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CLIVAR Ocean Model Development Panel (OMDP) mini workshop on forcing ocean and sea-ice models

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Content

Action Items

Explore running the CORE-II simulations without any surface salinity restoring.

Based on the outcome of above action item, revisit surface salinity restoring and E-P+R budget details.

Explore different spin up options.

Include guideline and explanation for use of absolute winds in CORE-II protocol (J. Le Sommer).

Evaluate current iceberg-melt estimates and future scenarios in collaboration with the SOP (J. Le Sommer).

Specify Antarctic liquid and solid freshwater flux estimates (with relevant references) in CORE-II protocol for groups to apply (J. Le Sommer).

This exciting prospect for a new high resolution, near real time forcing dataset for CORE-II and potentially OMIP will be supported through a community evaluation effort of the above issues by the workshop participants over the course of this year, i.e., 2015 (MRI, NCAR, GFDL, U. Reading, LGGE, others).

1. Background on CORE Simulations

The Coordinated Ocean-ice Reference Experiments (COREs) were first introduced in Griffies et al. (2009). The CORE framework defines protocols for performing global ocean – sea-ice coupled simulations forced with common atmospheric data sets. Therefore, the most essential element of the CORE framework is the forcing data sets, which were developed by Large and Yeager (2004; 2009). The overarching hypothesis of a CORE comparison project is that global ocean – sea-ice models run under the same atmospheric state produce qualitatively similar solutions. This hypothesis has been found to be valid for a few certain phenomena/diagnostics, but invalid for many others.

The first phase of COREs, namely CORE-I, involves using an idealized, i.e., synthetically constructed, one-year repeating annual cycle of forcing, referred to as normal year forcing (NYF). The primary goals of CORE-I simulations are to investigate and document the climatological mean ocean and sea-ice states obtained after long (at least 500 years) integrations. Griffies et al. (2009) provided a comprehensive analysis of seven CORE-I simulations, using ocean and sea-ice models of the CMIP3 (Coupled Model Intercomparison Project phase 3) era. They also highlighted general issues associated with the CORE framework. Although certain of the examined diagnostics indicated consistency across the CORE-I model suite, this study identified a number of places where simulations differ, thus prompting ongoing research into causes for the disparities.

The second phase of COREs, namely CORE-II, uses inter-annually varying atmospheric forcing (IAF). Presently, CORE-II simulations have been run over the 60-year period from 1948 to 2007. In the oceanographic community, the CORE-II simulations are usually referred to as *hindcast* experiments. These hindcasts provide a framework to evaluate ocean and sea-ice model performance, and to study mechanisms of time-dependent ocean phenomena and their variability from seasonal to decadal time scales for the recent past. Specifically, the CORE-II hindcast experiments directly contribute to:

i) evaluation, understanding, and improvement of the ocean and sea-ice components of earth system models;
ii) investigation of mechanisms for seasonal, inter-annual, and decadal variability;
iii) attribution of ocean-climate events to forced or natural variability;
iv) evaluation of robustness of mechanisms across models;
v) bridging observations and modeling, by complementing ocean reanalysis from data assimilation approaches;
vi) providing consistent ocean and sea-ice states that can be used for initialization of climate, e.g., decadal, prediction experiments.

Some examples of recent work demonstrating the use and benefits of inter-annually forced simulations include mechanisms and attributions studies on the mid-1990s weakening and warming of the North Atlantic sub-polar gyre (SPG), e.g., Lohmann et al. (2009), Yeager et al. (2012) and Barrier et al. (2015), respectively, and studies on the link between the SPG and the Atlantic Meridional Overturning Circulation (AMOC) as discussed in Hatun et al. (2005). We note that, among these studies, the Yeager et al. (2012) analysis utilized a CORE-II hindcast simulation as well as decadal prediction experiments that were initialized using ocean and sea-ice initial conditions from the CORE-II simulation.

The CORE-II effort has gained unprecedented momentum over the past few years and attracted participation of over 20 ocean and climate modeling groups world-wide. Quite simply, it is the most successful coordinated global ocean – sea-ice project ever. The resulting simulations are being analyzed in many diverse studies focusing on various aspects of the ocean and sea-ice climate system. The studies are being championed by leading oceanographers, including participation of the various modeling groups contributing to the model suite. To date, these studies are as follows:

- North Atlantic and AMOC: mean (Danabasoglu et al. 2014) and variability (Danabasoglu et al. 2015)
- Global and regional sea level (Griffies et al. 2014)
- Antarctic Circumpolar Current and Southern Ocean overturning circulation (Farneti et al. (2015)
- Southern Ocean water masses, ventilation, and sea-ice (Downes et al. 2015)
- Arctic Ocean: sea-ice and freshwater (Qiang et al. 2015) and hydrography (Ilicak et al. 2015[1])
- Ocean circulation in temperature and salinity space (Zika et al. 2015[1])
- Pacific Ocean circulation and variability (Tseng et al. 2015[1])
- Indian Ocean circulation and variability (Ravichandran et al. 2015[1])
- Indonesian Throughflow (England et al. 2015[1])

We anticipate that all projects will be mature by the end of 2015. Manuscripts documenting the analysis are being published in a Special Issue of *Ocean Modelling*.

2. CORE-II Protocol Summary

In the CORE-II protocol, ocean models are initialized using the January-mean potential temperature and salinity climatology from observations and typically from a state of rest. The sea-ice models are generally initialized from an existing state taken from another simulation. The surface heat fluxes are determined by the radiative fluxes from the CORE-II atmospheric state, as well as turbulent fluxes (sensible and latent) computed based on the evolving ocean model state and CORE-II atmospheric state. Bulk formulae for the turbulent fluxes follow those described in the protocol in order to facilitate comparisons between model simulations. There is no restoring term applied to the surface temperature field. In contrast, the surface salinity field is damped to a monthly observational climatology. However, the protocol does not specify a particular recipe for salinity restoring; it is left to the modeling groups to choose their optimal salinity restoring procedure. Using a unified salinity restoring across all models has not been feasible, due to physical sensitivities related to high latitude processes

[1] Analysis for this manuscript is in progress.

identified in Griffies et al. (2009). Further details of the experimental protocol and datasets are available in Griffies et al. (2012) and Danabasoglu et al. (2014). All data sets, codes for the bulk formulae, technical report, and other support codes along with the release notes are freely available at [http://data1.gfdl.-noaa.gov/nomads/forms/core.html](http://data1.gfdl.noaa.gov/nomads/forms/core.html).

3. Context and Background for the Mini Workshop

The CORE-II framework has now reached a relatively mature state. Specifically, it is widely recognized as the community standard for global ocean – sea-ice simulations, and it is being adopted by many groups world-wide for evaluation of ocean and sea-ice components of their coupled models. It has become a *rite-of-passage* as the modeling groups compare their solutions to those provided as *benchmarks* in the manuscripts published in the CORE-II Special Issue of the journal **Ocean Modelling**. As a signal to the success of the CORE-II effort, modeling groups and analysts have requested that we propose the CORE-II experiments as an Ocean Model Intercomparison Project (OMIP) for inclusion in CMIP6 (Coupled Model Intercomparison Project phase 6). With encouragement of the WCRP Working Group on Coupled Modeling (WGCM), we submitted an OMIP proposal to the CMIP panel. That proposal was revised in March 2015, including the merger with ocean biogeochemistry efforts (i.e., OCMIP). This expanded OMIP effort will be part of CMIP6.

To date, the CORE data sets and protocol have been collaboratively led and supported by the National Center for Atmospheric Research (NCAR) and the NOAA Geophysical Fluid Dynamics Laboratory (GFDL) under the umbrella of the Climate Variability and Predictability (CLIVAR) Ocean Model Development Panel (OMDP; formerly Working Group on Ocean Model Development, WGOMD). While the success and visibility of the CORE-II effort have been steadily increasing, no significant new developments or maintenance of the data sets or the protocol have occurred during the last 5-6 years. This situation is perhaps to be expected, given that scientific success of CORE-II has only recently become clear amongst the broader community. However, a frozen foundation for CORE-II cannot continue. Indeed, various shortcomings with the present CORE-II data sets and the protocol have been identified during the course of CORE-II studies. Aspects of these shortcomings were discussed at the CLIVAR WGOMD Workshop on High Resolution Ocean and Climate Modeling in April 2014 in Kiel, Germany, and at the pan-CLIVAR panel meetings and discussions in the Hague in July 2014. Given the widespread use of CORE-II, and the associated broad advances to ocean and climate science, we contend that there is an urgent need to advance the scientific and engineering foundations of CORE-II. This advance must proceed in a timely manner for the benefit of the ocean modeling communities around the world.

4.1 Requests / Requirements from the Ocean Modeling Community (roughly in priority order)

- Keep all forcing data sets up-to-date[2];
- No tuning and / or adjustments of the data sets based on model results;
- Balanced forcing data sets – heat and water budgets balanced together;
- Create finer spatial and temporal resolution versions of the data sets that can be used to force high-resolution (e.g., eddying, coastal) ocean and sea-ice models;
- Consider alternative (all available) data sets, e.g., other reanalysis products, radiation data sets, etc.;
- Revisit a few aspects of the CORE-II protocol such as surface salinity restoring. A specific goal is to investigate in a systematic way if ocean – sea-ice integrations without any surface salinity restoring could be achieved;
- Consider extending the data sets to years prior to 1948.

4.2 Opportunity to Revisit Various Other Aspects of Forcing Data Sets

- Assumptions and corrections used in Large and Yeager (2009) during the creation of the atmospheric data sets;
- Incorporation of new corrections based on new / different observational data;
- Forcing over sea-ice covered regions;
- Wave fields;
- Runoff data sets;
- Diurnal cycling of wind and solar.

4. Mini Workshop and Discussions

With the above background and context, the primary goal of this mini workshop was to reignite both science and engineering efforts to advance the foundations of CORE-II. The agenda (see Appendix 2) was intentionally kept informal. The participants (see Appendix 1) were fully engaged in all the discussions that included re-visiting practically all aspects of the current CORE-II protocol. As planned, a major focus was the state of various reanalysis products and efforts as well as of various surface flux data sets and satellite products (e.g., ERA, JRA-55, ECMWF, HOAPS, etc.). Following extensive discussions, a major outcome of the mini workshop is consideration of the JRA-55 reanalysis product to provide the next generation of atmospheric forcing data sets for use in the future CORE frameworks. This exciting prospect for a new high resolution, near real-time forcing dataset for future COREs and potentially OMIP will be supported through a community evaluation effort by the workshop participants and other members of the community and OMDP over the course of this year, i.e., 2015. We thank our colleagues working with JRA-55 for their efforts and for their willingness to share their product at this level with the international ocean modeling community.

[2] Currently, the CORE-II atmospheric data sets are available only through 2009.

In the following, we present an informal summary of mini workshop discussions with some action items. Furthermore, not all the presentations are included in this summary as they are available from the links provided in Appendix 2.

5. Revisiting the CORE-II protocol and discussion topics

5.1 No feedbacks between the evolving ocean and sea-ice states and the atmospheric data sets
The use of a thermodynamically active atmospheric boundary layer model that responds to model sea surface temperatures (SST), e.g., CheapAML, has been considered and discussed. Such alternatives appear to need additional development work for use by the broader community.

5.2 Surface salinity restoring and freshwater flux normalization
The CORE-II protocol currently permits groups to use their choice of surface salinity restoring strategy that enables the best possible simulation for a given model. The impact of this strategy should be evaluated, for example, by re-running the last cycle of a simulation with no surface salinity restoring. If the (Atlantic) meridional overturning circulation collapses during the integration, the use of a surface salinity restoring can be deemed necessary for a particular model. This will likely not be the case for all models, so this analysis would highlight particular model differences (not which model is better) and could lead to the emergence of a common strategy.

ACTION: Explore running the CORE-II simulations without any surface salinity restoring.

ACTION: Based on the outcome of above action item, revisit surface salinity restoring and E-P+R budget details.

5.3 Spin up and cycling of forcing
The CORE-II protocol of repeated forcing cycles leads to a spin up after the start of each new cycle, in particular of the Southern Ocean winds, impacting Antarctic Circumpolar Current (ACC) diagnostics. The adjustment sensitivity increases as model resolution is refined. Over multiple cycles, this adjustment could lead to a cumulative impact on the quasi-equilibrium solution and be a controlling factor of model drift. Multiple repeats of the forcing cycle leads to an increase in heat content due to the warming trend in the interannual forcing (IAF) dataset.

Various strategies can reduce the initial shock at the start of each cycle, for example, blending the first year with the last to create a smoother transition. A synthetic spin up forcing cycle could also be generated from randomly selected years, before running a final cycle over the actual hindcast period. Another approach would be to set the cycle to start when global climate mode indices are neutral, to avoid switching between different states.

A spin up period of 100+ years forced by the normal-year forcing (NYF) could be an option, but the model will nonetheless have to adjust between differing states, including differences in water mass formation. Extending the CORE-II dataset to prior to 1948 would provide an alternative spin up option to a spin up forced with NYF. Finally, the jump in temporal resolution of the forcing dataset that occurs with the start of the satellite observing era could motivate restricting the CORE-II analysis to after 1979, rather than the current practice of evaluating the period usually after 1958. For example, the OCMIP community starts its analysis period in 1979.

Given the variety of approaches that could be adopted, rather than specifying the spin up/cycle strategy, the protocol could be left open for now for groups to explore new approaches and alternatives to cycling of forcing data to reduce spin-up time and to minimize adjustment times.

ACTION: Explore different spin up options

5.4 Improvement, maintenance, and upkeep of forcing datasets, including increased spatial and temporal resolution

Forcing datasets need to be maintained current. There is a need to determine what important characteristics / properties the forcing data sets should have, e.g., mean distributions, temporal evolutions, variability, trends, etc. The CORE-II forcing dataset resolution of T62 has run its course, with resolution becoming increasingly important for ocean model applications such as coastal processes, fronts, upwelling. Going forward, this goal can only be supported by reanalysis products, thoroughly assessed by the ocean modeling community with known biases and imbalances comprehensively documented.

OMDP could formally encourage a sustained commitment by reanalysis development efforts to maintain certain resolutions over time, in return contributing to the evaluation and provision of feedback on reanalysis products.

5.5 Use of relative vs. absolute winds in bulk formulae

The use of absolute winds is recommended, rather than relative winds. The use of absolute winds is needed both for small scales, not knowing how to set the damping effect correctly, and at large scales, since the wind/current coupling effect has already been accounted for by correcting the winds using QuickScat data that measure the real stress.

ACTION: Include guideline and explanation for use of absolute winds in CORE-II protocol (J. Le Sommer)

5.6 Solid run-off

Freshwater fluxes from icebergs impact the generation of polynyas and have a major impact on ocean biogeochemistry. A weak flux can be applied uniformly south of 60°S (plus a strong coastal flux) but this is an unrealistic representation of the distribution of iceberg fluxes that vary geographically and have melt rates that vary seasonally. Alternative approaches are to include an interactive iceberg model or some derived model product that reproduces iceberg distributions and melt rates. Estimates of iceberg melt in the Southern Ocean over the recent period are being developed, as are future scenarios, and should be evaluated by OMDP in collaboration with the Southern Ocean Panel. Efforts are also needed for Greenland.

ACTION:	Evaluate current iceberg-melt estimates and future scenarios in collaboration with the SOP (J. Le Sommer)
ACTION:	Specify Antarctic liquid and solid freshwater flux estimates (with relevant references) in CORE-II protocol for groups to apply (J. Le Sommer)

6. Experience with DRAKKAR forcing sets (DFS)

ERA40, ERA-Interim (ERA-i), and other products (e.g., satellite) have been combined to produce a data set of surface atmospheric variables to drive DRAKKAR global model configurations for the period 1958 to present. The development of the DFS from ERA products has been driven by the need for higher resolution wind fields, relative to CORE (Brodeau et al, 2009). The challenge to maintain up to date products for modeling purposes that include those related to oceanographic cruises.

DFS5.2 combines ERA40 (prior to 1979) and ERAi afterwards. The mean net heat flux (Q_{net})of DFS5.2 is above zero, indicating a warming imbalance. The rate of warming decreases after 1979 when the product is based on ERAi. The change in temporal frequency to daily climatology from 1979 onwards causes a jump in Q_{net}. The latest version, DFS5.2, based on ERAi at a resolution of 0.7^{o}, will be released as soon as a “discontinuity” issue at tropical latitudes, due to a bias resulting from the assimilation of tropical moorings in the reanalysis, is solved. A report on the production of DFS5.1 (i.e. DFS5.2 over 1979-2012) is available and a report on DFS5.2 (1958-2012) is in preparation (Dussin et al. 2014).

Plans for DFS in the future:

- DFS6 questionnaire will be undertaken.
- Thorough evaluation (climatology, trends, weather, continuity, extremes, major variability patterns such as NAO, PDO, SAM, etc.).
- Interannual and associated climatological seasonal forcing.
- De-trended forcing since long term trends are not reliable.
- An ensemble of interannual forcing sets (CORE, DFS, JRA, MERRA, CSFR, ERA-20C, ERAclim, ...).

DFS is an alternate forcing to CORE. Both need to be improved and adapted to address future CORE-II directions. Satellite and reanalysis products, maintained up to date, assessed and with errors well documented, are likely to lead to improved datasets that will best suit the community's resolution needs. Trends in SST that are not captured in air temperature and flux reanalyzes products need to be addressed. The current status implies that climate change studies cannot be undertaken without coupled models.

7. Challenges and opportunities for surface flux datasets

There are around 15-20 current flux datasets available from a wide range of sources: reanalysis, satellite, ship observations, blended / hybrid products (Josey et al. 2013). Closure of the global ocean heat budget is still a long way from being obtained with products, tending to be biased warm by 10-25 Wm^{-2} due to multiple sources of errors at the 2-5 Wm^{-2} level. A major limitation, particularly over the Southern Hemisphere and at high latitudes, of forcing functions developed from reanalyses, including higher resolution products, is the assimilation of sparse and geographically heterogeneous ship-based measurements. Satellites are able to determine SST and wind speed with full coverage reasonably well. However, near surface humidity (qa) and temperature (Ta) remain poorly known. These limitations impede key sea-air temperature and humidity gradients being determined, resulting in large uncertainties in satellite turbulent flux estimates.

The CORE-II forcing dataset from Large and Yeager (2009) is a hybrid product based largely on NCEP/NCAR reanalysis. The CORE-II wind field has been adjusted using QuikSCAT, 2000-04; surface humidity uses NOC1.1 as a 'reference'; and radiation is combined with ISCCP-FD radiation data (shortwave reduced by 5 % from 50°S to 30°N, linearly tapered to 0% at 60°S and 40°N; there is no longwave adjustment). The resulting adjusted net heat flux exhibits global heat balance closure, while the base unadjusted fields have a 30 Wm^{-2} global imbalance. The QuikScat/NCEP ratio approach remains to be demonstrated to lead to more accurate winds compared with mooring winds. There are potential non-stationarity issues arising from the choice of the reference period.

Mooring measurements provide a key resource for reanalysis evaluation and, if used well, correction. There is potential for progress with the maturing air-sea flux reference site array (Jin et al. 2015). Such data may be used to identify biases in surface meteorological and radiative flux from reanalyses and other products. Correction functions can then potentially be developed at each mooring site and for surrounding regions that share similar air-sea interaction properties. Shortcomings in this approach include scaling issues arising from correction of grid-cell scale reanalysis output with mooring measurements and from incomplete coverage, with mooring data largely restricted to Tropics. It should however be possible to develop a more accurate flux dataset for the Tropics than currently available. Jin et al. (2015) combine satellite qa and Ta with OAFlux, resulting in better agreement with buoy measurements. Ship-based observations from hydrographic sections can also be used to balance flux products.

As a cautionary note, surface wind divergence/convergence anomalies and related humidity anomalies have been identified in ERA-Interim from the assimilation of TAO mooring data (Josey et al. 2014). Derived products (TropFlux, Drakkar Forcing Set) exhibit a strong TAO mooring related pattern in 2m specific humidity field and caution is needed for Tropical Pacific ocean heat uptake studies. NCEP (and in turn Large and Yeager (2009)) and OAFlux do not exhibit this problem.

Highlighting that mooring data are an important resource for the development of ocean model forcing functions is a major contribution that OMDP can make to support efforts for the development of sustained mooring networks, such as TPOS2020 in the Tropical Pacific.

In conclusion, reanalysis products are needed to produce a near real time CORE-II forcing product. Outstanding problems remain with how to improve both radiative and turbulent heat fluxes.

8. JRA-55 based surface atmospheric data set for driving ocean – sea-ice models

A new, near real time, surface atmospheric data set based on JRA-55 (Kobayashi et al. 2015) has been developed for use in driving ocean – sea-ice models (Tsujino 2015). The spatial resolution is 55 km, the temporal coverage is from 01 January 1958 to 06 February 2015 with a 3-hourly temporal resolution. All elements except for sea level pressure are modified from the original fields by applying scaling or offsetting, i.e., correction, factors so that their long-term means match those of reference fields derived from observations (QuikSCAT wind speed) or from the CORE-II data set (Large and Yeager 2009). The adjustment factors are climatological, that is, they do not vary interannually. After a first adjustment procedure, heat and freshwater fluxes are computed using COBESST (Ishii et al. 2005), Large and Yeager (2009) formula for albedo, and Large and Yeager (2004) bulk formula method. Following this evaluation, constant factors to downward fluxes are applied, i.e., short and long wave radiation and precipitation, to close the global budget. CORE-II, the original JRA-55 data, and the adjusted JRA-55 data global oceanic surface heat flux and fresh water budgets are evaluated. A detailed description of the data set are provided in Tsujino (2015).

The following aspects need to be thoroughly evaluated to assess the new product for use in forcing CORE-II simulations:

- Examining features of interannual variability and trends.
    - There is less variability in the JRA-55 time series of diagnosed heat fluxes relative to CORE-II. Publications that analyzed JRA-55 as well as programs used to compute fluxes should be verified.
    - Effects of the Pinatubo eruption in 1991 seems to be missing from radiative fluxes of JRA- 55.

    - Latent heat loss from the ocean increases in the period after 2000, in comparison with the preceding periods. Is this due to the inclusion of scatterometer winds in JRA-55?
- Comparison of diagnosed fluxes with those from in-situ or buoy observations.
- Creation of normal year fields.
- Creation of run-off fields. The Tsujino Group has a plan to provide run-off data based on a global river model. How to treat run-off from Greenland and Antarctica, which may not be obtained by the river model, has not been decided yet. Taking them out from the CORE-II run-off data set will be the first choice.
- Consideration of possible use of JRA-55C (Kobayashi et al. 2014), the JRA-55 using conventional data only, for the adjustment of atmospheric fields in the pre-satellite era.
- Empirical formulae of air properties used in the second adjustment phase for closing the budget should be reexamined. The current formulae are taken from the MRI model and are used for the second adjustment phase because the creation of this data set was originally intended for internal use at MRI. They likely should be revised by making use of this evaluation opportunity. Although it is considered that the effects of those changes will be minor, more widely used formulae will be used in the next version.

ACTION: *This exciting prospect for a new high resolution, near real time forcing dataset for CORE-II and potentially OMIP will be supported through a community evaluation effort of the above issues by the workshop participants over the course of this year, i.e., 2015.*

9. Overview of the use of satellite products for forcing ocean general circulation models

Satellite products have generally high potential to be used for building new forcing functions for numerical experimentation with ocean general circulation models. Moreover, satellite products can be extensively used for validation of forcing functions based upon NWP products. For these two prospects the following issues have been considered during the discussion:

9.1 Wind products

Currently satellite wind products from altimetry cover more than 24 years with effective resolution of about 1/4 degree in space and few days in time, however these data should be taken with caution since they have a little accuracy in determining wind directions, and therefore vector winds (actually the vectors should be computed a posteriori using dynamical algorithms, mostly based on consideration of wave fields also available from these products). Consequently, these data are useful for computation of heat fluxes, but less useful for driving

OGCMs. Scatterometer winds are much more accurate however they are available for much shorter periods of about several years. Their direct use to drive ocean models still poses problems that our modeling community has yet to solve (i.e., the strong signature of ocean currents in the curl pattern). The time sampling of satellite winds still does not match what NWP winds are offering (3-hourly).

9.2 Surface humidity products

These are available from as many as 6-7 groups operating with the output from SSM/I (HOAPS, J-OFURO, NASA-GISS (GISST), IFREMER, some others). There is no clear superior product among them, because they all use retrieval algorithms based on hybrids of statistical and physical methodologies. Bentamy (2003), Bouras (2006), and Anderson et al. (2013) provided some validation, however a comprehensive validation effort is still needed. Time coverage starts from early 1990's, space resolution of these data is about 0.5 to 1 degree with time sampling being daily at best.

9.3 Air temperature

Currently, state of the art of satellite retrievals is still poor to produce accurate air temperature fields, while it is formally included in all products and have formally the same resolution as humidity. Engineers say that more channels are needed to improve the accuracy, however, the progress observed during the last decades when this number increased in the range 20-70 channels, was not so impressive. It is hard to recommend satellite based air temperature to be used for ocean model forcing for now.

9.4 Radiances and clouds

Both SW and LW radiation are quite accurate when provided by ISCCP starting from 1984 and these are widely used in model simulations. Now MODIS with its 67 channels gives much more accurate SW radiances, and most importantly also with a better space resolution. MODIS has been extensively validated against buoys and is definitely waiting to be used by ocean modellers. The only problem is that it is limited in time to the recent 7-8 years. Radiances recently identified long historical periods of dimming and brightening which are most pronounced over oceans and it is a challenge to use ocean models to quantify potential responses of the ocean to these signals which (as some people believe) may have similar time scales to AMV. Unless forcing formulations do not include direct computation of SW and LW, clouds are of a lesser importance. However, if in the future forcing functions will be based on direct computations of SW and LW radiation, cloud information from ISCCP products as well as from more recent NASA crafts can be used in conjunction with in-situ measurements, these data are anyway much better than cloud cover from reanalyses.

9.5 Precipitation

Microwave products (GPCP) with 1-degree resolution cover the period 1979+ (monthly) and 1997+ (daily). These are major inputs into model forcing functions. Discussion did not clearly show the importance of daily and higher resolution fresh water forcing and experimentally based evidence is still lacking. HOAPS and all other products are quite similar in this respect. Shortcomings of microwave precipitation products are well known (excessive precipitation along coastlines and in convective clouds, also too much rain in the earlier stages of mid-latitude storm development yields more than in nature rain in the western ocean parts). Again, whether this is a problem for models is an open question. Radar precipitation available from TRMM is much more accurate than from microwave. Over ocean it is really an ideal product, but it is limited in space by +/- 42-43° in latitude and available in time only since the year 2000. TRMM-based products (combined products using GEO-IR and other microwave sensors) have a resolution of 1/4° and 3 hours (again, no evidence that we [modelers] need this). TRMM has also its derivatives, like CMORPH, PERSIAN and others which differ from each other by application of retrieval procedures and can be also used. GPM (global follow up of TRMM with better radars) was launched on 23 April 2014 and will soon provide first year-round series of precipitation (and other humidity related variables) with extremely high resolution and very high accuracy. General conclusion is that satellite precipitation products are better than those from reanalyses in terms of both temporal homogeneity and accuracy. However the biases of NWP should be precisely quantified. Some initial comparisons were done by Michael Bosilovich (2008) and a more comprehensive effort is to come from Sommer et al. (2015).

9.6 Turbulent fluxes from satellites

While no more directly used to drive OGCMs, these products have quite an importance for modelling since they allow for evaluating NWP fields as well as the fluxes computed through the bulk algorithms inside the models. 6-7 SSM/I based products (see above, humidity) provide reasonably realistic latent flux, while local spread between different products may amount to 40-60 $W.m^{-2}$ (Bouras 2006; Rossow 2011). Sensible fluxes are quite inaccurate because of poor quality of computation of air-temperature (no physical ground for its optimal retrieval). In this respect SEAFLUX products (Clayson et al., 2015, background paper in revision) are advantageous. They provide 3-hourly 1/4 degree resolution turbulent fluxes and flux-related variables for 2000-2007 (present release) and will be updated next year to cover at least the decade.

9.7 Conclusion

There are great expectations from our ocean modeling community for satellite precipitation and radiation products as they can be directly used to drive ocean hindcast simulations. It is very important that these fluxes are retrieved in a consistent way and precisely evaluated and that uncertainties are provided. There is a need to keep the availability of the product updates as close as possible to the current time, with one year lag being acceptable. There is a need for regular reprocessing as retrieval algorithm and technologies evolve and for a continuous assessment of these fluxes with regard to direct observations and with NWP products. Their consistency with NWP turbulent fluxes in terms of global budget is an issue that must be dealt with in the construction of the full forcing function of OGCMs. Spatial resolution should be high, but not at the expense of the daily sampling for radiation.

Turbulent fluxes from satellite are presently of interest mainly for evaluation of similar products from other sources (including when produced by ocean hindcast/reanalysis simulations). There is a need for such a consolidated effort and the ESA Ocean Heat Flux initiative will likely contribute to this.

Satellite winds are needed largely to verify the wind products of NWP reanalyses, especially regarding magnitude, variability, trends and large scale patterns. NWP winds are still preferred especially because of the high time sampling they provide (3 hourly at present) which is required by most state of the art ocean mixed layer parameterizations.

10. Update - March 2015

The newly developed JRA55 forcing product is a major opportunity for the international ocean modeling community for the continuation of the CORE-II framework and for the OMIP effort that OMDP is leading within CMIP6. OMDP and the workshop participants have offered full support in undertaking any tests and analysis that can help JMA finalize the release of the product. An internal Google Site and Group have been set up to facilitate this collaborative effort (contact anna.pirani@clivar.org for more details).

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Appendix 1: Participants

Left to Right:
C. Boening (GEOMAR, Germany)
A. Biastoch (GEOMAR, Germany)
S. Josey (NOC, UK)
H. Tsujino (MRI JMA, Japan)
A. Pirani (CLIVAR)
M. Valdiviseo (U. Reading, UK)
M. Balmaseda (ECMWF)
G. Nurser (NOC, UK)
W. Large (NCAR, USA)
A. M. Treguier (CNRS-LPO, France)
S. Griffies (GFDL, USA)
A. Andersson (DWD, Germany)
J. Le Sommer (LGGE, France)
B. Barnier (LGGE, France)
P. Durack (LLNL, USA)
G. Danabasoglu (NCAR, USA)
G. Madec (LOCEAN, France; NOC, UK)
Also:
S. Gulev (MSK, Russia)
K. Haines (U. Reading, UK)
F. Lemarie (INRIA)

Appendix 2: Agenda

Thursday:

G. Danabasoglu (NCAR): Background on CORE-II framework and OMDP efforts; Requirements (from community and OMDP) on forcing data sets; OMIP; End products
W. Large (NCAR): Data sets used in COREs (lessons learned and outstanding issues)
B. Barnier (LEGI MEOM): Update on data sets used in DRAKKAR (lessons learned and outstanding issues)
S. Josey (NOCS): Surface flux datasets - An overview of problems and opportunties
A. Andresson (DWD): Climate data records from CM SAF - Error budget estimation of HOAPS evaporation
M. Balmaseda (ECMWF): Reanalysis products vs. operational products; Reanalysis plans at ECMWF
F. Lemarie (INRIA): The combined effects of SST and oceanic currents on eddy-scale air-sea interactions: a modeling study
H. Tsujino (MRI JMA): On the use of JRA55 for driving ocean-sea ice models - Biases, correction (adjustment), results from preliminary model run

Friday:

Guided discussions; Path forward.
16:00 Adjourn