

Pilot Ocean Model Intercomparison Protocol

Working Group on Ocean Model Development

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Draft for the pilot phase

1 Introduction

One aim of the Working Group on Ocean Model Development (WGOMD) is to stimulate the development of ocean models for research in climate. During its annual meeting in Hamburg (may 2002) the group has decided to examine the possibility and usefulness of an Ocean Model Intercomparison (OMIP), by launching a pilot phase (P-OMIP). The results of this pilot phase will be examined at the next annual meeting (Brest, April 2003).

An OMIP will hopefully address many goals:

1. Assess the general performance of ocean and ice model components used in coupled models to study climate and tracer uptake;
2. Assess the quality of the forcing fields: identify limitations and critical issues linked with air/sea fluxes datasets;
3. improve understanding of the sensitivity of models to parameterizations and forcing aspects.

The general idea is to test together the ice and ocean components of the climate system, subject to a forcing as well defined and as similar as possible for the different participating models. Ocean-ice models must be truly global, including the Arctic ocean. Results will be compared after an experiment of 100 years, forced by a repeated annual cycle.

A first OMIP, involving only two ocean models, has been conducted at the Max Planck institute (MPI) in Germany. Forcing fields have been calculated for this purpose, based on the ECMWF reanalysis ERA-15 (Röske, 2001). At the Hamburg meeting, and after preliminary tests, the WGOMD has decided to use a modified version of those forcing fields for the P-OMIP. The new forcing fields are referred to as "the second version of the OMIP

forcing” on the web site, which is temporarily:

<http://136.172.119.17/Depts/Klima/natcli/omip.html>. This web site will be linked to the new MPI site www.mpimet.mpg.de. An atlas of figures is available on this web site; a precise description of the forcing field will appear in an article to be submitted to *Ocean Modelling* (Roeske et al, 2002).

A protocol for running the different models with this forcing has been agreed upon: it is the object of the present document. This protocol is valid for models with a fully prognostic ice component. Another protocol could be designed for other models if required.

When it comes to the details of the forcing fields, many issues arise only when ocean modellers start actually using the data. This is happening with the P-OMIP. As a consequence, this protocol, the data files and flux calculation algorithms will evolve during the next months. For up to date informations, modellers should consult the web site indicated above.

2 Model initialization and set-up

The models are initialized with the Polar Science Center Hydrographic climatology (PHC, Steele et al, 2001). The PHC climatology is based on the Levitus (1998) atlas of temperature and salinity but is improved in the Arctic ocean. It is available at psc.apl.washington.edu/Climatology.html Note that models need to be initialized with potential temperature (and not in-situ temperature).

The duration proposed for the experiments is a compromise. Ocean models take hundred of years to equilibrate under a given atmospheric forcing. However, running the models to equilibrium is very costly and this would prevent the newest climate models (with spatial resolution of order one degree or more) to participate in the OMIP. We propose a duration of 100 years, long enough to see a substantial climate drift. In the case of higher resolution models that cannot be integrated for 100 years, a common (shorter) duration will have to be agreed upon.

The proposition is to store annual averages of each individual year, and monthly means for the last 20 years. The average of the last ten years will be used for the intercomparison analysis, and should be made available to the other groups participating in the P-OMIP. In the case of eddy-permitting models, more frequent output is required (three days averages).

Fields to be stored include the model prognostic variables as well as all the components of the forcing (the fluxes will differ from model to model because of the retroaction term in the heat fluxes and the relaxation to

surface salinity, see below).

3 Transient tracers

Modelling transient tracers offers additional insight into the model dynamics and is extremely useful for validation purposes. Therefore, participating groups are encouraged to add tracers to their model if possible.

Because of the limited duration of the experiments, only CFCs allow a meaningful comparison with data. CFCs can be introduced starting in year 30 of the experiment and modelled for 70 years. A protocol has been designed for the phase 2 of OCMIP (Ocean Carbon-cycle Model Intercomparison Project) and is available on the site www.ipsl.jussieu.fr/OCMIP.

4 OMIP forcing files

The second version of the OMIP forcing consists in a series of Netcdf files (table 1), available on the mpi web site indicated above:

<http://136.172.119.17/Depts/Klima/natcli/omip.html>.

The data comes from the ECMWF reanalysis ERA-15, with a correction to achieve heat and freshwater balance over the globe (see the OMIP forcing report by F. Röske, available on the same web site). Each file contains 365 daily values for an average climatological year.

Besides the forcing data, bulk formulae are provided to recalculate evaporation, sensible and latent heat fluxes, based on Kara et al. (2002), in the form of a FORTRAN program (kara.f90).

Bulk formulae are provided for the open ocean as well as the ice surface (ice-atmosphere fluxes). Participants are strongly encouraged to use those formulae. In the case it is too difficult to change one's model, fluxes may be recalculated using the provided forcing fields and one's favorite bulk formulae.

5 Interpolations and masks

Fluxes of heat, freshwater and momentum differ greatly between ocean and land surfaces. When using data from an atmospheric model, care must be taken to ensure that land values are not used to force the ocean. Various land-sea masks are provided to help with that.

Name of netcdf file	Name of variable
10m_u_wind_component.nc	U_{10}
10m_v_wind_component.nc	V_{10}
2m_dewpoint_temperature.nc	tdew
2m_temperature.nc	T_a
east_west_stress.nc	taux
evaporation.nc	E
ice_concentration_obs.nc	icec
land_sea_mask.nc	m_2
land_sea_mask_ECMWF.nc	m_0
land_sea_mask_larger_continents.nc	m_1
mean_sea_level_pressure.nc	press
net_solar_radiation.nc	Qswp
north_south_stress.nc	tauy
runoff.nc	R
scalar_wind.nc	wspd
sea_surface_temperature.nc	T_o
std_dev_scalar_wind.nc	
thermal_radiation.nc	Qlw
total_cloud_cover.nc	
total_precipitation.nc	P
total_solar_radiation.nc	Qsw

Table 1: List of files provided on the German OMIP web site and corresponding notations for the variables (in the text and/or in the program kara.f90).

Ocean basin	Code
North Atlantic	10
South Atlantic	11
North Pacific	20
South Pacific	21
North Indian	30
South Indian	31
Arctic Ocean	12
Mediterranean Sea	13
Black Sea	14
Baltic Sea	15
Hudson Bay	16
Caspian Sea	40
Aral Sea	41

Table 2: List of the codes for ocean basins in the land-sea mask file

- `land_sea_mask.ECMWF.nc`: The original land-sea mask of the ECMWF model. The mask is $m_0(i, j) = 0$ over the ocean, $m_0(i, j) = 1$ over land, and intermediate values for coastal grid boxes.
- `land_sea_mask_larger_continents.nc`: A mask derived from the above one in the following way. First, all coastal and land points where $m_0(i, j) > 0$ are set to the new land value (zero): $m_1(i, j) = 0$. Then, the values over the ocean are set to a non-zero integer corresponding to the codes for ocean basins (Table 2). This mask ensures that no land information of the original ECMWF model spills onto the ocean.
- `land_sea_mask.nc`: mask calculated in the same way as m_1 , but coastal points may be either ocean or land. $m_2(i, j) = 0$ (land) if $m_0(i, j) > 0.5$ and $m_2(i, j) = n$ (ocean basin n) if $m_0(i, j) \leq 0.5$

Note that the transition from coast to land in the ECMWF mask (values of $m_0(i, j)$ between zero and 1) is spread over more grid cells when the area of the cells is smaller. The cell areas get smaller going polewards due to the convergence of the meridians.

6 Momentum forcing

The components of the wind stress (τ_{ux} and τ_{uy} , in $\text{N}\cdot\text{m}^{-2}$) and the components of the wind velocity at 10 m (U_{10} , V_{10}) are provided. The latter may be used in bulk formulae (stress and thermodynamic forcing) for participants who cannot use the OMIP formulae (kara.f90).

The wind stress in the files has been calculated with the observed ice cover. This creates a minor problem: where the models predict ice while none was present in the observations, or where the models melt ice that was in the observations, the wind stress will not be adequate (e.g., calculated over the wrong surface). OMIP participants may ignore this discrepancy and apply the provided stress everywhere in the model (on the ocean as well as on the ice surface); or else they may use the 10 m winds to recalculate the stress.

The scalar 10 m wind is also provided because it is used in the bulk formulae for the heat and freshwater fluxes.

7 Freshwater fluxes

The total freshwater flux to be applied in the model is $E - P - R$ (Evaporation - Precipitation - Runoff), over the open ocean as well as over the ice surface (or under the ice surface in the case of the runoff). The ice-ocean freshwater flux, resulting from ice formation or melting, will be calculated in the usual way of each model's ice component (there is no specific protocol for this part).

7.1 River runoff

The runoff R is intended to be distributed over all the coastal areas. It does not have a seasonal cycle, but has been adjusted daily to achieve a global water balance. The runoffs are provided on the atmospheric grid. They need to be interpolated onto the model grid, and then moved around so that no runoff data falls outside the ocean on the model's grid. An example of a program to bring the runoff back to the coast is available on the web site ("helpful codes", `correct_runoff.F`)

Relative to the runoff of the first version of the OMIP forcing, changes have been made to obtain more realistic runoffs in the polar regions (file "runoff.nc").

1. The procedure of correcting for negative runoffs - setting them to zero and reducing the positive ones accordingly - was modified such that

positive drainage runoffs in the polar regions were excluded from being reduced. The runoff around Antarctica is now 0.06 Sv.

2. The difference between the prescribed annual runoffs of the 35 rivers and the model estimates plus the runoff of the closed basins is now distributed among the drainage runoff of the whole globe instead of being put only into the Arctic Ocean. The runoff in this Ocean is now 0.1 Sv.

7.2 Evaporation and precipitations

The evaporation E (mm/month) is calculated using the model SST and a bulk formula provided in the routine `kara.f90`. Precipitation P is used as provided.

7.3 Relaxation to surface salinity

A difficult question is whether to keep a relaxation to observed surface salinity, on top of the $E - P - R$ flux. In the German OMIP, a relaxation flux Er was added for open water only:

$$Er = -(1 - ic) \frac{(S - S_l)}{S} * r$$

where ic is the model ice concentration, S is the model surface salinity, $S_l(x, y)$ is the annual mean surface salinity from Levitus, and the relaxation constant is $r = 0.5$ m/day. Note that in an OMIP it is important to specify this relaxation as a flux and not as a body force with given decay time, because in the latter case the flux depends on the model's first layer thickness.

Such a relaxation of surface salinity is not physical. It has the further disadvantage that it works against the runoff near the river mouths (climatological salinity tends to be too high at those locations). However, preliminary tests suggest that the relaxation is necessary due to errors in the freshwater fluxes, or incompatibility between the models and the freshwater fluxes. In the preliminary phase of the new OMIP, we propose to keep the same relaxation as in the German OMIP, but replacing the annual mean Levitus (1998) climatology of salinity by the monthly PHC climatology. Participants are invited, if possible, to make an additional model run without relaxation. The relaxation should be made in open ocean only (ice fraction of a grid cell lower than about 1%). Relaxation under ice is not justified because there are no salinity data under ice.

Finally, note that in the case of a model with a free surface it is necessary to do something to control the sea surface height (or total ocean volume). The provided forcing fluxes are balanced on the atmospheric grid (Röske, 2001) but the balance will not be verified in the models because of the relaxation term (and also the fact that evaporation is recalculated). One possibility is to calculate the trend in volume each year and subtract a uniform trend from the freshwater forcing the next year.

8 Heat fluxes

The total heat flux (Q in Wm^{-2}) has four components, net longwave, net shortwave, latent and sensible:

$$Q = Q_{lw} + Q_{swp} + Q_{la} + Q_{se}.$$

Each of those must be calculated over ice (ice-atmosphere fluxes) and over the ocean (ocean-atmosphere flux). The ice-ocean heat flux involving ice melting and ice formation will be calculated in the usual way of each model's ice component (there is no specific protocol for this part).

8.1 Net longwave radiation flux Q_{lw}

A net longwave flux is provided in the forcing files, but for the OMIP we propose to recalculate it using the model's surface temperature. For both the ocean and ice surfaces, $Q_{lw_{mod}}$ will be estimated as a balance between the ERA15 downward long wave and the re-emitted long wave, using the ocean/ice surface temperature T_{mod} for the re-emitted part:

$$Q_{lw_{mod}} = \left(Q_{lw} + e_m \sigma (T_o^4 - T_{mod}^4) \right)$$

Q_{lw} and the climatological T_o are provided in the OMIP netcdf files (see table 1), $e_m = 0.97$ is the emissivity of water, and $\sigma = 5.67 \cdot 10^{-8} \text{Wm}^{-2}\text{K}^{-4}$ is the Stefan-Boltzmann constant.

8.2 Net short wave radiation flux Q_{swp}

The net shortwave solar radiation (Q_{swp}) is part of the ERA-15 fields. For use in ocean models the total shortwave Q_{sw} has been derived as the sum of Q_{swp} (radiation that penetrates in the ocean/ice) and a part that is reflected back:

$$Q_{sw} = Q_{swp}/(1 - a),$$

where a is the albedo in ERA-15.

In the models the net radiation $Q_{sw_{mod}}$ should be calculated as follows:

$$Q_{sw_{mod}} = (1 - a_m)Q_{sw}.$$

with a_m the albedo of the model (varying according whether the grid cell is ocean, ice, snow...)

In the case of the ocean, a portion of the net solar flux will be assumed to penetrate at depth. A simple scheme is proposed according to Paulson and Simpson (1977), using water type IA (as in the German OMIP). In that case there are two depths of extinction, 62% of the flux having an extinction depth of 0.60 m and the rest having an extinction depth of 20 m. However, ocean models using a more complex scheme for the penetration of solar radiation may keep it for the OMIP.

8.3 The turbulent heat fluxes Q_{la} (latent) and Q_{le} (sensible)

The bulk formulae to calculate Q_{la} and Q_{le} are provided in the Fortran routine `kara.f90` on the German OMIP web site. They are intended to be applied in the following way in at each model grid cell

1. First, test if the grid cell has ice or not. In the routine `kara.f90` this test is performed by comparing the surface temperature to the freezing point rather than using ice concentration because the ice concentration from satellites is not exactly zero in the open ocean. In the models, we propose to replace this test by a test on the ice concentration.
2. Where the model ice concentration is non zero the flux is the sum of an ocean-atmosphere flux for the ice free part of the cell plus an ice-atmosphere flux for the ice covered part (`clw*qdifw` for Q_{la}).
3. Where the model ice concentration is zero, there is only an ocean-atmosphere flux (`xlatent_heat_vap*rhoa*wspd*cl*qdif` in the case of Q_{la}).

The only modifications to be made by the user from `kara.f90` is the test on ice concentration, and the use of the model sea/ice surface temperature and ice concentration instead of the climatological ones.

In order to balance the initial set of fluxes, Q_{la} is multiplied by a constant (`close.budgets=1.1925`) estimated in order to have a global heat balance in the original forcing fields. At some stage in the definition of the OMIP

forcing, another correction factor has been proposed to improve the meridional heat transports on the Southern Hemisphere: `corr_factor = 2` which should be applied only in the ice region defined by ($SST \leq T_{\text{frez}}$), and there only in the ice-free part and only on the Southern Hemisphere (see program `kara.f90`).

The use of those constants to close the budgets is now under discussion within the Working Group.

REFERENCES

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