Request to Ocean Carbon and Biogeochemistry Program for Workshop Sponsorship:
Pathways Connecting Climate Changes to the Deep Ocean – Tracing physical, biogeochemical, and ecological signals from the surface to the deep sea: A Joint US CLIVAR - OCB Workshop

Purpose: We propose a joint OCB and US CLIVAR sponsored workshop, in partnership with the Deep Ocean Observing Strategy (DOOS) community, to increase communication between science communities on the topic of climate change impacts on the deep ocean. The goal of the workshop is to bring together observational oceanographers and modelers across physical, biogeochemical, and ecological communities involved in climate research and ocean exploration to develop a collective set of requirements for improved characterization of baseline variability and the detection and attribution of change in the deep ocean system.

Scientific rationale and detailed description: The deep ocean is a significant but under-observed part of the earth system. This vast volume of water can store heat and carbon dioxide for hundreds to thousands of years and hosts elusive ecosystems. Over the past decades, despite limited observations, various changes have been revealed in the deep ocean, such as warming, freshening, de-oxygenation, acidification, and other carbonate changes. Also, contrary to the common conception of the deep ocean as a single, slowly changing body of water, many observed changes are regional and can be high-frequency. With physical and BGC observations already limited, corresponding (e.g., collocated) ecological and biological observations are virtually non-existent, preventing assessment of associated changes of life in the deep ocean.

Tight coupling between ocean circulation, biogeochemistry, and life in the deep sea calls for extensive exchange of data and knowledge across ocean science disciplines. These disciplines are investigated in various forms by the ocean climate and the ocean exploration communities, but with little overlap or coordination. With deep-ocean biodiversity losses either observed or anticipated in many areas, there is an urgent need for bolstering these exchanges and co-designing both observational campaigns and modeling experiments to understand, monitor, and predict deep ocean evolution under climate change and other anthropogenic stressors.

Another important question to ask is how changes in the deep ocean occur and how they are connected to forcings at the ocean surface. A number of processes play a role in the surface-to-seafloor connections for different ocean properties and materials. For instance, the well-known overturning circulation connects the surface and deep oceans over very long timescales. Mesoscale eddies, strong convection, and particle sinking are all mechanisms that link the surface and seafloor in a much faster manner. It is important to explore these and other potential processes that propagate surface climate change signals to the deep ocean and affect deep-ocean ecosystems.

The surface-to-deep ocean connection was explored in the 2021 US CLIVAR POS panel summer meeting, which featured speakers across physical, biogeochemical, and ecological disciplines. A key action item identified in this meeting was to expand the conversation spanning communities, including DOOS and OCB, and to develop a future interdisciplinary workshop on surface-to-seafloor pathways connecting climate variability and changes to the physics, biogeochemistry, and ecology of the deep ocean.

Such a workshop will also provide a critical culmination point for years of efforts by DOOS to increase communication between modeling and observing communities toward increasing coordination to tackle large-scale climate issues. This need was outlined in the DOOS Science and Implantation Guide in 2019 and is a key theme of the iDOOS project funded by the NSF in 2021 (see Smith et al., 2022). Community discussions to scope these efforts have recently accelerated beginning with the 2021 UN Ocean Decade Predicted Ocean Laboratory in which DOOS hosted

a satellite activity focused on societal needs and coordination between deep sea biologists and modelers. Further input from the observing and modeling communities have been solicited across DOOS events (working group meetings and the DOOS Annual Meeting) and community events where DOOS has been invited to speak. These discussions are successfully stimulating funding applications to support new collaborations between the modeling and observational communities.

After this scoping from the community, the necessary next step is to bring key community players together for a focused, intensive workshop to outline a community-wide path forward and future actions. A US CLIVAR - OCB workshop would provide this opportunity. In this workshop, we seek to bring together observational oceanographers and modelers across physical, biogeochemical, and ecosystem communities involved in climate research and ocean exploration to develop a collective set of requirements for improved characterization of baseline variability and the detection and attribution of change in the deep ocean system. Key contributions sought include efforts to (i) identify critical observation gaps, (ii) identify model deficiencies, (ii) propose beneficial data acquisitions, (iv) propose beneficial model developments, and (v) suggest new protocols to improve coordination between communities.

We welcome insights from highly localized to global-scale studies. We welcome efforts focused on individual system components (e.g., physics focused studies) but strongly encourage that implications for other components are considered to increase the opportunity to unify inputs and ensure impactful discussions. With this in mind, the workshop aims to:

1) Assess our current understanding of deep ocean changes and processes propagating climate variability and change to the deep ocean. Gathering perspectives from across disciplines will provide an updated comprehensive assessment of deep-ocean changes and key quantities in which these changes are expressed, as well as pathways and timescales connecting the surface to the seafloor.
2) Review existing observation and modeling tools and their adequacy for constraining, understanding, and attributing changes in the deep ocean system. Identify critical knowledge and observational data gaps, model deficiencies, and missing exchanges of needs between ocean science communities.
3) Develop a collective set of recommendations for improved detection and attribution of change in the global deep ocean system, with a focus on better serving and supporting deep ocean science across disciplines.
4) Build an interdisciplinary network of ocean modelers and observers across disciplines. Our aim is to open communication channels and facilitate collaborative exchange of data, knowledge, and tools across communities.

Advancing OCB research and observational priorities: This workshop is multidisciplinary in nature and will strongly benefit from being a joint effort between three programs, each with a different focus: US CLIVAR (climate change), OCB (biogeochemistry), and DOOS (deep ocean). Because this workshop specifically addresses climate change impacts in the deep ocean via surface-to-deep connections (including biogeochemical and ecological connections), it targets OCB's overarching goal to explore the ocean's role in the global carbon cycle and the response of marine ecosystems to environmental changes. It also addresses most of OCB research priorities, but more particularly *Climate- and human-driven changes in ocean biogeochemistry and associated impacts on marine ecosystems*, *Ocean carbon uptake and storage including from the air-sea interface to the deep ocean*, and *Marine organism-mediated carbon cycling and export via the biological pump*.

Deliverables: The major deliverables of this workshop will be:
- Community building across modeling and observational communities as well as across physical, chemical, and biological oceanography disciplines studying the deep ocean
- Consensus state of understanding of the connections between the surface and deep ocean
- Identification of needs for better understanding, observing, and predicting climate impacts on the deep ocean and approaches for supporting them.
- The organizing committee will share results with the broader community through a workshop report or review paper in Oceanography or BAMS and an ESRI StoryMap.

Venue and dates: The workshop venue is the Virden Retreat Center at the University of Delaware, Lewes, DE USA (https://conferences.udel.edu/lewes-campus/). The workshop would take place for 2.5 days in May 2023. Considering the uncertainties related to the COVID-19 pandemic, the organizing committee will closely follow the guidance of the public health officials. In the case of another COVID-19 outbreak around the planned date, the workshop will be postponed.

Scientific Organizing Committee (include affiliations):
- Xinfeng Liang (co-Chair, University of Delaware, US CLIVAR POS Panel)
- Monique Messié (co-Chair, Monterey Bay Aquarium Research Institute, US CLIVAR POS Panel)
- Leslie Smith (co-Chair, Your Ocean Consulting LLC, DOOS Project Director)
- Isabela Le Bras (Woods Hole Oceanographic Institution)
- Patrick Heimbach (University of Texas at Austin, DOOS Lead PI)
- Helen Pillar (University of Texas at Austin, DOOS ECR)
- Zachary Erickson (NOAA/PMEL, OCB)
- Charlie Stock (NOAA/GFDL, OCB, Pending Confirmation)

Proposed attendees and efforts to promote DEIJ: We anticipate approximately 80 in person participants and 40+ virtual participants. This workshop will only be as successful as the diversity of expertise and perspectives that we are able to bring to the table. It is essential to have representation from across ocean observing and modeling communities (physics/biogeochemistry/ecosystems) as well as from early career and international communities. With this in mind it is important to craft the event to be inclusive while also ensuring that diversity of expertise and perspectives is maintained. To that end, we have made the event hybrid to better facilitate participation from those in the international community and those without the resources to be able to travel to the workshop, such as from less well funded countries and institutions.

Additionally, while the workshop will be open to the broad community, we will have a participation list that includes key networks and organizations to ensure we capture the breadth of disciplines and connectivity to established programs: e.g., Deep Argo, Bio-GO-SHIP (Global Ocean Shipboard Hydrographic Investigations Program), EXPORTS (Export Processes in the Ocean from Remote Sensing), ECCO-Darwin (Estimating the Circulation and Climate of the Ocean), DOSI (Deep Ocean Stewardship Initiative), Challenger-150, PICES (North Pacific Marine Science Organization). The workshop will be advertised across the global deep ocean community, US CLIVAR, international CLIVAR, and OCB communities, UN Ocean Decade network channels, and through early career specific programs, including the global ECOP (Early

Career Ocean Professionals) program and DOOS's international DOERs program (Deep Ocean Early-career Researchers).

While advertising the workshop, sorting abstracts, and selecting invited speakers, a dedicated effort will be made to balance contributions across disciplines, career stage, gender, and geographical location. Our Scientific Organizing Committee has been selected to also be representative of the types of diversity we wish to see in our participants, with a range of disciplines represented, women making up half of the committee, including early-career researchers and representatives from underserved communities (e.g., persons of color and the LGBTQ+ community).

In order to ensure that the diversity of perspectives from the community are included, we will host a series of monthly "scene-setting" webinars leading up to the workshop. These presentations from the community will focus on elucidating important mechanisms propagating climate change to the deep ocean and highlighting major uncertainties. Subsequent Q&A sessions will serve to kick-start community discussions, inform refinement of workshop scope, and highlight priority areas for focused discussion, to allow for an element of co-design in the workshop planning process. Webinars will begin 4 months ahead of the meeting (in early 2023) and will be open to the community to broaden participation; all webinar attendees will be invited to attend the workshop.

Format of the meeting: The workshop will be hybrid. It will last 2.5 days and include plenary, smaller breakout, and poster sessions. For the breakout sessions, we will communicate with attendees in advance of the workshop to identify key processes/phenomena to prioritize for focused discussion. Tentative program:

Day 1 AM:
  Introduction and objectives
  Plenary 1: Physical processes/pathways (4 talks + discussion)
Day 1 PM:
  Plenary 2: Biogeochemical processes/pathways (4 talks + discussion)
  Poster session 1
Day 2 AM:
  Plenary 3: Ecosystem processes/pathways (4 talks + discussion)
  Breakout session 1: current understanding of vertical pathways connecting climate
    variability and change to the deep ocean
Day 2 PM:
  Breakout session 2: adequacy of existing observation and modeling tools
  Poster session 2
Day 3 AM:
  Breakout session 3: recommendations
  Conclusions and future steps

Budget request: We request support for meeting logistics and preparation as well as travel support for our 12 invited speakers, 7 of 8 of the organizers (one is local), and 20 early career researchers and scientists from underrepresented racial and/or ethnic groups.

Travel for 39	$63,316
Catering for 80	$17,332

Meeting Space	$2,000
A/V and Multimedia Services	$7,700
Poster Board Rental	$2,200
Supplies	$500
Travel Coordination Staff Time	$2,423
Indirect Costs	$853
Subtotal	$96,324
Less Registration Revenue	($16,000)
Total Request	$80,324
US CLIVAR Request:	$40,162
OCB Request:	$40,162

Other sources of funding: A similar proposal was submitted to US CLIVAR. If funded, we anticipate an even cost share between OCB and US CLIVAR to reflect an even distribution of participants. Travel grants, offered through the Deep-Ocean Stewardship Initiative (DOSI) to enable participation in workshops, will be promoted among registered participants as a potential avenue for travel support. We will also work with other collaborating networks to provide travel support for their members. Registration revenue was estimated at $16K based on in-person at $250 regular, $125 for early career and underrepresented and virtual at $200 regular, $100 for early career and underrepresented participants.

Appendix: Tentative example list of participants:
There will be 12 invited speakers. Our final selection will ensure engagement of key networks and balanced representation across discipline, gender and career stage. A tentative list is given below, arranged by expertise, with affiliation and key network associations given in brackets (two per bullet to be selected):

- Biogeochemical processes/pathways modeling perspective:
John Dunne (NOAA/GFDL), Dustin Carroll (MLML, ECCO-Darwin), Stephanie Dutkiewicz (MIT, Darwin Project, CBIOMES), Ric Williams (U. Liverpool)

- Biogeochemical processes/pathways observational perspective:
Rachel Stanley (Wellesley College, EXPORTS), Sophie Clayton (ODU, Bio-GO-SHIP), Jaime Palter (URI), Colleen Durkin (MBARI, EXPORTS)

- Ecosystem processes/pathways modeling perspective:
Kerry Howell (U. Plymouth, Challenger 150), Adrian Martin (NOC, JETZON)

- Ecosystem processes/pathways observational perspective:
Chih-Lin Wei (IONTU), Paul Snelgrove (NSERC Canadian Healthy Oceans)

- Physical processes/pathways modeling perspective:
Henri Drake (Princeton-NOAA/GFDL, BLT-Recipes), Andy Hogg (ANU), Mike Spall (WHOI), Graeme MacGilchrist (Princeton)

- Physical processes/pathways observational perspective:
Nathalie Zilberman (Scripps, Deep Argo), Amy Bower (WHOI), Alberto Naveira Garabato (NOC, BLT-Recipes), Damien Desbruyères (IFREMER, Deep Argo), Sarah Purkey (Scripps, GO-SHIP), Greg Johnson (NOAA/PMEL)