Proposal for a SCOR Working Group on Quality Control Procedures for Oxygen and Other Biogeochemical Sensors On Floats and Gliders

Rationale

The OceanObs'09 Conference (Venice, Italy, September 2009) brought together more than 600 scientists from 36 nations to build a common vision for the provision of routine and sustained global information on the marine environment sufficient to meet society's needs for describing, understanding and forecasting ocean variability. This common vision, as documented by 99 Community White Papers and 47 Plenary Papers, calls for significantly enhancing internationally coordinated provision of sustained observation and information of the world ocean, as a part of the larger Earth system observing effort, for public good and stewardship. The conference documented the state-of-the-art of observation technologies, highlighted the most promising observational approaches and provided concrete recommendations towards sustaining and enhancing the global ocean observation network.

Among the many breakthroughs in observational technology and capabilities the Argo float observatory is one of the most impressive and successful examples (Freeland et al., 2010). As Argo enters its second decade and chemical/biological sensor technology has improved significantly, it is becoming obvious that this observatory will be embraced by the ocean biogeochemistry community. An augmentation of the global float observatory, however, has to follow rather stringent constraints regarding sensor characteristics as well as data processing and quality control routines. Owing to the fairly advanced state of oxygen sensor technology and the high scientific value of oceanic oxygen measurements (Gruber et al., 2010), an expansion of the Argo core mission to routine oxygen measurements is perhaps the most mature and promising candidate (Freeland et al., 2010). But sensor technology also has reached a stage for other biogeochemical properties such as bio-optics (Claustre et al., 2010; Boss et al., 2008), nitrate (Johnson et al., 2009; 2010), pH (Martz et al., 2010) and CO_2 (Fiedler et al., subm.) that makes these sensors suitable for future integration into the float observatory.

While in terms of sensor characterization, calibration and assessment of field performance many studies have been performed and a lot of published information has become or is becoming available – particularly for float-based oxygen measurements – a coherent assessment of the overall status is lacking and firm recommendations and protocols for sensor calibration, data processing and data quality control have not yet been made. This situation calls for action and an effort to improve the situation should be made by a group of international experts. The establishment of a SCOR working group on this issue is timely and arguably the best, if not only, way to bring available information and expertise together and develop community-based and accepted procedures. The WG will put its main focus on the "Oxygen on Argo" topic but will also address float and glider-based observations of other biogeochemically relevant properties that have the potential to follow oxygen and hence require a concerted approach.

Scientific and Technological Background

The challenge of understanding the impact of global change on ocean biogeochemistry and major elemental cycles of carbon, oxygen, nitrogen etc. and any potential feedback to Earth's climate cannot be met with traditional oceanographic sampling techniques but requires a major expansion of observation capabilities in time and space. This, in fact, is calling for a revolution in observation technology which already is, or soon will, be at hand (Johnson et al., 2009). The rapid progress in both observation platform technology and chemical/biological sensor technology made during recent years is impressive and it is time now to bring the two strains together in a concerted fashion.

There are compelling scientific arguments for the addition of robust oxygen sensors to the global Argo observing system. Gruber et al. (2010) have summarized many of these scientific reasons for undertaking detailed global-scale measurements of the temporal evolution of the ocean's oxygen distribution. These include:

- Detect and document the ocean's deoxygenation (Keeling et al., 2010);
- Predict and assess anoxic or hypoxic events (Stramma et al., 2008);
- Determine seasonal to inter-annual changes in net community and export production;
- Improve atmospheric O_2/N_2 constraint on the oceanic uptake of anthropogenic CO_2;
- Aid interpretation of variations in ocean circulation/mixing;
- Provide constraints for ocean biogeochemistry models;
- Aid in interpretation of sparse data from repeat hydrographic surveys;
- Determine transport and regional air-sea fluxes of oxygen.

Quite a number of showcase studies employing oxygen floats have been performed successfully (e.g., Kihm & Körtzinger, 2010; Körtzinger et al., 2004; Martz et al., 2008; Prakash et al., 2012; Riser & Johnson, 2008; Tengberg et al., 2006) illustrating both the feasibility and the high and manifold utility of high-quality float-based oxygen measurements. However, several such studies (e.g., Czeschel et al., 2011; Fiedler et al., subm.; Körtzinger et al., 2005; Uchida et al., 2008) identified significant accuracy issues with the oxygen optode sensor that required dedicated post-calibration and correction exercises and call for the development of explicit pre-deployment calibration routines and facilities (e.g., Bittig et al., subm.). All this information needs to be cast into a coherent approach to data quality assurance and control procedures which then can be disseminated within the community and implemented into standard Argo routines. This is particularly important as a "global" system is developed. Each investigator needs to be able to compare oxygen data seamlessly from each float, just as is done with Argo temperature and salinity. To a large extent, that is not possible for oxygen today because of varying standard processes for sensor calibration and data reporting (Thierry et al., 2011).

The "Oxygen on Argo" initiative may in fact serve as a model case which provides the blueprint for data quality assurance and assessment procedures for other biogeochemical sensors. Some of these, for example, bio-optical (Claustre et al., 2010) and nitrate sensors (Johnson et al., 2010), are already available off the shelf in float-adapted versions, which have undergone serious testing and produced impressive showcases. Other sensors such as the Durafet® pH sensor (Martz et al., 2010) are approaching float-readiness and may soon provide much sought-after access to the marine CO_2 system. Undoubtedly the implementation process of any of these other biogeochemical sensors into a float observatory will benefit from the lessons learned and the procedures established for the model case oxygen.

Statement of Work/Terms of Reference

The proposed working group would

(1) Summarize and assess the current status of biogeochemical sensor technology with particular emphasis on float-readiness (pressure and temperature dependence, long-term stability, calibration accuracy, measurements time constant, etc.) → Year 1.

(2) Develop pre- and post-deployment quality control metrics and procedures for oxygen and other biogeochemical sensors deployed on floats and gliders providing a research-quality synthesis data product → Years 2+3.
(3) Collaborate with Argo and other data centers to implement these procedures in their standard routines → Years 3+4.
(4) Disseminate procedures widely to ensure rapid adoption in the community → Year 4.

***Pre-Briefing*:** The 4th Argo Science Workshop (ASW-4), which is entitled "Argo – 10 Years of Progress – A new decade to prepare" and takes place in Venice, Italy on September 27- 29, 2012, would represent an ideal occasion for a pre-briefing among the members of the proposed SCOR WG and further discussion with the Argo community.

***Kick-off Meeting*:** In order to provide good international visibility (and assure high attendance) the idea would be to piggyback this meeting onto a major relevant international conference. A thematically suitable and internationally visible such platform could be the IMBER IMBIZO III (January 2013, Goa, India). An alternative and similarly appropriate meeting would be the 2013 EGU General Assembly (April 2013, Vienna, Austria).

Further Meetings: Two further working group meetings will be held – one about half-way through and the other one towards the end of the WG lifetime. Potential candidates for the first meeting are the AGU fall meeting in 2014 or an expected 5th Argo Science Workshop in 2015. Candidate for the final meeting could be the 2016 Ocean Sciences Meeting or the 2016 AGU fall meeting.

Products: The WG will write an article for EOS after its first meeting to inform the community about the objectives and further plans of the SCOR WG. Also, a written document will be produced from each meeting. As the final product some kind of "best practices" manual is envisaged which will provide the community with a consistent approach to data handling and quality control of oxygen data from autonomous platforms and form the basis for the implementation of oxygen measurements in the Argo program. The final product and recommendations from the group will also be highlighted within a group article.

Capacity Building: Many of the major science issues of biogeochemical cycles in a changing ocean (e.g., ocean acidification, deoxygenation, eutrophication and changes in primary productivity) take place near and are socioeconomically highly relevant for developing countries. Modern autonomous observatories could potentially provide scientists from these countries with both cost-effective ways of mounting their own observational programs and open access to relevant high-quality data. This important aspect is reflected by having two distinguished scientists from developing countries on the list of proposed (full or associated) members. Also, a close contact will be established between this WG and the Argo capacity building activities. Building necessary capacities in developing countries can be fostered by providing access to "best practices" documents which specifically address the often limited financial and infrastructural resources that are available to them. The aspect of capacity building could be further augmented by hosting a session (in conjunction with a WG meeting) to discuss the needs and capabilities of developing countries with respect to using the Argo observatory and other suitable programs. Similarly a group article on this topic could be written for and presented to the relevant audiences. Finally, the WG plans to get in contact with the Partnership for Observation of the Global Oceans, POGO, to see if the WG products and procedures could be added to POGO's portfolio of training & education activities.

Working Group Composition (full members)

(1) Arne Körtzinger (Co-chair), GEOMAR, Kiel, Germany – chemical oceanography, oxygen minimum zones, oxygen & CO_2 sensors and floats
(2) Ken Johnson (Co-chair), MBARI, Moss Landing/CA, USA – chemical oceanography, nitrate and pH floats
(3) Herve Claustre, Villefranche-sur-Mer, France – biological oceanography, bio-optical floats
(4) Katja Fennel, Dalhousie University, Halifax/NS, Canada – marine biology, physical-biogeochemical modeling
(5) Denis Gilbert, Institut Maurice-Lamontagne, Mont-Joli/QC, Canada – physical oceanography, oxygen minimum zones, oxygen floats
(6) Steven Riser, UW School of Oceanography, Seattle/WA, USA – physical oceanography, Argo program & technology
(7) Virginie Thierry, IFREMER, Brest, France – physical oceanography, Argo data quality control
(8) Bronte Tilbrook, CSIRO, Hobart, Australia – chemical oceanography, oxygen floats
(9) Hiroshi Uchida, Research Institute for Global Change, JAMSTEC, Yokosuka, Japan – physical oceanography, in-situ sensor calibration
(10) Wajih Naqvi, National Institute of Oceanography, Goa, India – ocean biogeochemistry, ocean minimum zones & deoxygenation

Working Group Composition (associate members)

(1) Steve Emerson, UW School of Oceanography, Seattle/WA, USA – chemical oceanography, marine oxygen dynamics
(2) Hernan Garcia, NOAA-NODC, Silver Spring/MD, USA – chemical oceanography, ocean climatology, data quality control
(3) Nicolas Gruber, ETH Zürich, Switzerland – biogeochemical modeling, analysis of observational data
(4) Osvaldo Ulloa, Universidad de Concepción, Chile – marine biology, oxygen minimum zones, oxygen floats

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