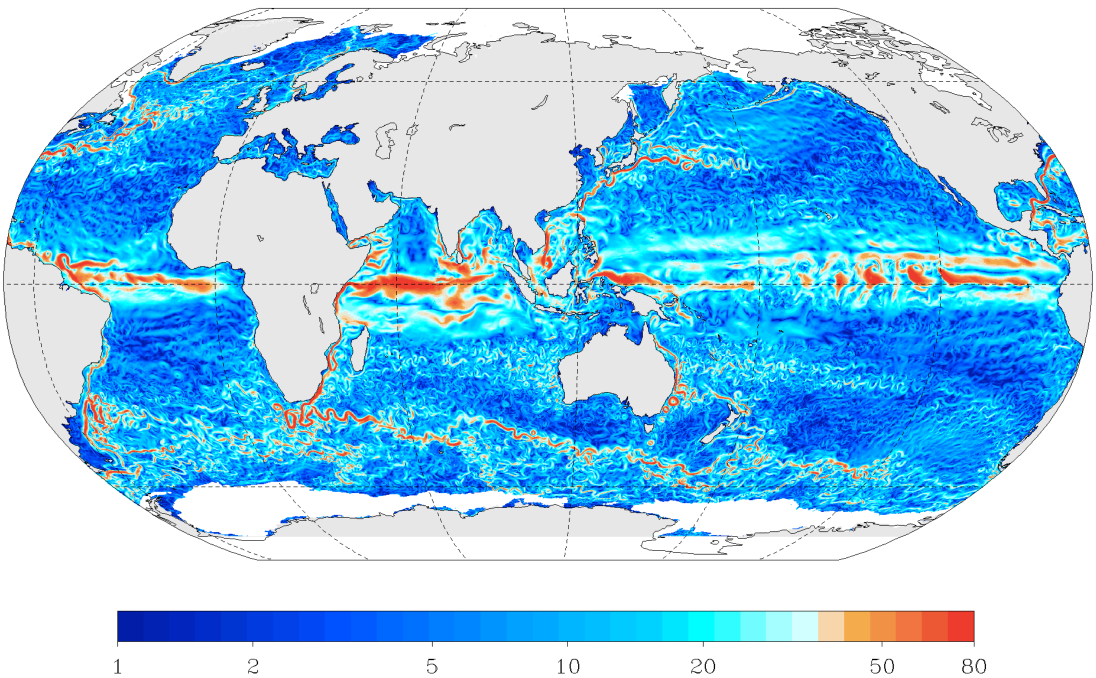
DRAKKAR

Coordination of high resolution global ocean simulations and developments of the NEMO modelling framework.

Coordinators: A.M. Treguier and B. Barnier

Project INSU-LEFE and GMMC report of activity 2010 - 2012

September 2012



Instantaneous surface velocity in the ORCA12 model (cm/s)

Laboratories: LEGI, LPO, LOCEAN, MERCATOR-Océan

Contacts: Anne.Marie.Treguier@ifremer.fr, Bernard.Barnier@legi.grenoble-inp.fr

Summary

DRAKKAR is a scientific and technical coordination project between French research teams and MERCATOR-ocean, with close collaborations in the U.K., Germany and Canada. We design, carry out, assess, and distribute high-resolution global ocean/sea-ice numerical simulations performed over long periods (five decades or more), and improve and maintain a hierarchy of state-of-the-art ocean/sea-ice model configurations for operational and research applications. This effort is motivated by the need for better numerical simulations of the ocean state and variability over the past decades, in order to address e.g. the following issues: what are the mechanisms that drive the interannual to decadal oceanic variability? what are the relationships between the variabilities of water masses and the circulation? what is the impact of boundary currents, eddies and small scale processes on the large scale circulation and its variability?

Such simulations do complement and bridge gaps between sparse observations, low resolution IPCC-like climate simulations, idealized and theoretical studies, and thus benefit a wide scientific community.

Our general objectives are the following:

- Maintain a coherent hierarchy of global model configurations with up to date parameterisations and numerical algorithms, and in particular, continue the improvement of the global 1/4° model ORCA025 now widely used in Europe for operational applications and climate research;
- Perform coordinated (at the European level) global ocean hindcasts at eddy-resolving resolution (1/12°) and make the results available to a wide community;
- Develop and share among us, and make available to others, the tools and expertise necessary to the development and use of regional model configurations;
- Use realistic ocean simulations as a testbed for new parameterizations, and to evaluate the benefits of higher spatial resolution.

During the three years of the project (2010-2012) we have completed a transition from eddy permitting (1/4°) to eddy resolving regime (1/12°) at the global scale, for the model configurations, the simulations, and the parameterizations, in partnership with MERCATOR-ocean. The ocean variability revealed by the 1/12° simulations is documented by a number of studies either published or in preparation.

The DRAKKAR coordination fosters the sharing of tools and expertise within major ocean modelling groups in France, Germany and the United Kingdom, and between the research and operational communities. It contributes to a number of scientific projects within LEFE (GLORYS, TANGGO) and beyond (MyOcean, EMBRACE, Eurobasin and other FP7 projects). DRAKKAR participates in the continuous evolution of the NEMO system, helps improve model configurations used for operational oceanography, prepares the ocean components of future coupled climate systems, and contributes to studies of biogeochemical tracers.

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1.Introduction

1.1. Scientific questions and projects

The DRAKKAR coordination, supported by LEFE and GMMC over the period 2010-2012, has gathered scientists and engineers from different laboratories in France (Table 1) in collaboration with colleagues from Europe and Canada. The DRAKKAR coordination has developed the modelling tools and produced the simulations necessary to address a wide range of open questions about the oceanic variability and scale interactions, in particular:

- Which mechanisms drive the variability of the global and regional ocean circulation and water masses over a few decades period, and what are the relative contributions of these mechanisms?
- What is the effect of fine scale processes (mesoscale eddies and mixing, boundary currents and fronts, surface mixed layer processes...) on the ocean dynamics at larger space and time scales?

These questions and others have been addressed within dedicated scientific projects (Table 1). A common requirement of all these projects was a set of coarse to eddy-resolving ocean-ice global hindcasts of the last five decades, either to serve as a basis to study mechanisms of variability or in order to provide boundary conditions to regional configurations. DRAKKAR hindcasts are based on the NEMO modelling system (Madec 2008) and the rich hierarchy of model configurations it develops (Drakkar Group, 2007). Before 2009, the focus of DRAKKAR had been the development of the global eddy-permitting model ORCA025 (1/4°). The improvements realized by the Drakkar group are documented by Barnier et al (2006); the high impact of this publication (> 120 citations) demonstrates the success of this model configuration. The main challenge for the second phase of the project (2010-2012) was to develop the eddy-resolving global configuration ORCA12.

Table 1 : DRAKKAR team members (France), 2010-2012.

Name	Position	Laboratory	Role
Bernard Barnier	DR CNRS	LEGI Grenoble	Coordination, Forcing, Global and regional configurations, Assessment...
Xavier Capet	CR CNRS	LPO Brest and LOCEAN Paris	Parameterisation, Regional configurations & simulations,
Julie Deshayes	CR CNRS	LPO Brest	Assessment, regional simulations
Julien Le Sommer	CR CNRS	LEGI Grenoble	Parameterisation, Regional configurations & simulations,
Gurvan Madec	DR CNRS	LOCEAN & NOCS	NEMO development, global simulations
Jean Marc Molines	IR CNRS	LEGI Grenoble	Models configurations, simulations, diagnostic tools, optimisation, database management & distribution, ...
Thierry Penduff	CR CNRS	LEGI Grenoble, FSU Tallahassee	Forcing, assessment, global simulations analysis
Claude Talandier	IE CNRS	LPO Brest	Models configurations, simulations, diagnostic

			tools, numerical improvements and validations
Anne Marie Treguier	DR CNRS	LPO Brest	Coordination, simulations analysis
Albanne Lecointre	INSU CDD (3 years)	LEGI Grenoble	ORCA12 development and simulations, data base management & distribution, ...
Y. Drillet and collaborators	IR Mercator	Mercator, Toulouse	Coordination ORCA12 development and simulations
Mélanie Juza	IR CDD CNES/INSU	LEGI Grenoble	Development and applications of diagnostic tools for model/observation comparison.
Raphael Dussin	IR CDD MyOcean	LEGI Grenoble	Forcing, eddy-permitting simulations, monitoring
Sandy Gregorio	Postdoc MYOCEAN	LEGI Grenoble	ORCA12 and ORCA025 simulations . Intrinsic variability of the meridional circulation
PhD Students	Contributions from Henrick Berger, Nicolas Barrier, Camille Lique (LPO); Carolina Dufour, Mélanie Juza, Angélique Melet, Marion Meinvielle, Nicolas Freychet, Gildas Mainsant, Bughsin Djah, (LEGI).		
Post docs	Contributions from J Zika (Southern Cross project, LEGI) and G. Maze (OVIDE project, LPO).		

Table 2 : Scientific projects of the French DRAKKAR team members over the period 2010-2012, that have benefited from the DRAKKAR collaboration.

Scientific Project	**P.I. (in France)**	**Description**	**Duration**	**Support**
GLORYS	B. Barnier N. Ferry	Global Ocean Reanalyses	2009-2012	PPR GMMC
Southern Cross	J. Le Sommer	Southern Ocean variability and Cross-scale interactions : Understanding and modelling the mechanisms of climate variability in the Southern Ocean	2009-2011	ANR
SSINOC	T. Penduff	enhancing Synergies between Satellite In-Situ and Numerical OCeanography	2009-2011	OST/ST (CNES-NASA)
RICCO	A.M. Treguier	Climate change and variability in the ocean at the regional scale (North Atlantic)	2010-2012	Ifremer
FCVAR	J. Deshayes R. Curry	Relation between changes in freshwater content and circulation in the North Atlantic	2008-2010	NSF
MyOcean	B. Barnier	WP3: Ocean physical modelling WP4: Ocean Reanalysis	2009-2012	FP7
CO2SUD	J. Le Sommer M. Gehlen,	Variability of air-sea CO2 fluxes in the southern Ocean (proposed).	2010-2012	LEFE
Eurobasin	L Memery J Deshayes	Basin-scale Analysis, Synthesis & INtegration	2010-2014	FP7
EMBRACE	G Madec A.M. Treguier	Earth system Model Bias Reduction and Assessing abrupt Climate changE	2011-2015	FP7

1.2. Objectives of the DRAKKAR coordination

The **overall objectives** of the DRAKKAR coordination may be summarized as follow:

- Develop and maintain the coordinated DRAKKAR hierarchy of global model *configurations*, share tools and expertise necessary for the development and use of regional model configurations,

- Complement the existing set of coordinated DRAKKAR *simulations and reanalyses* by designing, performing, assessing and distributing new global ocean hindcasts relevant for studies of the ocean variability over the past decades.

- Contribute to the improvement of NEMO, its parameterizations (providing realistic sensitivities for their calibration) and configurations for both research and operational (i.e. MERCATOR-Océan and the GMES Marine Core Services) applications.

To address these objectives, five tasks were defined for the period 2010-2015 (Table 3).

Task	**Objectives**	**Coordinators**
Task 1: coordinated global ocean-ice simulations	Develop the configurations, perform, analyze, distribute simulations for: 1.1. laminar and eddy-permitting simulations: 1.2: Eddy resolving simulations	A.M. Treguier, T. Penduff
Task 2: forcing the ocean	2.1: Evaluation of new forcing functions 2.2 Strategies for future scenarios	B. Barnier, A.M. Treguier
Task 3: algorithms, parameter-ization, submesoscale dynam-ics	Develop and evaluate new parameterizations for eddy permitting and eddy resolving models	X Capet, J. Le Sommer
Task 4: numerical code, tools, database management	Develop common tools for the simulations (Drakkar configuration manager), analysis and monitoring.	J.M. Molines, C. Talandier
Task 5: Enhance capabilities for regional configurations	Improve the possibilities offered by grid refinement (AGRIF) and treatment of open boundary conditions in NEMO.	J. Deshayes
Task 6: coordination of strate-gy and Drakkar meetings	Coordination at the national and international level	B. Barnier , A.M. Treguier,

Table 3: list of tasks defined in the DRAKKAR proposal (2010-2012)

Each of the following section presents one task. In this report we focus on the added value of the DRAKKAR coordination for the scientific projects of the DRAKKAR team members. The **scientific impact** of the coordination is shown by a few highlights presented in sections 2 and 3, as well as the list of publications using the DRAKKAR configurations and tools (section 8), and the list of users of Drakkar simulation outputs or model configurations (section 9).

2. Task 1: Coordinated global ocean-ice simulations

2.1. Laminar to eddy-permitting simulations: strategy

The existing 2°, 1°, 1/2° and 1/4° DRAKKAR configurations (ORCA2, ORCA1, ORCA05 and ORCA025) have been maintained, and have made possible the analysis of the impact of model resolution on the ocean variability (e.g., Penduff et al, 2010 and 2011).

The eddy-permitting ORCA025 configuration (global 1/4°) has undergone significant improvements, that have been implemented in the simulations carried on since 2010, using a refined vertical grid (75 levels). The list of reference simulations is indicated in Table 4; a large number of additional sensitivity experiments are documented on the Drakkar monitoring web pages at LEGI. The following section summarizes a few scientific results obtained using these simulations.

Simulation	Year of completion	Vertical levels	Duration	Forcing	Comments
ORCA025-G70	2006	46	1958-2004	DFS3	First long experiment
ORCA025-B83	2008	46	1958-2007	DFS4.1	Companion to MJM01
ORCA025-MJM01	2008	46	Climatology: 327 years	DFS4.1 climatology	Grand challenge on CINES
ORCA025.L75-G85	2010	75	1958-2007	DFS4.3	NEMO3.1, tidal mixing, light penetration depending on sea color, EVP ice rheology.
ORCA025.L75-MJM95	2011	75	1989-2009	Era Interim	"free" simulation companion to the reanalysis GLORYS
ORCA025.L75-GRD100	2012	75	1958-2009	DFS5.0 (ERA40+ERA Interim)	First evaluation of forcing combining ERA40 and ERA Interim.

Table 4: list of long simulations with ORCA025 available for scientific analyses.

2.2. Laminar to eddy-permitting simulations: results

a) Forced and intrinsic variability of the global ocean

Contact :Thierry.Penduff@legi.grenoble-inp.fr

Most IPCC Climate prediction models have been implemented with laminar (ORCA2 or ORCA1-type) ocean components until now, but will include eddy-permitting ocean models in for the next IPCC Assessment Report (AR6).

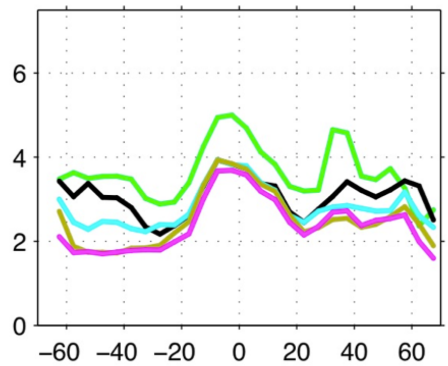

Figure 2.1 : zonally-averaged standard deviation (ordinates, cm) of the large-scale interannual SLA variability as a function of latitude, from AVISO observations (green) and increasingly fine grid DRAKKAR simulations (ORCA2, ORCA1, ORCA05, ORCA025) forced identically (DFS3). From Penduff et al (2010).

Juza (2011) and Penduff et al (2010) have quantified in atmospherically-forced mode how successive doublings of model resolution (from 2° to ¼°)

impacts the global ocean variability in distinct frequency bands with respect to ARGO data (quasi-annual and interannual) and altimeter data (same bands plus mesoscale), respectively[1].

The laminar ORCA1 and ORCA2 models can simulate certain large-scale features of the interannual SLA variability (see Figure 2.1 above), albeit with weak amplitudes. Simulating the observed broadband (mesoscale but also interannual-to-decadal) SLA variability observed in eddying regions requires the eddy-permitting regime: realistic mesoscale ocean variability and much narrower (more realistic) mean frontal structures are simulated at ¼°, along with a strong improvement of the SLA interannual variability (better distribution, larger amplitude). These latter improvements also concern the large-scale part of the interannual variability, hence confirming the benefits of ¼° resolution for climate-oriented simulations.

The latter study revealed that increased resolution yields a decrease in interannual correlations between local AVISO and simulated SLA timeseries as the resolution increase. Using a pair of seasonally- and fully-forced[2] ¼° DRAKKAR simulations, Penduff et al (2011) showed that the increase in interannual SLA variability up to observed levels along with its decorrelation from AVISO is due to the emergence at ¼° of a low-frequency *chaotic* intrinsic (ocean-driven) variability superimposed on its atmospherically-driven counterpart. This chaotic component (see figure 2.2 below) exceeds 40% if the total variance over half of the open-ocean area and exceeds 80% over one-fifth of it (especially in the Southern Ocean and western boundary current extensions as qualitatively[3] predicted by idealized studies). The interannual SLA variance is almost entirely due to intrinsic processes south of the Antarctic Circumpolar Current in the Indian Ocean sector, while half of this variance is forced by the atmosphere north of it. The atmosphere directly forces most of the interannual SLA variance at low latitudes and in most mid-latitude eastern basins.

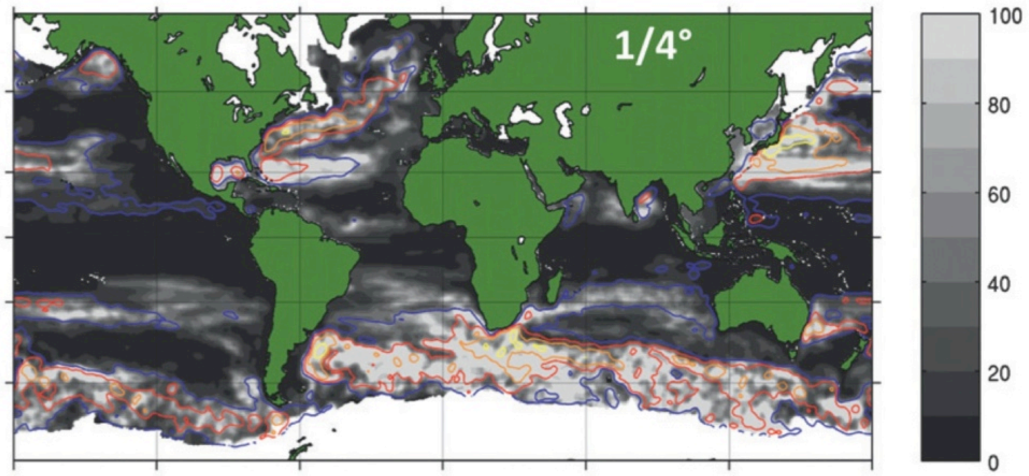

Figure 2.2 : Percentage (gray shading) of total interannual SLA variance that persists in a seasonally-forced run devoid of any interannual forcing; this percentage of low-frequency variance is due to purely intrinsic (and chaotic) ocean nonlinearities. From Penduff et al (2011).

[1] Specific tools have been developed in LEGI by T. Penduff and M. Juza (with CNES support) to collocate in space and time model outputs onto observational data, and to quantitatively assess model-observation and model-model mismatches.

[2] Using the regular DFS4.1 atmospheric forcing function

[3] This phenomenon has been investigated for 2 decades in very idealized contexts (e.g. quasi-geostrophic or shallow-water ocean models in rectangular flat-bottomed domains), but is barely known in realistic simulations, either in terms of origin, structure, magnitude, and impacts.

The same pair of simulations was performed and analyzed in ORCA2: switching back to this laminar regime yields a forced variability comparable to its ¼° counterpart (large-scale distribution and magnitude) but almost suppresses the intrinsic variability. This likely explains why laminar ocean models strongly underestimate the interannual SLA variance, and strongly suggests that the eddying oceans used in future IPCC climate predictions will generate a low-frequency intrinsic "noise" that also has a substantial imprint on the SST variability (and might then impact the atmosphere and the whole climate to a certain extent). This study was presented on web-INSU in September 2011 (http://www.insu.cnrs.fr/environnement/ocean-littoral/la-part-chaotique-de-la-variabilite-oceanique).

b) Variability in the Southern Ocean

Contact :Julien.LeSommer@legi.grenoble-inp.fr

The large database of DRAKKAR ORCA025 model simulations has been used for studying specific mechanisms involved in the variability of the Southern Ocean (Dufour et al. 2011; Venaille et al. 2011). The methods and procedures set by the DRAKKAR consortium have also been used during SouthernCross ANR project (2008-2012; PI: J. Le Sommer) for studying the role of mesoscale eddies in the response of the Southern Ocean to climate trends (Dufour et al. 2012; Zika et al. 2012).

Pulsation Mode. Dufour et al. (2011) have investigated the subsurface variability of temperature and salinity south of Australia along 130°E over 1980-2004. Their study reproduces and complements the analysis based on repeat hydrographic sections along the SR3 line of Sun and Watts (2002). By using an EOF the composition in geostrophic streamfunction coordinate, they identified the dominant mode of water mass variability South of Australia, namely the Pulsation Mode. Fig. 2.3 shows typical temperature sections obtained along 130°E during positive and negative phases of the Pulsation Mode. The high time resolution of the model output is then used for investigating the driving mechanism of the Pulsation Mode. The pulsation mode is found to be related to movements of the Sub-Antarctic Front constrained by the bathymetry of the Southeast Indian Ridge. The Pulsation Mode is shown to display many similarities with cold-core eddy events rather than being related to variations of the westerly wind stress, as previously proposed by Sun and Watts (2002). This study is a good example of what can be learned from the joint use of observations and model output.

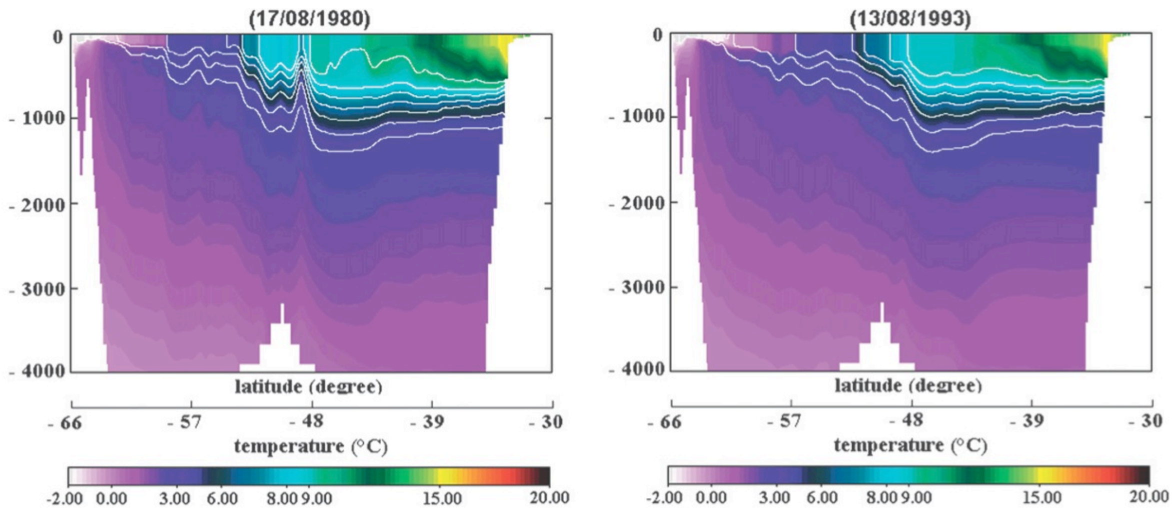

Figure 2.3: Snapshot of potential temperature during a positive phase of the pulsation mode (left panel) and a negative phase of the pulsation mode (right panel). White lines show isopycnals depths ranging from 26.8 kg/m3 to 27.4 kg/m3.

Zapiola Eddy. Venaille et al. (2011) have studied the intrinsic eddy-driven variability of the Zapiola anticyclone in the Argentine basin. As shown by Saraceno et al. (2009) from altimetric observations, the Zapiola anticyclone (a prominent circulation feature located above the Zapiola Rise in the Argentine basin) exhibits a strong variability on a broad range of time scales. As noticed by Penduff et al. (2011) in their study of intrinsic SSH variability at global scale with DRAKKAR model output, the Argentine basin in a hotspot of intrinsic eddy-driven variability. Venaille et al. (2011) have shown that a large fraction of the low frequency variability of the transport of the Zapiola anticyclone can indeed be attributed to intrinsic eddy-driven mechanisms. Their study also investigates in detail the nature of this forcing mechanism. Fig. 2.4 shows the very particular regional configuration of surface eddy kinetic energy and geostrophic contours in the Argentine basin. This configuration allows mesoscale eddies to force Topographic Rossby Waves (TRW) along geostrophic contours. In turn these TRWs create a rectified current over the Zapiola Rise therefore forcing the Zapiola Anticyclone. Venaille et al. (2011) have shown that this forcing mechanism also allows for low frequency fluctuations in the eddy field to induce low frequency fluctuations of the transport of the Zapiola Anticyclone. This study was presented on web-INSU in September 2011 (http://www.insu.cnrs.fr/environnement/ocean-littoral/la-part-chaotique-de-la-variabilite-oceanique).

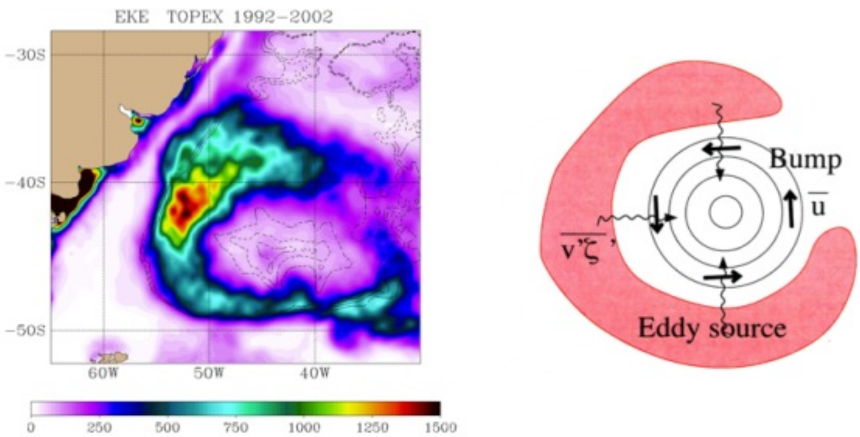

Figure 2.4: (left panel) surface eddy kinetic energy in the Argentine basin from TOPEX altimeter (1992-2002). Dash lines indicate the closed geostrophic contours. (right panel) schematic illustration of the eddy forcing of the barotropic circulation along closed geostrophic contours.

Role of eddies in the response of the Southern Ocean dynamics to current wind intensification. To refine understanding of how Southern Ocean responds to recent intensification of the Southern Annular Mode (SAM), the ocean-sea ice model NEMO was run with the DRAKKAR regional configuration PERIANT at two eddy-permitting resolutions (0.5° and 0.25°) and forced with two synthetic interannual forcing. The first forcing corresponds to homogeneously intensified winds, while the second concerns their poleward intensification, consistent with positive phases of the SAM. This strategy allows to investigate both the impact of eddies and of wind pattern on the response of Southern Ocean dynamics to wind intensification.

Resulting wind-driven responses differ greatly between the nearly insensitive Antarctic Circumpolar Current (ACC) and the more sensitive Meridional Overturning Circulation (MOC). As expected, eddies mitigate the response of the ACC and MOC to poleward intensified winds (Fig. 2.5). However, transient eddies do not play an increasing role in meridional transport with increasing resolution. As winds and resolution increase, meridional transport from standing eddies becomes more efficient at balancing wind-enhanced overturning (Fig.2.5b). These results question the current paradigms on the role of transient eddies and highlight the importance of resolving standing eddies.

Results also indicate that spatial patterns of wind anomalies are at least as important as the overall change in intensity in influencing the Southern Ocean's dynamic response to wind events. Poleward intensified wind anomalies from the positive trend in the SAM are more efficient in accelerating the ACC than homogeneous wind anomalies.

Therefore, these results have some implications for climate models which still need some eddy transport parameterization. They also induce that the relevance of climate projections are highly dependant upon the resolved SAM pattern. In light of this study, further investigations are being carried out as for the response of the Southern Ocean CO_2 sink to the SAM using the same model configuration coupled with a biogeochemistry model.

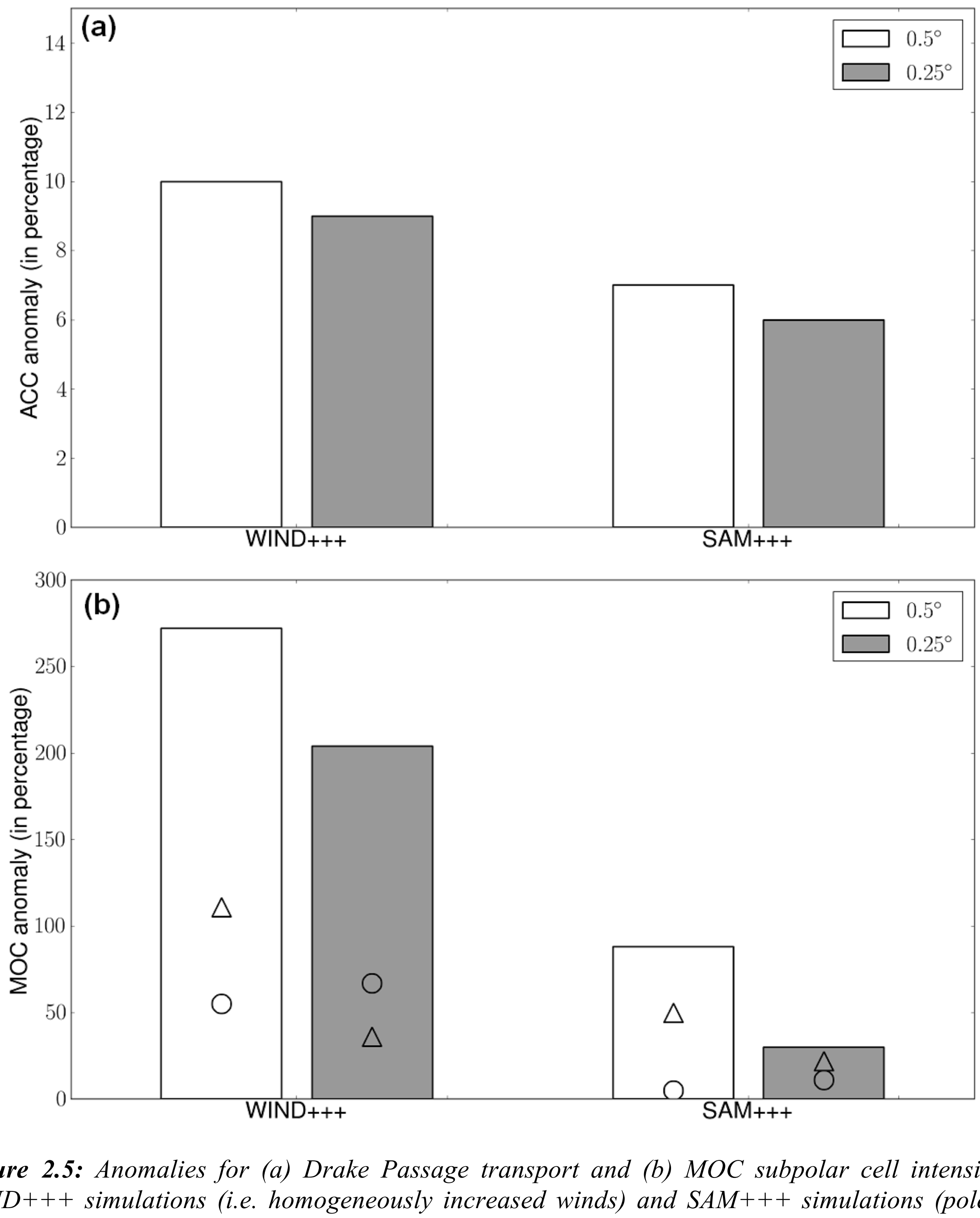

Figure 2.5: *Anomalies for (a) Drake Passage transport and (b) MOC subpolar cell intensity for WIND+++ simulations (i.e. homogeneously increased winds) and SAM+++ simulations (poleward intensified winds) at 0.5° and 0.25° resolutions relative to the respective reference simulations, given in percent for the 1995–2004 mean. In (b) Vertical bars represent anomalies in total MOC, circles correspond to anomalies in standing-eddy component of the MOC, and triangles indicate anomalies in transient-eddy component of the MOC. ACC is nearly insensitive to wind intensification while MOC is far more sensitive. For a given set of experiment (WIND+++ or SAM+++), grey bars being systematically smaller than white bars indicate that better resolving eddies induce a mitigation of the response of the ACC and MOC to wind intensification. Moreover, when getting to higher resolution (from white to grey), the response of transient eddy –induced meridional transport (b, triangles) to wind intensifi-*

cation reduces while the response of standing eddy-induced meridional transport (b, circles) increases.

c) Variability of the Arctic Ocean

Contacts: Camille.lique@ifremer.fr, Anne.Marie.Treguier@ifremer.fr,

The DRAKKAR global 1/4° has an average resolution of 12 km in the Arctic ocean, which allows to resolve the main bathymetric features and represent (albeit crudely) the flow through the Canadian Archipelago. The database of long ORCA025 simulations, with different forcing fields, vertical grid and intensity of the sea surface salinity restoring, has allowed Camille Lique and collaborators to perform detailed studies of the freshwater and heat budget of the Arctic Ocean.

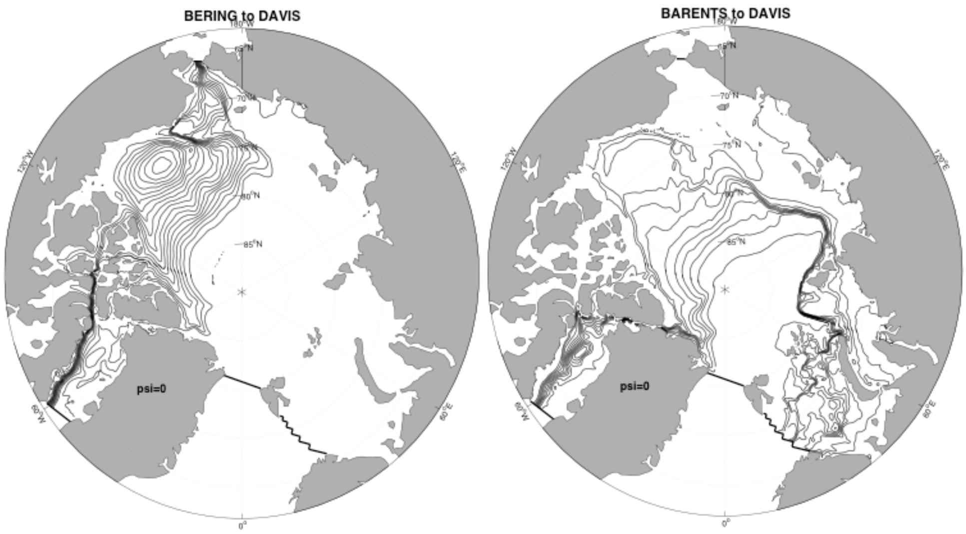

Figure 2.6: *Mass streamfunction describing the time-mean Lagrangian transport of waters from Bering Strait to Davis Strait (at the entrance of the Labrador Sea) and from the Barents sea to Davis Strait. In the ORCA025 model, both pathways contribute equally to the export from the Arctic through Davis Straits (about 1Sv each). Contour interval is 0.1 Sv, the streamfunction is set to zero over Greenland. Lique et al, 2010.*

After a quantification of the freshwater budget and its variability (Lique et al, 2009), the origin of the freshwaters exported from the Arctic on both sides of Greenland has been investigated. Recent measurements have shown that the net mass export through Davis Strait is larger than the inflow of Pacific water at Bering, which means that some water of Atlantic origin exit the Arctic through the Canadian Archipelago and Davis Strait. These pathways are revealed by a Lagrangian analysis using the ARIANE software in ORCA025 (Lique et al, 2010, Figure 2.6).

The GLORYS global reanalysis carried out at MERCATOR-Ocean in collaboration with DRAKKAR, using the ORCA025 model, reproduces very well the minimum in sea ice exension that has been observed in 2007, even though almost no in-situ observation was available for assimilation in the Arctic. The correlation of the model with observations (figure 2.7) is 0.84. The analysis of the model has shown that during years 2007 and 2008, the properties of the Canadian and Eurasian basins have evolved in a contrasted manner, with a freshening of the surface water masses in the Canadian Basin but a salinisation of the Eurasian basin of advective origin (Lique et al, 2011).

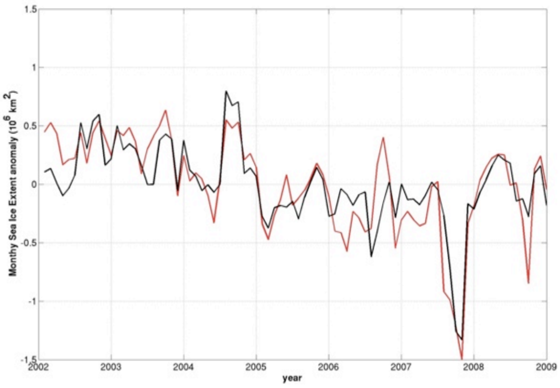

Figure 2.7: *Sea ice extension, Glorys reanalysis in black and observations in red. Almost no observations were assimilated in the Arctic Ocean in this version of Glorys, especially no sea ice data.*

Recently, the vertical grid of ORCA025 has been refined from 46 to 75 levels, with 1m thickness of the top level. This new model has been successful in reproducing the seasonal cycle of the Atlantic waters in the Arctic and has allowed to study the mechanisms driving this seasonal cycle (Lique and Steele, 2012). Other investigations have been carried out using ORCA025 within the framework of the Arctic model intercomparison AOMIP project (Jahn et al, 2012).

2.3. Drakkar models for reanalyses

Contact: bernard.barnier@legi.grenoble-inp.fr

In a unique and successful cooperation between the climate research community (DRAKKAR/CLIVAR) and the operational ocean forecasting community (MERCATOR/GODAE), the GLORYS/MYOCEAN project produced two global re-analyses of the global ocean/sea-ice circulation at eddy-permitting (1/4°) resolution, one for the Argo years (GLORYS1-V1 reanalysis, 2002-2009) and one for the altimetry period (GLORYS2-V1 reanalysis, 1993-2009). These reanalyses and their companion simulations without data assimilation have been widely distributed to the international community and are presently available through the MYOCEAN portal. The DRAKKAR coordination had a major contribution to improve the physical model used in the MYOCEAN reanalyses: compared to originally planned, the ORCA025 version used follows the DRAKKAR customisation of NEMO3.1 with all most recent improvements in mixing parameterisations, forcing parameterisations, and a significantly increased vertical resolution (75 levels) as suggested by the ocean climate community. The major partners involved in the GLORYS project, (the French DRAKKAR group and MERCATOR-Ocean) have strongly reinforced their cooperation, something that could not have been realized outside the framework of the GLORYS GMMC project.

DRAKKAR also contributed to several validation studies and to the assessment of the quality of the reanalyses. In summary;

- **GLORYS2V1 overall performance is better or similar to GLORYS1V1, and similar in many aspects to PSY3V3R1 operational system**

- (http://bulletin.mercator-ocean.fr/html/produits/psy3v3/psy3v3_courant_en.jsp). Some aspects are significantly improved; others are similar (see below). In GLORYS2V1 the ocean state is well controlled and during the common period with PSY3V3R1 operational system (2007-2009), the analysis and reanalysis are close one to the other.
- **Data assimilation diagnostics**: the data assimilation system is stable and produces for all the observations satisfying "hindcast" skills consistent with the observation error specified. Sea surface height and sea surface temperature are well controlled: global averaged innovation root mean square is constant throughout the reanalysis. Due to strong changes in the in situ temperature and salinity observation network, GLORYS2V1 water masses properties are improved when Argo network is present (2001-2009).
- **SST**: is of high quality, with little bias (i.e. within observation error bar). SST is however overestimated in the Mediterranean sea by ~0.5°C.
- **Sea Surface Salinity**: It is underestimated in the tropical region (20°N/20°S) in GLORYS2V1 due to overestimated precipitation in ERA-INTERIM atmospheric forcing. The SSS bias is reduced when Argo network sets up.
- **Sea Level Anomaly**: is very good, strong correlation with observations. Some local bias against CNES-CLS09 mean dynamic topography can be found locally (mostly in the Antarctic Circumpolar Current region, in the Indonesian region, and in some coastal areas).
- **Global heat balance**: the global average surface heat flux is constant throughout the period, slightly unbalanced (+4W/m^2 in global average). However, data assimilation provides a realistic correction that shifts the balance around 0~+1 W/m^2.
- **Surface currents**: the mean currents are well located and exhibit a realistic variability. However their intensity is generally underestimated: this is the case in the ACC and the tropical regions except in the Western equatorial Pacific where errors in the assimilated mean dynamic topography lead to too strong surface currents.
- The surface eddy variability is in good agreement with altimetric data. Surface eddy kinetic energy compares very well with observations.
- **3D temperature & salinity fields**:
    - In the first 300 meters: little bias, climate signals are realistic and close to available observations; mesoscale variability is in agreement with observations.
    - Below 300m: Biases are weak, except in some specific areas (Gulf Stream region, ACC region).
- **Sea Ice**: The winter seasons are well reproduced for both hemispheres in terms of sea ice extent mean and variability. Trend and interannual variability of both Arctic and Antarctic sea ice extent are particularly well correlated with observations. Trend and interannual variability of Arctic sea ice speed compare also well with observations.
- **Tropical variability**: analysis of tropical SST / SLA shows realistic equatorial wave propagations at all wavelength (intensity, phase and phase velocity). Subsurface (0-300m) thermohaline structure exhibits a realistic mean state and annual to interannual variability. However, the Equatorial Under Current intensity is underestimated and its variability is not very realistic.
- **Integrated Quantity**:
    - Transport at straits: stable, low drift
    - Meridional Heat Transport: realistic intensity at all latitude
    - Meridional Overturning Circulation (MOC): realistic values. The Atlantic MOC is close to RAPID independent estimate.
- **Comparison with independent data**:
    - Tide gauges: excellent correlation / variance explained
- **Climate variability:**
    - ENSO variability is well captured by the model both in surface and subsurface.
    - global / regional mean sea level and SST trends are in very good agreement with observation estimates.

These results have been presented in several international conferences, and especially at EGU in 2011 and 2012 and at the 2011 GODAE OceanView Technical Workshop on Observing System Evaluation and intercomparison (as a solicited lecture).

MERCATOR and DRAKKAR held together a reanalysis workshop (June 2011 in Toulouse) that gathered the users and the producers of the GLORYS reanalysis products, as well as other reanalysis products (e.g. MyOcean WP4, etc.) in order to assess the scientific value of the reanalyses, to identify ways of improvements of those products, to prepare the next generation of reanalyses to be carried out in the framework of the Marine Core Services (e.g. MyOcean2). The workshop gathered more than 40 scientists, with significant international contributions (e.g. UK, Italy, Canada, Spain, ...). All the MyOcean partners were represented.

2.4. Eddy-resolving simulations

a) North Atlantic regional model

Contact: Julie.Deshayes@ifremer.fr

For more than a decade now, it has been well established that a resolution higher than 1/4° is needed to represent at first order the eddies and recirculations in western boundary current systems. In the previous phase of the DRAKKAR project (2007-2009), a North Atlantic model configuration at 1/12° resolution has been developed. NATL12 is based on a similar configuration used at MERCATOR-ocean. Within DRAKKAR, the configuration has been adapted to perform multidecadal experiments with open boundary conditions at the North (Canadian Archipelago, Nordic seas and Barents Sea) and at the south (20°S). The sensitivity of the ocean response to high frequency forcing has been explored by A. le Boyer during his PhD thesis (2010).

In 2010-2012, NATL12 has been used for two major scientific studies. Maze et al (2012) have diagnosed the contribution of eddies to the formation of 18° mode water in the Gulf Stream region. The model was found to reproduce remarkably well the characteristics of the 18° water, and allowed Maze et al to investigate the importance of turbulent fluxes by comparing NATL12 with lower resolution models such as ECCO. Mesoscale eddies have been found to intensify the fluxes of mechanichal energy and the diabatic fluxes at the air-sea interface, but the wind contribution to mode water formation remains significantly lower than the contribution of heat and freshwater fluxes. Another study (Treguier et al, 2012) has been devoted to the investigation of meridional fluxes of salt across the North Atlantic basin. This study takes advantage of the hierarchy of DRAKKAR model, contrasting eddy-resolving and eddy-permitting cases. The study confirms the cancellation of mean and eddy fluxes of salt. This cancellation is sometimes obscured in eddying models integrated for short periods, because of the large artificial drifts in the model salt content. The divergence of eddy salt fluxes out of the subtropical gyre represents one third of the evaporation over the area between 10°N and 40°N, and thus cannot be ignored.

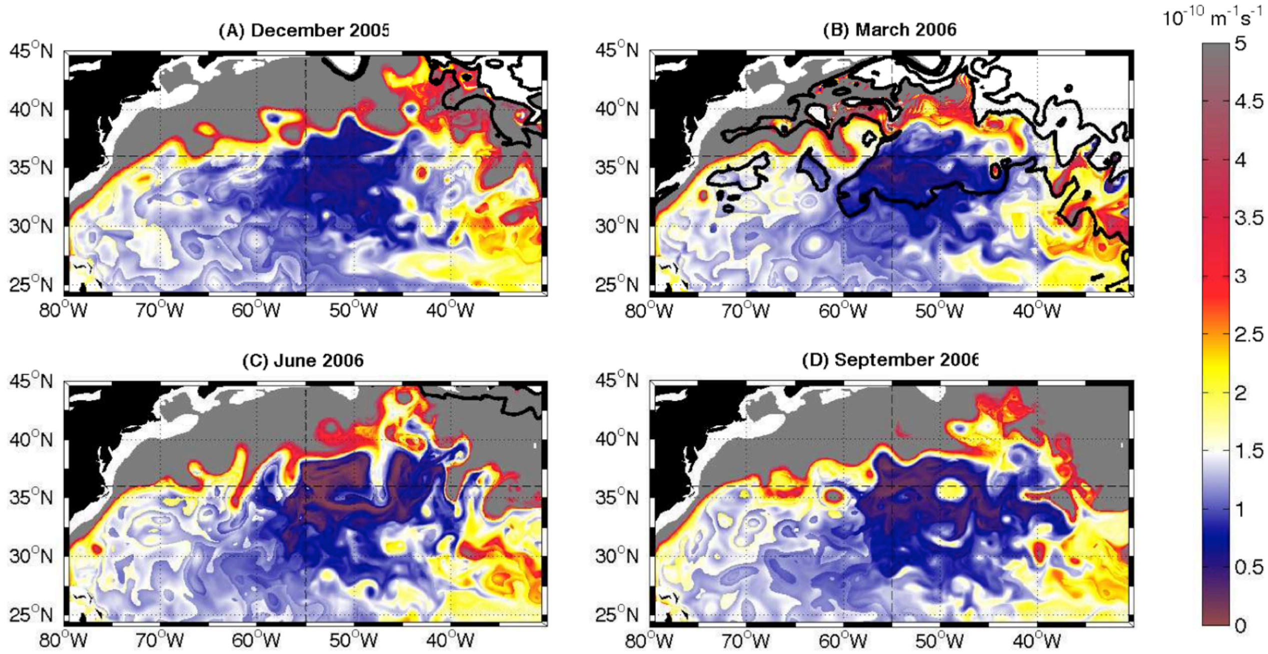

Figure 2.8: *Monthly maps of potential vorticity (color bar) in the NATL12 model, on the isopycnal surface σ_0=26.4, characteristic of the 18° mode water. The potential vorticity minimum corresponds to the core of the 18° water mass. The black contours represent the outcrop of the σ_0=26.4 isopycnal surface. These plots demonstrate the turbulent character of the mode water reservoir and of the formation process (Maze et al, 2012).*

b) Development and optimization of the global ORCA12 model

Contact: Albanne.Lecointre or Jean-Marc.Molines @legi.grenoble-inp.fr

Strong optimization efforts have been conducted on targeted SGI-Altix-Ice JADE supercomputer (Nehalem nodes) since 2010.

At the beginning (before any performance computing investigations), in october. 2010, we were able to compute one year ORCA12 with 46 vertical levels in 33 elapsed hours and 66000 CPU hours using 2000 Nehalem cores (computing performance including IO). Our computing performance (measured in steps/min) was 50 steps/min (black dots on the figure 2.9. The poor scalability beyond this 2000-core limit prevented us to use more computing cores (performance rate was only 60 steps/min when computing with 3000 cores). We were front of a memory contention problem during the message passing on the node and the only solution was to compute in depopulated-core condition but with an unacceptable CPU cost.

A first level of optimization (investigation study conducted during 2011) introducing an optimal placement of the MPI processes on the cores allowed us to reach a more comfortable performance rate of 60 steps/min (magenta dots on the figure 2.9), allowing us to compute one year ORCA12 in 27.5 elapsed hours and 55000 CPU hours. But scalability was always limited at 2000 cores.

A second level of optimization (based on the work of Andrew Coward and John Donners about north-fold boundary condition management) allowed us to reach a significant better scalability until 3000-4000 cores (but computing performance still increase up to 8000 cores). We are now able to compute with a very improved performance rate of 110 steps/min using 3000 cores or 85 steps/min using 2000 cores (green dots on the figure 2.9). Computing with 3000 cores with all our optimizations will allow us to simulate one year ORCA12 in 15 elapsed hours and 45000 CPU hours. Compared to the initial state (oct. 2010), the elapsed time is now 45% of the initial one and CPU time is now 68% of the initial one.

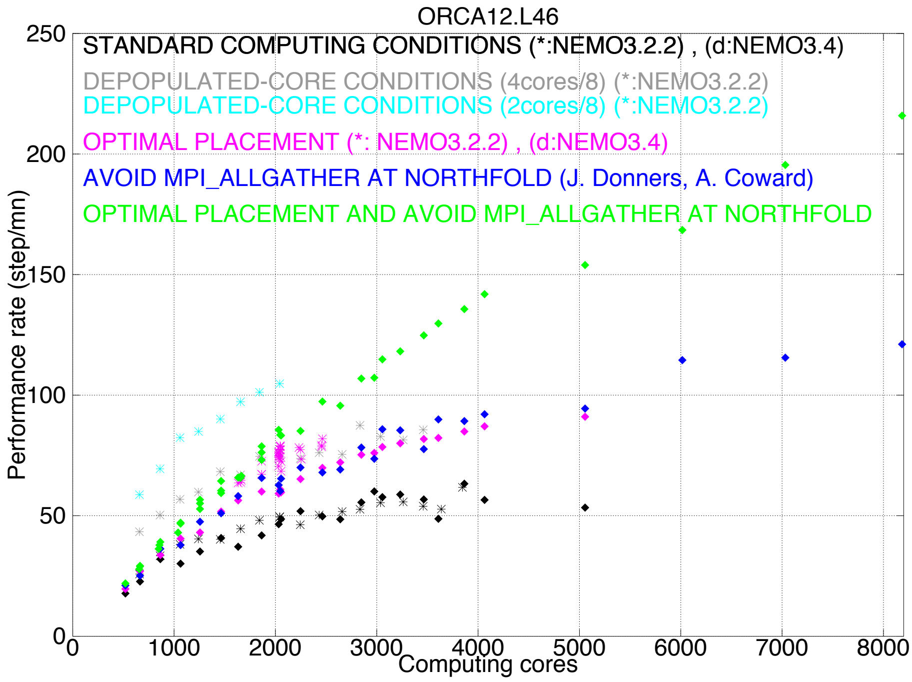

Figure 2.9 *parallel performances of ORCA12.*

All these optimizations and resulting performance on NEMO3.4 are fully described in Lecointre, 2012 (see list of DRAKKAR reports).

First level of optimization concerns the way to submit jobs and more particularly the core-binding (the placement of the MPI processes on the computing cores). Standard core-binding is “by-core”: as illustrated on figure 2.10a. We found that using core-binding “by-node” strategy (fig. 2.10b), i.e. separate neighboured geographical domain (which communicate between each other throughout their North, South, East, West boundaries) on different computing nodes allowed to significantly increase the performance rate (less memory contention on the node during the message passing).

Second level of optimization concerns the code itself and more particularly the north-fold boundary condition treatment (Donners et al, poster, EGU 2012, Vienna). ORCA configuration uses a regular, tri-polar grid to eliminate the north-pole singularity. This creates a north-fold, where indexing on neighbouring domains is not trivial. Point-symmetry connects grid-points with different i- and j- coordinates. The staggered grid and the decomposed domain further complicates copying the boundary data. Therefore, the original code gathers all data on one processor, applies the T-point symmetry and scatters the data. This is effectively a serialization of the code. In the modified code, domains only communicate with multiple neighbouring domains along the north-fold. This strategy (avoiding MPI_Allgather at north-fold) allowed us to reach similar performance rate as first level of optimization does (blue dots on fig. 2.9). And associating these two different optimizations allowed us to reach the best performance rate described above (green dots on fig. 2.9).

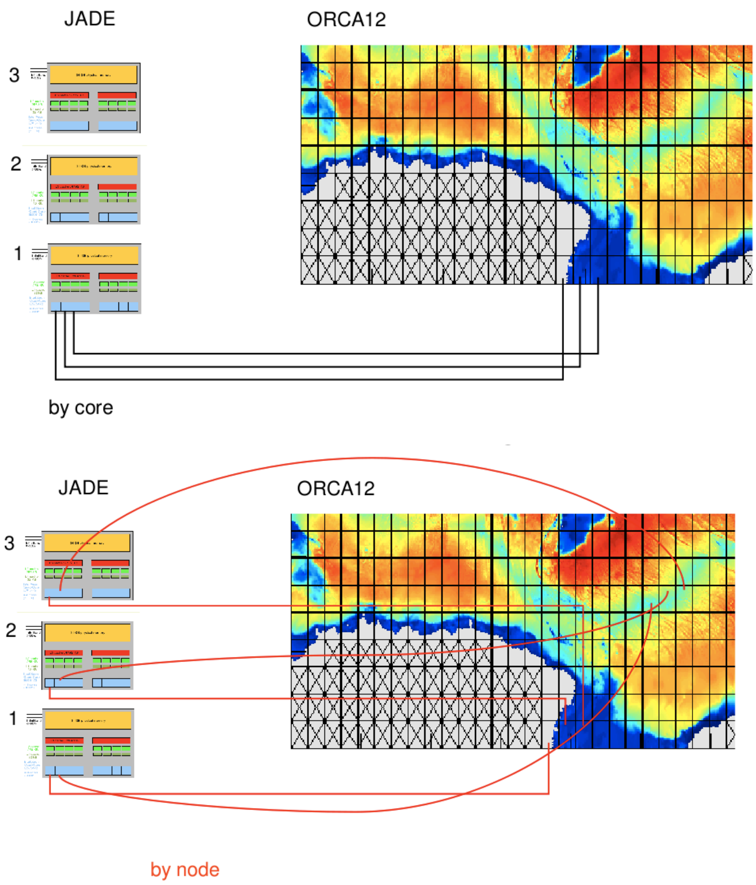

Figure 2.10 *a (top): placement by core; b (bottom): placement by node.*

c) ORCA12 global model analysis

The development of the global model at 1/12° was the major goal of DRAKKAR for 2010-2012. Starting from a configuration provided by Mercator-Ocean, a number of improvements have been made; parameterizations have been adjusted (see section 4) and the configuration has been optimized to run efficiently on a larger number of processors (see section 2.4.b).. The objective is to have a long (of order 50 years) reference experiment by the end of 2013, of a quality significantly improved compared with the eddy permitting simulations.

The development of ORCA12 has been coordinated with colleagues at Mercator, NOCS Southampton and Geomar in Kiel. A workshop entirely dedicated to ORCA12 has been held in Kiel in september 2011. A reference ORCA12 publication is in preparation (to be submitted, in september) (Bourdalle-Badie et al, see abstract below).

Because eddy-resolving modeling of the world ocean is still in its infancy and is extremely demanding in computational means, the necessary sensitivity experiments that need to be done to improve the solutions must be well coordinated. The DRAKKAR group has a number of muti-decadal sensitivity experiments, making possible original scientific studies, such as the following (two manuscripts in preparation):

1) Contribution of eddies and turbulent fluxes to the freshwater transport at 30°S in the Atlantic Ocean; J. Deshayes and collaborators (LPO, Geomar, NOCS).

Recent studies suggest that the sign of the meridional freshwater transport at 30°S by the Atlantic Meridional Overturning Cell (AMOC) is an indicator of AMOC stability. These results have been obtained in low resolution climate models which do not represent eddies. The sign and the variability of the freshwater transport at 30°S will be analyzed in various DRAKKAR simulations, eddy permitting and eddy resolving. The different components of AMOC (gyre, overturning, turbulent correlations) will be calculated separately. The most realistic ORCA12 simulations will be useful to assess the observability of the freshwater flux.

2) Dynamics of western boundary current in ORCA12; F Fransner, B. Barnier, J. Hirshi, T. Penduff (LEGI and NOCS)

Model simulations carried out by the various European participating groups allowed to investigate the sensitivity of ORCA12 to the choice of momentum advection scheme (MAS) and lateral boundary conditions. More explicitly, we compared two simulations, one with a flux MAS (FLX scheme) and one with partial slip (PS) to a reference simulation (REF) with vector MAS (EEN scheme) and free slip (see Le Sommer et al, 2010 for a description of the schemes). We investigated how these numerical settings impact the representation of western boundary currents in the model. We focused on their transport and variability at mid latitudes, as well as their horizontal structure and meridional coherence.

It was found on one hand that *(i)* the flux scheme and the partial slip both gives more variable and unstable currents that are less coherent than the ones in REF, *(ii)* the partial slip was unable to represent correctly the separation of the surface boundary currents, a very crucial feature of the circulation, and *(iii)* the flux scheme was enhancing the instability of the large scale currents in an unrealistic way. On the other hand, the standard setting used in REF (free slip and EEN scheme) seems to give too low variability compared to observations. For further simulations with ORCA12, it is suggested to use the REF settings, although further investigations need to be done in order to get a more realistic variability of the currents.

ORCA12 reference publication

ORCA12: A global ocean model at 1/12° resolution for ocean prediction systems and long term variability studies

R. Bourdallé-Badie, B. Barnier, R. Benshila, A. Biastoch, C. W. Böning, C. Bricaud, A. C. Coward, Y. Drillet, G. Garric, J. M. Hirschi, A. Lecointre, O. Le Galloudec, J. Le Sommer, C. Lévy, G. Madec, S. Masson, J. M. Molines, A. L. New, T. Penduff, M. Scheinert, C. Talandier, B. Tranchant, A. M. Treguier

Abstract: In the framework of the MyOcean project, Mercator Ocean has developed for operational oceanography applications a global eddy-resolving (1/12°) ocean/sea-ice model based on the NEMO modelling framework. The ocean model part of this system, hereafter called ORCA12, allows for the representation of mesoscale eddy structures and improves the simulated mean flow. Thanks to the increase of computing facilities, this configuration is now a realistic choice for the next generation of models to be used to study the ocean variability over the last decades. In this context, the European Drakkar consortium and Mercator Ocean have taken joint charge of improving and validating this configuration, which now constitutes the top end of the Drakkar portfolio. In this paper, first, we present an overview of the first series of coordinated multi-decadal ORCA12 simulations and results obtain by the Drakkar partners. Second, we describe the next steps of the ORCA12 developments that will take advantage of this unique European collaboration to build a common model and perform coordinated ensembles of ORCA12 runs.

3. Task 2: Forcing the ocean

3.1. Development of the DRAKKAR forcing datasets

Contacts: Raphael.Dussin and Bernard.Barnier @legi.grenoble-inp.fr.

ERA-interim (ERAi hereafter) is the latest reanalysis provided by ECMWF. It covers the period 1979-2010 and will be updated for following years. A lot of improvements have been implemented to both the atmospheric model and data assimilation system compared to ERA-40, which was the basis for DRAKKAR Forcing Set 4.3 (hereafter DFS4.3) used in the past few years. The spatial and temporal resolutions have also been improved (0.7° and 3-hourly for ERAi, 1.125° and 6-hourly for ERA-40). Despite a better representation of the atmospheric state, the reanalysis still has some flaws when forcing an ocean general circulation model, which have been identified with the global 1/4° global configuration ORCA025, based on NEMO code.

Intensity of **Subtropical Gyres**: compared to DFS4.3 forced simulations, ERAi forced ones show a collapse of the Florida-Bahamas transport, which is a good proxy for North-Atlantic subtropical gyre intensity. This behavior is observed in a large number of ERAi forced simulations performed by the DRAKKAR group, and is not due to vertical resolution or spin-up. We concluded that gyre circulation has to be strengthened, which can be achieved by increasing the wind module, in a way that is consistent with the fact that ERAi winds are weaker than QSCAT estimates and are suspected to be underestimated by ~0.5 m/s at mid and tropical latitudes (P. Jensen, Personal communication).

Freshwater input: compared to DFS4.3 (which is satellite-based), ERAi precipitations are intense and likely overestimated at low latitudes and underestimated at mid-latitudes. Hence a major issue is to decrease precipitations at low-latitude, which is already unbalanced in ERAi (E-P-R = 0.33 mm/day).

Radiation fluxes: ERAi also provides daily radiation fluxes at 0.7° resolution, whereas satellite-based DFS4.3 radiation fluxes have only 2.5° resolution. However ERAi shortwave radiation is likely to be overestimated, in particular in eastern part of ocean basins if we compare them to DFS4.3. In those regions, we see that the longwave radiation has opposite sign compared to shortwave which can be due to flaws in the representation of the cloud cover.

The corrections made on ERAi to build the new forcing set (DFS5.1) are the following:

1. Correction of ERAi 2m air temperature and specific humidity (t2/q2) in the Arctic. Arctic mean temperatures are significantly too warm compared with POLES climatology. We used the same procedure as used by Brodeau et al. (2010) to correct ERA40 in making DFS4.3.

2. ERAi Winds are rescaled towards QuikSCAT satellite data.

3. Radiative fluxes are corrected towards DFS4.3 (based on ISCCP satellite data) to reduce shortwave radiation in eastern part of the basins (partly compensated by an increase of long-wave)

4. Precipitations are de-trended and the corrections of Storto et al. (2012, Ocean Science Discussion) are applied to decrease fresh biases in the equatorial Atlantic and Western Pacific, and a too dry North Atlantic.

The effects of these corrections on the net fluxes model solution have been evaluated and validated with FOTO procedure (flux calculated with observed SST and the standard CORE bulk formulae) and with a series of ORCA246 simulations (2° resolution, 46 vertical levels). The net heat and freshwater budgets obtained with FOTO before and after correction are presented in the Table below. DFS5.1 net heat flux is closer to equilibrium but slightly negative which induces a negative drift (cooling) of the global temperature in ORCA256 simulations (of the order of 0.004°C/ year). The freshwater budget is less balanced and shows a greater deficit in precipitation than in ERAi (a difference of 0.39 mm/day). However, we found that ERAi-forced ORCA2 simulations without sea-surface salinity restoring show a global freshening, inconsistent with the excess evaporation of 0.33 mm/day estimated with FOTO. This indicated that the model feedback of the fluxes decreases evaporation. Our tests show that DFS5.1-forced ORCA2 simulations using the standard SSS restoring piston velocity of 10 m for 60 days do not show any significant salinity drift after an adjustment period of 4 year drift, and this option is recommended. This can be further corrected using the multiplicative ratio on precipitations available in NEMO.

Table: Global average heat and freshwater budgets in ERAi and DFS5.1

	ERA-interim	DFS5.1
Net Heat Flux (W/m^2)	5.34	-2.24
E-P (mm/day)	0.55	0.94
E-P-R (mm/day)	0.33	0.72

A report describing in details the making of DFS5.1 is available on the Drakkar web site (www.drakkar-ocean.eu)

3.2. Assess strategies for future scenarios

A new atmospheric downscaling technique has been developed by colleagues at CERFACS with the specific aim to force ocean models for future scenarios, focussing on the North Atlantic region (Cassou et al, 2009; Minvielle et al, 2009). The method makes use of the decomposition of the atmospheric variability in weather regimes. The ultimate goal is to understand the ocean response to future changes in the frequency of the weather regimes due to the changing climate. Before using this method to compute future scenarios with the DRAKKAR models, it was necessary to understand better the ocean response to the different weather regimes. Although the description by weather regimes has similarities with the decomposition of the atmospheric variability into empirical modes (EOF), there are important differences. For example, the four dominant weather regimes in the North Atlantic include two distinct patterns corresponding to the phases of the North Atlantic oscillation, while the EOF analysis produces only a single spatial pattern of NAO. Nicolas Barrier, during his PhD thesis in the framework of the Ifremer RICCO project, has demonstrated the importance of the "Atlantic ridge" blocking weather regime and has studied the response of a regional North Atlantic model to the persistence of each regime (one paper is in revision and another is submitted).

4. Task 3: Algorithms, parameterizations and submesoscale dynamics

An improved version of the Fox-Kemper mixed layer eddies is currently being implemented in the NEMO system. The improvements we are seeking concern the parameterization behavior toward the bottom of the surface boundary layer so that heat/buoyancy fluxes at the mixed layer base be controlled depending on the conditions (the existing FK implementation ensures no flux through the mixed layer base which seems restrictive). 3D tests of the parameterizations in low-resolution configurations (orca2 or orca1) and eddy permitting solutions (1/4 ORCA and 1/8 ERNA) will be carried out toward the end of 2012 and evaluated for i) their impact on mixed layer depth ii) the consequences that mixed layer depth changes have on the global ocean and in particular the North Atlantic. This will be done collaboratively between LOCEAN (G. Madec, X. Capet), LPO (C. Talandier, J. Deshayes, A.M. Treguier) and NOCS (Georges Nurser). This effort is timely given control exerted by the frontal processes on spring bloom initiation [Mahadevan et al, 2012, Science, Eddy-Driven Stratification Initiates North Atlantic Spring Phytoplankton Blooms).

A new parameterization of lateral stirring at submesoscale due to mesoscale eddies has been proposed by Le Sommer et al. (2011) on the basis of DRAKKAR-ORCA025 model configuration. This parameterization has been implemented in NEMO and tested in PERIANT8 regional model configuration. This parameterization will be further assessed and evaluated within the COMODO and DRAKKAR community in 2012 and early 2013.

Parameterization of subgrid stirring in eddy resolving ocean models. Part 1: Theory and diagnostics

J Le Sommer, F D'ovidio, G. Madec

Abstract

Horizontal stirring by time-varying mesoscale flows contributes to forming submesoscale tracer filaments. In this paper, we propose a parameterization of the passive transport associated with filamentation by mesoscale flows for use in O(10 km) resolution ocean models. Theoretical motivations are provided for modelling subgrid stirring by the resolved mesoscale flows with an anisotropic generalization of Smagorinsky operator. For level coordinate models, an isoneutral formulation of the proposed subgrid operator is provided. The proposed subgrid operator is diagnosed with DRAKKAR global 1/4° eddy-resolving model output. In the Southern Ocean, the parameterization is shown to provide diffusiv- ities peaking at about 400 m2/s. If applied prognostically, the proposed subgrid operator could drive meridional heat transports of about .5PW at 45°S. This suggests that a significant fraction of the transport by mesoscale flows could be associated with tracer features of scale smaller than our model grid size (20 km at 45°S). A large contribution to this transport is associated with differential advection by the time-mean flow at subgrid scale.

5. Task 4: Numerical code and tools

A technical achievement of the DRAKKAR project has been the development of software tools around the NEMO code. These tools are now well structured and organized, documented on wiki pages, with version control. They also have been put under the CeCILL licence (Open code), for coherency with NEMO itself. Schematically there are 3 groups of tools: i) The DRAKKAR Configuration Manager (or DCM) and associated companion softwares, for model developement and production. ii) the CDFTOOLS for analysis of the model output and iii) the DRAKKAR Monitoring Tools (DMONTOOLS) for near real-time monitoring of the simulations. This latter package is thought to work together with DCM and CDFTOOLS.

5.1. Drakkar Config Manager (DCM)

DCM is a working environment implemented for easy share of model configurations. It has been proved in the past projects (e.g. CLIPPER) that it is very difficult to track code modifications between various groups working in the same project. After a while, it appears that supposedly identical codes differs substantially.

With DCM, the locally modified modules (for a given configuration) are clearly identified. Each release of DCM corresponds to a NEMO official release (or even beta-release). This NEMO official release is checked-out from the NEMO forge at LOCEAN, and saved under DCM in a read-only directory (NEMOREF), never modified. All modifications valid for the whole DRAKKAR project (such as bug-fixes, new developments, DRAKKAR customization ...) are saved in the DRAKKAR directory, which has exactly the same tree of directories, but ideally empty (if no modifications were to apply). NEMOREF and DRAKKAR directories are the core of the DCM, in term of numerical code.

A set of tools (ksh scripts) are implemented in order for the end-user to easily use the system. Thus, DCM appear as a wrapper of the NEMO system, were tedious operations such as creating a new configuration, building a Makefile, compiling the code etc... are handled by the DCM tools, which makes use of the capabilities of NEMO.

Any DCM user can create a configuration [which means set up the NEMO code for a given model configuration], and eventually modify some modules for its own purpose. The modified modules are visible in its configuration directory (and only these modified modules are there). When building a configuration (installing a config in the DCM jargon), a working area is created with a sequential copy of NEMOREF, DRAKKAR, and configuration directory, so that at the end, in this working area the code corresponds to the user choices. As far as DCM is versionized, (under SubVersioN) and the version number is saved in the installation process, it is very easy to exactly reproduce the very same code.

Another advantage of using DCM, is that it make much more easy the phasing with new NEMO release. DCM commands are not changed in their form, even if the NEMO system changes (from modipsl to fcm compiling environments, for example). The phasing is the responsibility of only one person, end everybody benefits from this port. It also facilitates the feedback of DRAKKAR developments to the NEMO reference version.

So, DCM is a very valuable tool for code maintenance, but not only! When using DCM, a quite strict directory tree is defined (and automatically maintained !) for the numerical code on the production machine, but also for the model production on the production and storage machines. Thus using DCM also facilitates the sharing of results.

For model production on super computers, a collection of scripts were developed and are distributed besides DCM itself, in a companion package named RUNTOOLS. In RUNTOOLS, a great effort has been made to isolate machine dependent actions from generic actions, so that porting the system to a new machine or new computing center is reduced to porting the machine dependent functions.

Finally, for configuration using a very large number of processors, we implemented a I/O strategy based on output on binary files (where each individual processor/core writes). A post-processing tool was developed for recombining the binary files into standard NetCdf files. This tool, is also distributed as a companion package of DCM with the name BUILDNC.

DCM is in phase with the latest NEMO version (i.e. Release v3_4).

5.2. CDFTOOLS

CDFTOOLS is a collection of fortran programs that perform any kind of diagnostics on model output. There is a wide range of applications: computing statistical fields (mean, variance ...), computing derived quantities (potential density, potential vorticity, mixed layer depth ...), computing transport (across section, overturning, barotropic stream function), either in z-coordinates or for density classes etc...

The actual version of CDFTOOLS (version 3.0) has been completely rewritten in 2011 for a major update after many years of inhomogeneous developments. The code is now homogeneous and systematically self documented. It is written with the same coding standard than NEMO and therefore is quite friendly for NEMO users. By the way, CDFTOOLS is now used in a much wider community than the original DRAKKAR community. In the last release, CDFTOOLS has the possibility of user customization for variable names and file names which were hard coded in previous versions. It has been used successfully by other ocean models than NEMO.

CDFTOOLS is a community tools, and the DRAKKAR technical staff gather all developments made by users in order to include them (after checking and eventual editing) in the package.

5.3. DMONTOOLS

DMONTOOLS is an integrated package used for monitoring DRAKKAR simulations. It produces 2 kinds of information: i) Time evolution of some selected quantities, in the form of maps or sections and ii) Time series of some integrated quantities.

For the maps and sections, we actually work with annual means, in order to more easily detect medium range or long range trends as well as anomalies in the run production.

For the time series, the last version of DMONTOOLS, allow for both monthly and annual periods. The improvement toward monthly means has been done with the goal of matching CMIP requirements for model analysis.

The strength of DMONTOOLS, is that it can be run automatically on the computing centers in such a way that there is a very short delay between the end of a run and the vizualization of the evolution of some index, allowing for a better control of the run. Produced plots are automatically disposed on a dedicated web server, accessible for the DRAKKAR community. Comparison between different experiments is also one the useful capability of DMONTOOLS. It helps a lot in the interpretation of sensitivity experiments, for instance.

From a technical point of view, DMONTOOLS is split in 4 different sub-packages some of them being parallelized (MPI) for efficiency on supercomputers:

i) computation of mean fields, and variance fields, in order to transform high frequency model output (5d or 3d) into monthly and annual means and variance.

ii) computation of derived quantities (e.g. EKE, BSF, MXL PV MOC or transports through selected sections). This part is parallelized so that a full experiment can be processed or reprocessed very quickly. i) and ii) are mainly ksh scripts, calling CDFTOOLS in order to produce the required diagnostics. DCM layout for data output is assumed.

iii) Drawing of maps and sections: This part is realized with ksh scripts, calling MEOM made plotting software, based on NCL (ex NCAR Graphic) library and written in fortran 90. This quite old package has been rewritten in 2011 in order to follow the NEMO coding standards. Output are made in the Color Graphic Metacode format (cgm) which can be transformed in any type of raster images. Final plots are gathered in the form of animated gif files, with one frame per year, and disposed on a web server. This part of the monitoring is parallelized.

iv) Drawing of times-series: this part is realized using python scripts, which take small netcdf files produced by step ii) as input. Results are automatically disposed on the same web server. Each plot corresponds to a python function which makes easy the comparison of several experiments on the same plot, by looping across the selected experiments.

DMONTOOLS is customizable by the user in order to choose the relevant diagnostics and plots. It has been recently updated to take care of simulation coupled with bio-geochemistry (PISCES).

6. Task 5: Enhancing capability and tools for regional simulations

6.1. Development of peri-antarctic models (PERIANT)

PERIANT configurations are used in DRAKKAR associated projects such as Southern-Cross or BIOCOSM. This domain corresponds to the Southern Ocean, south of 30 south. The mesh is a subset of ORCA global model at a given resolution (1/2 degrees, 1/4 degrees) or a standalone mesh (1/8 degree). With respect to ORCA grid, the domain is extendend southward by 2 degree in order to reach the Ross Ice shelf as generally defined in Geographic Systems of Information. The major difference with other DRAKKAR configuration is that the northern boundary of the domain is an open boundary, treated with the OBC capability of NEMO.

OBC are treated using radiative conditions together with some relaxation toward data. In the case of PERIANT configurations, OBC data come from global simulations at the same resolution or, for the case of PERIANT8 from the ORCA025 global simulation, where the data points are repeated twice, as we took care of having the same land-sea mask at the northern boundary. However, we had to adapt the standard volume control done in NEMO when using OBCs (obcvol module): as far as no conservation law is applied when computing boundary normal velocity, it is likely that the entire PERIANT domain suffer some water flux imbalance, which directly impacts the sea-level. In order to correct this flux imbalance, a full estimate of water flux across all boundaries (lateral and surface) is performed at each time step; this imbalance is converted to a barotropic velocity across the lateral open boundary. Then, the normal velocity is corrected by this barotropic velocity in order to close the water budget. This is the way standard OBC work in NEMO. But doing so, and because the northern boundary is composed of three ocean segments (Atlantic, Indian and Pacific Ocean) we observed some spurious variations in each sub-basin meridional transports at the boundary. We fixed this problem by imposing the transports deduced from the data for the Atlantic and Indian Ocean segments. The barotropic correction was only applied to the Pacific segment. This technique gave much more realistic behaviour and was validated for the PERIANT simulations.

6.2. Development of the AGRIF Sea-Ice refinement capabilities

AGRIF allows to refine the horizontal grid over a determined area and to couple it to a coarser regional or global one using the 2-ways nesting; so the coarse and fine grid share information at the boundary and on the common area beneath the refined zone. This capability has been widely used for years in the DRAKKAR framework and shown its utility and efficiency to address scientific issues requiring the “eddy resolving” resolution range.

The objective of the work was to extend the AGRIF existing capability for the ocean model to the sea-ice model NEMO-LIM. This work has been done in developing the ERNA (‘Eddy Resolving for the North Atlantic’) configuration based on a global ORCA ½° grid and an AGRIF zoom spanning the North Atlantic from 20°N to 70°N including part of GIN seas. The sea-ice is a source of freshwater into the Labrador and Irminger seas respectively from the Davis Strait and along the east Greenland coast so it is important to be able to solve the sea-ice component at the same resolution as the ocean one in these key regions.

The starting point of the work was based on a preliminary version mainly developed by the NEMO system team and which was only weakly tested. We used the NEMO release v3.2.2 with the LIM2-EVP sea-ice model on the IBM-SP6 of the IDRIS center.

The development step has been quite long and related to the complexity of the configuration and also the necessity to run in MPI mode. Many troubles concerning the behavior of the sea-ice model at the edge between the coarse and fine grid arise such as discontinuities on fields as the sea-ice thickness or fraction among others. Tests have been done for instance on the coupling frequency between sea-ice and ocean models in the zoom, the time step ratio between coarse and fine grid or also on sea-ice fields updated from fine to the coarse grid.

Finally a first set of experiments have been realised and preliminary results are interesting and promising for the next DRAKKAR configurations at high latitudes. Some information on parameters we retain and performances are summarized in table below.

This development will allow to explore behavior of the sea-ice model at high resolution and also to develop further parameterisation of sea-ice processes. It should be integrated in the future official NEMO release v3.5.

<table>
<tr><th>ERNA configuration</th><th>Domain size (ixjxk)</th><th>Ocean Time step Δt</th><th>Ocean-Ice Coupling frequency</th><th>Ice Time step Δt</th><th>MPI decomposition
(112 CPU)</th><th>Elapsed time for 1 year</th></tr>
<tr><td>ORCA ½°</td><td>722x511x64</td><td>36 minutes</td><td>4</td><td>2h24</td><td rowspan="2">14x8</td><td rowspan="2">~17h</td></tr>
<tr><td>AGRIF zoom 1/8</td><td>724x632x64</td><td>12 minutes</td><td>12</td><td>2h24</td></tr>
</table>

7. Task 6: Coordination of strategy and meetings

7.1.Drakkar meetings and European collaboration:

The DRAKKAR coordination holds an annual internationnal workshop in winter in Grenoble since 2004 to review progresses and coordinate the annual work between the groups. This workshop gathers between 60 to 70 scientists from over 20 different research laboratories, more than half of which are out of France. For example, the 2012 workshop gathered 68 scientists from France, UK, Germany, Canada, USA, Australia, Mexico and Italia). The last 3 editions of the workshop were jointly organized with the MYOCEAN project. If necessary a topical meeting on burning issues is organized (like the meeting dedicated to the subpolar gyre dynamics and the use of AGRIF organized by J. Deshayes in Brest in july 2009, or the meeting dedicated to ORCA12 organized by Markus Scheinert in Kiel in September 2011).

The objectives of the workshop vary every year, but follow the 5 main axes below:

- To review the scientific and technical progresses achieved with the Drakkar hierarchy of model configurations, with as main objective to identify its strengths and weaknesses.
- To share expertise regarding "working with NEMO based configurations"
- To analyse the appropriateness of the hierarchy of models for the scientific projects (including MyOcean) of the various groups.
- To identify and prioritise model improvements and new developments that DRAKKAR would like to see implemented in the future.
- To think about the long-term outlook of these developments (4 to 10 years time frame).

The Agenda of the workshops as well as the presentations made by the various participants (password required) are available to the public through the website of the MEOM Team at LEGI (http://www-meom.hmg.inpg.fr/Web/meom.html.en, item "events")

7.2. Collaboration with MERCATOR

Collaboration between DRAKKAR and MERCATOR-Ocean has always been very tight, with a clear focus on the development and the improvement of model configurations and forcing fields **suited for climate research and operational applications** (GMMC and joint participation to the FP6 MERSEA project). This cooperation was reinforced within the projects GLORYS and FP7 MyOcean, DRAKKAR and MERCATOR getting together to carry out series of global ocean/sea-ice reanalyses at eddy permitting resolution (ORCA025 model configuration, ERAinterim forcing fields). The coordination has recently tighten these links even more by setting procedures for a common management of the simulation and reanalysis data base, for a convergence between operational and research configurations, and for the joint development of the eddy permitting configuration ORCA12 that is now running operationally at MERCATOR. In the longer term, it is expected that MERCATOR will significantly contribute to the production of eddy-resolving hindcasts simulations relevant for research studies of the ocean variability over the past decades.

8. Publications 2010-2012

8.1. Peer-reviewed scientific papers of the French DRAKKAR team

2010:

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2. Brodeau L., B. Barnier, T. Penduff, A-M. Treguier, S. Gulev, 2010: An ERA40 based atmospheric forcing for global ocean circulation models, *Ocean Modelling*, 31, 88-104.
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4. Griffies, S. & Co-Authors (2010). "Problems and Prospects in Large-Scale Ocean Circulation Models" in Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 2), Venice, Italy, 21-25 September 2009, Hall, J., Harrison D.E. & Stammer, D., Eds., ESA Publication WPP-306.
5. Fairall C., Barnier B., Berry D., Bourassa M., Bradley F., Clayson C.A., de Leeuw G., Drennan W.M., Gille S.T., Gulev S.K., Kent E.C., McGillis W.R., Quartly G.D, Ryabinin V., 2010: Observations to Quantify Air-Sea Fluxes and Their Role in Climate Variability and Predictability. in *Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 2),* Venice, Italy, 21-25 September 2009, Hall, J., Harrison, D.E. & Stammer, D., Eds., ESA Publication WPP-306, doi:10.5270/OceanObs09.cwp.27
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9. Laanaia N., A. Wirth, J. M. Molines, B. Barnier, and J. Verron, 2010: On the numerical resolution of the bottom layer in simulations of oceanic gravity currents, *Ocean Sciences*, 6, 563-572
10. Levy M., P. Klein, A.M. Treguier, D. Iovino, G. Madec, S. Masson, and K. Takahashi, 2010: Modification of gyre circulation by sub-mesoscale physics. Ocean Modelling, 34, 1-15. doi:10.1016/j.ocemod.2010.04.001
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8.2. Communications at international conferences

2010

Barnier B., 2010: Research in physical oceanography and its link with operational Ocean Weather Forecast. IGBP, Grenoble meeting, March 19, 2010.

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Jourdain N., Barnier B., Le Sommer J., Molines J.M., Chanut J., Ferry N., and Mercator Team, 2010: What can we learn about deep convection in the Labrador Sea using increments of an ocean reanalysis ? Geophysical Research Abstracts Vol.12, EGU2010-2438, 2010. EGU General Assembly 2010, May 2010, Vienna.

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Juza, M., T. Penduff, and B. Barnier, 2010: Does the Argo array accurately sample the thermal variability of the Global Ocean? 3rd Euro-Argo User Meeting, June 2010, Paris.

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Juza, M., T. Penduff, and B. Barnier, 2010: Recent (2008-2009) improvement of Argo accuracy in estimating the (mixed layer) heat content: a DRAKKAR model study. Journées 2010 du Groupe Mission MERCATOR/CORIOLIS, Météo-France, Nov 29-30 2010, Toulouse, France.

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Penduff, T., B. Barnier, M. Juza, J. Le Sommer, and A.-M. Treguier, 2010: Intrinsic interannual variability in the ocean: global simulations and altimeter observations. Proceedings of the OST/ST meeting, Lisbon, 18-20 October 2010.

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Treguier, A.M., J. Deshayes, R. dussin, P. Klein, C. Lique, 2010 : Meridional eddy transports of heat and freshwater in a 1/12° numerical model of the North Atlantic. Oral presentation, PO54A-06, Ocean science meeting, Portland.

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2011

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Lecointre, A., J.M. Molines, N. Audiffren: High resolution ocean modelling and high performance computing: Computing performance analyses. Journées 2011 du Groupe Mission MERCATOR/CORIOLIS, Météo-France, Nov 7-9 2011, Toulouse, France.

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Penduff, T., 2011: On the intrinsic and forced components of the interannual sea-level variability. Department of Oceanography, Florida State University, Tallahassee, USA. May, 11th, 2011.

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Treguier A.M., Julie Deshayes, Raphael Dussin, and Jean-Marc Molines, 2011: Interannual variability of the subpolar Atlantic and role of eddies: contribution of numerical models at increasing spatial resolution. Invited talk, EGU, Vienna, EGU2011-4645.

2012

Barnier B.: Modeling the global ocean circulation at eddy-resolving resolution. *Invited lecture, SA DUE GlobCurrent User Consultation meeting*, IFREMER Centre de Brest, March 7-9, 2012.

Barnier B.: Global Ocean Reanalyses at Eddy-Permitting Resolution: Insights from the European Project MyOcean. *Keynote lecture* at the 4th International Conference on Reanalyses ICR4, Silver Spring, MA, USA, 7-11 May 2012.

Barnier B.: What Data Assimilation Increments of an Eddy-Permitting Global Ocean Reanalysis tell Us about Deep Convection in the Labrador Sea. Oral presentation at 4th International Conference on Reanalyses ICR4, Silver Spring, MA, USA, 7-11 May 2012.

Barrier N., A.M Treguier, and C. Cassou Impact of winter weather regimes on the North Atlantic oceanic circulation. Oral presentation (N. Barrier), EGU2012-2212, Vienna.

Berger, H., A.M. Treguier, and N. Perenne: Dynamic contributions to the sea surface salinity variations along the equator and the coast of the Gulf of Guinea. Oral presentation (H. Berger), EGU2012-4923, Vienna.

Gregorio, S., T. Penduff, B. Barnier, J.-M. Molines, and J. Le Sommer: Low-frequency variability of the Atlantic MOC in the eddying regime : the intrinsic component. Geophysical Research Abstracts, Vol. 14, EGU2012-8752. EGU general assembly, April 2012 Vienna.

Penduff, T., S. Gregorio, M. Juza, B. Barnier, W.K. Dewar, and J.-M. Molines: Intrinsic variability in the eddying ocean at low frequency: climate-relevant fingerprints. Geophysical Research Abstracts, Vol. 14, EGU2012-8060. EGU general assembly, April 2012 Vienna. (solicited talk):

Treguier, A.M., J. Deshayes and C. Lique, 2012: Mechanisms of eddy-mean flow compensation in the Gulf Stream, Oral presentation, Ocean Science meeting, Salt lake City, 20-24 february 2012.

Donners, N. Audiffren, J.M. Molines, A. Lecointre, A. Coward,, 2012: Towards Petascaling of the NEMO ocean model, EGU, Vienna, poster.

Lecointre, A., J.M. Molines and the DRAKKAR Group, 2012: Overview of the ORCA12 global configuration. NEMO User Meeting, May 22-23 2012, EXETER, U.K.

8.3. Other peer-reviewed publications using DRAKKAR simulations

15 other publications using the results of French global DRAKKAR experiments (publications without direct participation of the French DRAKKAR team members), 2010-2012.

Becker M., Meyssignac B., Llovel W., Cazenave A. and Delcroix T. 2011: Sea level variations at Tropical Pacific Islands during 1950-2009. Global and Planetary Change. 80/81:85-98. doi:10.1016/j.gloplacha.2011.09.004.

de Boisseson E.; Thierry V.; Mercier H.; et al. 2010: Mixed layer heat budget in the Iceland Basin from Argo. JOURNAL OF GEOPHYSICAL RESEARCH-OCEANS Volume: 115. Article Number: C10055 DOI: 10.1029/2010JC006283 Published: OCT 27 2010

Döös, K., J. Nilsson, J. Nycander, L. Brodeau, and M. Ballarotta, 2012: The World Ocean Thermohaline Circulation. J. Phys. Oceanogr. doi:10.1175/JPO-D- 11-0163.1, in press.

Grenier, M. S. Cravatte, B. Blanke, C. Menkes, A. Koc'h Larrouy, F Durand, A. Memet, C. Jeandel, 2011: From the western boundary currents to the Pacific equatorial undercurrent: modeled pathways and water mass evolutions. J. Geophys. Res., 116, C12044.

Jordà G., and D. Gomis, 2010: Accuracyof SMOS Level3 SSS Products Related to Observational Errors. IEEE Transactions on Geoscience and Remote Sensing, 48, 4.

Jordà G., and D. Gomis, 2010: Toward SMOS L4 SSS Products: Improving L3 SSS With Auxiliary SSS Data. IEEE Transactions on Geoscience and Remote Sensing, 48, 5.

Keerthi, M.G., M. Lengaigne, J. Vialard, C. Deboyer-Montegut, A. Muraleedaran, 2012 : Interannual variability of the Indian Ocean mixed layer depth, online release, Climate Dynamics.

Langlais C., S Rintoul, A Schiller, 2011: Variability and mesoscale activity of the Southern Ocean fronts: Identification of a circumpolar coordinate system. Ocean Modelling, 39, 79-96.

Meyssignac B., Becker M., Llovel W., Cazenave A. 2011: An assessment of two-dimensional past sea level reconstructions over 1950-2009 based on tide gauge data and different input sea level grids. Survey in Geophysics, online.

Minvielle M., C. Cassou, L Terray, R. Bourdalle-Badie, J. Najac, 2011: A statistical-dynamical scheme for reconstructing ocean forcing in the Atlantic. Part II: methodology, validation and application to high-resolution ocean models. climate dynamics, 36, 401-417 DOI: 10.1007/s00382-010-0761-y.

Nidheesh, A.G., M. Lengaigne, J. Vialard, A.S. Unnikrishnan, H. Dayan, 2012 : Decadal and long-term sea level variability in the tropical Indo-Pacific Ocean, online release, Climate Dynamics.

Renner A.H.H., Thorpe S.E., Heywood K.J., Murphy E.J., Watkins J.L., and M.P. Meredith, 2011: Advective pathways near the tip of the Antarctic Peninsula: Trends, variability and ecosystem implications, Deep-Sea Research, 63(2012) 91–101.

Rouault, M. (2012), Bi-annual intrusion of tropical water in the northern Benguela upwelling, Geophys. Res. Lett., 39, L12606, doi:10.1029/2012GL052099.

Storto A., Russo I., and Masina S., 2012: Interannual Response of Global Ocean Hindcasts to a Satellite-Based Correction of Precipitation Fluxes. Ocean Science, Submitted.

van der Werf, P. M., P. J. van Leeuwen, H. Ridderinkhof, and W. P. M. de Ruijter, 2010: Comparison between observations and models of the Mozambique Channel transport: Seasonal cycle and eddy frequencies J. Geophys. Res., 115, C02002, doi:10.1029/2009JC005633

8.4.PhD thesis using DRAKKAR simulations (2010-2012)

PhD completed :

de Boisseson, E., 2010: Les Eaux Modales du gyre subpolaire de l'Atlantique Nord : origine, formation, variabilité. LPO, Université de Bretagne Occidentale.

Despres, A., 2010: Les fronts de méso-échelle dans la mer d'Irminger : origine dynamique et variabilite. LOCEAN, Université Pierre et Marie Curie, Paris.

Ducousso, N., 2011: Coexistence et interactions de la circulation décennale moyenne et des structures transitoires dans l'océan Atlantique Nord. LPO, Université de Bretagne Occidentale.

Dufour C., (2011): Rôle des tourbillons de méso-échelle océanique dans la variabilité récente des flux air-mer de CO_2 dans l'océan Austral, *PhD, university of Grenoble*, supervised by J. Le Sommer, M. Gehlen, B. Barnier and J.C. Orr.

Freychet N., 2012: Assimilation rétrospective de données par lissage de rang réduit: application et évaluation dans l'Atlantique tropical. LEGI, Université J.Fourier, Grenoble.

Lique C., 2010: Etude des échanges entre l'Océan Arctique et l'Atlantique Nord : Origine, Variabilité et Impact sur les mers Nordiques. LPO, Université de Bretagne Occidentale.

Hamon, M., 2012: Caractérisation des effets du réchauffement climatique sur l'océan superficiel au cours des 50 dernières années. Université de Bretagne Occidentale, Laboratoire d'océanographie Spatiale (Ifremer).

Le Boyer, A, 2010: Variabilité intra-saisonnière des courants de pente continentale forcés par la turbulence méso-échelle. LPO, Université de Bretagne Occidentale.

Juza, M., 2011: Modélisation numérique et observations océaniques: développement des interfaces, évaluation de simulations et de réseaux d'observations, investigations dynamiques. Université Joseph Fourier.

Meinvielle M., 2012: Ajustement optimal des paramètres de forçage atmosphérique par assimilation de données de température de surface pour des simulations océaniques globales. LEGI, Université J.Fourier, Grenoble.

Melet, A., 2010: Les circulations océaniques en mer des Salomon: modélisation haute-résolution et altimétrie spatiale. LEGI, Université J.Fourier, Grenoble.

Vidal-Vijante E., 2012: Analysis of Mediterranean ocean variability using 5 numerical simulations. Thèse Universidad de Las Palmas de Mallorca.

Ongoing PhD projects:

Akuetevi Q. (2011-2013): Provisional title: Eddyscale dynamics of the Somali Current. Supervisors; A. Wirth & B. Barnier.

Berger, H. (2010-2012): Origine des variations de la salinité de surface du Golfe de Guinée, analyse saisonnière et interannuelle à partir d'un modèle numérique, Université de Bretagne Occidentale, supervisors: A.M. Treguier and N. Perenne.

Barrier, N (2011-2013): Atmospheric weather regimes and the North Atlantic circulation: mechanisms and implications for climate scenarios. Université de Bretagne Occidentale, supervisors: A.M. Treguier and C. Cassou (Cerfacs).

Desbruyères, D., (2010-2012): Meridional overturning and horizontal circulation in the northern North Atlantic: Decadal variability and impact on heat content changes in the eastern Subpolar Gyre.

Djah Bughsin (2011-2013): Provisional title: Origins and impacts of the mesoscale eddy variability in the Salomon Sea. Supervisor: J. Verron.

Mainsant, G., (2011-2013): Impact du Mode Annulaire Austral sur les flux air-mer dans l'Océan Austral : caractérisation des incertitudes dues à la glace de mer. Supervisors: J. Le Sommer & H. Gallée

Talandier, C., (2011-2013): Variabilité des courants de bord du Gyre Subpolaire en Atlantique Nord et impact sur l'AMOC. Thèse UBO, LPO (formation continue CNRS).
Tiago Queiroz, Provisional Thesis Title: Ocean atmosphere interaction in the tropical South East Atlantic. University of Cape Town, Supervisor: Dr Rouault, Dr Jenny Veitch

8.5.Master thesis using Drakkar simulations (2010-2012)

David Brohan, 2010: Estimation of Arctic Ocean Surface currents based on satellite ice drift data and comparison with a numerical model simulation. Master 2 Physique Océan-Atmosphère, Université de Bretagne Occidentale. Encadrement: C. Lique and F. Ardhuin, Laboratoire d'océanographie spatiale, Ifremer.
Antoine Grouazel, 2010: Etude des mécanismes de variabilité dans le courant Est Groenland, stage de master 2 et de fin d'études de l'ENSTA-Bretagne. Encadrement: A.M. Treguier and N. Daniault, Laboratoire de physique des océans.
Clément Vic, 2012: Dynamique d'un panache fluvial en zone équatoriale, modélisation numérique et application au fleuve Congo. M2 Océan, ATmosphère, Cliamt et observations spatiales, UPMC et ENSTA-Paris, Encadrants: H. Berger et A.M. Treguier.
Kirsten du Plessis, 2012: Provisional thesis title: Relationship between SAM, ENSO and the position of the subtropical front in the southern Ocean. Supervisor: Prof Chris Reason, University of Cape Town.
Sarah Yates, Provisional thesis title: Investigating seasonal and interannual variability of the poleward undercurrent in the Benguela System. Supervisor: Dr Jenny Veitch and Dr Mathieu Rouault, University of Cape Town.
Filippa Fransner: Effect of model setting on western boundary currents in an eddy-resolving model. Supervisor: Dr. B. Barnier. Université de Grenoble.

8.6. Newsletters

Ferry N., Parent L., Garric G., Barnier B., Jourdain N. C. and the Mercator Ocean team, 2010: Mercator Global Eddy Permitting Ocean Reanalysis GLORYS1V1: Description and Results. *Mercator Ocean Quarterly Newsletter* #36, January 2010, 15-27.
Meinvielle M., P. Brasseur, J.-M. Brankart, B. Barnier, T. Penduff, J.-M. Molines, 2011, Optimally improving theatmospheric forcing of long term global ocean simulations with sea surface temperature observations, Mercator Quarterly Newsletter, 42, 24-32.
Juza M., Penduff T., Barnier B., 2011: How should the Argo array be extended to better monitor the Global Ocean heat content variability? *Mercator Ocean Quarterly Newsletter* #41, April 2011, 41-48.
Ferry N., L. Parent, G. Garric, C. Bricaud, C-E. Testut, O. Le Galloudec, J-M. Lellouche, M. Drévillon, E. Greiner, B. Barnier, J-M. Molines, N. Jourdain, S. Guinehut, C. Cabanes, L. Zawadzki, 2012: GLORYS2V1 Global ocean Reanalysis of the Altimetric Era (1993-2019) at Mesoscale. Mercator Ocean - Quarterly Newsletter, #44, January—28

8.7.Drakkar reports

Drakkar reports are available from the web site www.drakkar-ocean.eu.

2010: Evaluation of the NATL12-BRD81 simulation. R. Dussin and A.M. Treguier, LPO report LPO-2010-03.

2011: Definition of the interannual experiment ORCA12.L46-MAL95, 1989-2007. Lecointre A., Molines J.-M., Barnier B. LEGI-DRA-23-10-2011

2011: Definition of the interannual experiment ORCA12.L75-MAL83, (1978-1982 and ORCA12.L46-MAL83/84/85 (1978-1982 and 1978-1992) Lecointre A., Molines J.-M., Barnier B. LEGI-DRA-23-10-2011

2011: Collocation and validation tools. Juza, M., LEGI, Grenoble.

2012: NEMO3.4 performance tests with ORCA12.L46 on JADE (GENCI-CINES supercomputer, A. Lecointre, MEOM-LEGI-CNRS, LEGI-DRA-2012-05-11, 2012.

9. Distribution of Drakkar simulations

This is the list of the know users of the DRAKKAR 1/4° and 1/12° experiments for years 2010-2012. "Drakkar contacts" in the table are B. Barnier, G. Madec, T. Penduff, J.M. Molines, A.M. Treguier, J. Le Sommer. There are 40 entries, from French laboratories (mainly LEGI, LPO, LOCEAN, but also LEGOS, LGGE, IFREMER), from other labs participating in Drakkar (NOCS Southampton, IFM-Geomar Kiel) and other laboratories in the world (Spain, Mexico, U.S.A., Australia, Denmark, Brasil, Russia, South Africa...).

User Name	Lab	Drakkar contact	Region	Experiment	Theme	Collaborations
Akuetevi Q.	LEGI	BB	Indian Ocean	ORCA12.L46-MAL95		B. Barnier A. Wirth
Babonneix A.	LEGOS	JLS	Tropical Pacific	ORCA12.L46-MAL95		J. Le Sommer ???
Chazal-Dibon T.	LEGI/UJF	BB	Gibraltar Strait	ORCA12.L46-MAl95	Regional dynamics and tracer at the entrance of the Med. Sea	B. Barnier
Cheng Y.	DTU (Denmark)	TP	Arctic Ocean	ORCA025-G70 ORCA025-G70fo		???
Cravatte S.	LEGOS/IRD	JMM	Tropical pacific	ORCA025-G70 ORCA025.L75-G85	Salinity	B. Barnier
Deremble B.	FSU (USA)	TP	North Atlantic	NATL12-BAMT20	Mode waters	T. Penduff, A-M. Treguier
Deshaye J., Biastoch A.	LPO, and GEOMAR Kiel	JMM	South Atlantic section	ORCA12.L46-MAL95 ORCA12.L75-MAL83 ORCA025.L75-MJM95 ORCA12.L46-MAL950/ MAL83/MAL84/MAL85	Salinity contribution to MOC	A.M. Treguier, A. New
Djath N.	LEGI	JMM	Solomon Sea	ORCA12.L46-MAL95	Regional modelisation	J. Verron L. Gourdeau
Durand F.	LEGOS/IRD	JMM	Tropical Pacific	ORCA246-G70 ORCA1-R70 ORCA05-G70.114 ORCA025-G70	Tropical Dynamics	B. Barnier
Duval T., Arnaldi B., Blayo E.,	Immersia Rennes, IMAG/INRIA, LPO	AMT	Carribean	ORCA12.L46-MAL84	3D Data visulation test	A.M. Treguier, E Blayo
Ferrer A.	U. Sao Paulo (Brasil)	BB	SE Pacific, SW Atlantic	ORCA025.L75-G85		B. Barnier
Fransner F.	LEGI	BB	Boundary current	ORCA12.L46-MAL95 ORCA12.L46-MAL85 ORCA12.L46-MAL84	Dynamics of Western Boundary currents	B. Barnier, J. Hirshi
Gulev S.	SIO (Moscow)	BB	Global	ORCA025-G70	Forcing response	B. Barnier
Hausson A. Cravatte S. Delcroix T.	LEGOS/IRD	JMM	Tropical Pacific	ORCA025.L75-MRD911	Tropical mode waters	B. Barnier, T. Delcroix, S. Cravatte
Jourdain N.	LEGI	BB	Labrador Sea	ORCA025.L75-MJM91b ORCA025.L75-MJM95 ORCA025-G70fo	Boundary conditions and regional strudy	B. Barnier
Koch-Larrouy A.	LEGOS	JLS	Austral	ORCA025-MJM01	Tracking of Antarctic Mode waters	J. Le Sommer
Lazar A.	LOCEAN/LOP	JMM	Tropical Atlantic	ORCA025.L75-MRD911	Salinity strudies	B. Barnier
Lengaigne M	LOCEAN	GM	Tropical Pacific	ORCA025-B83	ENSO/ IOD	A. Santoso (Australia), India
Levy M., Martinez E.	LOCEAN/LOV	JLS	North Atlantic	ORCA025-G70	Carbon cycle	J. Le Sommer
Marin F. Jouano J.	LEGOS	JMM	Tropical Atlamtic Caribbean	ORCA025-G70 ORCA025-G70fo	Tropical Dynamics	B. Barnier
Mathiot P.	UCL (Louvain)	JMM	BSF Austral	ORCA12.L46-MAL95 ORCA025.L75-MJM95	Barotropic transport	B. Barnier
Meyssignac B.	LEGOS	TP	Tropical Pacific SSH,SST SSS global	ORCA025-MJM01 ORCA025-B83	Sea Level variability over 1058-2009	T. Penduff
Pares A.	CICESE (Mexico)	BB	Eastern Pacific	ORCA12.L46-MAL95		B. Barnier
Penduff T.	LEGI/FSU	TP	Global	ORCA025-MJM01 ORCA025-B83	Intrisic variablility	W. Dewar, E Chassignet
Rousset C.	LOCEAN	JMM	Svalbard Area	ORCA12.L46-MAL95	Regional modelisation	G. Madec
Sekma H.	LOP	JLS	Kerguelen Area	PERIANT8-GJM04		J. Le Sommer

						Y. Park
Sen Gupta A. Horenkamp C.	UNSW (Australia)	AMT	Austral Sector south of Africa	ORCA025-G70		A-M. Treguier
Singh A.	LEGOS	TP	Tropical Pacific	ORCA025.L75-G85		T. Delcroix
Treguier A.M, Talley L.	LPO/ Scripps, USA	AMT	Sections at 25N and 30S	ORCA025-G70 ORCA025-MJM01 ORCA025.L75-G85	Meridional transports of salt	A.M. Treguier, L. Talley
Venaille A.	LEGI	JLS	Zapiola Anticy-clode	ORCA025-MJM01	Variability of the Zapiola anticyclone and driving processes	J. Le Sommer
Vidal E.	UIB (Palma de Mallorca)	BB	Mediteranean Sea	ORCA025-G70 ORCA025.L75-G85 ORCA025.L75-MJM91b ORCA025.L75-MJM95 ORCA12.L46-MAL95	SSH variability, Tracer variability	B. Barnier
Rouault Mathieu, Golhen Mathieu	UCT Cape Town, South Africa	AMT	South Altantic	ORCA025-G70	Variability of the "Ben-guela nino" events	A.M. Treguier
Philip Sura	Dpt Meteo, FSU	TP	global	ORCA025-G70 OR-CA05-G70 ORCA1-G70 ORCA246-G70 RO-CA025-D025	Analyse de Skewness et Kurtosis de la SLA (colocalisée AVISO) dans les simus	T Penduff, S. Gille
Dudley Chelton, Michael Schlax	COAS - Oregon State University	TP	global		Eddy tracking	T Penduff, M Juza,
Antoine Grouazel	LPO Ifremer	AMT	Subpolar Atlantic	ORCA025-G70	Stage de master: varia-bilité du courant Est Groenland	OVIDE (N. Dani-ault)
Damien Desbruyeres	LPO Ifremer	AMT	Subpolar Atlantic	ORCA025-G70	Thèse sur la variabilité de la dérive Nord Atlan-tique	OVIDE (V. Thier-ry)
Guillaume Maze, Lukas Vollmer	LPO Ifremer	AMT	subtropical Atlan-tic	NATL12	Etude de la formation des eaux modales sub-tropicales	J. Deshayes
Rennelys Perez	NOAA Miami	AMT	South Atlantic	ORCA025.L75-G85	Variability of the MOC	S Garzoli, A.M. Treguier
Martin Huret	Ifremer Nantes	AMT	English channel	ORCA025-B83	Open boundary for a long experiment with the MARS model (MANGA)	
S. Theetten	Ifremer Dyneco Brest	AMT	North East Atlantic	ORCA025-B83	Boundary conditions for regional model (MARS)	P. Lazure, V Garnier, F. Du-mas
H. Berger	Actimar Brest	AMT	Tropical Atlantic	ORCA025-B83	Boundary conditions for tropical Atlantic model	P. Craneguy, A.M. Treguier