VARIABILITY IN THE OXYCLINE & ITS IMPACTS ON THE ECOSYSTEM

Variability in the Oxycline and Its Impacts on the Ecosystem (VOICE)

Science Plan Workshop

13-15 September 2017, Monterey, CA, USA

Workshop Report

GOOS Report No. 224

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International Ocean Carbon Coordination Project (IOCCP)

Surface Ocean-Lower Atmosphere Study (SOLAS)

National Oceanic and Atmospheric Administration (NOAA)

Cover photo:

VOICE workshop participants.

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Motivation for the workshop

In February 2017, the Global Ocean Observing System of the IOC-UNESCO (*GOOS*) and the OceanObs Research Coordination Network (OceanRCN) held a workshop to address the Implementation of Multi-Disciplinary Sustained Ocean Observations (IMSOO) in Miami, Florida, USA. This workshop identified priorities for improving the coordinated planning and implementation of multi-disciplinary observing activities and demonstrations. Detailed outcomes of the IMSOO workshop can be found in the report: *www.goosocean.org/imsoo-report*. In general, the outcomes focused around three demonstration themes:

(i) Plankton community changes (including ocean colour),
(ii) Open ocean, shelf & coastal ocean interactions,
(iii) Oxygen minimum zones (OMZ);

and include a clear series of actions and milestones to strengthen the collaboration between physicists, biogeochemists, biologists and ecosystem scientists working towards a better understanding of the phenomena related to the three themes.

The IMSOO OMZ Demonstration Theme working group identified as their high level and overarching observing objective "How do changing OMZs affect the spatio-temporal distribution, productivity and trophic structure of the benthic and pelagic communities?" - an objective that includes all three main drivers for a GOOS: Climate, Operational services and Ocean health. As an approach to design an observing system towards this overarching observing objective, the group decided to limit the design to the observations of one important control surface in the OMZ system - the oxycline. In the direct aftermath of the IMSOO workshop, the leaders of the IMSOO OMZ Demonstration Theme, supported by the GOOS Biogeochemistry Expert Panel coordinators, started planning for a workshop that would refine the proposed science plan for a project called 'Variability in the Oxycline and its ImpaCts on the Ecosystem (VOICE),' ambitiously laid out by the IMSOO OMZ participants, to be carried

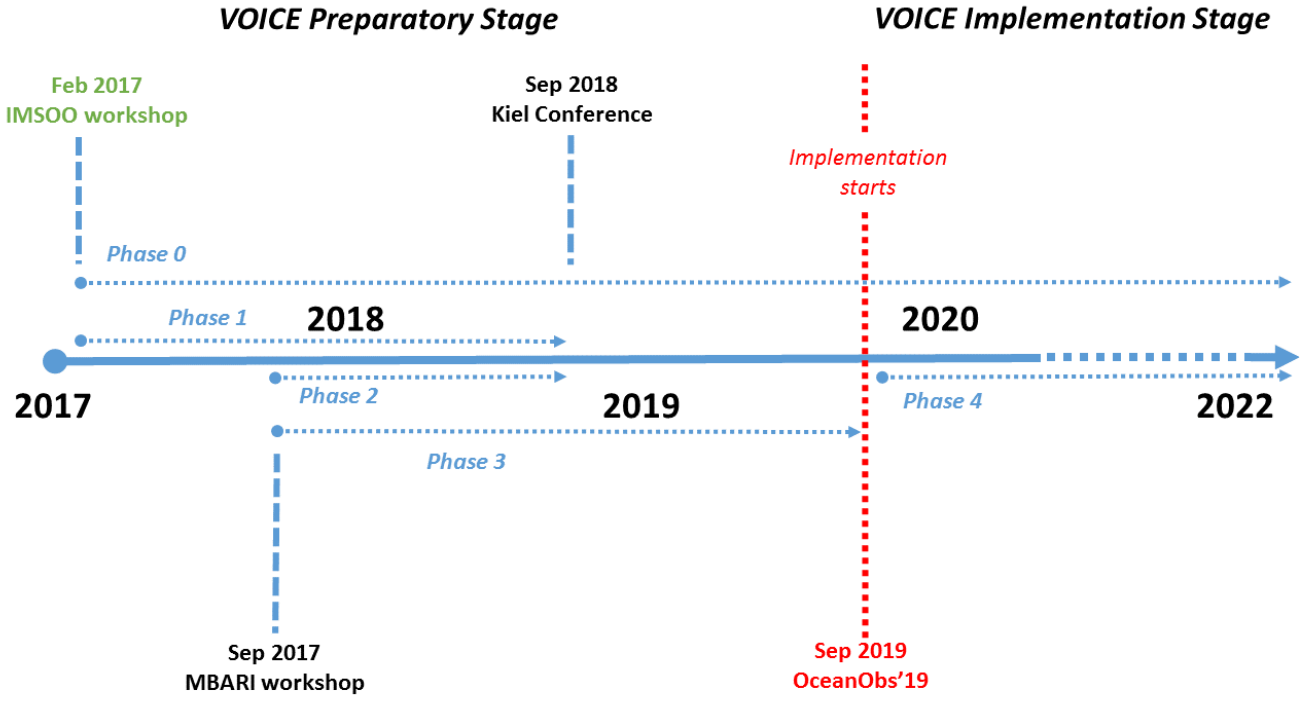

Figure 1. The VOICE project timeline as envisioned during the IMSOO workshop.

out across a number of selected OMZ regions around the globe: the Humboldt Current System, West Africa (Canary and Benguela Current Systems), Northern Indian Ocean, and the California Current System.

As seen from the VOICE time line (Figure 1), the first, preparatory, stage of VOICE consists of four phases:

Phase 0: Communication and coordination efforts including definition of "societal issues" via stakeholder dialogue
Phase 1: Literature review / historical data analysis to define science driven observing requirements
Phase 2: Identify existing and planned experiment/ocean observing opportunities in OMZ regions
Phase 3: Develop the conceptual framework and observing system design for selected science cases related to oxycline variability

The key outcome at this stage of the project is to perform a preliminary assessment of the current readiness level with respect to all three categories distinguished by the *Framework for Ocean Observing* (FOO):

(i) requirements setting process,
(ii) existing observing capabilities,
(iii) data and information products management.

A table with Framework processes by readiness levels on a 1-9 point scale, extracted from the FOO, is added to the Appendix of this document.

If successfully implemented, VOICE would ultimately provide a blueprint of a multi-disciplinary sustained OMZ observing system, outlining a minimum and optimized set of observational and modelling requirements for a fit-for-purpose system, capable of informing the society about the variability in the oxycline and its impacts on the ecosystem, applicable within the global ocean observing system, and contributing to the overarching question: "How do changing OMZs affect the spatio-temporal distribution, productivity and trophic structure of the benthic and pelagic communities?"

Workshop structure and objectives

While the goal is to complete the readiness level assessment for the three FOO categories by September 2019 and for OceanObs'19, the VOICE Science Plan Workshop, a three-day event held on 13-15 September 2017, in Monterey, CA, USA, was an important milestone in the process. The workshop objectives were thus set as to enable or directly contribute to the delivery of anticipated outcomes of the VOICE preparatory stage, as defined in the IMSOO report:

- a number of national and international project partnerships built,
- scientific objectives defined based on literature review and historical data analyses
- first set of relevant phenomena and EOVs defined
- data sharing agreements reached,
- a preliminary assessment of the fitness-for-purpose (or readiness level) of the system with respect to observing oxycline variability and its impacts on the ecosystem performed,
- a proposal to fund the 3-year implementation stage of the project submitted to one of the funding agencies.

The workshop was held back to back with the Global Ocean Oxygen Network (GO_2NE) third annual meeting (11-13 September 2017, Monterey, CA, USA), and was attended by 22 scientists from around the globe. It was the first opportunity to establish communication and initiate coordination of efforts leading up to the implementation of the VOICE project. To this end, the first day of the meeting was organized as a joint event with the members of GO_2NE, many of whom are also active in VOICE. The complete list of workshop participants can be found in the Appendix to this document.

One of the aims of the workshop was to collect information on the current observing system status with respect to all three FOO categories across all VOICE OMZ regions. A specific focus was placed on the societal requirements, including gathering information on who the stakeholders and key players engaged in observing system design and/or operation are. To this end, the participants were thus expected to discuss:

- Societal issues related to oxycline variability and motivations for current observing system designs, as well as selection of a common focus application for VOICE (e.g. Benguela Nino/El Nino impact on fisheries)
- Associated scientific approaches with respect to a common set of phenomena and Essential Ocean Variables identified
- Challenges and opportunities for data sharing & expertise exchange
- Current status of literature review and historical data analyses with respect to VOICE
- Revised VOICE time line and work flow

To facilitate the process of readiness level assessment, all participants were provided with a comprehensive spreadsheet questionnaire to be filled out based on the information exchanged during the workshop, but also based on information collected from all relevant players and stakeholders over the course of a few months after the workshop. The readiness level assessment ought to result in an identification of gaps that eventually prevent the current observing system to deliver the information the stakeholders are asking for.

Summary of workshop outcomes

The outline for a common roadmap for GO_2NE and VOICE presented in this report was deemed an important outcome with respect to enhancing coordination of observation and modelling efforts leading to a better understanding of OMZ functioning, and in particular of deoxygenation and associated phenomena, as well as building awareness of their consequences. The development of the actual roadmap for OceanObs'19 and beyond will require refinements in the near future, in particular, through assigning persons responsible for implementation (that includes both coordination and fund-raising efforts) of individual recommendations and actions agreed upon.

The VOICE workshop provided an excellent and in depth summary of the regionally set requirements, observing capability, and data and information product management, forming a basis for comprehensive observing system readiness level assessment in accordance with the FOO guidelines. The information conveyed through presentations and during discussions will be documented and expanded upon through a spreadsheet questionnaire distributed among the workshop participants, to be filled out before the end of 2017.

Despite the fact that only a limited number of stakeholder groups could be represented at this workshop, the participants have agreed to assume the role of champions in their disciplinary and/or geographic domains, or in few cases, pointed at other experts potentially available to play that role. It is thus through the institutional functions and well-established professional networks of the champions that a continued dialogue with all relevant stakeholders is meant to be ensured.

A central point in the established plan of actions is the realization of a global literature review for VOICE. Specific means of achieving this tasks were proposed and actions undertaken. Recognizing the importance of performing historical data analyses prior to a successful VOICE conceptual model development, it was agreed that steps will be taken to initiate such analyses. In some cases, the data is readily available but additional resources and expertise is needed to carry out the work. In other cases, the focus will be on attempting to mobilize the existing data and information products, for example through unprecedented integration of oceanographic and higher trophic level data.

In order to enable progress of VOICE into its implementation stage beyond 2019, the group has agreed to review data sharing agreements by September 2018. The regional observing system champions will therefore act on the potential opportunities to increase access to local information and eventually report on the level of data availability for VOICE and the global community.

The following sections of the report provide a detailed account of arriving at the outcomes above, and include important information on many general as well as very specific issues that are critical to the development of the VOICE Science Plan and its future implementation.

Towards a Common Roadmap for GO_2NE & VOICE

Wednesday, September 13th was organized as a shared day for GO_2NE and VOICE, dedicated to introducing the groups' goals and planned activities for the purpose of delineating a common roadmap for the OceanObs'19 Conference, and beyond. The two groups met at the Monterey Bay Aquarium Research Institute (MBARI), in Moss Landing, CA, USA. The meeting started with an introduction by the local host, Francisco Chavez, who gave a brief overview and history of MBARI, which in 2017 was celebrating its 30th anniversary.

The meeting was opened by Co-Chairs of GO_2NE (Denise Breitburg and Marilaure Grégoire) and Co-Chairs of VOICE (Véronique Garçon and Johannes Karstensen), who all expressed their gratitude for bringing the two groups together in order to benefit from each other's largely complementary efforts. A quick tour de table revealed a vast range of expertize gathered in the room, both in terms of geographic and disciplinary coverage. Out of the 29 attendees present on that day, 22 were later to attend the remainder of the VOICE workshop. The complete list of attendees of both meetings can be found in the Appendix to this report.

The significance of holding this joint meeting was perhaps best reflected in Maciej Telszewski's comment who expressed his hope that the GO_2NE-VOICE meeting was the beginning of a realization of what was first envisioned back in 2014 during a small side meeting to the Liege Colloquium on Low oxygen environments in marine, estuarine and fresh waters (*http://modb.oce.ulg.ac.be/colloquium/2014/*). At this meeting a few people, now involved in GO_2NE and VOICE, had agreed that coordination of oxygen-related ocean observations and research was urgently needed and agreed to make any possible effort to lay ground for such coordination.

In order to set the stage a number of overview presentations were first given.

Requirements for multidisciplinary sustained ocean observations

Maciej Telszewski gave a presentation on the *"Requirements for multidisciplinary sustained ocean observations."* After introducing the goals and structure of the Global Ocean Observing System (GOOS), Maciej spoke about the GOOS value chain, in particular the need to better connect observations with their benefit for the society, and the realization that it is the information generated from ocean observing that provides the motivation for the existence of GOOS. This idea is reflected in the newly formulated GOOS mission and strategy.

The approach of GOOS is described by the FOO. A key concept used in the FOO to connect observations with societal motivations driving these observations is that of a phenomenon, defined by GOOS as:

> *'A GOOS phenomenon is an observed process, event, or property, with characteristic spatial and time scale(s), measured or derived from one or a combination of EOVs, and needed to answer at least one of the GOOS Scientific Questions.'*

It is the characteristic of a given phenomenon, e.g. its spatio-temporal scales, that should in fact set the requirements for designing a multi-platform and multi-disciplinary ocean observing system. These phenomena need then to be observed through a set of Essential Ocean Variables (EOVs), defined as:

> *'A GOOS EOV is a sustained measurement or a group of measurements necessary to assess state and change at a global level, and to increase societal benefits from the ocean on scales from global to regional.'*

The call for EOVs, selected based on the criteria of their impact and feasibility, responds directly to the fact that *"we cannot measure everything, nor do we need to."* The other dimension of the phenomena are the time and space scales and which are addressed by the capabilities of the observing networks (ships, satellites, moorings, gliders, etc.).

The final concept from the FOO, which was of prime importance to this workshop, was that of 'readiness levels', describing the level of maturity of the observing system and ranging from concept, through pilot, to mature. Readiness levels need to be assessed in each of the three categories of the FOO, i.e. requirements setting, observing capacity, and data and information product management. See the Appendix for a more detailed description of the Framework processes by readiness levels. One of the prime objectives for VOICE is to assess the current state of FOO implementation across the regional observing systems and addressing oxycline variability. The assessment is done to identify critical gaps which require priority actions from GOOS in order to increase the respective readiness levels. The importance of the data management component of the FOO is typically underestimated, yet its readiness level is very low, regardless of which EOV or which observing platform we consider. Thus, a critical statement stemming from the FOO, is that without an open and coherent data management strategy, a GOOS-based sustained OMZ observing cannot be implemented.

Much of the discussion after the talk focused on the ability to properly evaluate the impact of a given measurement for the purpose of classifying a measurement as an EOV. It was made clear that the impact assessment performed to date was purely qualitative. Hence, the modellers perspective on, for example, impact of inclusion of a given variable into a model data assimilation scheme, was not taken into account, at least not quantitatively. An example of such an impact assessment is well illustrated by carbon isotope measurements. Though these measurements are only performed in a few laboratories around the globe, they have a significant impact from the societal perspective, i.e. for quantifying anthropogenic components of the global carbon cycle. In conclusion of the discussion, it was suggested that a list of measurements essential to observe deoxygenation be made. A detailed impact and feasibility assessment specifically with respect to this phenomenon would be a valuable asset for the specific OMZ question of oxycline variability addressed in VOICE, but for sure on the implementation of the FOO for OMZs in general.

IOC Ocean Science

Kirsten Isensee presented a portfolio of the UNESCO Intergovernmental Oceanographic Commission (IOC) paying close attention to IOC's role in outreach and capacity building initiatives. Relating to Maciej's talk, Kirsten emphasized the fact that IOC is at the heart of GOOS, not only as one of its sponsors, but also through the fact that it hosts the main offices of GOOS in Paris. A key message from the talk was that it is within IOC's mandate to enhance ocean observations as well as other elements: assessment and management, adaptation/mitigation solutions, or training and capacity building.

The *Global Ocean Science Report*, recently published by UNESCO IOC, identifies and quantifies the key elements of ocean science at the national, regional and global scales, including workforce, infrastructure and publications. It is the first collective attempt to

systematically highlight opportunities as well as capacity gaps to advance international collaboration in ocean science and technology.

The large portfolio of IOC working groups and initiatives, including GO_2NE, is operating under several high-level frameworks, such as Agenda 2030. Striving towards meeting the targets set by Agenda 2030 requires consideration of links that exist between deoxygenation and ocean acidification, as well as other phenomena. Within IOC there is cooperation between several groups concerned with ocean issues, such as GO_2NE, the *Global Ocean Acidification Observing Network (GOA-ON)*, the *Harmful Algal Bloom (HAB) Programme*, the *Climate Change and Global Trends of Phytoplankton in the Ocean (TrendsPO)* working group, the *International Group for Marine Ecological Time Series (IGMETS)*, or the *Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP)*.

GO_2NE was established by IOC in 2016 as its working group to improve the overall communication around the science concerned with impacts and knowledge gaps related to deoxygenation, as well as to increase scientific collaborations and provide advice to policy makers, and local and regional managers. Kirsten pointed at the 4th International Symposium on the *Effects of Climate Change on World's Oceans*, due to take place in June 2018, as one of the key events to which IOC will contribute to through GO_2NE and otherwise.

VOICE as a demonstration project of IMSOO – overview of the VOICE Science Plan

During this session the VOICE project Science Plan was introduced by VOICE Co-Chairs. First, Véronique introduced how VOICE originated from the Oxygen Minimum Zones (OMZ) Demonstration Theme discussed at the Implementation of the Multi-disciplinary Sustained Ocean Observations (IMSOO) workshop held in February 2017, in Miami, FL, USA. For details of the process, workshop outcomes and the preliminary VOICE Science Plan, see the workshop report at *www.goosocean.org/imsoo-report*.

Apart from reiterating the overall goals and objectives of VOICE, Véronique gave her perspective on who the users and beneficiaries of VOICE would be. The challenges set for the project and the solutions needed to overcome them require the participation and endorsement of many groups of stake-holders, some of which we were able to gather in the room for this MBARI workshop. The societal requirements for VOICE related questions are vast: from fisheries and aquaculture to greenhouse gas emissions and carbon sequestration. Acknowledging the complexity of OMZ systems, it is critical to demonstrate that by implementing a multi-disciplinary, sustained and fit-for-purpose observing system GOOS can provide essential information in response to these requirements.

Second, Johannes presented the objectives and anticipated outcomes from this workshop, being an important milestone on the timeline of VOICE. He pointed out the different phases of VOICE, split between the Preparatory Stage (2017-2019) and the Implementation Stage (2019-2022). Johannes illustrated how VOICE is meant to realize the principles of FOO, going through the complete cycle from requirement setting to increasing readiness level of observations to optimized data management and information product delivery. A similar process was followed in the example of the Argo program established in response to the need to estimate upper ocean heat content variability on seasonal and longer time scales and thus answer the question 'how fast is the ocean warming?' Johannes emphasized that one reason why Argo was so successful was that data was freely accessible, allowing it to be widely explored

by users but for applications the system was not designed for. For VOICE we aim for clear design goals but based on open access data.

Except for defining societal issues driving the regional observing systems represented here at the workshop, it is important that we begin to assess the readiness levels in all three aspects of the FOO: requirements setting, observing capacity, and data and information product management. To this end, participants of the workshop were encouraged to fill out the spreadsheet questionnaire prepared by the Workshop Organizers. The goal is to distribute the questionnaire to all key players responsible for some element of the regional observing systems, and provide such comprehensive information within the next few months.

The group inquired about the fate of the other two IMSOO demonstration themes: Plankton Community Changes and Open Ocean Shelf Interactions. Francisco Chavez informed all that the Open Ocean Shelf Interactions Demonstration Theme group, also known as the Boundary Currents group, split their efforts into two: Western Boundary Current Systems and Eastern Boundary Current Systems (EBUS). As the leader of the latter, he saw potential overlaps between his group and VOICE in the sense of the questions asked: what are the motivations for observations in EBUS? What measurements are needed, where, when and how? It should also be noted that an *EBUS SCOR Working Group* proposal was lately approved, co-led by Ivonne Montes, also a member of GO_2NE, which will be keen on finding synergies with VOICE. Another SCOR WG, *P-OBS* (Integration of Plankton-Observing Sensor Systems to Existing Global Sampling Programs), was also just *approved*. This group was formed directly in response to the recommendations from the Plankton Community Changes Demonstration Theme group during the IMSOO workshop.

Overview of GO_2NE activities and plans

Marilaure Grégoire introduced GO_2NE: the structure, members, and the Terms of Reference. She also gave a list of ongoing activities, which included preparing a technical brief on deoxygenation issues, a scientific paper accepted for publication in Science, advisory work in the scoping committee for IPCC and lead on chapters for the IPCC reports, and much more. The group is also actively engaged in capacity building, e.g. through partnership with the *IOC Sub-commission for the Western Pacific (WESTPAC)*.

Among the future plans is the organization of a GO_2NE Summer School in China in 2019, chairing sessions at the Effects of Climate Change on World's Oceans Symposium, and active engagement in the *SFB754 International Conference* in Kiel, Germany, in September 2018. For a more complete roundup of activities and plans please consult the *GO_2NE website*, as well as the Ocean Oxygen site hosted by GEOMAR in Kiel: *https://www.ocean-oxygen.org/*.

In response to a question whether GO_2NE will be long-term maintained, it was explained that from the IOC's current perspective, GO_2NE has been established as a long-term initiative for as long as there is a need to communicate science on the deoxygenation problem, and for as long as the problem exists. Initial ToRs were set for 5-6 years, and will need to be revisited after their time is due. GO_2NE should be viewed as a dynamic process, responding to any new emerging challenges.

How to combine synergistically VOICE and GO_2NE ongoing and future efforts?

Based on the overview presentations, the discussions then shifted towards creating a common roadmap for the two groups. In general, as GO_2NE integrates the coast with the open ocean, and at the same time, brings together environmental and social scientists, it stands close to the society and its needs with respect to the problem of ocean deoxygenation. In the GOOS framework, this would give GO_2NE a strong mandate for reviewing the requirements setting process with respect to the Oxygen EOV, and the phenomenon of deoxygenation. This is then highly complementary to VOICE which is primarily looking at the current observing capacity and data management structures but also needs to account for the requirement processes, thus encompassing all aspects of the FOO through this demonstration project. With that in mind, the groups came up with a list of the activities which would benefit from a joint GO_2NE-VOICE collaboration:

OceanObs'19 Conference

- Need for volunteers from both groups to join the *OceanObs'19* Program Committee

  An open call for joining the Program Committee was released on 29 September, two weeks after the VOICE workshop. In anticipation of the call, active participants of both groups attending the MBARI meeting were encouraged to address this call in order to ensure proper representation of global oxygen observing efforts and future needs at the Conference. Deadline for responding to the Call was unfortunately extremely tight, and passed soon afterwards on 15 October 2017. A joint nomination of Ivonne Montes was submitted by IOCCP Office prior to the deadline.

- A joint session and white paper for OceanObs'19 Conference

  When discussing ideas for such a joint paper, the group was reminded that the OceanObs'09 white paper on Argo oxygen had the goal of advocating for detection of long-term changes in oxygen content, similar to the Argo heat content question example. A new overarching theme was needed for a potential OceanObs'19 white paper from this community. There seemed to be consensus on the fact that the OceanObs'19 white paper should first of all focus on defining the societal needs for the fit-for-(oxygen)-purpose observing system. Knowing these needs would define the scientific problem(s) at hand, and thus determine the types of applications we should be concerned with. It is only when the application specifications are established, we can begin to first test and then execute cases of deploying instruments and sensors performing measurements required to deliver a given application product.

  The white paper would then stress the importance of optimizing the observing system with respect to the many phenomena that contribute to deoxygenation, describe the characteristics of the system in terms of which variables, spatial and temporal scales, sensors, and geographical areas should be part of it. It would also highlight the societal benefits of sustaining such an ocean observing system, through demonstrating the value of oxygen and related data in answering the relevant societal questions motivating the creation of the system in the first place.

  An example of a very practical dilemma that lies at the heart of designing an optimal observing system, and to be potentially considered, was also brought up. Namely, one of the issues faced by the animal tagging community is to decide whether to invest in a low

grade sensor put on the animal itself to know what were the conditions exactly when the animal was there, or, following an alternative pathway, to invest in high grade sensors measuring from a ship but at the expense of measuring at roughly the same location but not at the same time as the animal was passing. It was realized that the two observational strategies address very different scientific approaches - but both may contribute to the global scale question on the multiple facets of deoxygenation.

Furthermore, the group seemed to be in accord as to the fact that the white paper should also stress the needs for sharing a common data strategy. Currently, 'red dots' marking areas with highest deoxygenation trends on the global map coincide with areas of least systematic measurements being available.

An oxygen data synthesis product modelled after SOCAT

The Surface Ocean CO_2 Atlas (SOCAT; *www.socat.info*) is a synthesis activity for quality-controlled, surface ocean fCO2 (fugacity of carbon dioxide) observations by the international marine carbon research community, with more than 100 contributors. SOCAT data is publicly available, discoverable and citable. SOCAT enables quantification of the ocean carbon sink and ocean acidification and evaluation of ocean biogeochemical models. SOCAT, which celebrates its 10th anniversary in 2017, represents a milestone in biogeochemical and climate research and in informing policy, and as such, could and should be viewed as an exemple of how mature data and information product management maybe achieved through a dedicated bottom-up activity.

Following the discussions held earlier during the first two days of the GO_2NE meeting during which the SOCAT data product was presented, it was proposed that the two groups work together towards a SOCAT-like product for oxygen. A significant part of the discussion was devoted to identifying motivations and societal needs for such a product, and consequently, for specifying its exact scope. Obtaining more reliable climate and ecosystem models and gaining a better understanding of the ecology of the marine systems was seen as the end game in the process. Model evaluations and IPCC-type assessments were given as just two types of examples motivating improved global oxygen data availability, quality and comparability. The importance of pointing at the societal benefits of submitting and quality controlling data in general was seen as critical in regions where data is not being submitted anywhere, or is inaccessible beyond a single institution.

Initially, there was a dispute over whether a SOCAT-like oxygen product is in fact needed, largely stemming from an apparent misconception that SOCAT might act as a global data repository which would replace existing national and regional data repositories, and partly stemming from the fact that the *2013 World Ocean Atlas version 2* oxygen climatology product is still perceived as sufficient for many current applications. It was argued in response that relative to what is currently available in the World Ocean Atlas in terms of oxygen data, such a product would aim to increase the proportion of coastal data, and significantly improve data comparability through mandatory secondary quality control (QC). Meeting these requirements would be in direct response to what was recommended by *Schmidtko et al. (2017)* in their review paper on the "Decline in global oceanic oxygen content during the past five decades."

It was moreover clarified that what is meant by this initiative would be solely a data synthesis effort which is neither a data collection effort, nor a dataset or database creation effort. What SOCAT does for surface pCO_2 data is secondary QC, i.e. a procedure enabling every user to know what level of accuracy a given data point is good to. The SOCAT QC protocol was agreed upon by more than a hundred of scientists from around the world. Hence, in order to create a

SOCAT-like oxygen product the critical first step would be to assemble a group of a dozen or so PIs, representing GO_2NE, VOICE and observing networks deploying a vast range of platforms and oxygen measuring techniques (e.g. *GO-SHIP*, *Biogeochemical Argo*, *OceanGliders/EGO*, *OceanSITES*), who through the course of several workshops would develop a common secondary quality control protocol and perform this QC on the data that the users submit for these purposes. The data would not be submitted to this group exclusively, and not be in conflict with any national data repository submission requirements. Finally, training would be provided for those submitting data and willing to have their measurement quality improved, e.g. from flag D to flag A.

Although much discussion also took place on what level of data accuracy would be delivered by such a product and whether it would match the different application needs, it should be noted that a data synthesis product with secondary quality control flags in principal should enable the application of such a product to a wide range of possible applications, from climate models requiring very low uncertainty levels, to high trophic level models which would accept lesser but nevertheless good quality oxygen data. For fishery model purposes, as you average point measurements over larger spatial domains, precision errors lose their importance at the expense of increasing uncertainty due to spatial averaging. While you may be more interested in relative change and indices rather than absolute numbers, one still needs to evaluate the levels of uncertainty. These are important considerations that should also be taken when designing multi-purpose monitoring surveys and other observing schemes.

In an attempt to prioritize potential steps towards the creation of such a product, three levels of improvements to current oxygen data management were proposed. Progress on these discussions will be made via email communication after the workshop.

- First level improvements
  - Gathering data from the existing several databases in which data is readily accessible in electronic format (data mining from scientific publications is discarded at this stage)
  - Removing duplicate data
  - Filtering data, e.g. by applying methodology from *Schmidtko et al. (2017)*
- Second level improvements
  - Correcting information for OMZs
- Third level improvements
  - Including coastal regional data through the efforts of GO_2NE, WESTPAC, VOICE, EBUS SCOR WG, EMODnet Chemistry, NOAA, etc.
  - Establishing a connection with the Argo and OceanGliders communities.

Elaborating on the last point, it was suggested that perhaps VOICE would be best suited for initiating a dialogue between glider and profiling float observing communities. The complementarity in the technologies could be used with benefit especially in the coastal regions where float coverage will always be sparse.

GO_2NE webinar as part of the monthly GOOS webinar series

After GO_2NE revealed their plans to increase their visibility in the public space through webinars, it was suggested that one such webinar could take place as part of the monthly *GOOS webinar series*. GO_2NE Co-Chairs confirmed their interest in holding such an event, and it was agreed that the group contact Forest Collins at IOC-UNESCO, responsible for scheduling the webinars for GOOS. As a result, a GOOS webinar on GO_2NE's actions and future plans in the context of GOOS was tentatively scheduled for Spring 2018.

Stimulating new scientific publications

In addition, it was also commented that the interaction between the participants of the two groups would likely stimulate new scientific publications. This process would be facilitated by the fact that there is considerable overlap among members of GO_2NE and participants of VOICE.

A review paper on the comparison of systems subject to low oxygen

In particular, GO_2NE's current plans to publish a review paper on "the comparison of vulnerability of the systems to further oxygen loss" could also benefit from inputs from the VOICE group. Grant Pitcher has taken the lead on this effort. After some initial thoughts on the paper outline were described, the two groups were invited to try and better define its currently very broad scope. Below is a summary of this discussion split according to several issues, with suggestions for overcoming them.

- Coastal vs open ocean

  There was a plea NOT to divide according to coastal vs open ocean low oxygen waters in the review paper. The focus for this group should be to keep them together and figure out how to best compare them. This was in contrast to some suggestions on focusing on comparison between major OMZs only. Another idea was to describe conceptually only one coastal and one open ocean system, and draw comparisons between the two case studies.

- Steady state vs dynamics

  An alternative proposal was to conceive one paper describing the steady state system in each location, and to follow up with another paper dedicated to the dynamics of the system. It was argued that even unravelling the dynamics controlling a steady state in low oxygen waters would be challenging enough to compare in a single paper. To estimate the susceptibility of the system to further oxygen decline might be much more difficult as it would have to define deoxygenation in terms of crossing thresholds which are different for each region, both open ocean and coastal.

- Physics vs biology dominant drivers

  It was noted that each system exhibits very different responses. Mechanistic understanding of one system does not necessarily translate onto another one. For instance, oxygen decline rates observed in the Pacific would mean that Bay of Bengal should long have been anoxic, albeit it is not the case. There was concern over whether comparing physical, biogeochemical and biological drivers could be sufficiently covered in a single paper, or whether there should be a paper devoted to each separately. Discussion evolved around whether you can classify any system in steady state as being either physically or biologically dominated, as opposed to always being in a balance between the two. It was suggested that in some cases you could, for example Northern Indian Ocean OMZs being dominated by physical processes, Namibian OMZ waters dominated by biological production, and Gulf of Mexico OMZ maintained by nutrient run off, i.e. subject to dominant biogeochemical control.

  Ultimately, there was a suggestion that the paper should perhaps not concern itself with describing the processes behind deoxygenation, also considering that Francisco Chavez

was already working on a paper discussing various processes in low oxygen systems. Hence, the two efforts could take place in parallel, while avoiding significant overlaps.

- Assessment of future observation needs

  It was suggested that one area in which the OceanObs'09 white paper on oxygen fell short was the assessment of future observations needs. Perhaps this would be a novel and easy aspect for the white paper to focus on.

All in all, there was no immediate consensus on where the paper should focus on. Grant Pitcher agreed to synthesize the results of the discussion and update the paper outline accordingly.

Summary of common actions for VOICE and GO_2NE

The following is a summary of actions based on the discussions between GO_2NE and VOICE. Actions with a determined time line are listed as Action Items. Actions with no specific time line are listed as recommendations.

Action Item #1	To invite GO_2NE to one of the next GOOS webinars, introducing GO_2NE's actions and plans through the lens of requirements for sustainable ocean oxygen observations.
Responsible	GOOS Secretariat
Time line	Immediate
Status	COMPLETED This action was followed up immediately after the workshop. A GOOS webinar on GO_2NE was tentatively scheduled for Spring 2018.

Action Item #2	To nominate or self-nominate an oxygen expert to join the OceanObs'19 Conference Program Committee in response to an open call released soon after the VOICE workshop.
Responsible	All of GO_2NE and VOICE
Time line	15 October 2017
Status	COMPLETED This action was followed up with GO_2NE and VOICE jointly nominating Ivonne Montes for the OceanObs'19 Program Committee.

Action Item #3	To decide on the topic and scope of the OceanObs'19 white paper(s).
Responsible	All of GO_2NE and VOICE
Time line	Early 2018, pending the release of Call for Abstracts.
Status	

Action Item #4	To organize a joint session for OceanObs'19.
Responsible	All of GO_2NE and VOICE
Time line	In response to the call for session proposals.
Status	

Action Item #5	To synthesize the discussion and propose a new scope of the review paper and subsequently solicit input for writing contributions from amongst GO_2NE and VOICE groups.
Responsible	Grant Pitcher
Time line	Ongoing
Status	

Recommendation #1	To make a list of measurements essential to observe deoxygenation through a comprehensive impact and feasibility assessment, including the perspective on the variable's impact on model performance. This exercise would potentially inform the EOV implementation process, for example through an update of the Oxygen EOV Specification Sheet.
Responsible	Selected participants of GO_2NE and VOICE
Time line	To be determined
Status	

Towards readiness level assessments in VOICE regions

This part of the workshop, devoted to reviewing monitoring and research needs in regions identified for implementation of VOICE aimed towards performing a preliminary readiness level assessment, was initiated already on the first day of the workshop and occupied the whole of remaining two days. Scientist(s) most familiar with a given region's specific characteristics, and knowledge of ongoing and planned efforts, were asked to give a comprehensive presentation, which was then followed by questions and an open discussion. While the focus of the presentations was meant to be on the oxycline dynamics, it was not limited to it. In some regions, the upper oxycline has not been examined at great length to date, so a more general account of the observing efforts and OMZ-related research hypotheses was presented. However, representatives of each system were asked to state whether the societal and scientific requirements for the regional observing systems are or could be in line with any of the VOICE questions posed during the IMSOO workshop and listed below.

1. What are the processes that create and maintain an oxycline, its extent and intensity?
2. What are drivers for spatial (horizontal and vertical) and temporal variability of the oxycline from sub-diurnal to multiannual time scales?
3. What are drivers in vertical extent, depth range and intensity of the oxycline?
    a. Do mesopelagic fish/crustaceans/cephalopods affect the oxycline to an extent comparable with the role microbes have?
    b. What is the role of zooplankton Diel Vertical Migration (DVM)?
4. What are the impacts of oxycline variability in space or time on fish biomass, abundance, community structure, and susceptibility to fishing gears?

The anticipated end product of VOICE is a blueprint of a multi-disciplinary sustained OMZ observing system, outlining a minimum and optimized set of observational and modelling requirements for a fit-for-purpose system that is capable of informing the society about the variability of the oxycline and its impacts on the ecosystem, and which is applicable within the global ocean observing system. Therefore, for a region to become a potential beneficiary of VOICE implementation activities, there must be interest among its stakeholders in one or more of the VOICE questions. The blueprint would of course be available to implement in any region but unless the regional requirements are compatible with VOICE, they would not be taken into consideration when drafting the blueprint.

The talks also outlined other limitations/expectations for the region (e.g. need for knowledge transfer, capacity building) that could be integrated as components to VOICE and GO_2NE. Moreover, the key aspect of each presentation was to present the status of data (oxygen, hydrography, ecosystem, biogeochemistry) availability and quality control procedures. Attention was also given to the data products that are available or would be needed to address the questions of VOICE. In general, the presentations addressed the following points which were identified as critical to meeting the workshop objectives:

- Measurements required to answer VOICE questions in this particular region
- Major motivations for observations in the region based on funded projects and how do they tie in with VOICE
- Existing and planned capacity: observations, data quality procedures, data sharing protocols, as well as overview of ongoing and planned observing and modelling opportunities
- Existing and/or required societal benefit data products of relevance to VOICE
- Historical data analysis and literature review aimed at developing a conceptual framework of the effects of oxycline variability on changes in intermediate and upper trophic in a given OMZ system

Each presentation was then followed by a discussion on readiness level assessment with respect to: maturity and integrity of requirements set for observations, current observing capability, and data and information product management. Throughout the workshop it was strongly emphasized that the ultimate goal of the assessment was not to discard the low readiness level components of the observing system (i.e. some regions) but rather to promote efforts leading to a gradual increase in the readiness level where it is most needed, as stated in the first draft VOICE Science Plan published as part of the IMSOO Report.

Prior to the workshop, all the participants received a spreadsheet questionnaire prepared by the Workshop Organizing Committee. Once filled out, the questionnaire will serve as a valuable resource summarizing observing system information from each region necessary to analyse the existing observing system and its capabilities for the purpose of the VOICE project. The questionnaire seeks to gather information about the requirements, observing capabilities, as well as data management and information products – three components of the FOO. The questions are posed in the context of the overarching issue of "How do changing Oxygen Minimum Zones (OMZs) affect the spatio-temporal distribution, productivity and trophic structure of the benthic and pelagic communities?", as stated in the IMSOO workshop report. However, bearing in mind the objectives of VOICE, we ask the participants to specifically focus, if possible, on the aspect of oxycline variability and its impacts on the ecosystem.

In this section of the report we summarize the discussions held in response to the regional presentations but do not summarize the presentation contents themselves. Much of the information about requirements, observing capacity, data management and information products will be summarized in the spreadsheet questionnaires.

California Current system

The California Current System observing efforts were represented in the room by Tony Koslow, Lisa Levin, Francisco Chavez, Elliott Hazen, Kevin Weng, and with contributions from others. The background for workshop discussions was given through Tony Koslow's presentation on "Oxycline variability in the California Current system and its apparent influence on the ecosystem." The information provided was based on the observing and modelling efforts conducted as part of the *California Cooperative Oceanic Fisheries Investigations (CalCOFI)*, and the *California Current Ecosystem Long Term Ecological Research Network (CCE-LTER)*. Tony informed the group that as he was moving to Australia, he would not be a suitable champion for the California Current region in the context of VOICE. It was agreed that Tony would contact two contemporary leaders of CalCOFI with a request to take up the roles of VOICE champions in the region.

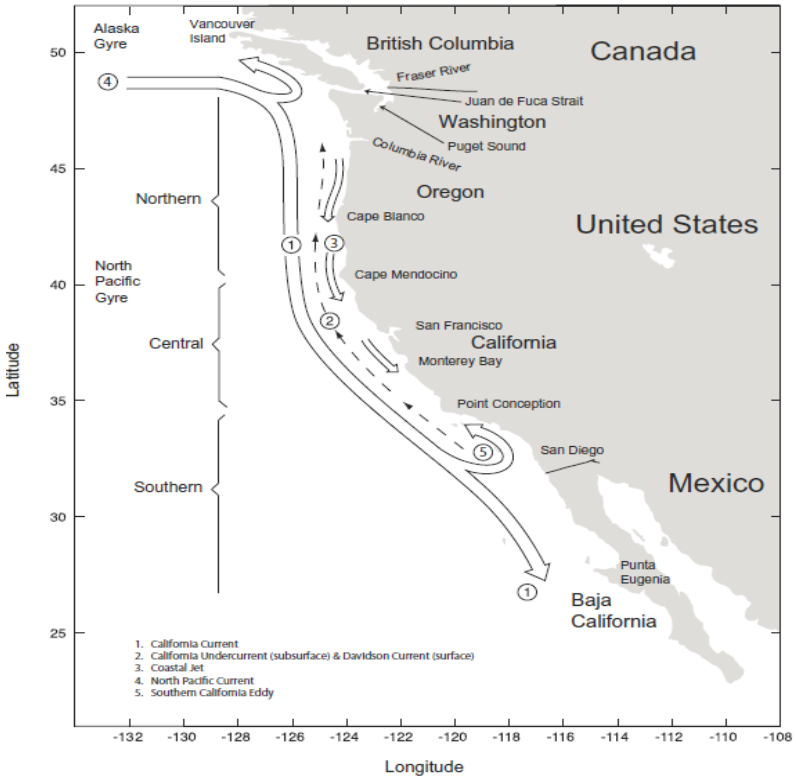

Figure 2: California Current system graphic.

On requirements setting process

This region was confirmed as one with strong interests in all of the VOICE questions. The fact that in the Southern California the oxycline is rather deep and it tends to affect mesopelagic fish more than the pelagic fish, makes the region a rather unique setting for VOICE. Considering the oxycline's shoaling towards the coast, effects of and on benthos are also relevant. At the same time, it is clear that neither of the VOICE questions were used as motivations for the design of the current state of the observing system. Any attempts to reconcile VOICE-related requirements with future enhancements and/or modifications of the CalCOFI monitoring activities would require consulting a large number of stakeholders responsible for various elements of the observing system. Distributing the spreadsheet questionnaire among the key players, starting from the CalCOFI Director, is a necessary first step in that direction.

Some aspects that were not covered during the talk and the discussions are related to the fishery, environmental changes on fishermen behaviour, etc. These aspects may need to be considered when describing interests of relevant stakeholders in the California Current region.

On the initial design of CalCOFI

The first question concerned the initial reason for setting up CalCOFI, and whether it was set up according to any best practices, or whether it followed any design. CalCOFI was formed in 1949 as a multi-agency partnership between NOAA Fisheries Service, Scripps Institution of Oceanography, and California Department of Fish and Wildlife, to investigate the collapse of the sardine population off California. Sardine was once a key resource and source of income for the Monterey Bay area population. Climate and fisheries have been concluded as factors that caused the decline in the fish population. CalCOFI initially focused on the spatio-temporal distribution of spawning, but with time developed the egg surveys used for stock assessments. It was not until the '80s that additional co-incident sampling of nutrient and chlorophyll-a concentrations started. Although there are currently interests in modifying the fishery surveys, there is a great deal of resistance to changing the sampling design. Any intense surveys need to be done in addition, not in place of the current ones.

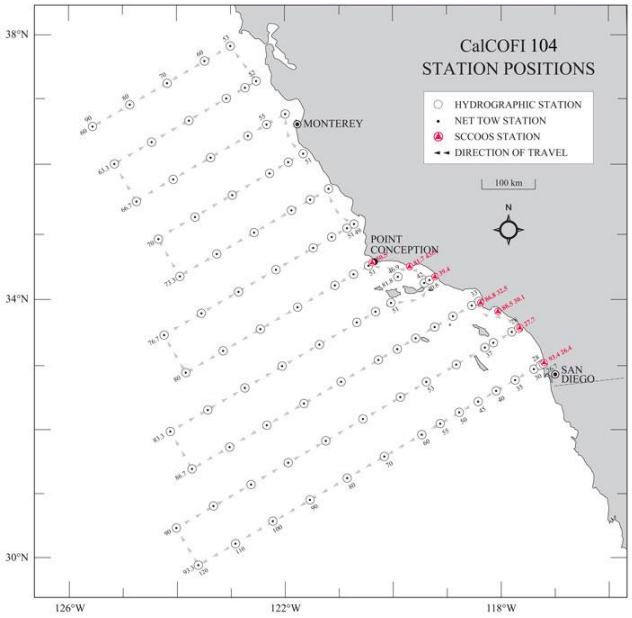

Figure 3. CalCOFI station positions. Source: Tony Koslow's presentation at this workshop.

On current drivers of the region's observing system

Tony stated that one of the main drivers behind sustainable observations in the region is still the requirement to manage sardines. Stock assessments are conducted based on the egg and larval acoustic surveys. It was also pointed out that there is a federal mandate to continue assessments for commercial fish. At the same time, there are other stakeholders, related to climate, with interests in CalCOFI. One of the reasons why CalCOFI is held in such high regard by NOAA is that it is more than just a survey program. Considering the needs for ecosystem based management, the mammal and seabird surveys are equally important for NOAA. The program owes its success partly to the realization that to manage fish, one needs to know the oceanography of the region. The requirement for having an oceanographic component in the partnership was fulfilled by the Scripps Institution.

On the historical data analysis and use for management

The work presented in Tony's talk was funded by NOAA. The purpose behind collecting observations is to use the data for integrated ecosystem assessments, and thus the data presented in the talk is available for management purposes. CalCOFI appeared as a very good example of what VOICE wants to achieve. According to Tony, it seems clear that for much of the time period analysed, in Southern California there was an impact of changing oxycline on the mesopelagic fish biomass. This relationship was not clear in the case of the sardine through. Nonetheless, it is necessary to point out that oxycline variability and/or deoxygenation is not the only driver for the system.

With respect to whether the analysis included commercially harvested or assessed species, Tony explained that the second component of the PCA had some commercial species. In terms of their drivers of change, they included changes in transport, upwelling strength, and temperature. The results indicated a ca. 70% change in larval abundance for anchovy/sardine. It was also suggested that there is potential in analyzing predator gut contents in order to test the hypothesis of whether the mesopelagics were being forced into the shallower water.

On outstanding knowledge gaps and capacity for enhancement

In light of the fact that it is still not fully known why the fish are declining, there was a question on whether the major knowledge gaps had been identified. Lots of multi-decadal variability and the discovery of their new modes were given as one example of knowledge gaps. The North Pacific Gyre oscillation had not been known until 1997/98. Similarly, the discovery of El Niño Modoki was done fairly recently. Moreover, it was pointed out that while CalCOFI goes out four times a year, there are lots of phenomena that need to be observed with continuous oxygen measurements. There are of course extensions to the CalCOFI surveys, through glider deployments, several moorings in key places, thus provide continuous data locally. The challenge is to piece together the different platforms and their outputs.

With respect to reducing uncertainty in surveys through addition of new platforms and technologies, a paper by Uwe Send on moorings in the California Current was cited. In the paper, large variability in the near-shore oxygen and pH were revealed. While the CalCOFI cruises were able to detect the main trends adequately, the very large variability occurring in between the cruises, was only captured once the moorings were deployed. This result demonstrated the added value of multi-platform observations in the region.

On coordination of various observing elements in the California Current region

There is currently some coordination outside of CalCOFI. For instance, every year since 2000 there is the *Trinational Sardine and Small Pelagics Forum* between the US, Canada and Mexico, comprised of a wide range of participants from government, academia, and industry. This year the meeting is held on 7-8 December, in La Jolla, CA, USA. Besides that, there are a number of universities, state agencies and many other organizations that are not coordinated with each other. If we had a VOICE project being implemented, it would be critical to bring in all the key players to a workshop. There is plenty of good will among the key players involved in the California Current system observations. The names of players are well known, and there were initiatives in the past that were successful in bringing such groups together from all along the coast, e.g. the *NOAA At-Sea Hake Observer Program*. In such a case, there were no issues with people bring data to the table. Francisco Chavez, leading the EBUS efforts stemming from the IMSOO workshop, added that they would try to bring such a group of people together for the California Current system, both nationally and internationally.

Summary of action items

Action Item #6	To contact two contemporary leaders of CalCOFI, forwarding all relevant VOICE information, with a request to assume the roles of VOICE champions in the California Current region. The message should have the Workshop Organizers in CC.
Responsible	Tony Koslow
Time line	As soon as possible, pending workshop report publication
Status	

Action Item #7	To fill out and submit the spreadsheet questionnaire to be used to assess the regional observing system readiness levels
Responsible	Tony Koslow and/or regional Champions
Time line	December 2017
Status	

Action Item #8	To make a list of key players, including stakeholder representatives, engaged in the California Current observing system.
Responsible	Tony Koslow, VOICE regional champions with potential contributions from Lisa Levin, Francisco Chavez, Elliott Hazen
Time line	Spring 2018
Status	

Action Item #9	To declare the status of data and information product accessibility, its scope and format, to VOICE project participants
Responsible	VOICE regional champions
Time line	August 2018
Status	

Recommendation #2	To seek synergies between VOICE and EBUS group formed as an IMSOO follow-up, as well as the SCOR WG EBUS, in an effort to bring the key players from the California Current Observing system together at a workshop (e.g. around the Trinational Sardine and Small Pelagics Forum).
Responsible	Francisco Chavez, regional champions & VOICE Co-Chairs
Time line	To be determined
Status	

West Africa: Senegal

The Senegal OMZ region was represented by Baye Cheikh Mbaye from Maurice Lamontagne Institute in Canada, who represented the Laboratoire de Physique de l'Atmosphère et de l'Océan Simeon Fongang in Senegal. Baye presented the talk entitled "Ecology and Oxygen variability over the West African upwelling ecosystem." The talk was given in the context of integrated oceanographic measurements being available since the early '90s, and the potential for the Senegalese shelf to constitute a very promising case study to understand the fish-environment relationships. Baye agreed to assume the role of a VOICE champion in this region. Hence, he will be responsible for coordinating all future efforts as part of the project.

On requirements setting process

It was stated that all the VOICE questions should be considered relevant in light of this region's scientific and societal needs. Baye described the Canary upwelling region dynamics and how the local OMZ fits in the context of tropical Atlantic trends in deoxygenation. The southern upwelling region remains vastly unexplored in the context of VOICE, and the first VOICE question on processes controlling the oxycline is especially important to resolve. It was suggested that using data collected up to date with a skilled circulation model with a high resolution could provide the answers to these questions.

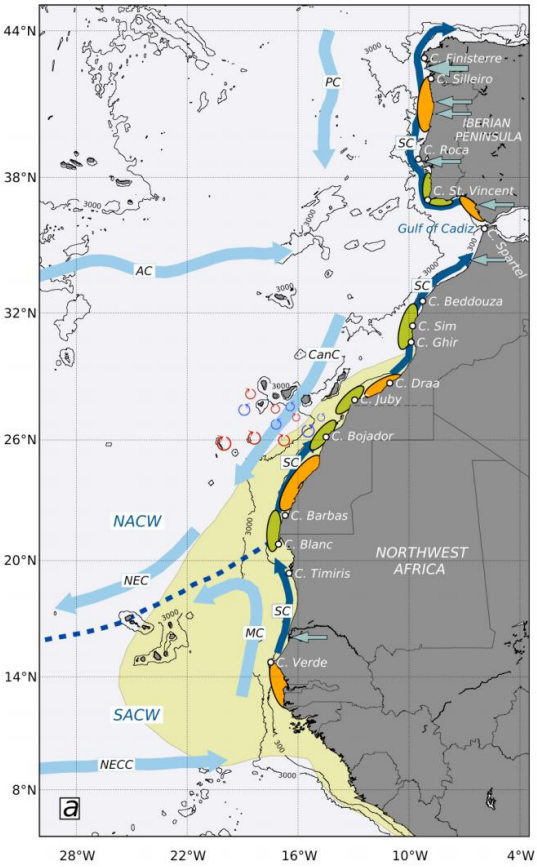

Figure 4. Canary Current System oceanographic setting. From Aristegui et al. (2009).

In terms of the mechanisms controlling the OMZ development off Senegal, there was a question about the link to anti-cyclonic eddies that migrated across from West Africa. It turns out that while the eddies might play a role in the northern part of the region, they do not reach the southern part of the coast which is dominated by the Senegalese upwelling. Regardless, it was pointed out that the eddies which travel from the north are oxygenated at their birth, and only lose oxygen as they propagate due to significant near-shore primary production occurring in the eddy waters.

As the shelf region affected by low oxygen conditions is both very wide and very shallow, potential effects of oxycline variability are expected to be seen on both the benthic and pelagic fish. Therefore, it will be of interest to look at the fishery data from both realms. It appears that the local fishermen continue fishing despite of the fact that they observe fewer fish. Except for the fisheries, the researchers have connections with other stakeholders, such as the oil industry. Baye's institute is being invited to every meeting held between the ministry and oil companies. There is potential in attempts to engage these additional stakeholders in funding the observing system enhancement as important end users of the data generated by the system. Although HAB-forming species, such as *Noctiluca scintillans*, are present in these waters, so

far no HAB incidences were detected. Consequently, shellfish monitoring is not yet a concern. No one in the room had any knowledge of potential aquaculture activities off Senegal.

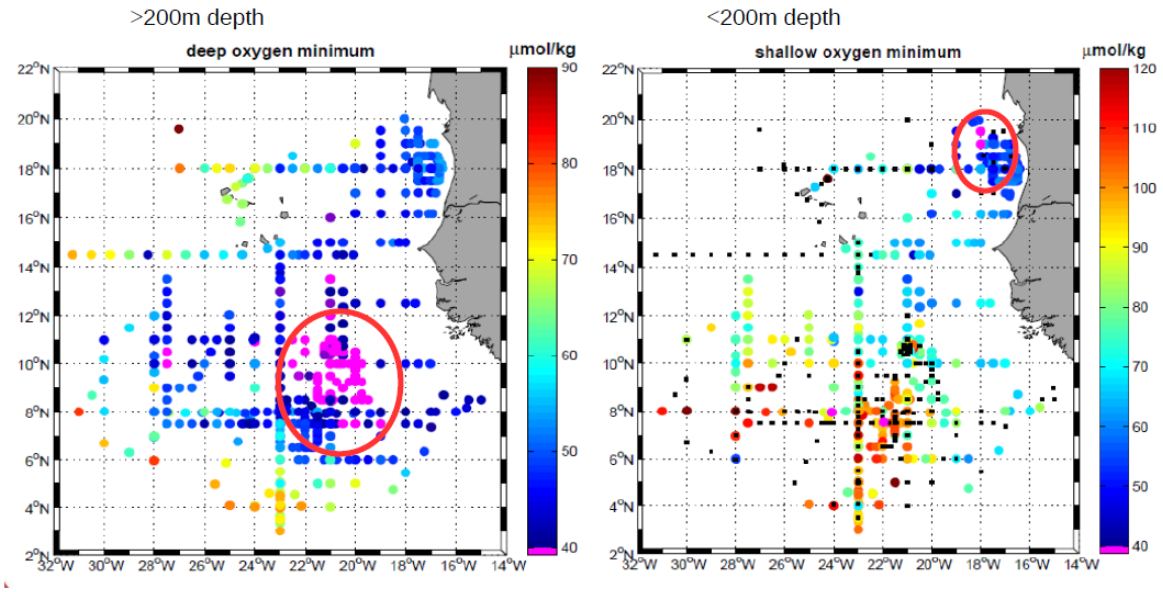

Figure 5. Location of a deep (>200m; left) and shallow (<200m; right) OMZ off the coast of Senegal. Oxygen concentration measurements on a colour scale. Source: Adapted from Brandt et al. 2015.

On observing system capability

The Laboratoire de Physique de l'Atmosphère et de l'Océan Simeon Fongang in Dakar, Senegal, has been operating since 2006 only. Prior to that, oceanographic and ecosystem monitoring was done solely by the National Oceanographic Center, under the Ministry of Fisheries and Maritime Affairs in Senegal. Due to the fact that it is very difficult to obtain data collected by the National Oceanographic Center, there is no confirmed information on the measurements taken prior to 1990s. After the 1990s, there are few integrated oceanographic measurements available. According to personal communication, there are oxygen measurements dating back as far as the 1920s. Unfortunately, there are no studies to confirm whether the observed hypoxic or even anoxic conditions are part of a long-term trend. This region does not appear on the map of OMZs published in the *Schmidtko et al. (2017)* synthesis paper, most likely reflecting the lack of data availability from this region.

In the context of the ongoing regional Dynamic Energy Budget (DEB) model, work which includes oxygen, it was interesting to know what the sampling frequency of the fish surveys was. Baye explained that while for physical and biogeochemical measurements the transects are 1 km apart, the fish surveys include only one station at the coast and one station in the offshore waters. These transects are very short and assume that if you find fish in the coastal waters, then you also find them in the waters in between the two stations. Offshore water sampling gives you unique information though. The surveys use CUFES (continuous underway fish egg sampler) to sample for pelagic eggs, and tow nets for fish. The results are integrated vertically. Some discussion then took place on whether the CUFES, which samples small volumes, smaller than tow nets, are suitable for surveying fish eggs. In general, the observing efforts are not following a design in terms of how regular the surveys are. Measurements are done in a project framework. For example, in 2015 there were no measurements, and only a

single survey in 2016 and 2017. The preference is to conduct a survey during the upwelling season, but in reality, at least two cruises per year are needed at minimum.

There are also regular fishery surveys done annually by the Norwegian with R/V Dr. Fridtjof Nansen, as part of FAO's *EAF-Nansen project*. Surveys are being performed more or less in the same region as the CUFES surveys, but not at the same time, rather towards the end of the year. The data collected comprise of fisheries, ichthyoplankton, plankton, and physical parameters. Part of these data were used by Baye in his PhD, for the period from 1980 to 2013. They can be obtained on request from the National Oceanographic Center because they were collected as a collaboration between the Senegalese and the Norwegians. Besides Nansen, there are other national and research project-based fisheries surveys being conducted. However, they are not regular. Recently, two surveys were run alongside the Nansen.

In terms of other components of the observing system that might be useful in the context of VOICE, there was mention of the need to integrate meteorological (because of the characteristics of the upwelling dynamics) and any relevant ocean acidification monitoring. It turns out that the mooring station provides data on winds, humidity and stratification. There is also a long-term station locally at the at the Dakar International airport which performs similar measurements. Moreover, a meteorological station was recently implemented at the Institute. Considering that an Ocean Acidification (OA) project was lately initiated following the *OA workshop* held just last February in Dakar, there was a question on whether pH sensors would be added to the moorings. The addition of an oxygen sensor and a pH sensor is planned within the ECLAIRS2 project on "Past and future African climate and marine variability," funded by the French IRD to start in 2018, led jointly by J. Mignot in France and A. Gaye from Senegal. Finally, acknowledging the proximity of the well-established *Cabo Verde Observing System (CVOO),* it was recommended that the Senegalese researchers attempt to collaborate with Cabo Verde on the questions of VOICE.

On critical needs

Regular and higher frequency measurements to be conducted at least twice a year were mentioned as the critical need for the system. When asked about the reasons for the ship not being used more often, Baye mentioned that (a) there are budgetary issues preventing more frequent ship usage, or (b) recently for maintenance as the ship was being renovated. There are possibilities for foreign scientists to rent the ship, however, the rental request should be done indirectly through the Senegalese collaborators. Extending the observing system capabilities through glider deployments should also be on the radar. For a summary of opportunities with respect to this observing platform it was suggested that Eric Machu be contacted. Furthermore, it was suggested that in this region which has much shallower depths than other OMZ regions, one could take advantage of the scuba diving capabilities. If set up no deeper than 30 meters, trawl-resistant moorings that are bottom anchored could be established and maintained at a much lower cost than surface moorings, which are subject to problems with fishing and vandalism.

The group concluded that perhaps it would be most helpful if VOICE attempted to synthesize the various datasets together, considering limited local resource to do such work. The plan would be for Baye to collect as much data as possible and by working with VOICE on historical analysis of the data, using simple GAM models to start with, and this way potentially demonstrate the added value of generating results and perhaps information products of relevance to the local stakeholders.

On data and information product management

The main issue discussed concerned a strategy towards improving access to the historical long-term data. The current status is that there is nothing available in an electronic format. When getting access to the data, right to access being shared between the Norwegians and the Senegalese, you are forced to manually type the data based on a technical report. The Nansen data cannot be released by Norwegians alone. These surveys go all along the Western African coast, and are shared with participating nations. The potential of these data is enormous since they include CTD, echosounder, oxygen and much more beyond fisheries. The key issue is to obtain information about the National Oceanographic Center activities, and include their representation as stakeholders in the VOICE project. Getting an idea about national expectations is key for evaluating the motivations for regional observations, that is specifying the requirements. Baye and Eric Machu have established contacts at the Center, therefore establishing such communication should be feasible, and is a necessary next step.

With respect to future international observing/research campaigns, it was noted that while the Senegalese don't need to apply to enter the EEZ, other foreign campaigns need an observer to enter and study the Senegalese coast. Observers should be military, not civilians. Thus, for an international research expedition it is best to communicate with the local researchers in advance.

On training and capacity building

In general, the French-Senegalese collaboration appears to be a very strong resource, conducive to fostering international exchange and capacity building. Concerning the moorings, the scientists operating the mooring receive proper training by French colleagues. Nevertheless, it was suggested that the local researchers could benefit from a freely available sensors software package distributed by the Ocean Foundation. Kirsten Isensee volunteered to inquire about the delivery of the software to the regional institutions.

Summary of action items

Action Item #10	To make a list of key players engaged in the observing system, in particular the data managers at the National Oceanographic Center.
Responsible	Baye Mbaye, Eric Machu
Time line	Spring 2018
Status	

Action Item #11	To develop a plan of action aiming at integrating oceanographic and fishery datasets and performing historical data analysis on all available observations data off the coast of Senegal.
Responsible	Baye Mbaye, Véronique Garçon, Kenny Rose
Time line	Spring 2018
Status	

Action Item #12	To arrange for sending the free sensor software package distributed by the Ocean Foundation to the Senegalese researchers
Responsible	Kirsten Isensee
Time line	Immediate
Status	

Action Item #13	To fill out and submit the spreadsheet questionnaire to be used to assess the regional observing system readiness levels
Responsible	Baye Mbaye + other local researchers and stakeholders
Time line	December 2017
Status	

Action Item #14	To discuss with other key players the suitability of potentially setting up diver-operated, bottom-anchored and trawl-resistant moorings as part of the regional observing system.
Responsible	Baye Mbaye
Time line	September 2018
Status	

Action Item #15	To contact the Cabo Verde observing system (CVOO) researchers and inquire about the potential to collaborate on the questions of VOICE.
Responsible	Baye Mbaye
Time line	Spring 2018
Status	

Action Item #16	To declare the status of data and information product accessibility, its scope and format, to VOICE project participants
Responsible	Baye Mbaye
Time line	August 2018
Status	

West Africa: Angola

Paulo Coelho from the Instituto Nacional de Investigação Pesqueira (INIP) and Carmen dos Santos from the Universidade Agostinho Neto gave the presentation entitled "Hydrographic circulation along the Angolan coast: Information and perspectives." They presented the main research programs at their institutions, gave a summary of the observing records and current capability, and provided perspectives on future activities. Both researchers confirmed their willingness to serve as VOICE champions in the Angola OMZ region. With their wide network of contacts in Angola and the Benguela Current region as a whole, they will be able to coordinate regional efforts as part of the VOICE project.

On requirements setting process

As far as applicability of VOICE questions is concerned, the two most important for the regional stakeholders' concern (i) the drivers of the vertical extent of the oxycline, and (ii) the impacts on the ecosystem. The local economy is based on fishing, mostly pelagic species: mackerel and sardine. However, there is currently a crisis in the fisheries. While only variability in temperature has so far been considered as a factor affecting the fish population distribution, there may be gaps in knowledge of the oxygen-related phenomena driving the observed decline. Moreover, it would be desirable to examine the potential role of oxycline and the changing OMZ as a whole, e.g. also in connection to HAB occurrences.

There are currently major knowledge gaps presented in the system. For instance, in 2011 the fisheries went down significantly (horse mackerel and sardines had zero biomasses in that year). Oxygen is very low in lots of parts along the coast. However, it is tough to disentangle the oxygen effects from the climate variability (e.g. Benguela Niño). The ecosystem can be affected by irregular disruptions in the atmospheric circulation, due to pronounced weakening of the southerly winds. As in all places, the fishermen have empirical knowledge of where to catch or not to catch. There is at the moment no advance warning from scientists who detect, e.g. an area of low oxygen at 50 m depth. In case of such events, technical reports are requested to explain the cause of such events. These reports are then communicated to the fishermen who however already know about the events. The reports serve as means of explaining what had happened over the past year. Additionally, INIP holds meetings with artisanal fishermen informing them about the reasons for changes in fisheries that might have occurred over the past year.

In general, the outstanding issue is that there is a large amount of data being collected but very little knowledge on how to process it. It was suggested that with some improvements and expansion of the sampling program, it should be feasible to account for the role of oxygen-related phenomena on ecosystem changes in the northern Benguela Current region. Moreover, the development of the *Abalobi* application, presented by Veronique as an example of fishermen collecting data and collaborating with scientists in South Africa, could potentially be applied in the Angola system. What started as a participatory action research project with a strong community development interface, has evolved into a social enterprise that is now being registered as a Non-Profit Organisation (NPO) and public benefit entity to better serve its fisher-driven mission

There is strong collaboration between Angola, Namibia and South Africa as part of the *Benguela Current Commission (BCC)*, which promotes the vision of the Benguela Current Large Marine Ecosystem (BCLME). One of the project called by the BCC was NASCLIM which made a survey in the three countries to do an inventory of causes and consequences of climate change. A series of workshops are being held in the three countries. At the last series that Carmen was in charge of, all relevant stakeholders were brought to the table. The new MARISMA project will do the first Marine Spatial Planning for Angola. There, also all stakeholders will be put in one place. As part of the BCC, countries share data among themselves, analyse it and produce technical reports. Each individual scientist conducting a project is submitting data into the BCC archive, with the main database located in Namibia. Concerning the Climate Change and Fisheries project advertised on the BCC webpage, it was deemed as having little potential for interest in VOICE activities. The project has not yet been initiated. Its goals are oriented around climate mitigation and policy, not about research activities. The results will feed into management efforts aiming at decreasing mortality in sharks and turtles, among other.

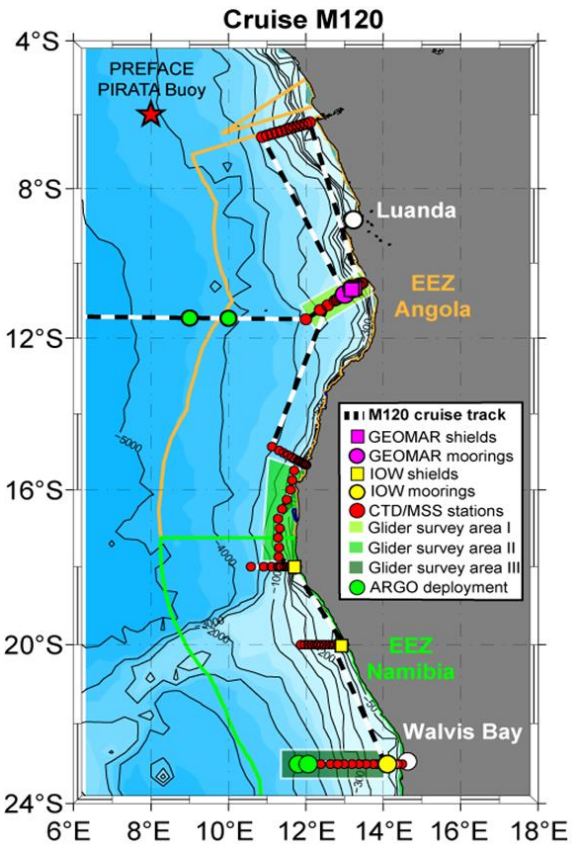

Figure 6: Observing elements in the Angolan OMZ system. Source: workshop presentation by Paolo Coelho.

In terms of the conceptual model development, it was suggested that the next step in the data analysis would be to integrate the oceanographic and fisheries data and proceed with attempts to draw basis correlations between time series. Such a historical data analysis aimed at establishing the fundamental linkages between the environment and key species were recommended as prior to any evaluation of the adequacy of the current observing system. The region champions were encouraged to take a look at the examples so far performed in systems such as California Current and the Humboldt Current.

On observing system capability

Conclusions from the work on the Global Ocean Sciences Report were that it is very little financial investment in sustained observations in LMEs, including the BCLME. Paulo and Carmen gave a long list of issues which require support, potentially from VOICE, and which are critically needed in order to enhance the capacity and improve accuracy of ocean observations in the Angola OMZ system. The topics include: data analysis, training in modelling, tide gauge installation along the coast, coupling physical with biological data, scholarship support for Masters and PhD students, and strengthening the institutional capacity.

Further expansions to the observing system are also required, especially deployment of more moorings. Currently, there is one mooring operating as part of the *PREFACE* project at 6°S. While the PREFACE project will end in 2018, there are some opportunities for maintain the GEOMAR-based mooring in the water for longer. The goal would be to add at least one mooring

at the southern edge of the Angolan coast, and another one on the northern edge, where there is influence from the Congo River but it is unknown how the river contributes to the observed oxygen depletion. There are also glider surveys taking place in the coastal zone, south of the mooring site (see Figure 6). All in all, at the moment, there is no strategy for expanding the autonomous component of the observing system. Furthermore, there is potential for exploring what was suggested for the Senegalese system, that is the diver operated shallow water moorings. In fact, the Angolans have some experience in these activities with South African students conducting regular dives to replace bottles and collect data on bottom-anchored floatation devices. Results from 3-years work already were used for a PhD project.

In terms of the expansion of ship-based observations, nutrient and pH measurements will be conducted starting from 2017 thanks to the R/V “Dr Fridjoft Nansen” operating in Angola waters under the EAF-Nansen Project. Furthermore, in 2018, the new R/V "Baía Farta" owned by the Ministry of Fisheries of Angola will be inaugurated. The Nansen cruises, split among two cruises, will continue to survey the off-shore waters. The new Angola ship will perform surveys closer to the coast. It is not clear whether the two efforts combined will provide a time series record. At the moment, there are gaps in the records, for example in 2017 due to the old Nansen ship being replaced with a new one. In fact, the Nansen project has a new strategy to cover the Benguela Current region. Next time they will come to Angola coast will be only in 2019.

On data and information product management

Sharing data in Angola is a challenging issue. There is a need to show that scientists worldwide share the data, and to demonstrate locally that necessity. Majority of data is published through internal ministerial reports, although Paulo’s group has recently contributed strongly to an increased activity leading to publishing scientific articles in peer-reviewed journals. Moreover, there is a need for a legal platform for data sharing being developed. INIP is currently in need of a data centre. As it is, data has to be re-organized, filtered and analysed separately for a given application. To access the data, including the Nansen project data, one must submit a written request to the Ministry and in most cases go through substantial amount of paper work. Access is not guaranteed, even for an Angolan scientist. It is anticipated that with the new Nansen project sampling strategies, there will be new contracts on data policy. This issue was also discussed during the *2nd AtlantOS General Assembly* in June 2016, in Kiel, Germany. Shortly after, a Norwegian representative visited Angola to discuss the notion. In contrast to the above, data collected by R/V Meteor as part of the PREFACE project is handled the same way as any German national science project. All data should be stored in *PANGAEA*.

Besides data collected by governmental agencies, there are rich, excellent quality data collected by oil companies such as BP Chevron and Total. Their sampling goes down to 2000 meters. Oil companies give out data for specific years requested. The most recent ones are never available. These observations include benthic invertebrates, marine mammals and fish surveys from the parts of the coast where companies have exploitation sites. Carmen has a strong personal connection with the industry. There are also established collaborations with researchers from University of Aberdeen (UK) and Florida University (USA).

On capacity building

In terms of capacity building, the most urgent need is for training in using the instrumentation and analysing the data. Lack of capacity to perform statistical analysis on the data is perceived as a major stumbling block for Angolan research. INIP is in urgent need for a new, younger working force, and is willing and able to organize summer schools for young scientists, but

need support from international groups. There are 20 master students trained each year at the Agostinho Neto University. In spite of their efforts, it was not possible to join the International Master's program. However, there are teachers from Lisbon, Portugal, coming to Angola on a regular basis to train in some disciplines for a period of one month. At this time, the opportunity for Angolan students is to attend one of the upcoming summer schools: the IOCCP Sensors Summer Course in Sweden (summer 2018), GO_2NE summer school (summer 2019).

Summary of action items

Action Item #17	To fill out and submit the spreadsheet questionnaire to be used to assess the regional observing system readiness levels.
Responsible	Carmen dos Santos, Paulo Coelho
Time line	December 2017
Status	

Action Item #18	To share the contact details of the person responsible for developing the Abalobi application with Carmen and Paulo
Responsible	Véronique Garçon
Time line	October 2017
Status	COMPLETED

Action Item #19	To encourage that INIP and Agostinho Neto University students/employees apply for the IOCCP and GO_2NE summer schools held in 2018 and 2019, respectively.
Responsible	Carmen dos Santos, Paulo Coelho
Time line	Pending the release of calls for summer school applications
Status	

Action Item #20	To declare the status of data and information product accessibility, its scope and format, to VOICE project participants
Responsible	Carmen dos Santos, Paulo Coelho
Time line	August 2018
Status	

West Africa: Namibia

Grant Pitcher and Lisa Levin gave presentations on the current and future observing activities in the Namibian OMZ waters, with significant input from Anja Van Der Plas who could not attend the workshop in person. Following the workshop, Anja submitted the filled spreadsheet questionnaire with near complete information on the regional observing system. Neither Lisa nor Grant felt they should assume roles of VOICE champions in the region. They recommended that the group approaches Anja with such a request.

On requirements setting process

The Namibian part of the northern Benguela Current region is very much concerned with the questions of VOICE. Temperature and oxygen are known key drivers of change in the ecosystem, affecting strongly the fluctuations in the bearded goby, several other pelagic fish species, but also jelly fish. Monitoring year to year variability in both the oceanographic and ecosystem components is high on the agenda of the regional observing system. Fishing for hake and horse mackerel is one of the main motivations for the sustained observing system in the Namibian waters. Commercial fisheries include pelagic, midwater and demersal species. Deep-sea fishery (e.g. deep-sea crab) is also exploited, with orange roughy being almost completely fished out locally. Namibian research focuses strongly on connecting environmental measurements to fish species distribution. This includes strong documentation between benthic processes and fisheries. Other regional stakeholders represent oil and gas exploration, and phosphate mining. There is also a very active aquaculture program which is a particularly strong driver for environmental monitoring. Considering ocean health issues, low O_2 conditions accompanied by H_2S outgassing events are said to cause significant nearshore mortalities in fauna. There is coastal monitoring of HABs. The role of episodic flood events, delivering tons of terrestrial debris, are also key in monitoring changes in organic matter transport and changes in oxygen concentration.

Based on the material presented and the discussions held, it appears that there is a rather well developed understanding of the system dynamics and mechanisms responsible for observed ecosystem changes and trends related to variability in oxygen conditions. However, a clearer focus on the oxycline variability and its specific impacts might be needed in order to complete a VOICE conceptual model in this region. In general, this very productive ecosystem has many benthic-pelagic linkages and observations of ecosystem changes would need to include all trophic levels, from sediment uptake and bacterial production (large methane accumulation, dense bacterial mats covering the OMZ bottom) through plankton and fish to seals and seabirds. Very different responses of main fish species: cape hake, horse mackerel and bearded goby, are observed due to changes in oxygen availability and long-term warming. Benguela Niño was quoted as an important climate driver. It could be summarized that increasing hypoxia causes an upward and northerly evacuation of hake (low tolerance to low oxygen levels), which reduces the predation on gobies. This coincides with a decline in sardines, which the gobies then replace as the primary forage fish. A fairly dramatic increase of the gobies in the region is viewed as detrimental for the other fisheries.

Considering the modelling capabilities vs requirements, it was mentioned that while the available coupled models simulate the off shore distribution of oxygen very well, their performance is not satisfactory in the shallow areas where simulating sediment control process is key. It is not clear to what extent this model limitation would hinder the application of current models to any VOICE studies. In terms of the funding situation and opportunities, lack of research funding bodies and lack of funding for basic research is a major obstacle. Consequently, there are only few academic scientists, and research is conducted by

government agencies. There are no means of training students for research other than fishery related.

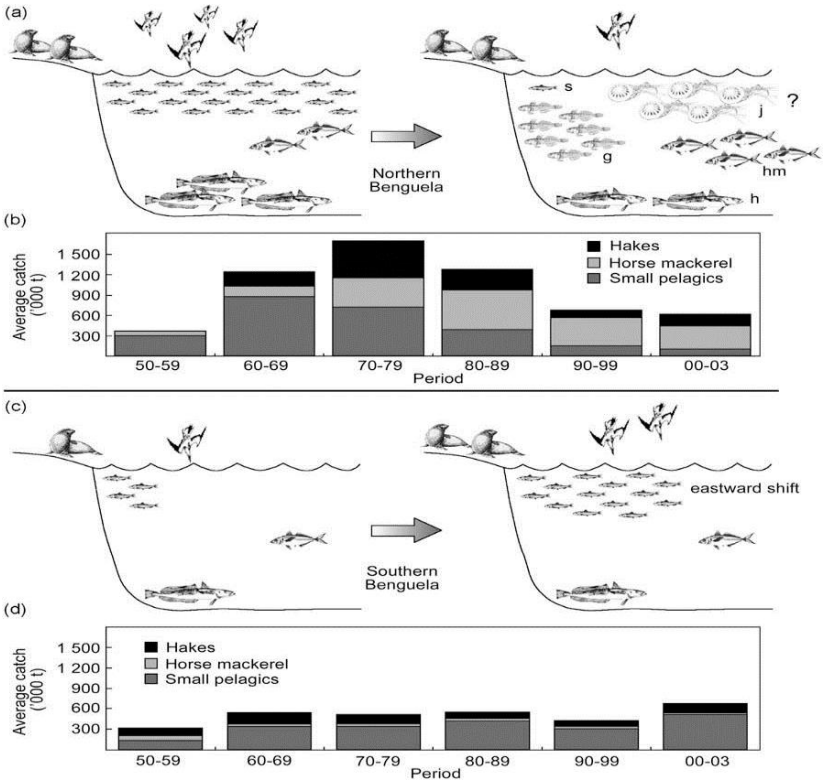

Figure 7. Conceptual model explaining changes in top predators observed in the Benguela Current system. From Hutchings et al. (2009).

On observing system capability

One specific issue discussed concerned the fact that it seems that German scientists from *Leibniz Institute for Baltic Sea Research in Warnemünde, Germany (IoW)* conduct regular annual ichthyoplankton surveys in the Namibian OMZ. However, it appears that their data are not being analysed. It was not known whether these data are being submitted to PANGAEA, as in the case of the mooring data. Kirsten Isensee volunteered to contact the IoW scientists to clarify the status and availability of these data.

On data and information product management

For external agencies to obtain access to data they need to apply to the Permanent Secretary (PS), and the *Ministry of Fisheries and Marine Resources (MFMR)*. Thus, it is so far best to work with an MFMR scientist to request any data access. Historical data is being submitted to the *South African Date Centre for Oceanography (SADCO),* and thus also to the World Ocean Data Centre (WODC). The IoW-MFMR mooring data is archived in *PANGAEA*. There is historical data on oxygen in the South African waters, from 1950s. They are archived at SADCO, but are not very consistent. The most recent data resides with Grant. Further discussions with Anja and other Namibian partners are necessary to evaluate the potential of reaching suitable data sharing agreements, in line with the needs of VOICE and in accord with GOOS expectations.

Summary of action items:

Action Item #21	To approach Anja van der Plas with a request to assume the role of VOICE champion in the Namibia OMZ region.
Responsible	VOICE Co-Chairs
Time line	Immediate
Status	COMPLETED Anja tentatively agreed to serve as regional champion.

Action Item #22	To fill out and submit the spreadsheet questionnaire to be used to assess the regional observing system readiness levels.
Responsible	Anja Van Der Plas
Time line	December 2017
Status	COMPLETED Following the workshop, Anja submitted the filled spreadsheet questionnaire with near complete information on the regional observing system

Action Item #23	To clarify the status of ichthyoplankton survey data and their potential availability for historical data analysis, as done in the California Current system.
Responsible	Kirsten Isensee, Anja Van Der Plas
Time line	Before September 2018
Status	

Action Item #24	To maintain contact with Brian Mudumbi from the National Commission on Research Science & Technology (NCRST), who attended the 2nd AtlantOS General Assembly in 2016, and who appeared to have substantial knowledge of the Namibian oceanographic observations.
Responsible	Johannes Karstensen, Artur Palacz
Time line	Before September 2018
Status	

Action Item #25	To declare the status of data and information product accessibility, its scope and format, to VOICE project participants.
Responsible	VOICE regional champion(s)
Time line	August 2018
Status	

Northern Indian Ocean: Arabian Sea and Bay of Bengal

The observing efforts in the Arabian Sea and Bay of Bengal OMZ systems were represented at the workshop by Wajih Naqvi and Damodar Shenoy, respectively. Both scientists agreed to assume the roles of VOICE champions in these regions. Following the presentations from both the Arabian Sea and Bay of Bengal regions, some more specific issues were discussed by the workshop participants.

On requirements setting process

The extent to which oxycline variability plays a role in the two systems is different. In the Arabian Sea the importance of oxycline dynamics will be greater along the west coast than at the east coast. In the Bay of Bengal, low oxygen waters do not come up to the surface as much as in the eastern Arabian Sea or elsewhere around the world, therefore VOICE questions might be less relevant. In the Bay of Bengal, it is the spatial expansion of the dead zone that is likely to have the most effect on the fishes of the region.

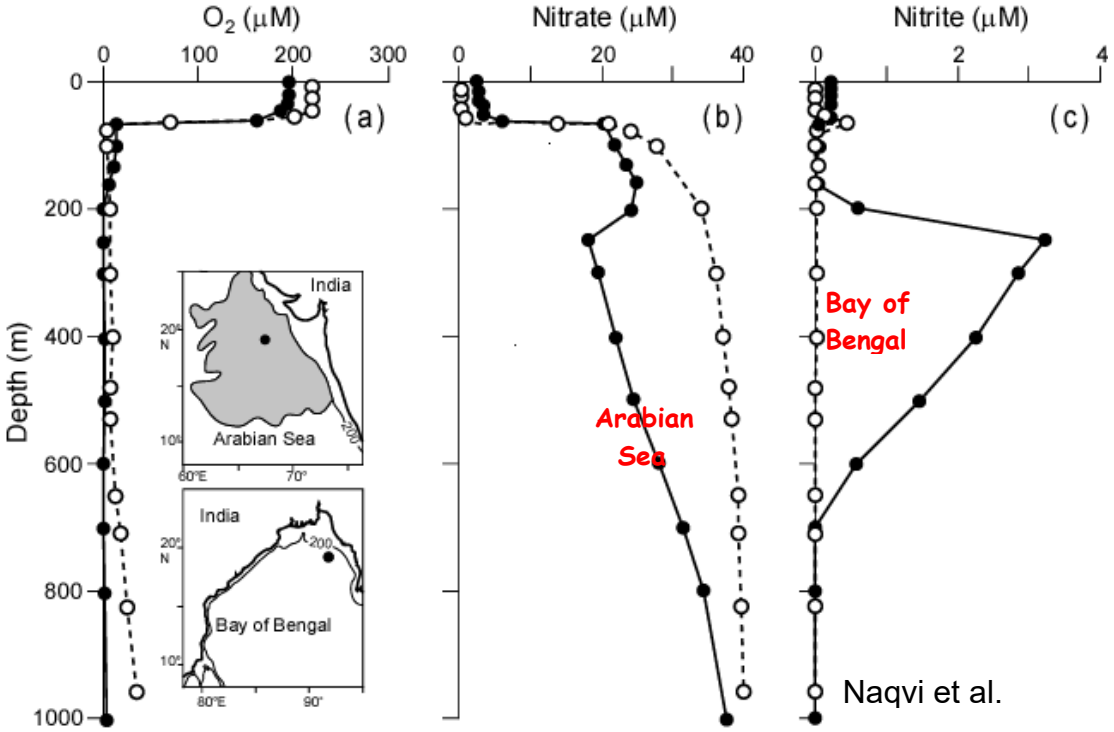

Figure 8. The differences in characteristic oxygen, nitrate and nitrite vertical profiles in the Arabian Sea and Bay of Bengal. Source: Naqvi et al. (2006).

The question of what determines the depth as well as intensity of the oxycline would certainly be focal to the implementation of VOICE in the Northern Indian Ocean OMZ waters. Determining concentration thresholds at which biological life becomes affected, thus having strong implications on the living resources, is of particular value to the society in this region.

While there are outstanding issues with respect to openly sharing data collected in the region, it appears that the data collected could be sufficient to answer some of the questions posed by VOICE, especially those related to understanding the biogeochemical and physical factors driving oxycline variability. The challenge would be to integrate the biological observations in order to answer the remaining, more biological and ecosystem related questions of VOICE.

These would not only require looking at ecosystem impacts but also at the biological phenomena that could exacerbate changes in oxycline depth, its extent and intensity.

The efforts carried out by the National Institute of Oceanography (NIO) focus on oceanographic conditions and do not examine changes in ecosystem levels beyond that of zooplankton. However, NIO and the fisheries institute have signed a Memorandum of Understanding (MoU) and plan to perform joint projects. Thus, there is an official channel formed possibly enabling a merger of the different datasets. VOICE project is hence seen as an opportunity to provide rationale for performing unprecedented, multi-disciplinary integration of physical, biogeochemical and higher trophic level biological datasets from around the Northern Indian Ocean waters.

One aspect discussed was the apparent lack of observed decline in oxygen concentrations. At least for the past four decades, based on the currently available data, the Arabian Sea system has been on the verge of becoming anoxic, yet it has not happened. This poses a challenge to setting the requirement for what exact phenomenon and magnitude trend to capture. In the Bay of Bengal, time series observations reveal significant long-term variability in the OMZ and the oxycline, with lots of potential impacts on the fisheries and other economic sectors exploiting regional marine resources.

On observing system capability

In general, it was stated that India already has the necessary expertize and observing capacity needed to maintain a fit-for-purpose observing system and generate information needed to address the societal requirements. Thus, increasing the readiness level of the observing system in India does not require capacity building, as in the case of some other VOICE regions. Implementation of state-of-the-art instruments and sensors, better coordinated sampling design, multi-disciplinary integration and stronger international collaboration are perhaps the themes that should be considered when discussing means of increasing the readiness level of the observing systems in both the Arabian Sea and the Bay of Bengal.

For instance, very strong oxygen gradients observed down the water column are also a challenge to the oxygen sensors deployed on different observing platforms. Classical oxygen optodes, used on the Biogeochemical Argo floats for instance, have issues in capturing such large oxygen gradients. They are also not adapted for ultra-low oxygen concentrations. The profiling floats, which can operate in the Indian Ocean for up to 2-3 years, can however be used for some studies, e.g. detecting advection of higher oxygen-content waters, detecting turbidity maxima, etc. In terms of low oxygen measurements, STOX sensors present an alternative to optodes. So far, there was only a single STOX deployment performed in the region, done by the German scientists. An array of moorings in the Northern Indian Ocean is also equipped with oxygen sensors, as well as with sediment traps at 600 m, 1000 m and deeper. Due to little material being accumulated, quantification of remineralization rates from these data was not possible. In either case, it was also argued that in terms of the capability to detect anoxia, nitrate maxima provide a more certain indicator of this process. Thus, any limitations in measuring ultra-low oxygen concentrations do not prevent researchers from drawing conclusions on the development of anoxic conditions.

On international access to Exclusive Economic Zone (EEZ) waters

With the invention of the EEZ concept in 1977, restrictions on data sharing appeared. Although currently there are some exceptions possible, in general international scientific expeditions are not permitted to do research in the Indian EEZ. With India leading the *Second International Indian Ocean Expedition (IIOE-2)*, there is potential for less restricted access in the future. In Bangladesh, other restrictions apply, with permissions granted to German campaigns but not to the Indian ones.

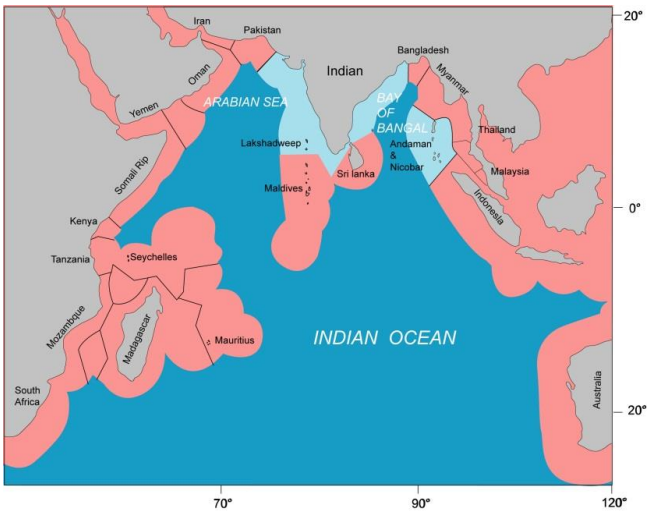

Figure 9. 25% of the area in the North Indian Ocean falls within exclusive economic zones (red areas) of littoral countries, and is thus not accessible for observations. Source: Damodar Shenoy's presentation at this workshop.

One peculiar issue related to the EEZ restriction is that for example when an Argo float moves into the EEZ, the data acquired during its transit through the Indian EEZ, must be removed prior to it being posted on the Argo data repository. This does not only undermine the successful model of Argo, but must be recognized as a stumbling block to scientific progress in general.

On meteorological observations

The group was informed that in India there are daily meteorological observations taken all along the coast. Since the oceanic circulation is predominantly wind-driven, the ocean-atmosphere interactions are being studied in great detail.

On international collaboration in the region

Over the past years, there were attempts to establish international collaboration between institutions from countries surrounding the Arabian Sea and Bay of Bengal. Such efforts were successful in the case of India-Oman collaboration. Despite similar attempts among India and Bangladesh, the collaboration was eventually not established. There was also an MoU signed between the institutes in India and Myanmar, resulting in some joint cruises. However, lack of adequate institutional support for such initiatives in countries like Myanmar and Bangladesh present a severe obstacle to the success of collaborative efforts. However, with the onset of IIOE-2, there might be new opportunities for working together on the international arena. Although formal collaboration with Iranian institutions is challenging, Iran has a long history of performing high quality, VOICE-relevant measurements. With a well-equipped ship, R/V Persian Gulf Explorer, there are now efforts to supply the Iranian scientific fleet with instruments and sensors for carbonate system measurements. IOCCP is in email contact with Dr. Abolfazl Saleh from the Iranian National Institute for Oceanography and Atmospheric Science. There might thus be a possibility of discussing the status of and opportunities for oxygen measurements in the western part of the Arabian Sea waters.

China is another key player in the Northern Indian Ocean, who however focuses its research efforts in the eastern part of Bay of Bengal, thus outside of the scope of VOICE. It was noted that apart from performing a number of cruises in the Indian Ocean, they have also established an observing station on Pukhet in Thailand. It was suggested that for countries such as

Bangladesh, impacts of ocean acidification might be of greater concern than those of deoxygenation. At a recent OA workshop in Thailand, there was a strong participation of scientists from Bangladesh who are active in submitting OA related research proposals, as well as establishing a local OA observing system. Separate from research collaboration is the ongoing exchange of knowledge and capacity building through NIO sending their faculty to teach in Dhakka, in Bangladesh, and Bangladeshi students visiting NIO.

On data and information product management

Access to oceanographic data in India and neighbouring countries was discussed in great detail. In general, while it is common and straightforward to exchange data on an individual basis as part of the publication process, obtaining permission to datasets on a government level will simply not be allowed. An example of a successful individual-based data sharing collaboration was given by Lisa Levin who was able to use a collection of 110 stations with CTD casts from 2000-2002 and later, performed during cross-margin transects along the Indian shelf, in a Nature publication. If of use to VOICE, it was recommended to contact Akhur Raman to inquire about the status and availability of those particular data.

In terms of the fisheries data, Indian fisheries institutes collect fish landing data, and once documented, they go into the ministry as a report. The Centre for Marine Living Resources & Ecology (CMLRE) are said to conduct some fish surveys. There are experimental fishing vessels in both the Arabian Sea and the Bay of Bengal. Unfortunately, the data is not interpreted in conjunction with oceanographic data. In fact, there is no integration of research between lower trophic levels and higher trophic levels. While this is recognized as a major shortcoming, it has proven difficult to bring the two traditionally distinct research communities together.

This lack of integration of oceanographic and higher trophic level data is perhaps one element of the regional observing system that requires most support from the VOICE project. Pending that adequate data sharing agreements can be established, the main objective will be to perform a historical data analysis on such an integrated dataset and ultimately produce a conceptual model of VOICE in the Northern Indian Ocean OMZ region.

It was noted that it is not unusual to retain control of the fisheries data. In most countries, including the US, one must request data with a proper justification. Such a policy is necessary to prevent individuals from redoing their own fishery indices and producing alternative commercial fish stock assessments. Thus, it is important to be sensitive as to what fishery dependent and independent data and why VOICE would use. Ultimately, it is unlikely that any international research efforts could affect the decision process for making Indian or any other countries' oceanographic data available. In India, without the support of the navy and the ministry of defence, any grass root scientist initiatives will not be effective.

Summary of action Items

Action Item #26	To establish a dialogue between the oceanographic and fishery science communities in Indian in order to integrate the oceanographic and fisheries data collected by Indian institutions in the Arabian Sea and Bay of Bengal.
Responsible	Damodar Shenoy, Wajih Naqvi
Time line	Spring 2018
Status	

Action Item #27	To fill out and submit the spreadsheet questionnaire to be used to assess the regional observing system readiness levels.
Responsible	Damodar Shenoy, Wajih Naqvi
Time line	December 2017
Status	

Action Item #28	To inquire about status of oxygen and related measurements performed by Iran. Contact through Abolfazl Saleh.
Responsible	Maciej Telszewski, Artur Palacz
Time line	Immediate
Status	

Action Item #29	To declare the status of data and information product accessibility, its scope and format, to VOICE project participants.
Responsible	Damodar Shenoy, Wajih Naqvi
Time line	August 2018
Status	

Humboldt Current system

Dimitri Gutiérrez from Instituto del Mar del Perú (IMARPE) and Ivonne Montes from Instituto Geofísico del Perú (IGP) represented the regional observing and modelling efforts from the Humboldt Current system OMZ. Both scientists confirmed their willingness and ability to act as champions for this VOICE region. During the workshop, Dimitri gave a presentation on the "Current oceanographic research and observation capabilities of IMARPE in the Peruvian upwelling system", and Ivonne presented the efforts on behalf of IGP, with a strong focus on the modelling capabilities with respect to VOICE.

On requirements setting process

It was clearly stated that the oxycline variability and its impacts on the ecosystem is an important issue for Peruvian management. This applies both to the tactical day to day decision making as well as the strategic planning, based on the recognition of the fact that the whole setting can change over the long term. The importance of observing oxycline variability was recognized in terms of management of living resources but also coastal management and climate change. Local policy makers are keen to observe the trends in the oxycline variability. In fact, this issue was given as one of the motivations for the current observing system. However, it was clear that in order to understand the observed trends, the mechanisms behind the trends also needed to be examined. An example of specific question targeted by the policy makers could be whether the spawning areas will be narrowed or expanded in response to changing trends in oxygen, seen in terms of the carrying capacity for fish. It was also noted that linking oxycline variability with changes in fish biomass is more challenging than linking to changes in oxygen regime or concentration. This is because the limits of the ecology/physiology are broader than just the feature of the oxycline. It was suggested that perhaps a more meaningful result would be to link the thresholds in oxygen concentration tolerance to fish biomass and biodiversity. Providing such information is beyond what is currently available in reports and what is an outstanding requirement. While there is great willingness to perform multi-disciplinary data integration in Peru, such an effort needs to take place across South American countries, first through linking of institutions, then regions and finally countries. Thus, implementation of VOICE is strongly and directly relevant to the societal requirements of Peru and other South American countries along the Pacific coast.

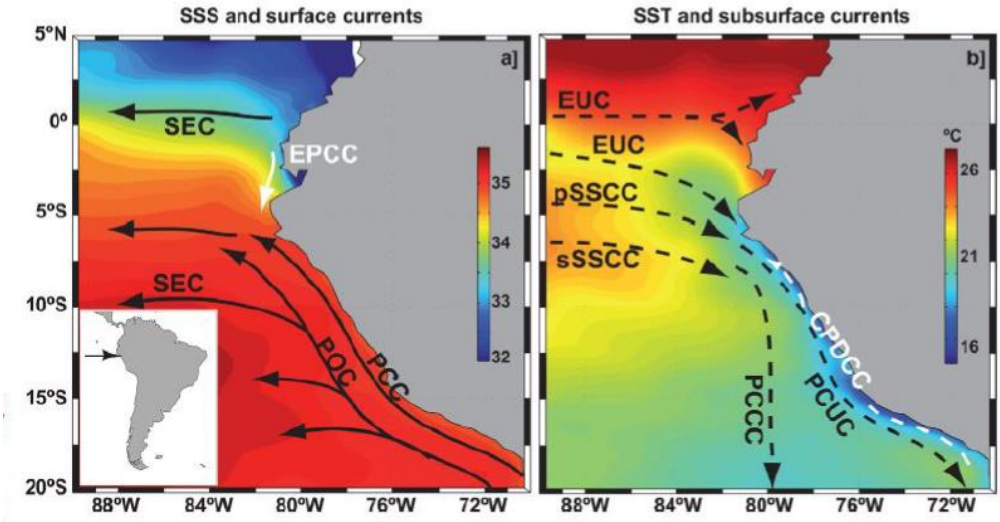

Figure 10. Surface salinity and surface currents (a) and surface temperature and subsurfuce currents (b) in the region. From Chaigneau et al. (2013).

On observing and modelling capability

There was an interesting discussion about the suitability of the currently used model (PISCES) to represent very low oxygen concentration levels in the region. Acknowledging that the model is limited in its ability to simulate and thus forecast anoxia, it is nevertheless an important component of VOICE in terms of setting the requirements for observations. Besides the hypothesis testing aspect of any modelling work, this particular case provides rationale for collecting more field information in the lower end spectrum of oxygen concentration range. Furthermore, it seems to suggest that explicit simulation of microbial community dynamics is also necessary, and requires a dedicated observing effort.

On the other hand, while increasing model complexity may lead to more accurate simulation of oxygen levels, lower accuracy in modelling biogeochemical rates and biological standing stocks may come as a trade-off. Moreover, considering the fact that modelling products need to be question-driven, it may not be necessary for VOICE to tweak the model further to better meet the strict biogeochemical requirements. Instead, it could be more beneficial to evaluate the model capability at oxygen levels to which other ecosystem elements are sensitive too. For instance, tuna fish respond negatively to the relative high oxygen concentration levels at around 120 µmol/l. Similarly, oxygen gradients at around 60-100 µmol/l might already drive the migration behaviour of some nekton. Therefore, it appeared critical that future model evaluation for the Humboldt Current system for the purpose of VOICE take into account the specific phenomena and scientific questions that are key to building the VOICE conceptual model.

On data and information product management

Data collected from observations performed by IMARPE so far resides only at the IMARPE repositories. The data is made available on request. This includes data already published in scientific journals. There are currently efforts undertaken to relax some of the restrictions on data sharing. One of the outstanding issues is lack of quality control being applied in an operational mode. While QC is being applied on historical time series and climatology products, there are no protocols to ensure that data available in near-real time undergoes QC.

In the context of VOICE, the current situation would mean that any request to perform new analysis in the region would have to go through the champions, who are then responsible for locally producing products tailored to the local requirements.

Summary of action items

Action Item #30	To fill out and submit the spreadsheet questionnaire to be used to assess the regional observing system readiness levels.
Responsible	Ivonne Montes, Dimitri Gutiérrez
Time line	December 2017
Status	

Action Item #31	To identify institutional or international (potential synergy with EBUS SCOR WG) opportunities for engaging a student or researcher on historical data analysis in the context of VOICE.
Responsible	Ivonne Montes, Dimitri Gutiérrez
Time line	Spring 2018
Status	

Action Item #32	To declare the status of data and information product accessibility, its scope and format, to VOICE project participants.
Responsible	Dimitri Gutiérrez, Ivonne Montes
Time line	August 2018
Status	

Recommendation #3	To approach *Comisión Permanente del Pacífico Sur (CPPS)* with a request to engage in attracting commitment of the regional institutions to implement a targeted capacity building action aimed at bringing 1-3 experts related to studying oxycline and its impacts to a regional VOICE workshop dedicated to increasing the readiness level in the Humboldt Current OMZ system.
Responsible	Dimitri Gutiérrez, Ivonne Montes
Time line	To be determined
Status	

VOICE next steps

In the final session of the workshop the group focused on naming realistic actions to be taken by the group as a whole before the next planned meeting of VOICE. The suggested actions described below might partially overlap with the more specific action items or recommendations listed under each VOICE region in the preceding sections, but are limited to the set of common actions to be applied across the regions. Having obtained an overview of what the regional requirements and capabilities are during this workshop, there is now a need for mobilizing both regional and global activities and concerted efforts towards meeting the particular objectives, such as the readiness level assessment, literature review, historical data analyses and data sharing agreements.

The next VOICE workshop is expected to take place around the *SFB 754 Conference* in September 2018, in Kiel, Germany. The exact meeting date will be confirmed and communicated at a later stage. It should be noted that GO_2NE is also planning to holds its 2018 annual meeting around this time.

Readiness level assessment

The most immediate task for all workshop participants is to lead or contribute to the effort of comprehensively filling out the spreadsheet, ideally by end of December 2017. VOICE experts not directly involved in a particular regional system are encouraged to provide feedback on the questionnaire and provide input as they see fit. In case the regional representatives attending the workshop suggested alternative persons to be approached as VOICE regional champions, it is critical that the champions be appointed as soon as possible. The workshop organizing committee, with assistance from regional representatives, will approach the suggested candidates with such a request. The regional champions are responsible for circulating the document to all relevant key players and stakeholders who could provide valuable information on the readiness level of any or all aspects of the three categories of the FOO that the questionnaire is concerned with. In case there are questions that cannot be answered or elements of the questionnaire tables that cannot be filled out in the time frame provided, it would be beneficial to indicate the name of the likely contact person with potential to fill out the given section of the table. Establishing a network of contacts will be an important element to the successful implementation of VOICE.

Literature review across VOICE regions

Several options for performing a global literature review on the topic of VOICE were put forward. On one hand, there is a possibility of mobilizing students in one of the labs, e.g. under Ivonne Montes in Peru, to jointly accomplish the task, in combination with the historical data analysis of data from this region. This could be facilitated by the fact that there might be a synergy with the EBUS SCOR WG in this respect.

The other possibility is to hire a short-term postdoc to carry out the work as a dedicated effort. This option seemed to be preferred by the group. In terms of the opportunities for funding such an action, Maciej and Artur agreed to look into a recent call for short-term postdoc fellowships at IO PAN, in Sopot, Poland. It was agreed that if jointly supervised by VOICE Co-Chairs and IO PAN researchers, it would be suitable to host a postdoc in Poland, even though it is not one of the VOICE regions. In the aftermath of the workshop, an application was submitted by a suitable candidate, but due to high competition and only a single grant available, it was not

successful. Currently, other opportunities for realizing this crucial task are being explored collectively by the VOICE group.

Historical data analyses

In terms of the approach for the analyses, one suggestion was to follow the sequence of steps taken by *Bertrand et al. (2010)* and subsequent publications. Future work should also strongly consider the excellent demonstration of data analyses performed by Tony Koslow in the California Current System. Regardless of the exact scope and format of the analysis, the aim must not be to conduct five different sets of region-specific historical data analysis. It must be kept in mind that we are looking for similarities in the data structure and commonalities in the conclusions drawn from the analyses with the aim of producing a general conceptual model across all systems, and ultimately, a blueprint for implementing a VOICE observing system.

While local efforts in the direction of historical data analysis with respect to oxycline variability and its impacts on the ecosystem are ongoing, independent of VOICE, there is a need for the VOICE group to provide feedback to enable more focused efforts. One possibility discussed was to hold regional workshops for local key players devoted to either assessing the local readiness levels with respect to VOICE, or to initiate concerted historical data analyses efforts, or both. The process of setting requirements for local observations would benefit from workshop discussions, e.g. on the sensitivity thresholds for animal species affected by oxycline variability, or on what is the role of boundary current transports in driving changing oxygen supply. However, the general sentiment was that such workshops are necessary but ought not to be coordinated and/or funded by VOICE until data sharing agreements are in place and until some progress in the direction of VOICE be demonstrated in a given region, for instance, completion of the historical data analysis.

Regional workshops as ad hoc activities were contrasted with the preferred long-term investment into activities, such as the development of the SOCAT-like data synthesis product for oxygen. A VOICE workshop in a region with no data sharing agreement established could not be part of VOICE activities. It was therefore decided that VOICE will not take an active part in coordinating and/or funding such workshops. These should stem from local initiatives and must be funded by ongoing projects or other resources. It would be the regional champions and their networks deciding about the timing and need for such a workshop. It was emphasized that regional capacity building for this purpose must be augmented by engaging and taking advantage of regional networks. Local institutions responsible for collecting observations must be able to carry out such analysis. In the case of Peru, it was deemed feasible to ask *Comisión Permanente del Pacífico Sur (CPPS)* to engage in attracting commitment of the regional institutions to implement such targeted capacity building action as to bring 1-3 experts related to studying oxycline and its impacts at a regional workshop.

The alternative suggestion for carrying out historical data analyses would be to employ Master and PhD students. Though not a long-term solution, a VOICE-related thesis could be the easiest to organize. In some regions, the first main task would be to transfer all available and relevant data into electronic format. In other cases, the students could proceed with engaging in dataset integration and statistical analysis. It was noted that these datasets are not trivial to merge, and require significant statistical skill. Therefore, local experts would need to be involved, and in some cases, VOICE experts could individually or collectively engage in short-term training and/or partial supervision. For regions such as Peru, Senegal and India, the task might be facilitated by the fact that there are active VOICE participants in these countries who

are also engaged in the EBUS SCOR WG. Upon identification of synergies in required tasks, people in respective laboratories could be engaged in suitable historical data analyses.

International capacity building opportunities

Opportunities for capacity building were discussed at length. While it is beyond VOICE's focus and capability to provide training on-site across all the VOICE regions, there are several opportunities sponsored by IOCCP, GO_2NE, SOLAS and IODE among others, which offer workshop, summer school and thematic training sessions for members of the international community. In particular, the 2nd International IOCCP sensors summer course in 2018 and the GO_2NE summer school planned for 2019 should be on the radar of those VOICE regions which expressed urgent need for increased capacity building in instrument and sensors deployment, calibration and validation, data processing, etc.

Data sharing agreements

As a project demonstrating the implementation of a multidisciplinary GOOS, VOICE will follow the open data policy and will not invest any resources into activities leading to generation of information products that cannot be freely and openly accessed by all members of the global community. The aspect of data availability has many dimensions, and it is no doubt very challenging to arrive at a common data sharing agreement with representatives of all VOICE regions. It was concluded that if a given region does not satisfy the agreed data sharing policy, then the assessment of the data and information product management component of the observing system will not be assigned any readiness level. In such cases, the regions may still participate in the VOICE project but will not be included among the direct beneficiaries of any efforts leading to an increased readiness level other than in the data management aspect (i.e. towards developing online databases, or developing proper, legal data sharing policy). In such case, we would not invest in increasing actual observing or modelling capacity until the data processing, analysis and distribution capacity is above a certain threshold level. At the same time, the expertise and knowledge generated from the VOICE project, including the final blueprint document, will be made available for every region to use.

Summary of action items

Action Item #33	To recruit a suitable postdoc candidate to apply for the IO PAN postdoctoral fellowship to perform the literature review across the regional systems.
Responsible	Artur Palacz, Maciej Telszewski
Time line	30 September 2017
Status	COMPLETED Due to an extremely high competition and only a single grant awarded, the application was unsuccessful.

Action Item #34	To determine the degree of potential synergy between EBUS SCOR WG tasks and VOICE objectives, in particular the literature review and historical data analyses.
Responsible	Ivonne Montes, Baye Mbaye, Damodar Shenoy, Francisco Chavez
Time line	Spring 2018
Status	

Action Item #35	To schedule the second VOICE workshop around the SFB754 International Conference in Kiel, in September 2018.
Responsible	VOICE Co-Chairs
Time line	Spring 2018
Status	

VOICE milestones and deliverables with revisions from this workshop

Milestones

- Milestone #0: IMSOO workshop in February 2017. Phase 0. Month 1 (February 2017). **COMPLETED**
- Milestone #1: First VOICE workshop organized in September 2017 at MBARI, jointly with the GO_2NE meeting. Phase 0. Month 8. **COMPLETED**
- Milestone #2: Demonstration of observing capability and data availability from the California Current System OMZ. Phase 1. Month 8. **COMPLETED**
- Milestone #3: Opportunities for VOICE within existing and planned observation and modelling activities initially identified. Phase 2. Month 8. **COMPLETED**
- Milestone #4: Overview of the requirements, observing capability and data and information product management across all VOICE region. Phase 2. Month 11. **ONGOING** *(pending spreadsheet questionnaires being submitted)*
- Milestone #5: Literature review across the regional systems completed. Responsible: VOICE postdoc at IO PAN pending fellowship grant, or an alternative arrangement, under supervision of VOICE co-chairs and selected VOICE experts. Phase 1. Month 16.
- Milestone #6: Historical data analysis initiated in regions with relatively mature data integration and management, e.g. California Current, Humboldt Current, Namibia system, Senegal System. In other regions, declaration whether such analysis would at all be possible, e.g. Angola, Arabian Sea, Bay of Bengal. Phase 1. Month 20.
- Milestone #7: Regional data availability and data integration status reviewed; data sharing agreements reached between partners from all OMZ study sites. Phase 1. Month 20.
- Milestone #8: Second VOICE workshop organized as a side-meeting to the International Conference on "Ocean Deoxygenation: Drivers and Consequences – Past – Present – Future", 3-7 September 2018, Kiel, Germany. Phase 0. Month 20.
- Milestone #9: Readiness level assessment of the ocean observing system with identification of gaps with respect to VOICE-relevant requirements across the VOICE OMZ regions. Phase 3. Month 23.
- Milestone #10: Third VOICE workshop organized as a side meeting to the OceanObs'19 Conference, in September 2019 in Honolulu, USA. Phase 0. Month 32.
- Milestone #11: Conceptual framework for observing oxycline variability and its impacts on ecosystems based on the literature review and historical data analyses. Phase 3. Month 32.
- Milestone #12: A minimum set of observation requirements for VOICE implementation across all four OMZ sites determined. Phase 3. Month 32.
- Milestone #13: VOICE implementation proposal submitted. Phase 3. Month 35.

Deliverables

- Deliverable #1: Historical data analysis in the California Current System, i.e. from CalCOFI and the Baja California LTER, in the context of oxygen variability impacts on ecosystems delivered as a presentation at the MBARI VOICE Science Plan Workshop. Phase 1. Month 8. **COMPLETED**
- Deliverable #2: Spreadsheet questionnaires from all VOICE regions filled and delivered to VOICE Co-Chairs. Phase 1 & 2. Month 11.
- Deliverable #3: Readiness level assessment across VOICE OMZ regions performed. A report on the gaps in the regional observing systems and recommendations for actions towards increasing the readiness levels as part of the VOICE implementation stage. Phase 3. Month 23.
- Deliverable #4: Conceptual framework and a minimum set of requirements for observing oxycline variability and its impacts on ecosystems paper published, based on global literature review and historical data analyses. Phase 3. Month 32.
- Deliverable #5: VOICE project proposal for funding the 3-year implementation stage submitted. Phase 3. Month 35.

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Appendix

VOICE Participants List

Names of VOICE co-Chairs are marked in red.

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GO_2NE Participants List

Names of GO_2NE co-Chairs are marked in red.

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Agenda

Wednesday, September 13, 2017

VOICE and GO_2NE joint meeting day

VENUE: **MBARI, 7700 Sandholdt Road, Moss Landing, CA, USA**

Transportation from/to hotel will be provided.

09:00-09:10 **Welcome and logistics information** – *Francisco Chavez, GO_2NE co-Chair and VOICE co-Chair*

09:10-09:40 **Requirements for multidisciplinary sustained ocean observations** - *Maciej Telszewski (20 + 10 min Q&A)*

- *The Global Ocean Observing System (GOOS) and its value chain.*
- *Delivering societal benefit products as part of the GOOS value chain. Customers are researchers as well as Operational users (e.g. fishery, ecosystem managers). Ensuring data accessibility.*
- *The Framework for Ocean Observing (FOO) and its implementation? From the legacy of OceanObs'09 to a vision for OceanObs'19.*
- *Short overview of GOOS structures and concepts used for FOO implementation: Expert Panels, Essential Ocean Variables (EOVs), phenomena, observing networks, readiness levels, regional projects (AtlantOS, TPOS2020), etc.*
- *Challenges (VOS multidisciplinary challenge) and opportunities (multiplatform SST observations (Jon Turton – OCG-8)) of multiplatform and multidisciplinary observing system design.*
- *Need for high level advocacy for sustained OMZ observing systems: CARIACO – why failed? Gulf of Mexico examples? The SFB754 Collaborative Research Center.*
- *Implementing Multidisciplinary Sustained Ocean Observations (IMSOO) workshop (02.2017, Miami, US) as a milestone in FOO implementation and the onset of VOICE.*

09:40-10:00 **IOC ocean science – human impacts on the ocean – IOC activities** – *Kirsten Isensee (15 + 5 min Q&A)*

- *IOC portfolio, including the different working groups and activities, e.g. GO_2NE, GOA-ON, HABs, IGMETS, TrendsPO*
- *Outreach and the bigger picture – UNFCCC, Agenda 2030*
- *Capacity building and regional efforts, e.g. WESTPAC*

10:00-10:45 **VOICE as a demonstration project of IMSOO - overview of the VOICE science plan** – *Veronique Garçon & Johannes Karstensen (35 + 10 min Q&A)*

- *Summary of the IMSOO workshop and its outcomes*
- *VOICE project objectives and anticipated outcomes, potential for 'using' GO2NE as a broader network, with more general objectives*
- *Two stages of VOICE and its timeline.*
- *Who will be the users of VOICE?*
- ***VOICE workshop objectives and expected outcomes:***
  - *Outcome #1: Literature review and historical analysis on the subject of oxycline variability and its effects on intermediate and upper trophic levels in VOICE demonstration areas*
  - *Outcome #2: Assessment of readiness levels (requirements, observing capacity, data management) in all regions considered as VOICE demonstration areas*
  - *Outcome #3: Agreement on pathways towards data sharing*
  - *Outcome #4: A common roadmap for VOICE and GO_2NE (with focus on specific milestones, e.g. OceanObs'19, IPCC AR6.)*

10:45-11:15 **Health break**

11:15-12:30 **Overview of GO_2NE activities and plans** – *Kirsten Isensee/Marilaure Grégoire/Denise Breitburg*

- *Outcomes of the GO_2NE meeting*
- *Objectives and activities of the working group and how to scale up*
- *Ideally including GO_2NE's potential role in implementing the FOO in general, and VOICE in particular (i.e. kind of response to what has been said earlier)*
- *GO_2NE activities and plans presented with potential VOICE/GOOS/FOO roles*
- *A common roadmap for the 4th International Symposium The effects of climate change on the World's Oceans, Deoxygenation Conference 2018, OceanObs'19 and beyond: GO_2NE potential input?*
- *Concerted efforts towards other milestones (e.g. IPCC AR6, SR IPCC Ocean and Cryosphere), oxygen measurements to be more predominantly in the GCOS implementation plan updates*
- *Any other issues important for GO_2NE which could be potentially more efficiently addressed through collaboration with VOICE?*

12.30-13:30 **Lunch time**

Moderators of discussion: Marilaure Grégoire and Veronique Garçon

13:30-14.15 **How to combine synergistically VOICE and GO_2NE ongoing and future efforts? Creating a common roadmap** – *A discussion in plenary*

- *Common publications, common conferences/sessions, IPCC AR6, IPCC special reports, GCOS*
- *Specifically address any possible efforts prior to OceanObs'19.*

14.15-15.15 **Common publication: Comparison of systems/regions subject to low oxygen** *– Grant Pitcher (20 + 40 min discussion)*

- *A comparison of systems subject to low oxygen – covering coastal, shelf, open ocean, and as well as estuaries and inland seas – focussing on the primary causes/controls of low oxygen in each of the systems and their susceptibility to further deoxygenation in response to global change*

15.15-15.45 **Health break**

15.45-16.30 **Initial attempt at achieving VOICE workshop outcomes 1-3 (listed above) in one of the VOICE demonstration areas: California Current system**

Oxycline variability in the California Current system and its apparent influence on the ecosystem *-Tony Koslow (35 + 10 min Q&A)*

- *Measurements required to answer VOICE questions in this particular region.*
- *Major motivations for observations in the region based on funded projects and how do they tie in with VOICE.*
- *Existing and planned capacity: observations, data quality procedures, data sharing protocols, as well as overview of ongoing and planned observing and modelling opportunities.*
- *Existing and/or required societal benefit data products of relevance to VOICE.*
- *Historical data analysis and literature review aimed at developing a conceptual framework of the effects of oxycline variability on changes in intermediate and upper trophic in a given OMZ system.*

16.30-17.15 **Assessment of the readiness level of the regional requirements, observations and data streams relevant for the implementation of VOICE** – *Moderated by Telszewski and Palacz*

- *Recommendations for improving the readiness levels.*

17.15 **Wrap up**

Joint GO_2NE and VOICE dinner (self-paid). Time and location to be determined.

Thursday, September 14, 2017

VENUE: **Heritage Harbor, 99 Pacific Street, Monterey, CA**

A 15-minute walk from the hotel.

Thursday and much of Friday will be devoted to reviewing monitoring and research needs in regions identified for implementation of VOICE. For each system, a presentation from scientist(s) most familiar with region's specific features is envisaged. The focus will ideally be on the oxycline but will not be limited to it. It is very important that the status of data (oxygen, hydrography, ecosystem, biogeochemistry) quality procedures AND data availability protocols are presented. This should also include a discussion on data products that are available or would be needed to address the questions of VOICE, and which will help judge where and how to increase the readiness levels of the observing system, with respect to VOICE objectives.

To the extent possible please make sure to address the following points when preparing your presentation:

- *Measurements required to answer VOICE questions in this particular region.*
- *Major motivations for observations in the region based on funded projects and how do they tie in with VOICE.*
- *Existing and planned capacity: observations, data quality procedures, data sharing protocols, overview of ongoing and planned observing and modelling opportunities.*
- *Existing and/or required societal benefit data products of relevance to VOICE.*
- *Historical data analysis and literature review aimed at developing a conceptual framework of the effects of oxycline variability on changes in intermediate and upper trophic in a given OMZ system.*

Please also outline other limitations/expectations for the region (e.g. need for knowledge transfer, capacity building) that can be integrated as components to VOICE and GO$_2$NE.

Each presentation will be followed by a discussion on readiness level assessment with respect to: maturity and integrity of requirements set for observations, observing capability, and data management & information products. The ultimate goal is not to discard the low readiness level components of the observing system (i.e. some regions) but rather to promote efforts leading to a gradual increase in the readiness level where it is most needed, as stated in the VOICE Science Plan (based on the current IMSOO Report).

09:00-10:00 **West Africa: Senegal system**
Presentation of the existing and planned regional requirements, observing capacities, and data management and information products relevant for the implementation of VOICE – *Baye Cheikh Mbaye (45 + 15 min Q&A each)*

10:00-10:30 **West Africa: Senegal system**
Assessment of the readiness level of the regional requirements, observations and data streams relevant for the implementation of VOICE – *All (30 min discussion in plenary)*

10:30-11:00 Health break

11:00-12:00 West Africa: Angola system
Presentation of the existing and planned regional requirements, observing capacities, and data management and information products relevant for the implementation of VOICE – *Paulo Coelho and Carmen dos Santos (45 + 15 min Q&A each)*

12:00-12:30 West Africa: Angola system

Assessment of the readiness level of the regional requirements, observations and data streams relevant for the implementation of VOICE – *All (30 min discussion in plenary)*

12:30-13:30 Lunch time

13:30-14:30 West Africa: Benguela Current system
Presentation of the existing and planned regional requirements, observing capacities, and data management and information products relevant for the implementation of VOICE – *Grant Pitcher and Lisa Levin with contribution from Anja van der Plas (45 + 15 min Q&A each)*

14:30-15:00 West Africa: Benguela Current system

Assessment of the readiness level of the regional requirements, observations and data streams relevant for the implementation of VOICE – *All (30 min discussion in plenary)*

15.00-15.30 Health break

15:30-16:30 Northern Indian Ocean: Arabian Sea
Presentation of the existing and planned regional requirements, observing capacities, and data management and information products relevant for the implementation of VOICE – *Wajih Naqvi (45 + 15 min Q&A each)*

16:30-17:00 Northern Indian Ocean: Arabian Sea

Assessment of the readiness level of the regional requirements, observations and data streams relevant for the implementation of VOICE – *All (30 min discussion in plenary)*

17:00-17:30 Wrap up – *Veronique Garçon and Maciej Telszewski*

Friday, September 15, 2017

VENUE: **Heritage Harbor, 99 Pacific Street, Monterey, CA**

A 15-minute walk from the hotel.

09:00- 10:00 **Northern Indian Ocean: Bay of Bengal**
Presentation of the existing and planned regional requirements, observing capacities, and data management and information products relevant for the implementation of VOICE – *Damodar Shenoy (45 + 15 min Q&A each)*

10:00-10:30 **Northern Indian Ocean: Bay of Bengal**

Assessment of the readiness level of the regional requirements, observations and data streams relevant for the implementation of VOICE – *All (30 min discussion in plenary)*

10:30-11:00 **Health break**

11:00- 12:00 **Humboldt Current system**
Presentation of the existing and planned regional requirements, observing capacities, and data management and information products relevant for the implementation of VOICE – *Ivonne Montes and Dimitri Gutiérrez (45 + 15 min Q&A each)*

12:00-12:30 **Humboldt Current system**

Assessment of the readiness level of the regional requirements, observations and data streams relevant for the implementation of VOICE – *All (30 min discussion in plenary)*

12:30-13:30 **Lunch time**

13.30-14.00 **Discussion on pathways towards data sharing agreements and open data protocols in GOOS** – *Moderated by Véronique Garçon and Johannes Karstensen*

Moderators: Kenny Rose, Denise Breitburg, Johannes Karstensen.

14:00-15:00 **Discussion on data products (operational) that VOICE would like to focus on regionally and globally**

- *The list of products will be used to ultimately judge where and how VOICE would focus its efforts to increase readiness levels per region.*

- *Short summary of recommendations for readiness level improvements based on discussions from Wed-Fri morning.*
- *Optional: Kenny Rose on a perspective on user/stake-holder needs in terms of potential VOICE-relevant data products.*

15:00-15:30 Health break

Moderators: Ivonne Montes, Veronique Garçon and Francisco Chavez.

15:30-17:00 Action plan for 2017-2019: milestones and deliverables from IMSOO report

- *Data sharing agreements between partners, historical data analysis, 2nd VOICE workshop SFB754/GO_2NE conference September 2018 Kiel, Germany, review of current status for observing oxycline variability and its impact on ecosystems, development of (draft) implementation plan, etc.*

17:00 Wrap up

Framework processes by readiness levels

FRAMEWORK PROCESSES BY READINESS LEVELS

Readiness Levels	Requirements Processes	Coordination of Observational Elements	Data Management & Information Products
Mature			
Level 9 "Sustained"	Essential Ocean Variable: • Adequate sampling specifications • Quality specifications	System in Place: • Globally • Sustained indefinitely • Periodic review	Information Products Routinely Available: • Product generation standardized • User groups routinely consulted
Level 8 "Mission qualified"	Requirements "Mission Qualified:" • Longevity/stability • Fully scalable	System "Mission Qualified:" • Regional implementation • Fully scalable • Available specifications and documentation	Data Availability: • Globally available • Evaluation of utility
Level 7 "Fitness for purpose"	Validation of Requirements: • Consensus on observation impact • Satisfaction of multiple user needs • Ongoing international community support	Fitness-for-Purpose of Observation: • Full-range of operational environments • Meet quality specifications • Peer review certified	Validation of Data Policy • Management • Distribution
Pilot			
Level 6 "Operational"	Requirement Refined: • Operational environment • Platform and sensor constraints	Implementation Plans Developed: • Maintenance schedule • Servicing logistics	Demonstrate: • System-wide availability • System-wide use • Interoperability
Level 5 "Verification"	Sampling Strategy Verified: • Spatial • Temporal	Establish: • International commitments and governance • Define standardized components	Verify and Validate Management Practices: • Draft data policy • Archival plan
Level 4 "Trial"	Measurement Strategy Verified at Sea	Pilot project in an operational environment	Agree to Management Practices: • Quality control • Quality assurance • Calibration • Provenance
Concept			
Level 3 "Proof of concept"	Proof of Concept via Feasibility Study: • Measurement strategy • Technology	Proof of Concept Validated: • Technical review • Concept of operations • Scalability (ocean basin)	Verification of Data Model with Actual Observational Unit
Level 2 "Documentation"	Measurement Strategy Described • Sensors • Sensitivity • Dependencies	Proof of Concept: • Technical capability • Feasibility testing • Documentation • Preliminary design	Socialization of Data Model • Interoperability strategy • Expert review
Level 1 "Idea"	Environment Information Need and Characteristics Identified: • Physical • Chemical • Biological	System Formulation: • Sensors • Platforms • Candidate technologies • Innovative approaches	Specify Data Model • Entities, Standards • Delivery latency • Processing flow

Figure 11. Framework processes by readiness levels (FOO, 2012; page 11).