Optimized design of an ocean observing system for biogeochemistry in a changing climate

1. Summary

While great strides have been made in ocean observing technology over the last decades, the ocean remains significantly under-sampled with respect to biogeochemistry. However, there is mounting evidence that the ocean is currently undergoing detectable changes and is not in steady state, with this having the potential to alter the ocean's future role in not only carbon uptake, but also the rates and locations of ocean acidification, the supply of oxygen to ocean ecosystems, and the availability of nutrients to fuel ecosystems and fisheries.

Concurrent advances in ocean biogeochemical models have facilitated the development of Observing System Simulation Experiments (OSSEs). OSSEs allow one to assess the skill of observing systems in identifying target signals. The goal of this Working Group is to make recommendations for optimal observing system design through combined consideration of observing platforms and state-of-the-art models.

2. Scientific Background and Rationale

In light of the public awareness and urgency of monitoring the oceans, the oceanographic biogeochemistry and ecosystem communities have articulated a number of key questions:

(A) How is the ocean uptake and storage of carbon distributed in time and space? Is it changing?

(B) What are the climatological structures of net community production (NCP), export production (EP), and primary production (PP) in the ocean?

(C) What are the climatological structures of ecosystem stressors in the ocean, including ocean de-oxygenation and the saturation state of aragonite (Ω_{arag})? And how are these changing in time?

(D) How do the principal biological provinces evolve in time? And how are they modulated by the subduction and obduction of nutrients within the ocean?

A variety of methods have been developed to characterize the evolving ocean uptake of carbon, making use of both interior inventory changes and global air-sea fluxes inferred from surface pCO_2 data, and the suite of methods applied in the RECCAP efforts of the Global Carbon Project. The results from the RECCAP efforts revealed that for much of the global ocean, large discrepancies remain at all but the largest spatial and temporal scales among the different techniques used to estimate carbon uptake.

For productivity, community efforts have led to the development of climatologies for Net Community Production (NCP), Export Production (EP), and Net Primary Productivity (NPP), and time-varying NPP products from satellite data. Ocean biological provinces have been characterized through a variety of methods that synthesize a broad range of constraints (*Sarmiento et al.*, 2004). Combined use of time-series data and repeat hydrographic measurements has facilitated the characterization of the ocean climatology, as well as trends in ocean de-oxygenation and acidification.

Each of the above goals still faces challenges associated with data/sampling sparsity issues of the current observing system. One such challenge is temporal bias given the tendency for most ship-board measurements to be made in summer. Another is spatial bias clearly encompassing the sparse coverage over many regions of the Southern Hemisphere. It is also important to consider that many of the successes in monitoring with the existing observing network have relied heavily on surface measurements, including those relying on pCO_2 and remote sensing products. An emerging conceptual framework of using ocean water masses to understand biogeochemical provinces and ecosystems has begun to emerge, but to date this approach has tended to focus on models due to lack of seasonal coverage. Additionally, the current CMIP5 generation of Earth System Models indicates that biogeochemical provinces aren't stationary and will be impacted by shifting gyre boundaries and water mass structures (*Bopp et al.*, 2001; *Sarmiento et al.*, 2004; *Bopp et al.*, 2013). Importantly, these questions are largely interrelated since ecosystem patterns are tightly connected to biogeochemical processes as well as to the 3-D structure of the ocean circulation. Given this inter-relatedness, and the potentially high cost of expanding the observing system, it is critical to consider ways to optimize the observing system.

Our goal in proposing a SCOR Working group is to develop an integrated view of observing system design that will optimally sample the ocean to address the needs of the community. Our interests as a Working Group span the four questions detailed above, although given the time constraints and scope of a SCOR Working Group our priorities will be on the first two. The observational challenges of answering these questions will clearly benefit from assessment of a shared multi-platform observing network, with a number of the essential ocean variables being common to our central priorities. A critically important goal in optimizing the observing network will be the specification of quantitative thresholds for detection of the fields described above, and to optimize the observing system to balance the needs of the community. It would of course be advantageous to define such thresholds for specific variables measured (T, S, DIC, nutrients, etc.) rather than for the more abstract concepts listed above. This will benefit from work that has already been conducted to define Essential Ocean Variables (EOVs) for physics, biogeochemistry, and ecosystems. Sampling strategies for these variables can then make use of Observing System Simulation Experiments (OSSEs) with state-of-the-art forced ocean model runs. For OSSEs, the full evolving state of the model can be assessed to round-off precision, and strategies for observing system design can be tested. Of course all of the caveats involved with using models will need to be considered as well.

This type of strategy has already been investigated with OSSEs for the case of carbon uptake by the ocean (item "A" above), where the Large Scale CO_2 Observing Plan (LSCOP) of *Bender et al.* (2002) prescribed 10% uncertainty in net carbon uptake as an upper bound for the target accuracy of the Repeat Hydrography network. This has been considered by *Plancherel et al.* (2013) for the case of uptake of anthropogenic carbon over the North Atlantic between the 1990s and 2000s (WOCE-to-CLIVAR), where it was argued that the Repeat Hydrography network should be capable of detecting decadal trends to within 10%. This strategy was also considered for the case of monitoring pCO_2 (and thereby air-sea fluxes of CO_2) over the Southern Ocean by *Majkut et al.* (2014). There an idealized representation of floats measuring pCO_2 was used to argue that 200 floats could be sufficient to monitor decadal trends in air-sea CO_2 fluxes. The non-eddying ocean model configurations used in these studies provide a useful first platform for iterative interactions with the observational community, and it is expected that models will benefit greatly from this interaction.

If an uncertainty threshold of 10% is considered appropriate for the other variables of interest, the current ocean observing system is insufficient. Although important work has been done in characterizing decadal trends in ocean interior O_2, we are not yet able to construct a global monthly climatology of O_2 in the upper ocean to within uncertainties of 10%. Clearly, even greater challenges lie in developing monthly climatologies for NCP, PP, and EP over the global ocean within a 10% threshold. The question naturally arises, if one begins by specifying an uncertainty threshold, what would be the optimal path for expanding the current observing system in order to achieve this goal? In addressing this question, it is important to consider water masses as a unifying framework for ocean biogeochemistry (*Walin*, 1981; *Iudicone et al.*, 2011), and their value in the interpretation of data. The importance of water masses to classifications of biomes is already implicit in the study of *Sarmiento et al.* (2004), through the upwelling and subduction patterns over large scales.

2.1 Overview of target signals and tools

The central objective here is to recommend an optimally designed ocean observing system for addressing the science objectives listed at the head of this document. The system will need to be expanded to satisfy simultaneously the needs of physical, biogeochemical, and ecosystems communities, while at the same time integrating with and adding value to existing observing system elements such as Argo.

Through activities of the GOOS Framework for Ocean Observing (*Task Team for an Integrated Framework for Sustained Ocean Observing*, 2012), efforts are now underway to address a number of related objectives for ocean observing, including:

(1) To define a suite of Essential Ocean Variables (EOVs) for physics, biogeochemistry, and ecosystems for both scientific and resource management (monitoring) considerations
(2) To coordinate observing networks that contribute to the EOVs, including issues of standards, data sharing, and developing metrics etc.
(3) To coordinate with partner organizations to reach a consensus data model for EOVs
(4) To propose pilot projects for expansion of the observing network.

Although the larger objectives pertain to the science and resource management questions described above, the quantitative assessment of network design will hinge on measurements of a suite of Essential Ocean Variables (EOVs). We intend to build upon the recommendations provided by GOOS panels and advisory groups, themselves drawing on international expertise, in articulating the target variables and necessary sampling resolution for the expansion of the observing network.

The overarching goal of the Working Group will be to make a series of recommendations for pilot projects, as well more general recommendations for optimized design of the ocean observing system. Equally importantly, the group will also draw on the recommendations of GOOS panels in recommending a suite of unified EOVs for both the pilot projects and the global observing network. The recommendations will be focused on determining the optimal network design needed to address the set of community-shared scientific and monitoring priorities detailed at the head of this document. In other words, what is needed to achieve the high priority scientific goals listed above? What are the estimated costs?

Efforts to better quantify productivity (NCP, PP, and EP) will be important to both carbon cycle and ecosystems research, and improved estimates will be contingent on seasonally resolving, three-dimensional measurements. Important efforts have already been made to characterize these quantities through the use of remote sensing products. However, in the absence of seasonally varying subsurface fields, quantifying uncertainty associated with these fields has proven elusive. Thus, for the suite of biogeochemical and physical EOVs needed to characterize NCP, PP, and EP, the precision threshold should be ~10%. In addition to proposing optimal EOVs for monitoring the carbonate system in the ocean, *our goal will be to recommend strategies to detect global surface ocean trends, and to characterize thresholds for detection. It will be important to decide whether the 10% threshold is appropriate more generally, or whether a less stringent threshold of 20% or 25% would be appropriate.*

Even with a perfect observing system, there is also the ever-present question of whether measured decadal trends can be interpreted as the secular anthropogenic climate signal, or to what extent natural variability is included. For example, this question has been raised concerning the current decadal hiatus in global surface temperatures representing a pause in a trend towards global warming (*Meehl et al.*, 2011). In this context, it is useful to consider uncertainties associated with the observing system itself as "systematic uncertainty", and uncertainties associated with natural variability as "random uncertainty". Modeling efforts such as *Henson et al*. (2010) and *Henson et al*. (2013) have sought to address detection of secular trends in the presence of natural variability.

All of this needs to be considered within the context of the multi-platform observing system described above.

2.2 Modeling issues

Global ocean biogeochemical models have grown in sophistication over the last decade. Two commonly used classes of ocean-only models are used widely, (a) state estimates that assimilate observations such as the ECCO and SODA models, and (b) forward models such as MOM and NEMO. Although models are and will continue to be 'works in progress', they have demonstrated value in testing observing system design through Observing System Simulation Experiments (OSSEs).

Progress has been made in understanding the relationship between biogeochemical processes and water masses in the ocean (*Iudicone et al.*, 2011), and this has been complemented by important efforts with eddy-permitting models to better understand water mass transformation processes (*Nishikawa et al.,* 2013). The large-scale structures of biogeochemical properties are prescribed by the interplay between biological, chemical and thermodynamical processes and are thus best understood in terms of water masses. This three-dimensional dynamical view of the oceans needs to be coupled with ensembles of processes on seasonal and interannual time scales that further contribute to setting ocean properties in the photic zone. For example, the monitoring of nutrients in the interior has to be complemented by a characterization of the interplay between nutrient availability at the surface (as set by local physical and biological processes), and interior distributions via subduction-related processes and even non-local controls of surface processes (where obduction occurs). Important steps towards understanding the interplay between surface and interior processes have been taken (e.g., *Palter et al.*, 2005). Again, this is considered to set the context for the Working Group activities, which will be specifically focused on the observing network.

3. Terms of Reference

The main goals of the Working Group will be to make recommendations that fall into three general categories. The first will be to characterize the ocean biogeochemical state from the existing network. The second will be to articulate an appropriate suite of Essential Ocean Variables (EOVs) building on and extending the work of GOOS advisory groups and other experts, as well as to consider detection thresholds and OSSE design. The third and fourth will be focused on recommendations for pilot studies and on optimization of the global observing network. These questions will be considered within the context of the newly available technology, such as biogeochemical sensors for profiling floats and gliders, and complementing the existing global platforms such as Argo and remote sensing products.

4. Working Plan

4.1 Task Set #1: Characterize the ocean biogeochemical state from existing network

The first task set will involve a careful evaluation and review of what can be inferred from the existing observing network. Here we will identify 'state-of-the-art' estimates as those that have appeared in the peer-reviewed scientific literature.

(i) What is the optimal combination of Essential Ocean Variables (EOVs) for meeting the needs of communities monitoring physical oceanography, ocean biogeochemistry, and ocean ecosystems?
(ii) What estimates exist for the rate at which carbon is being absorbed by the global ocean?
(iii) What quantified estimates exist for biological productivity, and what are the associated uncertainties in current estimates of PP, NCP, and EP?
(iv) What is understood about the important ecosystem stressors, including ocean de-oxygenation and acidification parameters?
(v) What is the state-of-the-art for ocean biogeochemical modeling?

4.2 Task Set #2: Define detection thresholds and OSSE design

The second task set will focus on a synthesis of the candidate target variables and multiple-platform optimization:

(i) Refine and specify the target suite of Essential Ocean Variables (EOVs), incorporating the lists provided by the advisory panels to GOOS;
(ii) Refine and specify precision thresholds for these EOVs, both for climatological and secular trends;
(iii) Recommend a suite of models and conceptual tools that will be appropriate to the OSSE design;
(iv) Set a list of priorities as requirements for a unified OSSE design. It will be important to assess, for example, the degree to which winter under-sampling biases can be reduced with no cost through re-allocation of resources used for summer sampling.

4.3. Task Set #3: Design of pilot studies

The third suite of priorities concerns pilot studies for the observing goals described above. The goal will be to address temporal and spatial sampling issues in regions that are known to be important for the suite of questions listed at the beginning of this document. An important example would be that of subtropical mode waters, whose formation regions are at best severely under-sampled at the present time during winter. In this case one would choose a specific subtropical mode water formation region that can be considered broadly representative, and consider the pertinent spatial and temporal scales for monitoring. In addition to subtropical mode waters, it would be of interest to include regions representative of western and eastern boundary regimes, as well as subpolar and equatorial obduction or re-emergence regimes. Pilot studies will need to directly address the broader question of optimal system design. The important questions will include:

(i) Which dynamical regimes (mode water formations, boundary regions, obduction regions) and what seasons are most poorly constrained with the current observing system, for the suite of EOVs developed through Task Set #1?

(ii) What are representative regions well suited for Pilot Studies? And should a relatively stringent 10% uncertainty threshold be appropriate?

(iii) What pilot studies can help to identify the critical temporal and spatial scales for these regions?

4.4 Task Set #4: Recommendations for optimizing the global observing network

The fourth set of priorities concerns the more general question of the global observing network. This will draw on the recommendations made for OSSEs as well as the recommendations made for pilot studies. The questions to be addressed are:

(i) What is an appropriate uncertainty threshold for the EOVs as part of a global observing network? Would a less stringent threshold for uncertainty (e.g. 20% or 25%) be reasonable on global scales for 3-d fields, and a relatively stringent threshold (e.g. 10%) for surface fields?

(ii) What are the critical scales and processes needed for OSSEs on global scales?

(iii) What are the challenges for an integrated multi-platform OSSE?

5. Working Group Membership, Group Activities, and Capacity Building

5.1 Capacity Building

The members of the Working Group represent a broad international group of researchers with interdisciplinary research experience. In addition to scientific expertise in both observational- and modeling-based research, members of the Working Group have been actively involved in efforts to develop new observing strategies and/or the development and application of Observing System Simulation Experiments (OSSEs). In developing proposals for optimal observing system design, our interests are in building an international effort that builds capacity in developing countries as well as with younger scientists. Our final meeting will be held in a developing country. As two of our Full Members are representing South Africa and Brazil, it is our intention that the final meeting should occur in one of these two countries. It will be our intention with the final meeting to additionally organize a Workshop for two days on Observing System Design, with this meeting open to local participants. Special attention will be devoted to attracting early career scientists to the Workshop.

Full Members

Name	Gender	Place of work	Expertise relevant to proposal
1 Keith Rodgers (co-Chair)	M	US	Global ocean biogeochemical modeling
2 Daniele Iudicone (co-Chair)	M	Italy	Ocean biogeochemical modeling and water mass analysis
3 Toshio Suga (co-Chair)	M	Japan	Large-scale ocean circulation and ventilation processes
4 Moacyr Araújo	M	Brazil	Modeling of ocean circulation and turbulence, and modeling of ocean biogeochemistry
5 Hervé Claustre	M	France	Ocean color; optical oceanography
6 Katja Fennel	F	Canada	Regional biogeochemical modeling; data assimilation
7 Stephanie Henson	F	UK	Biological responses to climate variability and climate change
8 Masao Ishii	M	Japan	Ocean carbon and biogeochemical measurements
9 Eun Young Kwon	F	Korea	Global ocean biogeochemical modeling
10 Marcello Vichi	M	South Africa	Global ocean biogeochemical modeling

Associate Members

Name	Gender	Place of work	Expertise relevant to proposal
1 Claudie Beaulieu	F	UK	Statistical analysis and trend detection
2 Maria Cavanaugh	F	US	Ocean biological provinces
3 Fabrizio d'Ortenzio	M	France	Marine optics and remote sensing
4 Burke Hales	M	US	Ocean biogeochemical measurements
5 Andrew Lenton	M	Australia	Global ocean biogeochemical modeling
6 Sayaka Yasunaka	F	Japan	Variability in carbon and nutrient cycling in the ocean

5.2 Working Group Activities

Annual meetings will be organized by invitation, and will be limited to the members and invited experts to provide summaries of progress and to recommend future directions for the Working Group. We propose that one annual meeting be convened per year during 2015-2017. The first meeting will be in Japan, where Task Sets #1 and #2 will be considered. The second meeting will be conducted in New Orleans to coincide with the 2016 Ocean Sciences meeting, and this will be dedicated to Task Set #3. At the Ocean Sciences meeting, we will also organize a Town Hall meeting. The final meeting, which we intend to have in either South Africa or Brazil, will be dedicated to Task Set #4 as well as a synthesis of the first three Task Sets.

We also intend to develop and submit a paper on Observing System Design to Biogeosciences. Additionally, the suite of recommendations prepared by the group will be made available to the community in the form of reports of the annual meetings.

5.3 Deliverables

The principal deliverables of the Working Group will be consist of the set of recommendations for: a unified set of Essential Ocean Variables, thresholds for detection of these variables, and a suite of of Observing System Simulation Experiments. Additionally we will issue a set of recommendations for pilot studies and for the optimized global network. An additional deliverable will be the review article authored by the members on Observing System Design, to be submitted to Biogeosciences (open access).

6. Working Group Contributions

Here we present the contributions expected from the Full Members. Keith Rodgers' contributions will derive from his experience in using ocean models to interpret ocean biogeochemical measurements, as well as from experience in the design and interpretation of Observing System Simulation Experiments. Daniele Iudicone's contributions will reflect his research efforts to apply water mass transformation analysis to ocean carbon and biogeochemistry. Toshio Suga's contributions will derive from his extensive experience with Argo floats, as well as his extensive research experience involving ocean circulation and ventilation processes. Moacyr Araújo's contribution will stem from his broad interdisciplinary work with both observing system elements and models. Hervé Claustre's contribution to the Working Group will reflect his wide-ranging research into ocean ecosystems, through combined use of multiple elements of the ocean observing network, including Argo. Katja Fennel's contribution will derive from her broad experiences using models to interpret ocean biogeochemical measurements and ocean ecosystems. Stephanie Henson's contribution will result from her experience in trend detection for ocean biology and ecosystems, within the context of climate change, as well as her experience in questions of observing system requirements to detect trends in ocean biology and ecosystems. Masao Ishii's contribution will follow from his extensive work with measuring and interpreting ocean biogeochemistry and acidification trends, as well as through his leadership experience in producing the PACIFICA data product. Eun Young Kwon's contribution will reflect her expertise in modeling both ocean biogeochemistry and ocean ventilation processes. Marcello Vichi's contribution will follow from his extensive experience in modeling ocean biology and ecosystems.

7. Overview of existing SCOR elements

The proposed Working Group will build on the results of previous Working Groups supported through SCOR. In particular, we intend to build on the results of WG 142 focused on Quality Control Procedures for Oxygen and Other Biogeochemical Sensors on Floats and Gliders, as well as on WG 143, on Dissolved N_2O and CH_4 measurements. Interaction with WG 142 will be facilitated that both Hervé Claustre and Katja Fennel (Full Members in our proposal) are members of that WG. If our proposal is supported, we will also contact the co-chairs of WG143 so as to benefit from their work as well.

8. References

Bender, M., S.C. Doney, I.Y. Fung, et al. (2002), A Large-Scale CO_2 Observing Plan: In situ oceans and atmosphere (LSCOP), OAR Special Report NTIS: PB2003-00377, NOAA/OAR/PMEL, Seattle, WA.

Bopp, L., P. Monfray, O. Aumont, J.L. Dufresne, H. Le Treut, G. Madec, L. Terray, and J.C. Orr (2001), Potential impact of climate change on marine export production, Global Biogeochem. Cyc., 15, 81-99.

Bopp, L., et al. (2013), Multiple stressors of ocean ecosystems in the 21st century: projections with CMIP5 models, Biogeosciences, 10, 6225-6245.

Henson, S.A., J.L. Sarmiento, J.P. Dunne, L. Bopp, I. Lima, S.C. Doney, J. John, and C. Beaulieu (2010), Detection of anthropogenic climate change in satellite records of ocean chlorophyll and productivity, Biogeosciences, 7, 621-640.

Henson, S., H. Cole, C. Beaulieu, and A. Yool (2013), The impact of global warming on seasonality of ocean primary production, Biogeosciences, 10, 4357-4369.

Iudicone, D., K.B. Rodgers, I. Stendardo, O. Aumont, G. Madec, L. Bopp, O. Mangoni, and M. Ribera d'Alcala (2011), Water masses as a unifying framework for understanding the Southern Ocean Carbon Cycle, Biogeosciences, 8, 1031-1052.

Majkut, J., B. Carter, C.O. Dufour, T.L. Frölicher, K. Rodgers, and J. Sarmiento (2014), An observing system simulation for Southern Ocean CO_2 uptake, accepted by the Royal Society.

Meehl, G.A., J.M. Arblaster, J.T. Fasullo, A. Hu, and K.E. Trenberth (2011), Model-based evidence of deep-ocean heat uptake during surface-temerature hiatus periods, Nature Climate Change, 1, 360-364.

Nishikawa, S., H. Tsujino, K. Sakamoto, and H. Nakano (2013), Diagnosis of water mass transformation and formation rates in a high-resolution GCM of the North Pacific, J. Geophys. Res. Oceans, 118, doi:10.1029/2012JC008116.

Palter, J.B., M.S. Lozier, and R.T. Barber (2005), The effect of advection on the nutrient reservoir in the North Atlantic subtropical gyre, Nature, 437, 687-692.

Plancherel, Y., K.B. Rodgers, R.M. Key, A.R. Jacobson, and J.L. Sarmiento (2013), Role of regression model selection and station distribution on the estimation of oceanic anthropogenic carbon change by eMLR, Biogeosciences, 10, 4801-4831.

Sarmiento, J.L., et al. (2004), Response of ocean ecosystems to climate warming, Global Biogeochem. Cycles, 18, GB3003, doi:10.1029/2003GB002134.

Task Team for an Integrated Framework for Sustained Ocean Observing (2012), A Framework for Ocean Observing, UNESCO, 2012, IOC/INF-1284 rev. doi:10.5270/OceanObs09-FOO.

Walin, G. (1982), On the relation between sea-surface heat flow and thermal recirculation in the ocean, Tellus, 34, 187-195.

Biographical Information

Below is a summary of the contact information, educational background, and pertinent publications for the Full Members of our SCOR Working Group Proposal "Optimized design of an ocean observing system for biogeochemistry in a changing climate".

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Majkut, J.D., J.L. Sarmiento, and K.B. Rodgers (2014a), A growing oceanic carbon uptake: Results from an inversion study of surface pCO_2 data, Global Biogeochemical Cycles, 28, doi:10.1002/2013GB004585.

Majkut, J.D., B. Carter, C.O. Dufour, T.L. Frölicher, K. Rodgers, and J. Sarmiento (2014b), An observing system simulation for Southern Ocean CO_2 uptake, accepted by the Royal Society.

Plancherel, Y., K.B. Rodgers, R.M. Key, A.R. Jacobson, and J.L. Sarmiento (2013), Role of regression model selection and station distribution on the estimation of oceanic anthropogenic carbon change by eMLR, Biogeosciences, 10, 4801-4831.

Rodgers, K.B., R.M. Key, A. Gnanadesikan, J.L. Sarmiento, O. Aumont, L. Bopp, S.C. Doney, J.P. Dunne, D.M. Glober, A. Ishida, M. ishii, A.R. Jacobson, C. Lo Monaco, E. Maier-Reimer, H. Mercier, N. Metzl, F.F. Pére, A.F. Rios, R. Wanninkhof, P. Wetzel, C.D. Winn, and Y. Yamanaka (2009), Altimetry helps to explain patchy changes in hydrographic carbon measurements, J. Geophys. Res., 114, C09013, doi:10.1029/2008JC005183.

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Iudicone, D., G. Madec, B. Blanke, and S. Speich (2008a), The role of Southern Ocean surface forcings and mixing in the global conveyor, J. Phys. Oceanogr., 38, 1377-1400.

Iudicone, D., G. Madec, and T.J. McDougall (2008b), Water-mass transformations in a neutral density framework and the key role of light penetration, J. Phys. Oceanogr., 38, 1357-1376.

Iudicone, D., S. Speich, G. Madec, and B. Blanke (2008c), The global conveyor belt from a Southern Ocean perspective, J. Phys. Oceanogr., 28, 1401-1425.

de Boyer Montégut, C., G. Madec, A.S. Fischer, A. Lazar, and D. Iudicone (2004), Mixed layer depth over the global ocean: An examination of profile data and a profile-based climatology, J. Geophys. Res., 109, C12003, doi:10.1029/2004JC002378.

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5 pertinent publications:

Oka, E., B. Qiu, S. Kouketsu, K. Uehara, and T. Suga (2012), Decadal seesaw of the Central and Subtropical Mode Water formation associated with the Kuroshio Extension variability, J. Oceanogr., 68, 355-360.

Sukagara, C., T. Suga, T. Saino, K. Toyama, D. Yanagimoto, K. hanawa, an N. Shikama (2011), Biogeochemical evidence of large diapycnal diffusivity associated with the Subtropical Mode Water of the North Pacific, J. Oceanogr., 67, 77-85.

Toyama, K., and T. Suga (2010), Vertical structures of North Pacific mode waters, Deep-Sea Res., 57, 1152-1160.

Hosoda, S., T. Suga, N. Shikama, and K. Mizuno (2009), Global surface layer salinity change detected by Argo and its implication for hydrological cycle intensification, J. Oceanogr., 65, 579-586.

Kobayashi, T., K. Amaike, K. Watanabe, T. Ino, K. Asakawa, T. Suga, T. Kawano, T. Hyakudome, and M Matsuura (2012), Deep NINJA: A New Profiling Float for Deep Ocean Observation. The Proceedings for the Twenty-second (2012) International Offshore and Polar Engineering Conference, 2, 454-446.

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5 pertinent publications:

Brandt, P., M. Araújo, B. Bourles, P. Chang, M. Dengler, W.E. Johns, A. Lazar, C.F. Lumpkin, M.J. McPhaden, P. Nobre, and L. Terray (2013), Tropical Atlantic Climate Experiment (TACE), Exchanges (Hamburg), 18, 26-31.

Ferreira, B.P., M.B.S.F Costa, M.S. Coxey, A.L. Gaspar, D.R.A. Veleda, and M. Araújo (2012), The effects of sea surface temperature anomalies on oceanic coral reef systems in the southwestern tropical Atlantic, Coral Reefs, 32, 1-14.

Veleda, D., Araújo, R. Zantopp, and R. Montagne (2012), Intraseasonal variability of the North Brazil Undercurrent forced by remote winds. Journal of Geophysical Research, 117, C11024.

Araújo, M., C.M. Limongi, J. Servain, M.A. Silva, F.S. Leite, D.R.A. Valeda, and C.A.D. Lentini (2011), Salinity-induced mixed and barrier layers in the Southwestern tropical Atlantic Ocean off the Northeast of Brazil, Ocean Science, 7, 63-73.

Silva, M.A., M. Araújo, J. Servain, P. Peven, and C.A.D. Lentini (2009), High-resolution regional ocean dynamics simulation in the southwestern Tropical Atlantic, Ocean Modelling, 30, 256-269.

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5 pertinent publications:

Claustre, H., M. Babin, D. Merien, J. Ras, L. Prieur, S. Dallot, O. Prasil, H. Dousova, and T. Moutin (2005), Toward a taxon-specific parameterization of bio-optical models of primary production: A case study in the North Atlantic, J. Geophys. Res., 110, C07S12, doi:10.1029/2004JC002634.

Claustre, H., Y. Huot, I. Obernosterer, B. Gentili, D. Tailliez, and M.R. Lewis (2008), Gross community production and metabolic balance in the South Pacific Gyre, using a non intrusive bio-optical method, Biogeosciences, 4, 463-474.

Johnson, K.S., W.M. Berelson, E.S. Boss, Z. Chase, H. Claustre, S.R. Emerson, N. Gruber, A. Körtzinger, M.J. Perry, and S.C. Riser (2009), Observing Biogeochemical Cycles at Global Scales with Profiling Floats and Gliders, Oceanography, 22, 216-225.

Le Quéré, S.P. Harrison, I.C. Prentice, E.T. Buitenhuis, O. Aumont, L. Bopp, H. Claustre, et al. (2005), Ecosystem dynamics based on plankton functional types for global ocean biogeochemistry models, Global Change Biology, 11, 2016-2040.

Uitz, J., H. Claustre, B. Gentili, and D. Stramski (2010), Phytoplankton class-specific primary production in the world's oceans: Seasonal and interannual variability from satellite observations, Global Biogeochem. Cycles, 24, GB3016, doi:10.1029/2009GB003680.

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5 pertinent publications:

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Mattern, J.P., K. Fennel, and M. Dowd (2012), Estimating time-dependent parameters for a biological ocean model using an emulator approach, Journal of Marine Systems, 96-97, 32-47.

Hu, J., K. Fennel, J.P. Mattern, and J. Wilkin (2012), Data assimilation with a local Ensemble Kalman filter applied to a three-dimensional biological model of the Middle Atlantic Bight, Journal of Marine Systems, 94, 145-156.

Bagniewski, W., K. Fennel, M.J. Perry, and E.A. d'Asaro (2011), Optimizing models of the North Atlantic spring bloom using physical, chemical, and bio-optical observations from a Lagrangian float, Biogeosciences, 8, 1291-1307, doi:10.4195/bg-8-1291-2011.

Fennel, K., I Cetinic, E. d'Asaro, C. Lee, and M.J. Perry (2011), Autonomous data describe North Atlantic spring bloom, EOS Transactions AGU, Vol. 92, No. 50, 465-466, doi:10.1029/2011EEO500002.

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Beaulieu, C., S.A. Henson, J.L. Sarmiento, J.P. Dunne, S.C. Doney, R.R. Rykaczewski, and L. Bopp (2013), Factors challenging our ability to detect long-term trends in ocean chlorophyll, Biogeosciences, 19(4), 2711-2724.

Henson, S.A., H. Cole, C. Beaulieu, and A. Yool (2013), The impact of global warming on seasonality of ocean primary production, Biogeosciences, 10(6), 4357-4369.

Henson, S.A., R. Sanders, E. Madesn, P.J. Morris, F.D. Le Moigne, and G.D. Quartly (2011), A reduced estimate of the strength of the ocean's biological carbon pump, Geophysical Research Letters, 38(4), L94606.

Henson, S.A., J.L. Sarmiento, J.P. Dunne, L. Bopp, I. Lima, S.C. Doney, J. john, and C. Beaulieu (2010), Detection of anthropogenic climate change in satellite records of ocean chlorophyll and productivity, Biogeosciences, 7, 621-640.

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5 pertinent publications:

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Ishii, M., H.Y. Inoue, T. Midorikawa, S. Saito, T. Tokieda, D. Sasano, A Nakadate, K. Nemoto, N. Metzl, C.S. Wong, and R.A. Feely (2009), Spatial variability and decadal trend of the oceanic CO_2 in the western equatorial Pacific warm/fresh water, Deep-Sea Res. II, 56, 591-606.

Ishii, M., S. Saito, T. Tokieda, T. Kawano, K. Matsumoto, and H.Y. Inoue (2004), Variability of surface layer CO_2 parameters in the western and central equatorial Pacific, in: Global environmental change in the ocean and on land, edited by: Shiyomi, M., H. Koizumi, A. Tsuda, and Y. Awaya, Terrapub, Tokyo, 59-94.

Ishii, M., H.Y. Inoue, H. Matsueda, S. Saito, K. Fushimi, K. Nemoto, T. Yano, H. Nagai, nd T. Midorikawa (2001), Seasonal variation in total inorganic carbon and its controlling processes in surface waters of the western North Pacific subtropical gyre, Mar. Chem., 75, 17-32.

Ishii, M., and HY. Inoue (1995), Air-sea exchange of CO_2 in the central and western equatorial Pacific in 1990, Tellus B, 47, 447-460.

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Kwon, E.Y. (2013), Temporal variability of transformation, formation, and subduction rates of upper Southern Ocean waters, J. Geophys. Res. Oceans, 188, 6285-6302, doi:10.1002/2013JC008823.

Kwon, E.Y., J. Sarmiento, J.R. Toggweiler, T. deVries (2011), The control of atmospheric CO_2 by ocean ventilation change: The effect of the oceanic storage of biogenic carbon, Global Biogeochemical Cycles, 25, GB3026, doi:10.1029/2011GB004059.

Kwon, E.Y., F. Primeau, and J.L. Sarmiento (2009), The impact of remineralization depth on the air-sea carbon balance, Nature Geosciences, 2, 630-635.

Kwon, E.Y., and F. Primeau (2008), Optimization and sensitivity of a global biogeochemistry ocean model using combined in situ DIC, alkalinity, and phosphate data, Journal of Geophysical Research, 113, C08011, doi:10.1029/2007JC004520.

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Ruggio, R., M. Vichi, F. Paparella, and S. Masina (2013), Climatic trends of the equatorial undercurrent: a backup mechanism for sustaining the equatorial Pacific production, J. Mar. Sys., 121-122, 11-23.

Vichi, M., A. Navarra, and P.G. Fogli (2013), Adjustment of the natural ocean carbon cycle to negative emission rates, Climatic Change, 118, 105-118.

Vichi, M., J. Allen, S. Masina, and N. Hardman-Mountford (2011), The emergence of ocean biogeochemical provinces: a quantitative assessment and a diagnostic for model evaluation, Global Biogeochem. Cycles, 25, GB2005, doi:10.1092/2010GB003867.

Vichi, M., S. Masina, and F. Nencioli (2008), A process-oriented model study of equatorial Pacific phytoplankton: the role of iron supply and tropical instability waves, Progress in Oceanography, 78, 147-162.