Report of the DRAKKAR meeting
Grenoble, January 2011

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This short report summarizes the discussions and modelling issues (the talks are available on the Drakkar web site). These notes have been put together by Anne Marie Treguier.

1. Model results and discussions

1.1 Session on ocean variability (chairman Thierry Penduff)

The Ocean Variability section reported scientific results obtained from Drakkar model simulations. Beyond several interesting results that may be found in individual talks, this session highlighted general modelling issues:

1 - Interannually-forced simulations are initialized from a climatology and their solution are the sum of (hence may sometimes be decomposed into) an adjustment signal A(t) covering a wide range of timescales + a mean solution M over some averaging period + an atmospherically-forced variability F(t) + an intrinsic variability I(t).

> a) In some regions, short-term O(1 month) adjustment processes create significant biases in water masses (i.e. convection within the rim currents of the North Atlantic subpolar gyre, Myers) that persist throughout the integration. This highlights the importance of initial oceanic/sea-ice states (and potentially questions the relevance of resting initial states), even for long-term integrations.
> b) Long-term adjustment signals, and persisting drifts, may be isolated from seasonally-forced control runs and subtracted from interannually-forced runs, at least in the relatively linear intertropical band (Böning). Both short-term adjustments and long-term drifts reveal model weaknesses and may be studied specifically for model improvement.
> c) The intrinsic component of the simulated variability ranges from weekly/monthly to interannual/decadal timescales, and may be strong. A significant (sometimes dominant) part of the variance of local variables (SLA variability) and integrated quantities (AMOC) is due to chaotic ocean variability at high- and low-frequency (Hirschi, Penduff) hence raising the issue of Signal/Noise ratio for climate variability studies.

2 - All presentations confirmed the strong complementarity between model simulations, in-situ observations (Desbruyères, Lu, Hirshi) and satellite data (Penduff, Askenov, Myers) for model assessment/improvement, and observations-based dynamical studies. Presentations also highlighted the need for improved atmospheric forcing especially in polar regions.

3 - Drakkar models and AGRIF setups are being implemented at increasing resolution.

New modelling questions emerge at high resolution (water and ice transport variability across straits, more intrinsic variability, etc) but other issues seem to persist (too deep wintertime mixed layers, forcing issues). ORCA025 simulations will complement future ORCA12 simulations to keep track of these resolution impacts on A(t), M, F(t) and I(t), and help forcing improvements.

1.2 Sensitivities to forcing and parameterizations (chairman A. Biastoch)

Erik Behrens (IFM-GEOMAR) reported on Greenland hosing experiments, in particular the effect of horizontal resolution. One important prerequisite, potentially interesting for most other configurations too, is the minimization of the SSS damping. An analysis of the individual components of the freshwater fluxes and a series of sensitivity experiments in ORCA05 and ORCA025 led to the strategy of a moderate rain reduction. Even with a rain reduction of just 10% north of 55°N, an ORCA05 configuration with weak restoring (365 days + flux limitation $\Delta S \leq 0.5$) led to a stable MOC, about 8 Sv stronger than the reference case with a declining MOC. Erik demonstrated the impact of eddies on the distribution of the freshwater in the subpolar North Atlantic and presented first results with a 1/20° subpolar AGRIF nest (VIKING20).

Joke Lübbecke (IFM-GEOMAR) investigated the local vs. remote forcing of Benguela Ninos. She demonstrated that Benguela Ninos are in general remotely forced from the equatorial Atlantic via Kelvin wave propagation. While overall the simulated and observed SST time series from the Benguela area are in good agreement, all analyzed model runs of different resolution fail to simulate the observed amplitude of the 1995 Benguela Nino. By comparing different simulations it was hypothesized that the 1995 event was more locally forced. The poor simulation was attributed to a deficit in the CORE forcing in capturing a local wind event in that particular year and region.

Lavinia Patara (IFM-GEOMAR) outlined plans for a simulation to determine of the Southern Ocean's response to climate variability and change with explicitly simulated eddies. The first step is to set up a series of ORCA05 runs with weak SSS damping but minimal drift in the ACC. An analysis of the existing model runs underlined the loss of high-latitude dense waters, a reduced tilt of across-ACC isopycnals, and reduction of AABW formation. Plans with a deep restoring mask south of ACC were presented. The simulation strategy will be coordinated and based on the experience of Jan Zika and Julien Le Sommer with PERIANT.

Jan Zika (LEGI) presented analyses on the acceleration of the ACC using existing runs with PERIANT. The combination of a northward Ekman transport and a southward geostrophic transport at depth led to a tilt of the isopycnals and a corresponding impact on the ACC. In contrast, a flattening of the isopycnals was obtained by diabatic processes, eddy fluxes and a meandering of the ACC itself. In total, the ACC transport linearly increases due to increase in wind stress, but accelerates by wind shift.

Raphael Dussin (LEGI) presented the sensitivity of ORCA025 to the vertical grid resolution, salinity restoring, and forcing. A change from 46 to 75 levels reduced temperature biases in tropical/upwelling regions, slightly improved overflow and subpolar gyre salinity, but degraded the EUC. An evolution of the standard SSS restoring was tested that implemented three changes: (a) the coastal area remain free of restoring, (b) the model SSS is spatially smoothed (100 shapiro filters) before it is used in the calculation of the restoring term, (c) the restoring term is bounded to a maximum absolute value of 4 mm/day. Another experiment tested the replacement of the SSS restoring by a correction of the E-P forcing, the correction (a monthly mean climatology) being estimated by diagnosing the freshwater flux induced by the SSS restoring in an experiment carried out with a "strong" (i.e. G70 like) restoring. Both sets of experiments show ways of potential improvements to the standard SSS restoring, but required additional tuning.

Anne-Marie Treguier (LPO, Brest) reported on the insensitivity of ORCA025 to parameterization of overflows. The 1/12° North Atlantic model does not behave much better downstream of Denmark Strait (the NATL12 solution is very different from Hycom 1/12°). Why the different BBL parameterizations seem to work poorly in NEMO is unclear. A 1/3° North Atlantic developed by B. Ferron using OPA8.2 worked perhaps better, but attempts to reproduce this solution using Nemo3.2 have been unsuccessful so far.

The general discussion emphasized the needs for more adequate initial conditions, for a range of atmospheric forcing sets and for organized experiments (e.g. ORCA12) just differing by the forcing. It was noted that the resolution of the forcing has to keep up with the model resolution, which is especially important for upwelling areas. On the other hand, it was questioned if the model would be forced to produce eddies by a high-resolution forcing. In the mid-term range (4-year project) the generation of a 70-year reanalysis ERA-70 was mentioned. The needs to investigate model resisting (also to resolution) flaws (e.g. overflows, mixed layer, missing feedbacks) was also emphasized.

1.3 Data assimilation and reanalysis (chairman Keith Haines)

Keith Haines (Reading University) presented the results of an ORCA025 reanalysis assimilating EN3 hydrographic data. The Arctic circulation was analysed in a DFS3 forced run equivalent to G70. Assimilation improves the circulation in the Arctic as seen from the strength and shape of the Beaufort gyre and from the strength of the Siberian shelf edge current. The Arctic Ocean heat budget becomes more balanced after about 10 year of data assimilation. G70 has an sustained 8TW heat gain (more strait import than surface loss) while the assimilation run has only a 2TW imbalance with more surface heat loss than strait gain, while the assimilation increments have reduced to ~4TW (and will continue to depend on observation coverage).
A new experiment updates the observational dataset (especially in the Arctic) and uses ERA-Interim forcing. Assimilation increments are being interpreted to try to understand the process errors present in the model, particularly the surface heat and freshwater forcing and the vertical mixing controlling the mixed layer.

Laurent Parent (Mercator) presented the New GLORYS2 reanalysis at ¼ degree 1992-2009, focusing mainly on improvement in water mass distributions and mixed layer depths. The many improvements over GLORYS1 include the 3.1 NEMO and 75 levels, 3 hourly ERAinterim atmospheric forcing and the use of a bias correction scheme. Looking at SLA innovations in 2004 indicates where bias corrections are most active. These areas include southern ocean and upwelling regions off continents. T and S misfits are better after bias correction throughout thermocline. There is a better MOC in particular at the equator over GLORYS1. Improvements are noticed in ice cover (particularly in Antarctic), as well as in ice advection which shows greater (more realistic) speeds in the Arctic.

David Storkey (UK Met Office) gave a presentation on diagnosing short term (e.g. induced by fast physics) model biases from 2007 hindcasts with ORCA025 50levels and FOAM assimilation scheme. The mean assimilation increments are compared with the mean biases of the model assessed as free run – assimilation run properties, and similarities noted. North Atlantic and North Pacific looked at. Errors near the surface suggest vertical mixing errors. Met Office will start to run coupled models and will use similar approaches to diagnose coupled model errors.

1.4 Air-sea fluxes and coupled simulations (chairman S. Masson)

1 - Forcing the ocean
The issue of the calculation of the wind stress was raised again (it was discussed last year). Taking into account or not the ocean currents in the calculation of the wind stress has a huge impact on the surface eddy kinetic energy, and on the equatorial upwelling and SST. Regarding the equatorial currents (EUC) there should be a systematic comparison with TAO moorings to see which solution is closer to observations.

2- Coupled ocean-atmosphere simulations
The UK MetO and NOCS jointly develop a coupled global model based on ORCA025 75 levels for CMIP6 (with N265 atmosphere). A first 100 years run has started (results are being analysed). Comparison of coupled models with ORCA1 and ORCA025 are shown. The differences in ACC transport are large (does the difference come from the ocean or the atmosphere components?)
The EC-earth consortium (Andreas Sterl) is running ORCA1 coupled to IFS for CMIP5. A new albedo scheme for partially ice covered regions seems to improve (reduce) the sea ice extent in the Southern hemisphere in summer.
Models biases are discussed: overestimation of the seasonal cycle of the mixed layer, warm bias in the ACC (note: is this bias is not seen in forced mode because the air temperature is imposed?).

1.5 Biogeochemical activities with DRAKKAR model configurations (chairman J Le Sommer)

Discussion:
Several groups are pursuing/planning to carry out biogeochemical studies with DRAKKAR model configurations or model configurations adapted from DRAKKAR configurations (LSCE, LEGI, IFM-GEOMAR, LPO/LEMAR, NOC, Mercator-Ocean…).

It is unclear to what extent those activities could benefit from a certain level of coordination/interaction within the DRAKKAR consortium.

Two important aspects to be taken into consideration:

- the groups are using several different models depending on their scientific objectives (ecosystems, carbon fluxes…). This includes MEDUSA, PISCES, and possibly LOBSTER.
- There remain some uncertainty regarding the tools (LPO/LEMAR) and the groups involved (IFM-GEOMAR ?).

From the discussions it appears that there is an obvious problem with mixed layer depth in subpolar gyres with too deep ML in winter, too shallow ML in summertime. This is critical for coupled physical-biogeochemical activities. This problem is also critical to coupled atmosphere-ocean activities with DRAKKAR model configurations. No clear consensus has emerged on how to proceed in that respect.

Decision:

- With respect to mixed layer depth, we propose to establish a clear status of the problem. This involves in particular sharing namelists among the various groups: JLS will gather information during 2011 in that respect
- More interactions are possible among NEMO-PISCES users (LSCE, MERCATOR, LEGI, LPO/LEMAR). In particular,
    - we have agreed on rationalizing the choices regarding physical model parameters and forcing in particular at .5°;
    - the possibility of a videoconference/meeting within the TANGGO framework will be examined;
    - some work on PISCES time-stepping is needed and discussions have been initiated in that respect (O. Aumont, G. Madec, J. Le Sommer)

2. Model developments and 2011 research projects

Conceptual and practical issues involved in closing the energy budget of current ocean models were presented by Remi Tailleux. Gurvan Madec presented the status of NEMO v3.3 and its evolution. The 2011 workplan of several contributing teams/institutes was presented for LEGI/LPO (Bernard Barnier), NOCS (Adrian New), IFM-GEOMAR (Arne Biastoch), University of Alberta (Paul Myers), DFO/BIO (Youyu Lu), LOCEAN (Sébastien Masson). The project TOPOS, submitted to GMES FP7 by the Drakkar participants, was presented by Joel Hirschi. No summary is presented in this report since these presentations are available on the web.

The general discussion on ORCA025pointed again the need to improved our understanding of the mixed layer, and to quantify if flaws seen the Drakkar simulations are dominated by forcing issues or by physical parameterization issues. The use of GLORYS assimilation increments was suggested to evaluate the part due to the surface heat fluxes. The use of a convective adjustment algorithm that fully establishes the static stability after convection events has been mentioned.
The set up of AGRIF vertical refinement in key regions to investigate the overflows is suggested, although it may require a specific time stepping for vertical advection. It was also suggested to test a climatology derived from GLORYS2 as initial conditions.

3. Developing the global ORCA12 model

3.1 ORCA12@NOCS Summary

NOCS is running an ORCA12 configuration based on NEMO 3.2 with the following distinct features:

75 vertical levels
Non-linear free surface (key_vvl)
DFS 4.1 surface forcing
Started from Levitus in 1978

The bathymetry and physical parameters are otherwise as agreed following last year's Drakkar meeting. The NOCS run also differs in that full 5-day mean files have been collated and kept (in NetCDF4) throughout the run. The run has completed 6 model years and is progressing at around 2 model years per month. The first few years were run without any constraint on the freshwater budget but the decrease in global ssh of 20cm per year was unacceptable. Subsequent years have used nn_fwb=3 (global emp set to zero and spread out over erp area). Drake Passage transport peaks at 165Sv within the first year but declines rapidly to settle around 130Sv. SSH variability (based on analysis of the 5-day means for years 4 and 5) shows expected improvements spreading away from generation regions. In the NA, the NW corner is much improved (but can it be maintained?) but, so far, there is little evidence of an Azores current system. Currently no special treatment is applied to the Gibraltar outflow region. This needs to be investigated.
The Atlantic MOC (annual average) has a maximum of 18-20Sv but, in common with ORCA1 and ORCA025 runs, the MOC at the equator shows extreme variability over 5 day timescales. Swings from 60Sv to -30Sv on the Atlantic equator can occur over 5 days. Experiments with the lower resolution models have shown that these variations fade away if the winds are held constant in time but the reason for the amplified variability within 4 degrees of the equator is unclear. The OCCAM 1/12 (B-grid, with no-slip) did not exhibit this kind of variability but recent communication with Alice Karspeck suggests that similar behaviour is found in the POP 1/10 model. Investigations continue.

To do:

1. Check the state of the sub-polar gyre
2. Check overflows
3. Move to v3.3 and activate the diurnal cycle
4. Agree and implement common monitoring output

3.2 ORCA12 in Kiel

The Kiel group presented first analyses of 15 years (1978-1993) of ORCA12 simulation (ORCA12.L46-K001). The configuration is virtually the same as it has been discussed during the meeting in Grenoble 2010: The code is based NEMO 3.2.1 (DRAKKAR revision 403); the bathymetry and coordinate files (46 vertical layers) are inherited from MERCATOR. Atmospheric forcing is taken from COREv2 for the period 1978-2007 (using interpolation on-the-fly) while surface salinity is restored to Levitus with 36day timescale (rn_deds=-166.67 mm/d/psu) as long as the salinity difference does not exceed 0.5 salinity units which delimits smoothing effects of the salinity damping in regions with a broad range of salinity variations, e.g. in the fresh Greenland boundary currents or the NAC. The ocean time step is 360s and the LIM2 sea ice model is called each 6th step. The simulation started from rest and from Levitus climatology (input files from MERCATOR). To reduce the amount of disk space for the output fields, only key sections and some surface fields are written (~2.7 GB/model month) using the new input/output manager:

- Bering Strait
- Denmark Strait
- Labrador Sea 53N
- Atlantic MOC 36N,26N and 26S
- Drake Passage
- Indonesian Throughflow
- Mozambique Chanel
- Agulhas Current
- Sea Surface Height, Salinity, Temperature and Velocities

From 1996 on, the full 3D output is written (~20Gb per model month). One model month is integrated on 512 CPUs (incl. land processors) within 6 (6.5) hours wall clock time with reduced (full 3D) output.

Preliminary results
The focus for the first evaluation of the ORCA12.L46-K001 experiment was on the stability of the Atlantic Meridional Overturning circulation. The transport of Denmark Strait Overflow Water is within the range of observational estimates (2-3Sv) and the time series of the MOC maximum at 36°N first appears to be stable at ~19 Sv after 12 years but tends to slow down during the last years. The DSOW signal cannot be tracked downstream from the sills as a part of the Deep Western Boundary Current in the Labrador Sea (53°N) which indicates that the BBL formulation is (like in ORCA025) not working properly in ORCA12, and that the DSOW is presumably mixed away on its way down the sill. This is accompanied by a shift of the southward transport of dense waters across 36°N from deep to mid-depth layers.
Another focus is on the stability of the Antarctic Circumpolar Current through Drake Passage. The drift in the ACC transport during the first ~20 years is similar to experiments at coarser resolution (ORCA05 and ORCA025), the same holds for other ORCA12 simulations (e.g. NOCS ORCA12). Nevertheless, the inter-annual variability appears to be independent from the linear trend, showing the same variations as the second iteration of an ORCA05 run for the same period.

Future plans

- Evaluation will be continued (The documentation of the Kiel ORCA12 experiments and their ongoing analysis will be available under https://svn.ifm-geomar.de/trac/orca12; contact orca12@ifm-geomar.de to get access).
- Implement monitoring tool
- The current simulation of 30 years (1978-2007) will be finished in the end of March 2011.

- A following (shorter) experiment is planned (weaker SSS damping but maybe with southern ocean restoring).

3.3 ORCA12 in France

Romain Bourdalle-Badie (MERCATOR) describes the ongoing simulation, from 1999 to 2008 with the 50-level vertical grid. Forcing is from Era interim, short wave and long wave are corrected (like in DFS4) but not the precipitations. The model has shown instabilities (at high latitudes, near runoffs, or due to tidal mixing on European shelf). The solution adopted, was a reduction of the time step (480s -> 360s) and increasing the frequency of calls to the forcing and ice computations (nn_fsbc=2 namelist parameter). After that, 6 years without problem have been performed. Comparison with ORCA025 and with the first ORCA12 simulation shows that some aspects are improved: SSH mean, SSH variability (linked with not taking into account of the ocean velocities in the computation of the stress or a new bathymetry or 3h forcing fluxes), Gulf Stream and Kuroshio region, temperature field. But some biases are persistent in both simulations (ORCA12 and its twin ORCA025): biases in the ACC region, biases linked with the forcing, biases in the salinity field, biases in the ice representation. Few years should be rerun with a correction of the precipitation field, and with a damping to Levitus under sea ice.

The Grenoble group received support from CNRS for ORCA12 development (3 year contract for research engineer). In this framework, Albanne Lecointre joined the group in November 2010 and started working on performance/scalability assessment on the target computer at CINES, using the same ORCA12 configuration (46 levels) as the Kiel group. A wide range of domain decompositions was explored as well as different computing strategies on this multicore machine. A first bunch of experiments indicates that a bottle neck of the system seems to be the access to memory. Therefore, the best performances are obtained when using only a fraction of the available cores of a processor (core depopulating computing). At this time the best strategy that emerged from this study was to use 1000 cores, depopulating the processor by a factor of 2 (so that in fact 2000 cores are mobilized). Doing so, the estimated elapsed time for one year of integration is about 27.5h. A second bunch of experiments was performed after the meeting in early February 2011, playing with the placement of the processes on the different cores of the machine. After some tests, it has been found that the overall best efficiency of the computation was achieved when neighbour domains (hence cores) are placed on different computer nodes. Doing so, when running ORCA12 in 2000 cores, without depopulating the processors, the estimated elapsed time for one year of integration can be reduced to about 21 hours. This is now the nominal strategy for the ORCA12 runs performed on jade/CINES. Before the September meeting in Kiel, the Grenoble group will perform a 20 year experiment, forced by ERA-interim, completely similar to the Kiel configuration, starting in 1989 from a restart file provided by the Kiel group. Latest information: The run was started on March 14, 2011.

3.4 General discussion about ORCA12

- The French group emphasized the interest of using the monitoring package for all runs in order to be able to easily compare the different runs. Comments from other groups indicate that this monitoring package is not so easy to install and run. The Grenoble

group (Jean-Marc, Raphael and Julien) advertized a much more robust version of the monitoring tools, integrated in a single package that can be downloaded by svn at the following URL:
https://servforge.legi.grenoble-inp.fr/svn/DMONTOOLS/tags/DMONTOOLS_1.0
for a stable version of the trunk for the on going developments. The Grenoble technical team offered its help for installation and tutorial on the monitoring tool, if required. The tricky part of this system is mainly the installation of the graphic library (NCL –ex NCAR Graphics-, a third party software). The core of the tools is based on CDFTOOLS, which only require a recent NetCdf library, just as the NEMO code.

- We need to find coordinated solutions to handle the large output files
- Would it be useful to create a ¼° output database using the "degrad" tool?
- Find nice and significant science questions to address with ORCA12 (this will be discussed at the Kiel meeting)

4. Other issues (tools, web site, next meeting)

The old Drakkar web site (www.ifremer.fr/lpo/drakkar) is obsolete and has to be put offline. A new site is proposed to replace it : www.drakkar-ocean.eu . It has been designed by Tristan le Toullec (LPO Brest) using the Plone software and is located on a server at the university of Brest. This web site should offer a general view of the project with links to the sites of the different groups.
- Bernard needs to provide a short explanation of the different Drakkar forcing sets.
- Could the groups provide a few nice pictures, and check the list of participants and the publications?

The publications and the web site in general should be updated once a year before the winter meeting. A contact for each group will have a login and will be able to update the site.

Contacts in each group for questions regarding the web site:
Brest: Anne Marie Treguier
Kiel: Arne Biastoch, Markus Scheinert
Southampton: Andrew Coward
Grenoble: Bernard Barnier, Jean Marc Molines

A Drakkar meeting devoted to ORCA12 will be organized in September in Kiel. Due to the availability of the IFM conference room, the Kiel group would like to propose September 8th and 9th 2011.
To find the exact date, there is a poll (See the registration link at the workshop web site available under http://www.ifm-geomar.de/go/orca12 for further information (registration, agenda proposal) or contact orca12@ifm-geomar.de).