Meeting Report

Report of the 4th Session of the CLIVAR Ocean Model

9-12 October 2017 Exeter, UK

January 2018

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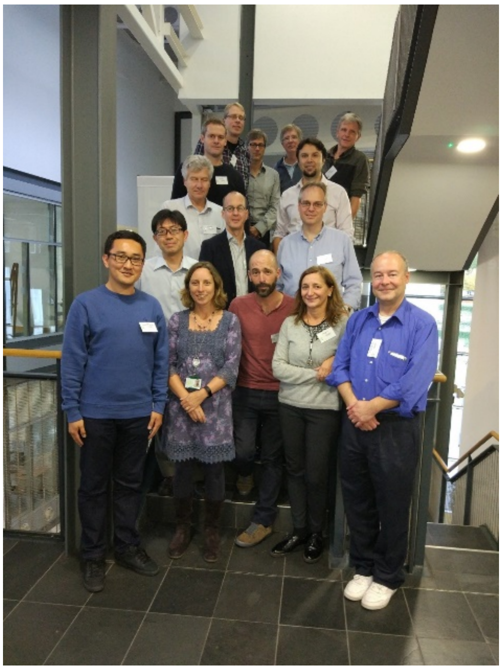
Action items

- Submit the manuscript describing the JRA55-do product by the end of 2017. *This is done.*
- Create a new version of the JRA55-do dataset (version 1.3) by early November 2017 (MRI). *This is done.*
- Update the Greenland liquid and solid runoff dataset to inter-annually varying when the observational data become available.
- Investigate the sensitivity of model solutions and, in particular, AMOC weakening to use of moist air physics in bulk flux calculations.
- Set up a slack web site (NCAR). *This is done. The web site is available at https://jra55-do.slack.com/messages/C7LEZT4KY/.*
- Finalize the Repeat Annual Forcing (RAF) dataset following the creation of JRA55-do version 1.3 and after resolving the issues with AMOC weakening.
- Encourage interested groups to perform high-resolution (HR) ocean – sea-ice simulations with the JRA55-do, following the broad guidance provided.
- Share the solutions from these HR simulations via the slack web site.
- Improve and update the protocol for running HR ocean – sea-ice simulations as the groups gain more experience.
- Prepare and submit a proposal in Spring 2018 to the US CLIVAR Inter-Agency Group to request funding for the 2019 workshop associated with the fifth OMDP session.

Introduction

The 4th session of the CLIVAR Ocean Model Development Panel (OMDP) was held on 9-12 October 2017 at the UK Met Office in Exeter, UK. This session was organized in conjunction with the pan-WCRP Modeling Meeting attended by all the modeling groups within WCRP. OMDP is grateful for the organization of logistical aspects of the meeting by our local host, Helene Hewitt. The meeting agenda and links to the presentations are available on the CLIVAR OMDP web site.



Participants of the 4th Session of the OMDP in Exeter, UK.

JRA55-do Dataset and Simulations

The meeting primarily focused on finalizing the new inter-annually varying atmospheric dataset based on the Japanese 55-year Atmospheric Reanalysis (JRA-55) product. The dataset is referred to as JRA55-do (driving ocean) to distinguish it from the raw product as it contains numerous corrections and adjustments that closely follow the methods used for the original Large and Yeager (2009; hereafter LY09) dataset. A new version of JRA55-do (version 1.3) was created and made available to the interested modeling groups for evaluation in early November 2017. The manuscript describing the JRA55-do product in detail, led by Hiroyuki Tsujino, was submitted to *Ocean Modelling* in early December 2017 (Tsujino et al. 2018). The JRA55-do dataset represents an update / improvement to the LY09 dataset for use in the next generation of the Coordinated Ocean-ice Reference Experiments (COREs) with its high spatial (55 km) and temporal (3-hourly) resolution. Moreover, it will be kept up to date, i.e., current, at least until 2023 with only a delay of a couple of months.

ACTION ITEM: Submit the manuscript describing the JRA55-do product by the end of 2017. *This is done.*

The majority of the meeting was devoted to presentations and discussions focusing on the evaluation of ocean – sea-ice hindcast simulations forced with the JRA55-do dataset. Several groups performed simulations using earlier versions of the dataset, i.e., prior to version 1.3. The discussions largely focused on the behavior of the Atlantic meridional overturning circulation (AMOC) seen in most of the model simulations. Specifically, in these models (e.g., ORCA025, HYCOM, and CESM-POP), the Labrador Sea convection ceased after a few decades of integration, leading to AMOC weakening and / or collapse. Such behavior occurred usually with weak surface salinity restoring, i.e., 4 years over 50 m. In contrast, MRI and COCO models did not suffer from this issue, both maintaining healthy AMOC transports. Noting also that some of the models that exhibit a weakened AMOC with JRA55-do do not encounter such a weakening when forced with the original LY09 dataset, subtle differences in precipitation, runoff, and winds between LY09 and JRA55-do were discussed as possible culprits resulting in weak AMOC. Among these, wind stress in JRA55-do was identified as being weaker by up to 10% than that of LY09. Hiroyuki Tsujino noted that the wind adjustments of JRA55-do follow a slightly different approach than in LY09 and that a multiplicative correction factor can indeed result in weaker winds in JRA55-do. To maintain variance, he proposed using an offset correction instead of a multiplicative one. This suggestion was agreed on by the panel and resulted in the version 1.3 of JRA55-do that is now documented in Tsujino et al. (2018). This version uses monthly-mean climatology for the liquid and solid runoff from Greenland based on the Bamber et al. (2012) dataset. With the anticipated new version of the Greenland runoff data becoming available in early 2018 (Bamber et al. 2018), the runoff dataset will be updated to become inter-annually varying soon after.

An additional aspect concerns the use of moist air physics in the bulk formulae during the production of the JRA55-do dataset as detailed in Appendix B of Tsujino et al. (2018). This represents a departure from the original LY09 approach. Many of the groups have not switched to use of moist air physics in their flux formulations yet. Thus impacts of this change on the AMOC weakening remains unclear.

ACTION ITEM: Create a new version of the JRA55-do dataset (version 1.3) by early November 2017 (MRI). *This is done.*

ACTION ITEM: Update the Greenland liquid and solid runoff dataset to inter-annually varying when the observational data become available.

ACTION ITEM: Investigate the sensitivity of model solutions and, in particular, AMOC weakening to use of moist air physics in bulk flux calculations.

The apparent weaker winds and wind stress in JRA55-do – in comparison with the LY09 dataset, renewed previous OMDP discussions on use of relative vs. absolute winds in bulk flux formulae. Preliminary results with the CESM-POP model using the JRA55-do dataset in which the ocean currents were not used in any flux calculations, including those of ocean – sea-ice, showed that AMOC stayed strong. Such a treatment essentially results in larger stress values, but more importantly appear to maintain larger sensible and latent heat loss from the ocean, keeping the Labrador Sea region saline. There is some justification for treating the JRA55-do winds as already relative. Specifically, because the long-term mean JRA55-do wind vector has been calibrated to match that of a scatterometer wind product (QuikSCAT), the long-term mean wind field of JRA55-do should be understood as the wind field relative to the surface currents. Thus, in principle, we should not subtract the surface ocean currents from the JRA55-do wind field in computing surface fluxes for the purpose of reproducing realistic long-term mean oceanic fields in ocean – sea-ice simulations.

In general, given this argument, the meeting participants thought that it was acceptable to treat JRA55-do winds as already relative and use no ocean currents in bulk formulae for non-eddy-resolving / permitting, i.e., coarse resolution models. In contrast, it was thought that the exclusion of ocean surface currents from the flux calculations would ignore the important effects of wind damping on the energetics of mesoscale eddies in high-resolution, eddy-resolving models. There may be some remedies for use in eddy-resolving applications, in particular. A possibility is to add the long-term mean ocean surface current field to the relative wind field to produce an absolute wind field. Such an ocean surface current field would be available from the surface drifter data, from the surface height data (by assuming a geostrophic balance), or a combination of both. There are several surface current datasets, e.g., OSCAR (Bonjean and Lagerloaf (2002) at 15 m depth), NOAA-AOML (Laurindo et al. (2017) at 15 m depth), and GlobCurrent (Rio et al. (2014) at 0 and 15 m depth). Inclusion of the surface currents may be sought in the second version of the JRA55-do dataset. An alternative is to apply a high-pass filter on the surface ocean current field and the fine-scale surface ocean current field is subtracted from the wind-field, or to subtract a small fraction of the surface oceanic field from the JRA55-do wind field and fine-tune the fraction.

Currently, we have not reached any definite conclusions or a recommendation for using relative vs. absolute winds in flux calculations with JRA55-do, but there seems to be some preference for the former for coarse resolution models. Of course, some participants also indicated that we should be consistent with the use of relative vs. absolute winds across model resolutions to the extent possible and justifiable. It was noted that the simulations with NEMO usually use absolute winds. Several groups agreed to perform simulations with no ocean currents in bulk formulae and report back to the OMDP. To expedite exchange of information and simulation results, NCAR agreed to set up a slack web site.

ACTION ITEM: Set up a slack web site (NCAR). *This is done. The web site is available at https://jra55-do.slack.com/messages/C7LEZT4KY/.*

Repeat Annual Forcing Dataset Based on JRA55-do

To compliment the inter-annually varying dataset discussed above, OMDP is interested in providing a single-year of forcing dataset to the community. In addition to its use in well-defined, coordinated experiments, such a dataset could be used to obtain reasonable ocean – sea-ice simulations for parameterization developments or hypothesis testing as well as to eliminate forced inter-annual variability in various flux components. In our previous meetings, the considerations that guided the creation of the original Normal Year Forcing (NYF; Large and Yeager 2004) were critically reviewed after years of experience using NYF and in anticipation of the need for a new single-year forcing dataset based on JRA55-do. The complex spectral averaging technique used to generate NYF was designed to preserve climatological fluxes, but the ostensible benefits of constructing NYF in this way have not been realized in practice. NYF-forced ocean – sea-ice simulations do not, in general, achieve the same equilibrium solution as the inter-annually-forced ocean – sea-ice simulations. Furthermore, there are serious drawbacks of NYF including that i) it yields unrealistic mean sea ice states (it was not designed for use over ice); ii) it is spatially noisy; iii) it does not yield physically-consistent atmospheric state fields; iv) it includes radiation and precipitation fields that lack weather variance; and v) it is complicated to construct. Following Steve Yeager’s proposal from the Yokohama OMDP Meeting (January 2016), OMDP is pursuing creating a single-year forcing dataset, called the Repeat Annual Forcing, RAF. The intention is to choose a year from the JRA55-do dataset in which the major climate indices such as North Atlantic Oscillation, El Nino Southern Oscillation, and Southern Annular Mode are small or near-neutral. NCAR group, in collaboration with Kial Stewart and Andy Hogg from

ANU, have identified May 1984 – April 1985, May 1990 – April 1991, and May 2003 – April 2004 as candidate years for the RAF designation. Although the RAF will cover a January – December period, a transition from April to May is preferred to avoid high wind variability periods during Austral summer. The final choice among these candidates will be made after the JRA55-do version 1.3 is created and after the issues with AMOC weakening are resolved.

ACTION ITEM: Finalize the Repeat Annual Forcing (RAF) dataset following the creation of JRA55-do version 1.3 and after resolving the issues with AMOC weakening.

High-Resolution Ocean – Sea-ice Simulations with JRA55-do

Now that the JRA55-do dataset is ready, OMDP would like to encourage and coordinate its use in high-resolution (HR) ocean – sea-ice simulations, taking advantage of the dataset's high spatial and temporal resolution. The panel discussion started with what HR means. Although it is highly subjective, usually globally eddy-resolving / -permitting horizontal resolutions of order 0.1° can be considered HR at present, noting that simulations with 0.1° and 1/12° behave quite differently and that the meaning of HR will likely change / evolve in the future. In addition, global models with regional refinement capabilities, such as FESOM and MPAS-O, can be configured to have much finer resolution than 0.1° in a particular region of interest, e.g., the North Atlantic, at the expense of much coarser resolution (> 0.1°) elsewhere. At present, running such unstructured mesh models at very high resolutions everywhere globally is computationally unaffordable. A preliminary consensus was reached to define a HR model as an eddy-resolving model in at least one ocean basin. If a simulation is HR only in one basin, then the results pertaining to that basin would be used in model comparisons.

The second discussion topic concerned a protocol for performing coordinated HR ocean –sea-ice simulations, specifically the lack of such a protocol. Many groups only recently started getting involved with HR simulations which are driven by specific science questions. As such and given the computational cost of the simulations – indeed, groups may have limited resources just enough to perform order a few decades of simulation, it is difficult to ask groups to follow a particular protocol. Moreover, there are no established best practices and there is an experience gap regarding parameter dependencies, initializations, parameterizations, etc. Nevertheless, the panel agreed that there is value in providing a broad guidance to reduce uncertainties. As a very preliminary guideline and for the purposes of a HR model inter-comparison / evaluation effort with the JRA55-do inter-annually varying dataset, we encourage groups to i) use the same bulk formulae; ii) use the forcing dataset without any additional modifications; iii) integrate the model at least one forcing cycle; iv) subject to resources, make sure to obtain and provide output fields for a common period; and v) include CFCs. With this broad guidance, the interested groups are encouraged to perform HR simulations and report back their experience and findings via the slack web site. It is the intention of the OMDP to improve and update the protocol as the groups gain more experience. The panel unanimously agreed on the acronym for this effort: High-CORE.

ACTION ITEM: Encourage interested groups to perform high-resolution (HR) ocean – sea-ice simulations with the JRA55-do, following the broad guidance provided.

ACTION ITEM: Share the solutions from these HR simulations via the slack web site.

ACTION ITEM: Improve and update the protocol for running HR ocean – sea-ice simulations as the groups gain more experience.

Analysis of fields from HR model simulations contain both scientific and technical challenges as highlighted by two presentations from Julien Le Sommer and Todd Ringler. Scientifically, model comparisons with observational data should take into account the uncertain nature of our ocean model simulations as well as the phase uncertainty of the eddies in HR simulations. Similarly, since HR model simulations are not yet routine, the community's protocol for comparing and contrasting the role of mesoscale ocean eddies among different ocean models is immature. One idea is to measure the influence of ocean eddies by the net force these eddies exert on the climatological ocean circulation and by the irreversible mixing of trace constituents induced by the stirring of these eddies. This approach provides the opportunity to knit together recent theoretical advances in formulating eddy-mean flow interaction, the growing upper ocean observational database provided by Argo, and the suite of HR model simulations that we hope to coordinate through this effort. These approaches advocate for comparisons of data with distributions and comparisons of distributions. On the technical side, the sheer size of data volume is quite daunting, ordinarily necessitating vast memory and disk space. Existing technological solutions from other communities can be adopted for our applications. One such example is the Python Data Stack. A start-up initiative (pangeo-data) funded by the US National Science Foundation and led by Ryan Abernathey (Columbia) is intended to leverage such existing tools for the use of oceanic and atmospheric science communities.

Pan-WCRP Modeling Meeting Breakouts

Goals of the Pan-WCRP Modeling Meeting included improving information exchange among the modeling groups and panels within WCRP and discussing the modeling needs of the broader WCRP community. In this spirit, in addition to the individual panel meetings, the meeting had several parallel breakout sessions, covering earth system modeling; regional climate modeling – both regional and global high-resolution; modeling infrastructure, data standards, and protocols; observations and use of models for designing observing systems; diagnostics, metrics, and evaluation; towards seamless weather and climate predictions; linking models to user communities; and multi-model synthesis and associated uncertainties. The OMDP meeting participants attended breakout sessions of their interest and reported back to the panel. Following is an ad-hoc list of some salient points:

- In the infrastructure breakout session, there was acknowledgement that various standards, e.g., file formats, CF conventions, and names, are not well optimized for ocean model output. Current approach to evolving standards is from individual suggestions. There is a process for updating standards which works, but relies on volunteer efforts. Groups like OMDP could organize more comprehensive suggestions for updates to standards.

- In the diagnostics and metrics breakout, the request was for collation of working tools for diagnostics / metrics. Currently ocean metrics are not well represented within the metrics packages. It was agreed that it is not the job of WCRP and that such tools must come from the troops on the ground (and used in published analysis). A group like OMDP can help collate and promote such tools, or encourage the extension of existing tools to work on multiple models, e.g., to fit within the metric packages. Simon Marsland is our representative on the Metrics Panel.
- Regional and high-resolution modeling breakout had discussions on the importance / effects of the side boundary conditions on regional model solutions. High-resolution aspects focused on the atmospheric models only.
- Earth system modeling breakout had discussions on mean state biases, such as in precipitation, how to go about addressing persistent systematic errors, and high sensitivity of BGC to errors in upwelling. It is hard to prioritize such systematic biases because different people / groups have different goals and opinions.Prediction breakout discussed the impacts of model biases on predictions, e.g., addressing the Gulf Stream separation problem may improve the prediction skill.

In general, Pan-WCRP Meeting participants agreed that addressing persistent model biases should be a high priority goal. However, it is unclear how to proceed with and organize such an effort at international level.

The Next Panel Meeting and Workshop

The panel members considered two offers for hosting the 5th Session of OMDP to be held in March – April 2019 time frame: Tallahassee, FL, USA and Bologna, Italy. After a short discussion, Tallahassee was chosen as the venue for our next meeting. OMDP usually holds an accompanying workshop. Unfortunately, our 3rd Session Meeting was held during the Pan-CLIVAR meeting, and this 4th Session Meeting is in conjunction with the Pan-WCRP Modeling Meeting, thus preventing us from holding a topical workshop. Noting that such workshops are important community outreach / education and information exchange activities for OMDP, it is essential that we hold a workshop at our next meeting.

The discussions then focused on possible topics for the workshop. A topic of interest is ocean mesoscale interactions with the atmosphere. This is also the topic of sessions and a short workshop at the upcoming Ocean Sciences Meeting (February 2018) organized primarily by the CLIVAR Atlantic Regional Panel (ARP) with contributions from OMDP. Some concerns were expressed for having a similar OMDP workshop topic especially in a limited funding environment. Nevertheless, the panel felt that focusing on *Sources and Sinks of Ocean Mesoscale Eddy Energy* would distinguish our proposed workshop and agreed to proceed with the topic. With input from Julien Le Sommer, OMDP has the following motivations and objectives for the workshop:

Motivation: The purpose of the workshop is to review the current understanding of mesoscale eddy-mediated exchanges of kinetic energy in the global ocean in order to guide their representation in future mesoscale eddy permitting ocean model components of earth system models. Ocean mesoscale eddies are the main oceanic reservoir of mechanical energy as well as an important energy reservoir in the climate system. However, because the earth climate system is a forced dissipative system, the ability of earth system models to estimate the long-term evolution of climate is constrained by how mechanical energy is dissipated in earth system models. Realistic representations of eddy-mediated energy exchanges in ocean circulation models are very important to obtain reliable estimates of future climate projections. Over recent years, observations and theory have documented several new eddy-mediated energy exchanges mechanisms. These include interactions with submesoscales, internal waves, boundary processes, surface winds, and surface waves. However, these processes are not yet fully represented in ocean circulation models so that eddy-mediated energy exchanges are still inadequately accounted for in these models. Arguably, the representation of eddy-mediated energy exchanges could be a key source of uncertainty in future earth system models. Due to these science aspects, we believe that this workshop is highly relevant to CLIVAR and WCRP science, including various basin panels, Research Foci, and Grand Challenges.

Objectives: The specific objectives of the workshop include i) to review recent theoretical and observational advances on the understanding of eddy-mediated mechanical energy exchanges; ii) to identify future observations that could contribute to better constrain our estimation of these exchanges; and iii) to guide the representation of these exchanges in ocean circulation models through physical parameterizations. Anticipated key agenda items include interaction of balanced mesoscale eddies with submesoscale flows in the surface ocean; status of sub-grid-scale closures for eddying models; interaction between balance mesoscales and the internal wave field; mesoscale eddy dissipation along boundaries (bottom and lateral); and key future sources of observations.

ACTION ITEM: Prepare and submit a proposal in Spring 2018 to the US CLIVAR Inter-Agency Group to request funding for the 2019 workshop associated with the fifth OMDP session.

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