Proposed Joint OCB/USCLIVAR synthesis and intercomparison working group/workshops on ocean carbon uptake in CMIP6 models

Proposed Dates: Saturday and Sunday, December 8-9, 2018, Washington DC and
Saturday and Sunday, December 7-8, 2019, San Francisco, CA

Steering Committee/currently identified: Scott Doney (VIMS), John Dunne (NOAA/GFDL), Matthew Long (NCAR), Anastasia Romanou (NASA/GISS), Galen McKinley (Columbia/LDEO)

Possible Invited Participants/Members:
Representatives of modeling centers: James Christian (CCCMA), Richard Matear (CSIRO), Jim Orr, Laurent Bopp (IPSL), Tatiana Ilyina (MPI)
Observationalists: Andrea Fassbender (MBARI), Christopher Sabine, Richard Feely, Adrienne Sutton, Greg Johnson (NOAA/PMEL), Laurie Juranek (OSU), Bronte Tilbrook (CSIRO), Lynne Talley (Scripps), Alison Gray (UW), David Ho (UH), Rik Wanninkhof (NOAA/AOML), Colm Sweeney (CU/NOAA), Britton Stephens (NCAR), Ralph Keeling (Scripps).
Data analysis: Peter Landschutzer (MPI), Christian Rodenbeck (MPI)
Inverse modelers: Tim Devries (UCSB), Francois Primeau (UCI), Andy Jacobson (NOAA)
Model analysts: Galen McKinley (Columbia/LDEO), Joellen Russell (AU), Nicole Lovenduski (CU), Taka Ito (GaTech), Curtis Deutsch (UW), Laure Resplandy (Princeton).
Program Representatives: Kathy Tedesco, Libby Jewett, Dwight Gledhill (NOAA), Paula Bontempi (NASA), Simone Metz (NSF), Fredric Lipschultz (USGCRP)

Summary:

Climate and Earth System Modeling Centers around the world are currently preparing their state of the art models to participate in the 6th phase of the Coupled Model Intercomparison Project (Eyring et al., 2016), which is intended to inform and support the United Nations Environmental Program's International Panel on Climate Change (IPCC) 6th Assessment. Despite the incredible investment in Earth System Modeling by the international community, there exists a long standing challenge in the model development / CMIP rounds, which is that there is not sufficient analysis done on the vast quantities of data before the next round of development ensues. This is due to several key barriers, including (1) the lack of easy and timely access to the vast datasets, (2) a lack of understanding of the detailed of model structures and parameterizations among potential model analysis leads, and (3) efficiencies in the models themselves. We propose a community response to address this issue by bringing the community together to spark the development of specific testable hypotheses and new collaborations, and also offer an opportunity for community sharing of the latest tools and techniques that can facilitate efficient analysis. Participants would return 18 months later to report out on findings at a second workshop.

This proposed effort would complement the existing coordination of European modeling centers through the CRESCENDO project (https://www.crescendoproject.eu/) by building lines of communication between the US observational and analysis communities and the various contributing modeling centers in the US (NASA/GISS, NCAR/CESM, and NOAA/GFDL), Canada (CCCMA), and Australia (CSIRO) as each is planning to perform experiments in the spring/summer/fall 2018 timeframe, which would make Fall AGU 2018 an optimal time to share initial results in a first workshop. We are proposing the weekend before Fall 2018 AGU (12/8/2018-12/9/2018) for this workshop to overview CMIP6 related heat/carbon/tracer uptake activities and galvanize community action. Workshop Goals will be:

1) Summarize high profile CMIP5 Ocean Carbon Uptake analyses and challenges.

2) Summarize new observational constraints including GLODAPv2, SOCAT, SOCCOM, GO-SHIPS, community observational synthesis efforts such as Obs4MIPs, ocean carbon inversions, and atmospheric observations of CO_2 and oxygen

3) Modeling center reports on model formulation and preliminary analysis of the CMIP6 models in their regional and global patterns in heat/carbon/tracer uptake

4) Discuss mechanisms of heat/carbon/tracer uptake differences across models and observations towards linking physical and biogeochemical drivers and their impacts

5) Discuss tools and techniques that can lower barriers to analysis.

Workshop Goals for the follow-up (possibly Fall 2019 AGU or Spring 2020) meeting would work toward further advancing the state of the science by synthesizing state-of-the-art model simulations and up-to-date observations of key metrics and identifying areas of further investigations, including more observations and modeling groups across the following themes:

1) Regional and vertical patterns and variability in carbon uptake/acidification and its detection and attribution.
2) Uptake, transport and storage including circulation pathways such as Atlantic and Southern Ocean Meridional Overturning Circulation.
3) Relationship between heat, carbon, oxygen and other tracer uptake and cycling.

Together, these workshops would form as a strong capacity building activity on to maximize the utility of CMIP6 class Earth System Models for Ocean Carbon and Biogeochemistry applications.

Scope:

Analysis of Earth system observational and model data products is commonly undertaken with a 'black box' approach, involving limited consultation of the scientific experts responsible for producing the models and datasets. This forum would provide a unique opportunity for representatives of observational efforts and modeling centers to share their detailed understanding of the inner-workings of these products, their strengths and weaknesses, and the drivers of differences between them. The proposed workshop would support two of OCB's Research Priorities: Climate- and human-driven changes in ocean chemistry (e.g., acidification, expanding low-oxygen conditions, nutrient loading, etc.) and associated impacts on biogeochemical cycles and marine ecosystems, and ocean carbon uptake and storage.

The ideal complement to the workshops would be the hiring of a postdoc who would be the nexus for core analyses. This junior scientist would be responsible for pursuing the most compelling hypotheses identified at the workshop from the outset through leading the writing of scientific manuscripts describing the findings. They would also assist the community with downloading of appropriate observational and modeling based data sets, conducting analyses, and communicating with the modeling center representatives. To fund this postdoc, the US workshop leads will work to secure funding in 2018 via a variety of fellowships and institutional funds. It remains the case that a truly comprehensive analysis and synthesis of the CMIP6 suite of model experiments and observational constraints will require a dedicated researcher with considerable community support and coordination. As analysis of these observations and models mature, this first workshop would be followed up with scientific papers describing these analyses and either a second workshop or session adjacent to either the 2019 OCB summer meeting, 2019 Fall AGU meeting, or 2020 Ocean Sciences meeting to communicate the results in a workshop report, and a proposal to the community for a special journal volume. The best scenario will be to have a postdoctoral scientist in this role, but even if that does not come to pass, the community-driven effort with support from these two proposed workshops will result in greater utilization of society's enormous investment in Earth System Modeling.

Scientific Motivation:

Future climate will be largely determined by the combination of fossil fuel CO_2 emissions and mitigation, land use, and uptake of anthropogenic carbon by land and ocean. Earth System Models (ESMs) have been developed to simulate not only climate dynamics, but interactive biogeochemistry, ecology, and land use—as well as the associated flows of carbon through the atmosphere, land, and ocean. The ESM framework thereby attempts to provide a comprehensive basis for evaluating coupled carbon-climate feedbacks. Model intercomparisons have several important benefits: (1) a scoping assessment of "state of the art" provides perspective on critical scientific gaps; (2) the ensemble average of models with independent and opposing errors provides a "best guess" projection of future dynamics and feedbacks; (3) a characterization of model spread about the mean in the context of model diversity enables an assessment of the origins of structural uncertainty in future projections; and (4) quantitative relationships across the models can be used to draw inferences and emergent constraints on climate-biogeochemistry interactions. Each of these benefits will be important elements of our proposed analysis of future climate scenarios for this project, and are strongly aligned with the main goals of the CMIP6 and IPCC AR6 efforts. The IPCC fifth assessment found high agreement between CMIP5 Earth System models that ocean warming and circulation changes will reduce the rate of carbon uptake in the Southern Ocean and North Atlantic, but that carbon uptake will nevertheless persist in those regions (Ciais et al., 2013). While CMIP5 models tended to agree on global ocean carbon uptake within 20%, various regional assessment of carbon uptake and storage in this class of model have found a high degree of variability in the regional uptake, meridional transport, sequestration of carbon (e.g. Froelicher et al., 2014; Figure 1). CMIP5 was also momentous in its moving the physical climate community forward in facilitating later model investigations with regards to AMOC and heat uptake, CFC and carbon (e.g. Romanou et al, 2017; Marshall et al, 2016; Kostov et al, 2014).

For CMIP6, modeling centers have focussed on improving the resolution from nominally 2 degree atmospheres and 1 degree oceans in CMIP5 to nominally 1 degree atmospheres and 1 to ¼ degree oceans in CMIP6. Similarly, they have made great strides in comprehensiveness, and fidelity including improving surface temperature, wind patterns and variability, and ocean boundary currents in of these physical models which will allow for more accurate and robust determination of ocean biogeochemical interactions. The experimental design of CMIP6 (Erying et al., 2016) includes not only a standard set of Design, Evaluation, and Characterization of Klima (DECK) experiments, but includes two dedicated Intercomparison efforts of ocean biogeochemical cycling through the Ocean Model Intercomparison Project (OMIP; Griffies et al., 2016; Orr et al., 2016) and experiments with fully coupled ESMs through the Coupled Climate-Carbon Cycle Model Intercomparison Project (C4MIP; Jones et al., 2016). These sets of experiments will provide an unparalleled comprehensiveness in terms of historical experiments of ocean heat, carbon and transient tracer uptake in the historical context with ocean only and fully coupled models as well as experiments designed to improve the mechanistic attribution of climate and chemistry driven changes. Analysis and synthesis of these models will require considerable community coordination.

Similarly, observations, syntheses, and inverse modeling activities have advanced considerably in recent years. These include GLODAPv2 effort to synthesize shipboard ocean carbon observations from programs like JGOFS, WOCE, CLIVAR, and GO-SHIPS (Olsen et al., 2016), the SOCAT effort to supply updated climatologies and time dependent analysis of ocean pCO2 and air-sea CO2 fluxes from surface underway sampling (Pfeil et al., 2012; Sabine et al., 2012), the SOCCOM and other biogeochemical ARGO efforts to characterize ocean biogeochemistry from remote drifting array (Johnson et al., 2017), individual inverse modeling studies (e.g. Wanninkhof et al., 2013; Khatiwala et al., 2013) and larger, programmatic efforts like the Global Carbon Project (http://www.globalcarbonproject.org/), NOAA's CarbonTracker (https://www.esrl.noaa.gov/gmd/ccgg/carbontracker/), and NASA's Carbon Monitoring System (https://carbon.nasa.gov/) and RECCAP (http://www.globalcarbonproject.org/reccap/) that provide ongoing syntheses of land and ocean carbon uptake.

In the context of coupled climate and carbon cycle sustainability, ocean carbon research and associated model intercomparison is increasingly important. Under "sustainable" (net zero) emissions, climate services provided by land and ocean carbon cycles re-equilibrating to changed climate will largely determine allowable energy trajectories. Ocean-related challenges requiring comprehensive Earth System Modeling include identification of climate services of carbon storage in marine environments, assessment of potential stressors and their tipping points such as acidification, deoxygenation, meridional overturning and other sources of ventilation and other factors determining climate carbon feedbacks and trajectories in dominant regional dynamics in carbon uptake and storage such as the Southern Ocean, North Atlantic, and dynamic coastal areas that was also Exclusive Economic Zones. This work has also increasing policy implications because the current uncertainty in natural carbon sink variability limits the ability of the carbon cycle community to identify the impacts of emission reduction efforts on the atmospheric carbon concentration (Peters et al. 2017).

Context from CMIP5 experience:

One of the important contributions of the 5th phase of the Coupled Model Intercomparison Project (CMIP5; Taylor et al., 2012), was the expansion of priorities to include models of the coupled carbon-climate system. One of the major contributions of this effort was the update of the preliminary Friedlingstein (2006) analysis of coupled carbon-climate interactions in a broader subset of CMIP5 models (Arora, 2013). While these analyses unfortunately did not include participation of any of the US modeling centers, both GFDL and CESM were ultimately able to participate in the critical assessment of feedbacks and uncertainties in the IPCC 5th assessment (Figure 1), but that. Doney, Dunne, Long and McKinley were involved in a USCLIVAR/OCB - sponsored working group to synthesize ocean carbon uptake outputs for CMIP5, but the timing of the effort wasn't early enough to inform the AR5 report. However, it was valuable in bring modeling centers and analysis communities together and resulted in a detailed workshop report (https://usclivar.org/sites/default/files/documents/2015/SO-OCU-Workshop-Report-final_0.pdf). Another contributing factor in the delay and subcriticality in ocean carbon cycle analysis of CMIP5 models was the 2013 US Government Shutdown and Budget Sequestration, which resulted in the delay and termination of funding initiatives at NOAA, NASA, and NSF for this work. One of the objectives of the proposed 2018 workshop would be to organize collaborative research/synthesis of US couple carbon-climate earth system models earlier in the process so that the scientific outcomes are timely and robust enough to substantively inform the IPCC 6th Assessment. The European modeling centers are already coordinated through the CRESCENDO project (https://www.crescendoproject.eu/), and it would be useful for the North American centers to similarly get together and compare experiences in a substantive way.

Budget:
We request \$25,900 from OCB to cover airfare (\$500), vehicle costs (\$200), Hotel and per diem for DC area (\$270/day), and a venue with audiovisual accommodations (\$3,000) for 20 people for the first two day workshop plus supplies (\$500) and publication costs (\$3000).

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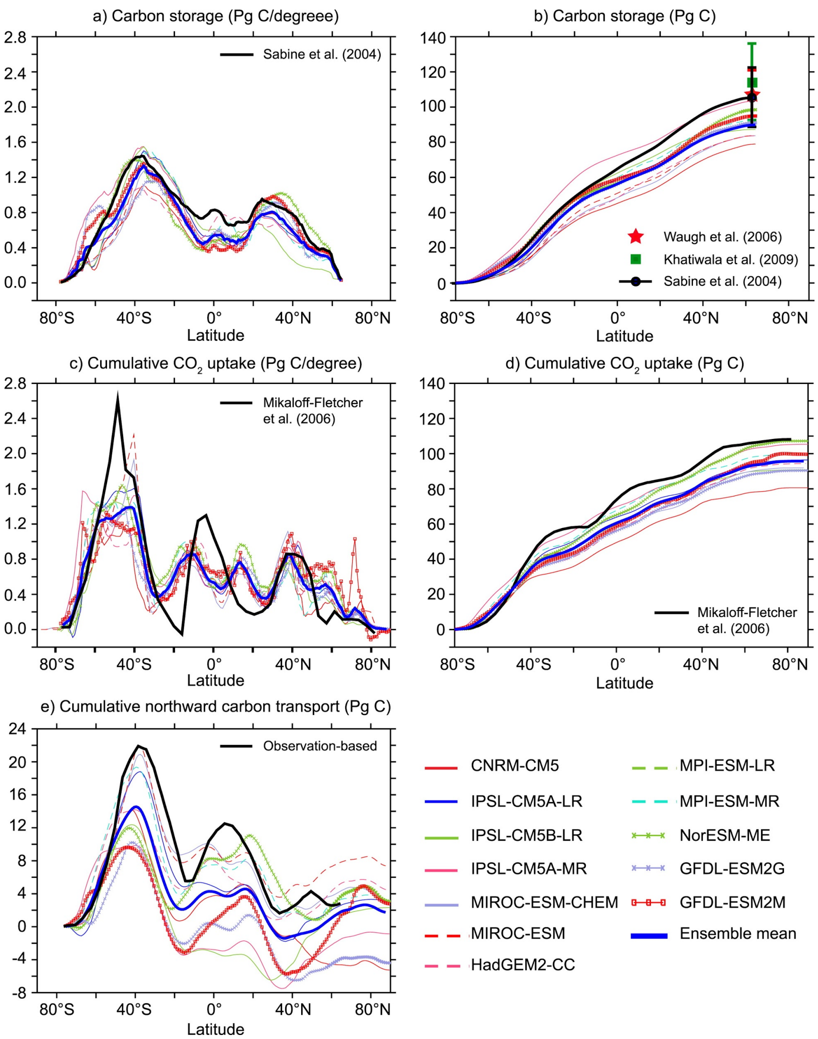
Figure 1:



From Froelicher et al., 2015 Figure 2:.Changes in oceanic storage, uptake, and transport of anthropogenic carbon between 1870 (represented by mean of period 1861–80) and 1995 (represented by mean of period 1986–2005) simulated by 12 CMIP5 models. (a) Zonal integrated oceanic anthropogenic carbon storage, (b) zonal integrated oceanic anthropogenic carbon storage integrated from 90°S to 90°N such that the vertical scale goes from 0 at 90°S to the total storage at 90°N, (c) zonal integrated cumulative ocean anthropogenic CO_2 uptake, (d) zonal integrated cumulative ocean anthropogenic CO_2 uptake integrated from 90°S to 90°N such that the vertical scale goes from 0 at 90°S to the total uptake at 90°N, and (e) northward oceanic anthropogenic carbon transport. The transport of anthropogenic carbon is the divergence of the anthropogenic CO_2 uptake and the anthropogenic carbon storage. The observation-based estimate of oceanic anthropogenic carbon transport is the divergence of the anthropogenic carbon flux estimates of Mikaloff Fletcher et al. (2006) and the anthropogenic carbon storage estimates of Sabine et al. (2004). Anthropogenic carbon storage in (a) and (b) is given for the GLODAP dataset area only, which does not cover coastal regions and several marginal seas, most notably the Arctic, the Caribbean, and the Mediterranean Sea. Excluded regions from the GLODAP area account for 7% and 10% of the total anthropogenic carbon storage in the CMIP5 models and the observation-based estimates, respectively (Table 2). Note that this has no impact when comparing results for the Southern Ocean (south of 30°S). Observation-based estimates are normalized to year 1994. Weighted mean estimates of inversion-based anthropogenic air–sea CO_2 fluxes are shown in (c) and (d).