IOCCG Working Group Title:
Ocean Colour Applications for Biogeochemical, Ecosystem and Climate Modeling

Rationale:
Numerical modellers are often listed as major users of ocean colour data. And yet there is relatively little communication between the ocean colour and the numerical modelling communities. From the ocean colour community is important to know how numerical models use ocean colour data. In particular: What products are used? How are they used? How are uncertainties dealt with? From the numerical modelling community perspective queries are: What products are available? How to choose between different products of the same variable (e.g. Chl-a)? What are the uncertainties associated with each product? But a dialogue between the two communities could address: How can models be useful for the ocean colour community? How to reconcile model output with ocean colour products? Are there betters methods to link satellite products and model output that draws on the best of each?

The rationale of this proposed working group is to facilitate a better dialogue by bringing together both a diverse group of numerical modellers, as well as ocean colour specialists to synthesize current uses of ocean colour products, to provide a document that can be used by both communities in addressing the above questions, and lay out recommendations for continued and better use of ocean colour products in the future.

Terms of reference:
An initial set of questions are provided below, but will likely be altered as the working group develops.

1) What types of models use ocean colour products?
An initial task will be to formulate a list of types of models, as each type will have distinct needs from ocean colour. Such as list will also be useful to the ocean colour community to emphasize that there are distinctly different groups of models, modellers and purposes of models.
Models can be specifically designed for

- carbon cycle/biogeochemistry
- ecosystem and ecosystem function

They can also be used in distinct ways, for instance

- operational
- for purposes of identifying variability and trends (e.g. climate models)
- to study and understand distinct processes (e.g. spring bloom dynamics, roles of mesoscale etc)
- to study ecology (e.g. role of traits in setting community structure, role of predation)

The spatial scales for different models/modelling groups may also be quite different from global to regional, from open ocean to coasts and lakes. As such models will have very different resolutions: some very fine (<km scale) and others relatively coarse (degree scale). Timescales will also vary: from short (days) process studies, year-long hind casts to century level projections.
A particularly important group of models that benefit from ocean colour products are those involved in data assimilation. Data assimilation can be divided into two very distinct groups: inverse or adjoint (or 4-D VAR) and sequential methods. The former uses techniques to alter the model structure, variables, initial conditions and/or forcing such that a newer simulation will better fit the data. The latter re-initializes the model at regular intervals with data, and nudges the model to that data using various techniques (e.g. Kalman filter) such that the final output is a synthesis of model and data. Each type of

assimilation has it benefit and drawbacks, and are used for different purposed. The data needs are different and each would need to be addressed separately by the proposed working group.

2) What ocean colour products are being used?

An informal survey of the literature in 2013 suggested that Chl-a was the most commonly used ocean colour product. Primary production from ocean colour products was also widely used. The qualitative use of PFT has been increasing in the last couple years. Not much use has been made of reflectance and other more fundamental ocean colour products as these link to current numerical model variables less clearly.

An important step in making a more formal determination of the products used would be to conduct a numerical modelling community wide survey. A larger scale survey on ocean colour community has been conducted as part of the EU funded Pools of Carbon in the Ocean (POCO) project. That survey also targeted ecosystem and climate modellers. The proposed working group will communication with the POCO group to structure a new survey which focuses on more specific issues.

3) How do numerical modellers deal with ocean colour product uncertainty?

Part of the survey will need to be specifically on how modellers deal with uncertainty in the ocean colour products. Informally it appears that the issue of ocean colour uncertainty is rarely addressed. For instance, modellers will make excuse why their models do not match ocean colour Chl-a in the Southern Ocean as well as it does elsewhere (e.g. Aumont et al. 2015), without little awareness that the Chl-a algorithms are much worse in some regions than others. An important task of the working group would be to address how the ocean colour community can better communicate the uncertainties in a manner that a non-expert can easily understand and use. A potential task of the working group would be consolidate references of different Chl-a algorithms specific to each ocean region (e.g. Szeto et al., 2011; Johnson et al., 2013). Uncertainties needs will differ between different types of models and as such these will need to be tackled separately.

4) How is ocean colour being use in model evaluations?

Ocean colour with it global, regular coverage offers a unique evaluation tool for models. However questions of biases, and lack of information with depth still need to be addressed by modellers. It is important to know how different numerical modelling communities use the ocean colour products for evaluation, how they deal with uncertainties, and how they combine with other evaluation products (e.g. in situ Chl-a). Useful discussions of model skill metrics (against many different datasets) are in a set of paper in a special issue of the Journal of Marine Systems (2009, volume 76). Often evaluation of models remain at the “looks pretty good” level (side by side figures from model and ocean colour, e.g Doney et al., 2009). More quantitative techniques such as Taylor diagrams attempt to include biases and correlations with ocean colour products (e.g. Doney et al., 2009). But such techniques have issues when the reference products (e.g. ocean colour derived Chl-a) have large uncertainties. Likely better communication between ocean colour experts and numerical modellers would facilitate better evaluation techniques specific for data such as ocean colour with large regionally differing uncertainties. A goal of the working group could be an update from the Journal of Marine Systems of the techniques and potential “best practices” for model skill metrics specific for ocean colour products. The working group will need input on these issues from different collections of modellers, including intercomparison groups such as CMIP6, MAREMIP and other groups such as GODAE GOV MEAP-TT.

5) How is ocean colour being use in data assimilation?

Combining ocean colour data and numerical models could potentially be a very powerful tool: numerical models can fill in for times and locations (including depth) where ocean colour is not available

and thus provide better platform for exploring variability, diagnosing processes etc. Such techniques (data assimilation) have been used (e.g. Gregg, 2008; Tijputra et al 2007; see also review in Gregg et al., 2009). But there is significant work underway addressing these issues. A task on the working group will be to identify the modeling groups using ocean colour and document which products are most beneficial (and when and where ocean colour products degrade the solution).

The challenges in data assimilation remain huge: reconciling model output (often phytoplankton carbon) with ocean colour products, lack of knowledge of the ocean colour uncertainty, inherent model errors (both in terms of model structure and by the underlying errors in the model physics). A significant part of data assimilation is assigning uncertainties to the data input. Progress on these assignments would also be better facilitated with more communication between data assimilation and ocean colour communities.

In inverse or adjoint assimilation several datasets are usually included and they are assigned a weighting on how much they will impact the results, usually with less weight with increasing uncertainty. Ocean colour products could potentially have very limited impact if the uncertainties are too large. As such, it would be beneficial to provide better information on regional uncertainties.

The needs of both data assimilation groups will be different and each would need to be addressed separately by the proposed working group. The task here will be to have experts from each camp synthesis how ocean colour is currently being used and provide recommendations for both ocean colour and data assimilation communities on the better use of these products.

6) How can models help ocean colour community?

Models also hold the potential to inform the ocean colour community. For instance model output can be probed to provide suggestions on how long ocean colour product records need to be to isolate trends from natural variability (Henson et al, 2010; Beaulieu et al, 2013). Such studies could be very helpful in evaluating ocean colour products and even helping guide future ocean colour missions. Again, more communication between those using models in such a way, and the ocean colour community could lead to greater strides in this direction. An important chapter in the working group report would be to highlight the past and current uses of the model in this way as well as provide a direction for the use of models in potential new ocean colour missions. For instance, a numerical modeller (Cecile Rousseaux, NASA Goddard), is part of the PACE science team.

7) How can clearer links between satellite products and model output be facilitated?

What are the directions that models can go to fully utilize ocean colour products? How to reconcile model output with ocean colour? The report will highlights models that are currently resolving variables that can more easily link with satellite products. These model include those with explicit optics and possibly also radiative transfer components. Such models can provide output of absorption and scattering, as well as reflectance (e.g. Gregg and Casey, 2007; Xiu and Chai, 2014; Dutkiewicz et al, 2015; Baird et al, submitted). A task of the working group will be to identify these types of models, explore potential links between the model output and satellite products, and provide recommendations on further developments that will enhance the use of ocean colour in models.

8) Recommendations

A final outcome from this working group will be a set of recommendations of how the products could be used better. Such a set of recommendations is likely to include how ocean colour community could better communicate what products are available, what the uncertainties are of each product, when several different products are available which is better for a specific purpose. The recommendations would also include how the numerical modelling community is missing opportunities and useful ocean

colour data, and how the numerical modellers could better communicate their results to the ocean colour community such that both would benefit.

Committee members:

Stephanie Dutkiewicz, Chair (MIT, USA)
Icarus Allen (PML, UK)
Mark Baird (CSIRO, Australia)
Alessandro Crise (OGS, Italy)
Fei Chai (University of Maine, USA)
Marion Gehlen (IPSL/LSCE, CNRS, France)
Stephanie Henson (NOC, UK)
Colleen Mouw (Michigan Technological University, USA)
Cecile Rousseaux (Goddard, NASA, USA)
Charlie Stock (GFDL, NOAA, USA)

Draft time line:

July-September 2015: contact prospective working group members; identify additional groups of modellers to include in working group

September 2015-Feb 2016: solidify terms of references, identify additional meetings and groups of modellers to reach out to for input

Feb/Mar/Apr 2016: Initial "in person" meeting for working group members (potentially linked with a major meeting such as Ocean Sciences, Feb 2016); identify additional contributors; list of targeted material/tables/syntheses; draft outline of report

Apr/May 2016: Working group member(s) attend MEAP-TT meeting in California (possibly present current status of working group).

Apr-Oct 2016: Structuring survey and identifying target potential respondents (with consultation with member of POCO) and conduct survey.
Identifying assimilation groups using ocean colour
Identifying models resolving optical properties.
Collection of material/tables/syntheses and identifying useful literature

Oct 2016: Potentially meeting of subset of committee in tandem with POCO/CCI workshop in Rome, skype conference between all committee members (and additional contributors as needed)

Oct 2016 -Mar 2017: Analyzing survey output, and above syntheses, skype conference between committee members; identifying additional individuals to help with chapter writing

April 2017: Draft outline of each chapter, skype conference between committee members

August 2017: First draft of chapters, skype conference between committee members

November 2017: Finalize report

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