Framework for Ocean Observing (FOO), we initiated readiness level (RL) assessments for ocean observing of the oxycline in highly productive and economically important OMZ waters. VOICE determines ocean observing design based on scientific and monitoring activities in selected OMZs, namely the California Current System (US West Coast, the Southern California Current system off Mexico), the Equatorial Eastern Pacific off Ecuador, the Peru-Chile Current system, West Africa off Senegal and Cape Verde Islands, the northern Benguela off Namibia and in the Northern Indian Ocean (Bay of Bengal, Arabian Sea). Regional champions aided in assessing FOO design elements for the respective OMZ, namely: requirements processes, coordination of observational elements, and data management and information products. The RL for FOO elements is derived for each region and points at system bottlenecks which prevent delivering information and products for end users with a goal of motivating consistency across regions. We found that fisheries and ecosystem management are a societal requirement for all regions, but maturity levels of observational elements and data management and information products differ. Identification of relevant stakeholders, developing strategies for RL improvements, and building and sustaining infrastructure capacity to implement these strategies are fundamental milestones for VOICE initiative over the next 2-5 years and beyond.

White paper 5: Measuring Global Ocean Heat Content to estimate the Earth Energy Imbalance

Meyssignac, Benoit, Tim Boyer, Zhongxiang Zhao, Maria Z Hakuba, Felix W Landerer, Detlef Stammer, Armin Köhl, Seiji Kato, Tristan L'Ecuyer, Michael Ablain, John Patrick Abraham, Alejandro Blazquez, Anny Cazenave, John A Church, Rebecca Cowley, Lijing Cheng, Catia Domingues, Donata Giglio, Viktor Gouretski, Masayoshi Ishii, Gregory C Johnson, Rachel E Killick, David Legler, William Llovel, John Lyman, Matthew Dudley Palmer, Steve Piotrowicz, Sarah Purkey, Dean Roemmich, Rémy Roca, Abhishek Savita, Karina von Schuckmann, Sabrina Speich, Graeme Stephens, Gongjie G Wang, Susan Elisabeth Wijffels and Nathalie Zilberman. 2019. *Frontiers in Marine Sciences*. Under Review.

Abstract

Careful monitoring of the radiation energy in and out of the Earth is essential for understanding many aspects of the changing Earth system. A critical challenge is the monitoring of the small energy imbalance ($0.5-1.W.m^{-2}$) between incoming and outgoing radiation at the top of the atmosphere (called the Earth Energy Imbalance –EEI). The EEI is associated with the warming of the planet. Over 93% of the excess energy that is gained in response to the EEI is stored in the ocean. For this reason the global Ocean Heat Content (OHC) places a strong constraint on the EEI and the ability to determine the global ocean heat storage change is essential to assess the state of climate and its future evolution. In this community paper we review the current four methods to estimate the global OHC: 1) the direct measurement of in situ temperature 2) the measurement of the net ocean surface heat fluxes from space 3) the measurement of the thermal expansion of the ocean from space and 4) the estimate from ocean reanalyses that assimilate observations from both satellite and in situ instruments. For each method we review the potential and the uncertainty of the method to estimate the global OHC changes. We also analyze the gap in the current capacity of each method and identify ways of progress for the future to fulfill the requirements on the EEI observation. Achieving the observation of the EEI with the

required accuracy will depend on merging the remote sensing techniques with in situ measurements of key variables as an integral part of the Ocean Observing System.

White paper 6: Adequacy of the ocean observation system for quantifying regional heat and freshwater storage and change

Palmer, Matthew Dudley, Paul Durack, Maria Paz Chidichimo, John Church, Sophie E Cravatte, Katherine Louise Hill, Johnny Johannessen, Johannes Karstensen, Tong Lee, David Legler, Matthew Mazloff, Eitarou Oka, Sarah Purkey, Ben Rabe, Jean-Baptiste Sallée, Bernadette Marie Sloyan, Sabrina Speich, Karina von Schuckmann, Josh Willis and Susan Elisabeth Wijffels. 2019. *Frontiers in Marine Sciences*. Under Review.

Abstract

Considerable advances in the global ocean observing system over the last two decades offers an opportunity to provide more quantitative information on changes in heat and freshwater storage. Variations in these storage terms can arise through internal variability and also the response of the ocean to anthropogenic climate change. Disentangling these competing influences on the regional patterns of change and elucidating their governing processes remains an outstanding scientific challenge. This challenge is compounded by instrumental and sampling uncertainties. The combined use of ocean observations and model simulations is the most viable method to assess the forced signal from noise and ascertain the primary drivers of variability and change. Moreover, this approach offers the potential for improved seasonal-to-decadal predictions and the possibility to develop powerful multi-variate constraints on climate model future projections. Regional heat storage changes dominate the steric contribution to sea level rise over most of the ocean and are vital to understanding both global and regional heat budgets. Variations in regional freshwater storage are particularly relevant to our understanding of changes in the hydrological cycle and can potentially be used to verify local ocean mass addition from terrestrial and cryospheric systems associated with contemporary sea level rise. This White Paper will examine the ability of the current ocean observing system to quantify changes in regional heat and freshwater storage. In particular we will seek to answer the question: What time and space scales are currently resolved in different regions of the global oceans? In light of some of the key scientific questions, we will discuss the requirements for measurement accuracy, sampling, and coverage as well as the synergies that can be leveraged by more comprehensively analysing the multi-variable arrays provided by the integrated observing system.

White paper 7: Evolving and Sustaining Ocean Best Practices and Standards for the Next Decade

Jay S. Pearlman, Mark Bushnell, Laurent Coppola, Pier Luigi Buttigieg, Françoise Pearlman, Pauline Simpson, Michele Barbier, Johannes Karstensen, Frank E. Muller-Karger, Christian Munoz-Mas, Peter Pissierssens, Cynthia L. Chandler, Juliet Hermes, Emma Heslop, Reyna Jenkyns, Eric 'Achterberg, Manuel Bensi, Henry Bittig, Jerome Blandin, Julie A. Bosch, Bernard Bourlès, Roberto Bozzano, Justin J. Buck, Eugene F. Burger, Daniel Cano, Vanesa Cardin, Miguel Charcos Llorens, Andres Cianca, Chen Hua, Caroline Cusack, Eric Delory, Rene Garello, Gabriele Giovanetti, Valerie Harscoat, Robert Heitsenrether, Simon Jirka, Ana Lara-Lopez, Nadine Lanteri, Adam M. Leadbetter, Giuseppe M. Manzella, Joan Masó, Andrea McCurdy, Eric Moussat, Manolis Ntoumas, Sara Pensieri, George Petihakis, Nadia Pinardi, Sylvie Pouliquen, Rachel Przeslawski, Nicholas Roden, Joe Silke, Mario Tamburri, Hairong Tang, Toste Tanhua, Pierre Testor, Julianna O. Thomas, Christoph Waldmann, Fred Whoriskey. 2019. *Frontiers in Marine Sciences*. Under Review.

Abstract

The oceans play a key role in global sustainability issues such as climate change, food security and human health. Given its vast dimensions, internal complexity, and limited accessibility, efficient monitoring and predicting of the ocean must be a collaborative effort of regional and global scale. A first and foremost requirement for such collaborative ocean observing is the need to follow well-defined methods. Summarized under "Ocean Best Practices" are all aspects of ocean observing that require proper and agreed-on documentation, from manuals and standard operating procedures for sensors, strategies for structuring observing systems and associated products, to ethical and governance aspects when executing ocean observing.

The best practices landscape is highly fragmented but the recent increase in specific documentation, using digital format such as PDF or Word, opens up new opportunities for best practice access and harmonization. The major step forward to reduce the fragmentation of such publications is a new open access, permanent, digital repository of best practices documentation (oceanbestpractices.org) that is part of the Ocean Best Practices System (OBPS). Through the repository, an opportunity space for improvement of ocean observing is created. The OBPS repository has embedded user-friendly software that supports best practice discovery and access. It also discloses the relation among best practice documents. The software includes advanced semantics for natural language (e.g. English) search and machine learning capabilities to enhance repository operations. In addition to the repository, the OBPS also includes a peer reviewed Journal Research Topic, a forum for community discussion and a capacity building component. An OBPS objective is to work with the ocean observing community to facilitate processes leading to a state where ocean best practices broadly exist as “community agreed methods for every activity in ocean observing research, operations and applications that are superior to others”. We show for selected ocean observing examples how the OBPS supports this objective. This paper lays out a future vision of ocean best practices and how OBPS will contribute to improving ocean observing in the decade to come.

White paper 8: Future ocean observations to connect climate, fisheries and marine ecosystems

Schmidt, Jörn Oliver, Steven J. Bograd, Haritz Arrizabalaga, Steven J. Barbeaux, John A Barth, Tim Boyer, Stephanie Brodie, Scott Cross, Jean-Noel Druon, Agneta Fransson, Jason Hartog, Elliott Hazen, Johannes Karstensen, Alistair James Hobday, Michael Jacox, Sven Kupschus, Jon Lopez, Lauro A. S.-P. Madureira, José Eduardo Martinelli Filho, Patricia Miloslavich, Cristina Pereira Santos, Kylie Scales, Sabrina Speich, Matthew B. Sullivan, Amber Szoboszlai, Desiree Tommasi, Douglas Wallace and Stephani Zador. 2019. *Frontiers in Marine Sciences*. Under Review.

Abstract

Ecosystem Based Fisheries Management is a meaningful concept to consider climate and marine ecosystems in the context of fisheries. Fisheries provides more than 500 million people with food, income and thus support their livelihoods. Sustainable management of fisheries is a mean to sustain these livelihoods. The basis for management is an understanding of the system and thorough monitoring of state and change in light of multiple pressures. To provide the basis for the understanding as well as identifying and monitoring relevant ecosystem components, many countries and organizations plan and conduct observations. Ocean observation, is also conducted for other means like understanding ocean state and processes, today increasingly in light of climate variability and change. However, the respective communities rarely communicate and thus synergies of identifying objectives and planning observing frameworks hardly happen. This paper explores options for a future observing system by i) identifying needs for different user groups, ii) showing already available large datasets, iii) describing technologies and iv) observational approaches for Ecosystem Based Management. It also presents a couple of case studies and explains how process studies can be linked to long-term monitoring. It concludes by describing capacity development needs and the vision for observing in support of the Ecosystem Based Fisheries Management.

White paper 9: Towards a global ocean observing system for research and applications (from operational services to climate)

Sloyan, Bernadette Marie, John Wilkin, Katherine Louise Hill, Maria Paz Chidichimo, Meghan F. Cronin, Johnny A. Johannessen, Johannes Karstensen, Marjolaine Krug, Tong Lee, Eitarou Oka, Matthew Dudley Palmer, Benjamin Rabe, Sabrina Speich, Robert Andrew Weller and Weidong Yu. 2019. *Frontiers in Marine Sciences*. Under Review.

Abstract

Climate change and variability are major societal challenges, and the ocean is an integral part of this complex and variable system. Key to the understanding of the ocean's role in the Earth's climate system is the study of ocean and sea-ice physical processes, including its interactions with the atmosphere, cryosphere, land and ecosystems. These processes include those linked to ocean circulation; the distribution and transport of heat, salt and other water properties; and exchanges of

heat, momentum, freshwater, and gases. Measurements of ocean physics variables are fundamental to reliable earth prediction systems for a range of applications and users. In addition, knowledge of the physical environment is fundamental to growing understanding of the ocean's biogeochemistry and biological/ecosystem variability and function.

Through the progress from OceanObs99 to OceanObs09, the ocean observing system has evolved from a platform centric perspective to an integrated observing system. The challenge now is for the observing system to evolve to respond to an increasingly diverse end user group. The Ocean Observing Physics and Climate panel (OOPC), formed in 1995, has undertaken many activities that led to observing system-related agreements. In this whitepaper OOPC will explore science-based recommendations for a fit-for-purpose, sustained and prioritized ocean observing system, focusing on physical variables that maximize support for fundamental research, climate monitoring, forecasting on different timescales, and society.

OOPC recommendations will be guided by the Framework for Ocean Observing; Identifying user requirements that consider time and space scales of the Essential Ocean Variables. This will provide a framework for reviewing the adequacy of the observing system, looking for synergies in delivering an integrated observing system for a range of applications and focusing innovation in areas where existing technologies do not meet these requirements.

White paper 10: Ocean climate observing requirements in support of Climate Research and Climate Information

Stammer, Detlef, Annalisa Bracco, Krishna AchutaRao, Lisa Beal, Nathan Bindoff, Pascale Braconnot, Wenju Cai, Dake Chen, Matthew Collins, Gokhan Danabasoglu, Boris Dewitte, Riccardo Farneti, Baylor Fox-Kemper, John Fyfe, Stephen Griffies, Steven Robert Jayne, Alban Lazar, Matthieu Lengaigne, Xiaopei Lin, Simon Marsland, Shoshiro Minobe, Pedro Monteiro, Walter Robinson, Roxy Mathew Koll, Ryan Rykaczewski, Sabrina Speich, Inga Smith, Amy Solomon, Andrea Storto, Ken Takahashi, Thomas Tonazzo and Jerome Vialard. 2019. *Frontiers in Marine Sciences*. Under Review.

Abstract

Natural variability and change of the Earth's climate have significant global societal impacts. With its large heat and carbon capacity and relatively slow dynamics, the ocean plays an integral role in climate dynamics, and provides an important source of predictability at seasonal and longer timescales. Understanding and monitoring ocean climate variability and change to understand and constrain and , and initialize models as well as identify model biases for improved climate hindcasting and prediction requires new more scale sensitive a substantial observing system. A climate observing system has requirements that significantly differ from, and sometimes are orthogonal to, those of other applications. In general terms, they can be summarized by the simultaneous need for both large spatial and long temporal coverage, and by the accuracy, precision, and stability required for detecting the local climate signals.

This paper reviews what a climate observing system needs to cover in terms of space and time scales and revisits the question of which parameters such a system should encompass to meet future strategic goals of the World Climate Research Program (WCRP), with emphasis on ocean and sea-ice covered areas. It considers global as well as regional aspects that should be accounted for in designing observing systems in individual basins. Furthermore, the paper discusses which data-driven products are required to meet WCRP research and modeling needs, and ways to obtain them through data synthesis and assimilation approaches. Finally, it addresses the need for scientific capacity building and international collaboration in support of the collection of high quality measurements over the large spatial scales and long time scales required for climate research, bridging the scientific rational to the required resources for implementation.