Report of the DRAKKAR Workshop
Grenoble, 3-5 february 2020

[Link to the workshop website]

Organizing committee

Bernard Barnier (CNRS, IGE), Arne Biastoch (GEOMAR), Claus Böning (GEOMAR), Julie Deshayes (CNRS, LOCEAN), Joël Hirschi (NOCS), Camille Lique (IFREMER, LOPS), Adrian New (NOCS), Anne Marie Treguier (CNRS, LOPS).

The agenda was organized in four oral sessions and a poster session.

1. Ocean variability and processes in high resolution models
2. Understanding and modelling ocean-ice-atmosphere interactions, and their consequences for climate
3. Progresses in numerical modelling and model data analysis techniques
4. Understanding and modelling the ocean mixed layer and its heterogeneity

The subject of the last session was chosen in line with the new project MEDLEY, MixED LayEr HeterogeneitY, funded by the joint programming initiatives Ocean & Climate. MEDLEY participants took the opportunity of the Drakkar workshop to hold a preliminary meeting on the wednesday afternoon.

The list of participants is included in this report (annex 1) as well as the list of abstracts (annex 2). Presentations are available on the meeting web site (password-protected).

1 Sessions highlights

1.1 Ocean variability and processes in high resolution models

A number of novel analyses of ocean processes using NEMO-based numerical simulations at high resolution were presented. The nested configuration VIKING20X of the Atlantic at 1/20°, developed at GEOMAR, has been used to document the influence of the mesoscale variability on the Deep Western Boundary current and the connectivity of the current between 26°N and 16°N, the latitudes of the RAPID and MOVE observations (T. Schulzki). The wind driven oscillations of the meridional overturning near the equator (an amplitude of 200 Sv in the Pacific over periods of a few days) have been analyzed and related to linear wave processes (A. Blaker, NOCS). Two talks based on DRAKKAR configurations at 1/12° and 1/4° focused on the Arctic Ocean: a study of the pathways and processes of dense water cascading (M. Luneva, NOCS) and a study of the seasonal cycle of eddy kinetic energy in the Beaufort Sea (H. Regan, LOPS).

Two new studies based on the **OCCIPUT large ensemble** of forced global 1/4° simulations were presented: a decomposition of the South Atlantic heat budget variability into forced and chaotic components (T. Penduff) and a study of the bimodal variability of the Kuroshio from a dynamical system perspective (G. Fedele, University of Venice).

Another highlight of this session was the new **high resolution NEMO configurations coupled with the atmosphere**. J. Kjellsson presented the FOCI strategy (GEOMAR) and the first results of the nested 1/10° North Atlantic nested into ORCA05, coupled with the atmospheric IFS model (ECMWF) with resolutions of 125km or 25km. A.M. Treguier (LOPS) presented an analysis of the Nordic Seas heat budget in a ORCA12 global coupled simulation run by the U.K. Met Office. In his invited talk, M. Roberts (MetOffice) presented results of coupled high resolution simulations carried out in the context of HighResMip (which is part of the Climate Model Intercomparison project CMIP6). Different ocean resolutions have been investigated in a systematic way (ORCA1, ORCA025, ORCA12). The good performance of ORCA12 for the representation of the AMOC was noted. In the Met Office simulations, the ACC transport is largest with ORCA1, and lower in ORCA025 compared with ORCA12. This suggests that the 1/4° grid may suffer from both an incomplete representation of mesoscale eddies and a lack of parameterization of their effects. The coupling of a high resolution ocean with a high resolution atmosphere seems key to obtain the right life cycle of eddies (ongoing work).

1.2 Understanding and modelling ocean-ice-atmosphere interactions and their consequences for climate.

Ocean-atmosphere interactions:
- P. Hyder (Met Office) presented a new framework of joint analysis of Coupled CMIP5 models and atmosphere-only, SST-forced AMIP5 simulations, that help to understand the source of coupled SST errors: ocean advection/diffusion or atmosphere (especially cloud-modified radiation). In coupled models, SST biases that are generated in the Southern Ocean propagate to the tropics. Such a propagation of SST biases does not happen in forced ocean-ice simulations, because bulk formulae computed with a fixed atmospheric state damp SST anomalies.
- A new atmospheric boundary layer model is being develop to overcome some of the drawbacks of forced ocean models. This work has been presented and discussed at previous DRAKKAR workshops. This year, T. Brivoal (Mercator-Ocean) reported result of the ABL1D model implemented in NEMO3.6 applied to the IBI (Iberia-Biscay) 1/36° configuration. The use of ABL1 allows to reproduce the wind-current feedback effects (cf L. Renault's invited talk at DRAKKAR 2019, and his papers), both the damping of eddy kinetic energy and partial re-energization of the wind. The next development will be to move to a 3D ABL, which will allow to represent the SST feedback in ABL/forced ocean simulations.

Ocean-ice interactions:
- G. Boutin (NERSC) presented results on the effect of coupling ocean-ice simulations with surface waves parameterizations. The wave parameterization has a significant effect in the case considered here, of a storm in the Barents sea.
- T. Martin (GEOMAR) used the FOCI coupled simulation (VIKING 1/10 coupled with ECHAM6) to study the effect of land-ice melting in Greenland on the ocean, at various resolutions. Regarding SST, the response of the coupled system appears to differ from the response to similar perturbations applied in forced ocean models.

1.3 Progress in numerical modelling and model data analysis techniques.

DRAKKAR workshops welcome modellers from **outside the NEMO community**, to share their expertise on different numerical methods, tools, and scientific analyses. Two talks were presented this year by S. Griffies (GFDL, MOM6 model) and M. Petersen (LANL, U.S. DOE, MPAS model), as well as a poster about the AWI climate model using FESOM (P. Schloz).

S. Griffies' invited talk was a synthesis of new knowledge on vertical Lagrangian-remapping and spurious diapycnal mixing in ocean models. The latter is a problem for climate-relevant simulations. Progress in designing and implementing physically-based mixing parameterizations in the models has no impact, if spurious numerical mixing induced by advection schemes is larger than the parameterized physical mixing. The talk discussed the different approaches to Lagrangian vertical coordinates (the material will appear soon in a paper in JAMES). In multidecadal and centennial coupled climate simulations, the hybrid isopycnal-z coordinates in MOM6 allows a significantly lower drift in temperature and heat content compared to z coordinates.

M. Petersen presented MPAS-O, Model for Prediction Across Scales, the ocean component of E3SM, the Energy Exascale Earth System Model developed by the DOE (US Department Of Energy). The 2018 version of MPAS had a moderately variable mesh (grid scale varying by a factor of 2 or 3). New configurations are being developed with higher mesh refinement for the coastal Arctic Ocean and the coast of the U.S.

In a similar spirit of "modelling across scales", C. Roberts (ECMWF) presented the impact of increased ocean model resolution in the ECMWF coupled forecast model. All ECMWF forecasts are coupled, using NEMO and LIM2. The impact of ocean resolution depends on forecast lead time: at subseasonal lead times in particular, increased ocean resolution (from ORCA1 to ORCA025) improves forecast skill over Europe.

Three talks in this session described developments of NEMO (ocean and ice).
- S. Hatfield (ECMWF) presented preliminary results from running NEMO with simple precision arithmetic at ECMWF. The speed up for ORCA025 can be up to 1.5, but some problems remain (due to "inexact' and "underflow" arithmetic errors, probably linked with sea ice & iceberg module?). The work is ongoing.
- J Sterlin (UCL) tested different methods to represent melt ponds in the sea ice model LIM3
- J. Le Sommer reported on the latest NEMO developments in the context of the European IMMERSE project. IMMERSE supports a number of the evolutions planned for the NEMO 4.2 release in 2021 (2-level time step, vertical refinement in AGRIF, tiling and loop fusion for better performance, surface forcing improvement with ABL and other physics. Testing at high resolution and new tools for sharing of configurations are also being developed.

1.4 Understanding and modelling the ocean mixed layer and its heterogeneity.

This session was organized by the project MEDLEY (MixED LayEr HeterogeneitY), and consisted of five presentations followed by a short presentation of the MEDLEY project and discussion points.

The **presentations** covered contrasted regimes of mixed layer variability. In his invited talk, C. Buckingham (LOPS) focused on the effect of submesoscales on the mixed layer turbulent kinetic energy budget (TKE). This presentation brought together observations from the OSMOSIS experiment (U.K.) and high resolution modelling. At the OSMOSIS location (North East Atlantic) dissipation due to surface processes dominates the effect of submesoscales (the latter resulting mainly from symmetric instability). D. Calvert (Met Office) presented the new OSMOSIS mixed-layer scheme that has been implemented in NEMO, a comparison with TKE and with observations, and the combined effect of the Fox-Kemper parameterization with OSMOSIS. P. Myers (University of Alberta) compared the Labrador Sea convection in models at various resolutions (1/4°, 1/12°, 1/60°). With CGRF forcing the highest resolution configuration does not show any deep convection (contrary to observations). Comparisons show that besides horizontal resolution (resolving or not the mesoscale and submesoscale), vertical resolution (change from 50 to 75 layers) as well as atmospheric forcing (CGRF vs. DFS) are important for the depth and properties of winter mixed layers. Finally, two presentations evaluated surface ocean dynamics in coupled mode, in the Mediterranean in the case of extreme cooling events (R. Waldman) and in salinity-stratified regions of the tropical Atlantic (M. Gevaudan).

Discussion points: science questions relevant for the MEDLEY project
- consider ocean processes vs atmospheric processes leading to mixed layer heterogeneity, and also the specificities of simulations forced or coupled to the atmosphere. The atmospheric heat capacity is assumed to be infinite in forced runs; the mixed layer tends to be shallower in coupled runs with the correct atmospheric heat capacity.
- need to consider the role of winds (for forced symmetric instability) as well as air-sea buoyancy flux. Both are important for the mixed layer evolution.
- Do we know the role of sea ice roughness on ocean mixing at the bottom of the ice? And conversely, the role of ocean mixing on sea ice roughness?
- many questions and progress to be made regarding the role of surface waves (surface waves and sea ice; role of swell on Langmuir cells and mixing; etc)
- Processes in the pycnocline are crucial, e.g., internal tides in the Arctic.
- Observations are needed: can we observe the mixed layer depth from space? Can we make better use of scattered observations like ARGO and ITPs?

Discussion points: scales of mixed layer heterogeneity and parameterizations
- Regarding the mixed layer heterogeneity, MEDLEY needs to clearly define the scales to focus on.
- Mixed layer heterogeneity depends on model resolution. Submesoscale eddy buoyancy fluxes have small spatial scales compared to the atmospheric forcing scale.
- Regarding ocean modelling for climate, ORCA025 (1/4°) falls in a "grey zone" in term of resolved physics vs. parameterized physics. Nevertheless, it is a resolution we will have to live with for some time in the future.
- In NEMO, the parameter "nn-etau" (additional penetration of TKE based on a geographical criterion) is not satisfying ("fudge factor" rather than physically based parameter).

1.5 Poster session.

This was the second year of having a poster session at a DRAKKAR meeting. The posters were on display for the whole meeting duration. Ample time was devoted to the posters during the first two days. 18 posters were submitted, which confirms the interest of the community for this type of presentation and interaction with other scientists. Posters covered the following themes.

Ocean variability and processes in high resolution models:
- Mesoscale energy budget in a gyre (Deremble et al)
- Sensitivity of Oceanic Fronts to nonlinearities of equation of state investigated using Numerical Experiments, using a global terrain-following NEMO configuration (Caneill et al)
- Ice shelf melt impact on the upper Southern Ocean heat content and its propagation using circumpolar Antarctic simulations, using a NEMO 1/4° circumpolar configuration (Pelletier et al)
- Sensitivity of a coastal polynya to forcing resolution and ocean-atmosphere feedbacks, regional modelling of the Mertz glacier in the Southern ocean with NEMO-LIM (Huot et al)
- Simulating changes in Southern Ocean tracer uptake and ventilation: CO2, CFC-12, and the role of mesoscale eddies, using a hierarchy of ORCA configurations et 1°, 1/4°, and nesting at 1/10° (Rieck et al)
- See-saw in the Indo-Pacific Oceanic mass: observations vs ORCA12 (A. Balkies Bai et al)
- Modelling the impact of flow-driven turbine power plants on great wind-driven ocean currents and the assessment of their energy potential, using ORCA12 (Barnier et al)
- Diagnosing eddy-to-small scale transfers in eNATL60 (Jamet et al)
- On the modulation of kinetic energy transfer by internal gravity waves in NATL60 (Ajayi et al)

Two posters presented results of the **OCCIPUT large ensemble**, complementing the two oral presentations in session 1: Forced and chaotic variability of interannual variability of regional sea level and its causes over 1993-2015 (Carret el al) and Forced and intrinsic variability of North Atlantic mode waters at interannual time scale (Narinc et al).

Three posters described **developments for operational oceanography**:
- Overview of the first year of the NEMO global 1/36° configuration (ORCA36) development at MERCATOR and BSC (C. Bricaud)
- Overview of the different ice-ocean prediction systems in operations & development at Environment Canada and their applications for Canada's Oceans Protection Plan (Paquin et al)
- High-resolution operational port modelling in Canada (Dunphy)

Two posters presented results of **coupled ocean-atmosphere simulations**:
- Sensitivity of Southern Ocean biases to coupling frequency and mixing in the coupled NEMO setup FOCI (Wahl et al)
- A strong Arctic-driven centennial AMOC variability in the CNRM-CM6 climate model (ORCA1, Waldman et al).

Finally, two posters presented **new model developments**:
- AWI climate models: From global to regional scales and new features of FESOM2.0 (Scholz et al)
- Overflow representation at ¼ degree resolution in NEMO (Mathiot et al)

2 Discussions

2.1 Conclusions of the COMMODORE conference

F. Lemarie presented the objectives of the conference that was held in Hamburg, 28-31 january (see COMMODORE web site https://www.conferences.uni-hamburg.de/event/76/ for the programme). COMMODORE aims to establish a more systematic bridge between methods used and developed by the applied math community and the ones used in realistic oceanic models. The focus of the conference was on numerical solution techniques of the partial differential equations that govern the ocean circulation from coastal to large scales, and sharing experience on numerical model development, perspectives on future model developments, and common test-cases to evaluate numerical models. This was the second workshop, after the first one held in Paris in September 2018 (see meeting report in BAMS, Lemarié et al, 2019, "Advancing Dynamical Cores of Oceanic Models across All Scales").

Many ocean models were represented: coastal and global, structured and unstructured grids, hydrostatic and nonhydrostatic. There were participants from the LES community and CFD codes, including a multiphase one. A collective paper: ”*Challenges and prospects for dynamical cores of oceanic models across all scales*” is in preparation for JAMES, in a new special issue on oceanic dynamical cores. The scope will include test cases for model evaluation.

Discussion items :
- Concept of "seamless" modelling between coastal and global ocean?
- is there an optimal model diversity? Some models disappear (Hycom is targeted to merge into MOM6). COMMODORE allows the ocean modelling community to exchange new ideas/news ways to build models.
- Testing models: there is a question of engineering (quick automatic tests, "unit testing"...) and a question of physics (evaluate parameterizations). Need to define community wide, clean, robust test cases. Need to find fair ways to compare, say, structured and unstructured grid solutions.
- Adapting to HPC, GPU, heterogeneous architectures.
- Issues of distributing and handling the data produced by the models were also discussed at the COMMODORE meeting. Related to this point, J. Le Sommer announced that the second meeting of PANGEO-Europe in will take place in June (cf PANGEO presentation by R. Abernathey at the DRAKKAR workshop in 2019).

2.2 Discussion: On the usefulness of moving towards higher resolutions : what do we actually gain?

- The drive towards higher resolution is present for all applications. The European IMMERSE project is driven by the needs of operational oceanography. The plan is to go to 1/36° globally

(see poster by C. Bricaud), and at higher resolution for regional systems (IBI at 1/100° for example). IMMERSE also deals with issues of initializing such high resolution forecasts.
- The improvement in the representation of the mesoscale by refining the grid into the sub-mesoscale regime is documented more and more. For example, R. Schubert's Ph.D. (Geomar) shows improvements at 1/60° but even at 1/20°.
- Ocean modelling for climate: it is now possible to run ORCA12 for hundreds of years. 1/12° is considered high resolution in the climate community. At this resolution, no mesoscale eddy parameterization is used.
- High resolution models for climate should strive to improve the representation of processes leading to carbon uptake by the ocean.
- The hydrostatic limit: the plan for NEMO is to remain in the hydrostatic regime. The model should operate at resolutions of 500m-1km in this regime. The community of CROCO (formerly ROMS-AGRIF) considers using the nonhydrostatic option for resolutions of 750m and finer.
- A driver for higher resolution models is the availability of high resolution observations (for example, context of the future satellite SWOT). A consortium is trying to make use of a special phase of the SWOT mission during which some regions will be revisited every day: organize measurements at sea and develop regional high resolution models
- High resolution models are costly in terms of carbon footprint. This raises the question of a better dissemination of results. Coarsening the model output at the model "effective resolution" could be a way. This has never been done in a systematic fashion in a project (it was considered for NATL60 but not pursued).
- The issue of tools to deal with high resolution models is raised. CDFtools (Fortran analysis routines) are not maintained by NEMO, but by Jean-Marc Molines (IGE) for the DRAKKAR community. They are difficult to use for some high resolution configurations. Should these tools evolve? Or is the future in PANGEO-type framework and cloud storage?

3 Conclusions relevant to the DRAKKAR IRN axes

3.1 DRAKKAR IRN axis 1: coordinating simulations and developments

“Lead the development of a coherent hierarchy of global model configurations based on the NEMO modelling framework, and in particular the development and improvement of the global 1/4° ORCA025 model and the 1/12° ORCA12 model. “

A proposition is made to work on a paper reviewing the expert knowledge gained by running DRAKKAR models at 1/12° (regarding NEMO options and parameterizations). This paper will be prepared for the special issue on NEMO in Geoscientific Model Development and be a legacy of the second phase of the DRAKKAR International Research Network.

3.2 DRAKKAR IRN axis 2: uncertainties

"Quantify the uncertainties in global numerical solutions of high resolution ocean models and their propagation. "

The scientific progress in this axis is driven by the analysis of the 56-year 1/4°-resolution global 50-member OCCIPUT ensemble. New results have been presented at this workshop (2 oral presentations and 2 posters). Beyond confirming the well-known fact that the chaotic/intrinsic part of the ocean variability spontaneously emerges as mesoscale features, these studies show that mesoscale features cascade subsequently toward much larger spatiotemporal scales, and contribute to feed a substantial part of climate-relevant climate variability in the ocean. In particular, the OCCIPUT ensemble simulations demonstrate that in eddy-active regions a large part of the interannual-to-multidecadal ocean variability remains uncorrelated with the atmospheric variability over scales ranging from O(1000km) to the scales of basins; this chaotic/intrinsic variability has a substantial imprint on SST, water mass properties and OHC (in particular in the Southern Ocean), AMOC and MHT, pathways and transports of main currents (e.g. Kuroshio), etc.

The variability and certain long-term trends in the ocean should thus be analyzed over most space and time scales as a combination of an atmospherically-driven (deterministic) component, and of a random-phased spatially-structured (chaotic) component. These findings raise important issues for the assessment, interpretation, detection and attribution of simulated and observed oceanic variabilities. The strength of interannual-to-multidecadal chaotic OHC and AMOC variabilities also suggest that the ocean may generate substantial sources of random variability that could drive atmospheric responses over the same range of scales, and affect present estimates of climate predictability (see DOI: 10.1175/JCLI-D-19-0295.1).

3.3 DRAKKAR IRN axis 3: towards higher resolution

"Develop and generalize the use of grid-refinement strategies (e.g. AGRIF) to study fine scale key ocean processes in their realistic global environment (downscaling) and to understand their role in the large scale circulation (up-scaling). This work will benefit from high resolution basin-scale frontier simulations."

This axis is the major focus of the groups and a large number of presentations and posters explore resolutions higher than 1/12°. It has been the subject of a discussion at the DRAKKAR meeting in 2019 and also this year (see section 2.2). Participants feel a need for sharing information about all aspects of the simulations in the "submesoscale permitting" regime (technical and scientific). The DRAKKAR workshops help fulfill this need.

3.4 DRAKKAR IRN axis 4: improved the representation of surface air-sea-ice interactions

The development of the ABL boundary layer model as a way to better "force" ocean models (see session 1.2) and the MEDLEY project (session 1.4) contribute to this axis.

3.5 General conclusion, and outlook

This DRAKKAR meeting was the last one organized by Bernard Barnier (who is planning his retirement). All participants thank him warmly for his welcome and his tireless dedication to this workshop during 15 years.

Next year (2021) will be the final workshop organized under the umbrella of the DRAKKAR International Research Network, with support from CNRS. The IRN has been in operation for 8 years (two 4-year terms) which is the maximum duration. The senior members of the DRAKKAR workshop organizing committee (Bernard Barnier, Claus Boning, Adrian New and Anne Marie Treguier) look forward future opportunities for scientific exchanges on NEMO-based high resolution models; such opportunities will be designed and proposed by a new generation of scientists.

ANNEX 1: List of participants

Registered Participants (80)

IGE - Grenoble (10): Bernard Barnier, Pedro Colombo, Jean Marc Molines, Ixelt Garcia-Gomez, Thierry Penduff, Olivier Narinc, Quentin Jamet, Takaya Ushida, Julien Le Sommer, Adekunle Ajayi
GEOMAR - Kiel (11): Arne Biastoch, Jan Klaus Rieck, Franziska Schwarzkopf, Wonsun Park, Joakin Kjellsson, Markus Scheinert, Klaus Getzlaff, Tobias Schulzki, Sebastian Wahl, Torge Martin, Jonathan Durgadoo
NOC - Southampton (4): Adrian New, Adam Blaker, Alex Megann, Simon Müller
Met Office Hadley Center - Exeter: (5): Malcom Roberts, Pat Hayder, Dave Storkey, Mike Bell, Pierre Mathiot
LOPS - Brest (5): Anne-Marie Treguier, Claude Talandier, Camille Lique, Heather Regan, Christian Buckingam
LOCEAN - Paris (4): Gurvan Madec, Casimir Delavergne, Antoine-Alexis Nasser, Sibylle Téchené
LEGOS - Toulouse (4): Alice Carret, Marco Larrañaga, Manon Gévaudan, Guillaume Morvan
UCL - Louvain la Neuve (3): Charles Pelletier, Jean Sterlin, Pierre Vincent Huot
AWI Bremerhaven (3): Dmitri Sidorenko, Qiang Wang, Patrick Scholz
Ocean Next - Grenoble (3): Aurélie Albert, Stéphanie Leroux, Laurent Brodeau
MERCATOR Ocean Intl - Toulouse (3): Clément Bricaud, Théo Brivoal, Olga Fernandez
IORAS Moscow (3): Polina Verezemskaya, Roman Sedakov, Natalia Tilinina, Sergey Gulev
ECMWF - Reading (2) : Chris Roberts, Samuel Hatfield
Los Alamos Natl. Laboratory (2) : Mark Petersen, Siddhartha Bishnu
NERSC - Bergen (2): Pierre Rampal, Guillaume Boutin
CNRM Toulouse (1): Robin Waldman
GFDL Princeton (1): Stephen Griffies
LIP6 - Paris (1): Marie Déchelle
Università di Venezia (1): Guisy Fedele
LSCE - Orsay (1): James Orr
LOC - Liverpool (1): Maria Luneva
University of Alberta - Edmonton (1): Paul Myers
University of Gothenburg - Sweden (1): Romain Caneill
Florida State University/IGE Grenoble (1): William Dewar
LMD Paris (1): Bruno Deremble
INCOIS - India (1): Afroosa Balkies Bai
Bedford Inst. of Oceanography, Canada (1): Zeliang Wang
DFO-MPO - Canada (1): Michael Dunphy
ECC Canada (1): Jean-Philippe Paquin

ANNEX 2: list of abstracts

Link to the book of abstracts

Session 1. Ocean variability and processes in high resolution models

1. Thierry Penduff (IGE Grenoble): Forced and chaotic variability of basin-scale heat budgets in the global ocean : focus on the South Atlantic crossroads.
2. Giusy Fedele (Univ. of Venice): Interannual-to-decadal variability of the Kuroshio Extension: Analyzing an ensemble of global hindcasts from a Dynamical System viewpoint.
3. Tobias Schulzki (GEOMAR Kiel): On the variability of the Deep Western Boundary Current transport between 26.5°N and 16°N in an eddy - rich ocean model.
4. Heather Regan (LOPS Brest): Investigating controls on the seasonal EKE of the Beaufort Gyre.
5. Zeliang Wang (BIO Canada): Characteristic evolution of the Atlantic Meridional Overturning Circulation from 1990 to 2015: an eddy-resolving ocean model study.
6. Joel J.-M. Hirschi (NOC Southampton): The Atlantic meridional overturning circulation in high resolution models.
7. Adam Blaker (NOC Southampton): Wind-driven Oscillations in the Meridional Overturning Circulation near the Equator.
8. Anne Marie Treguier (LOPS Brest) : Interbasin exchanges in the Nordic seas and their representation in the ORCA12 model.
9. Maria Luneva (NOC Liverpool): Dense water cascading in the Arctic Ocean and pathways of the Pacific water in the Canadian Basin.

Session 2. Understanding and modelling ocean-ice-atmosphere interactions and their consequences for climate.

10. Malcolm Roberts (Met. Office Exeter, solicited): Multi-century coupled climate simulations with an eddy-rich ocean.
11. Joakim Kjellsson (GEOMAR Kiel): Mesoscale-resolving coupled climate modelling with FOCI-OpenIFS-AGRIF.
12. Patrick Hyder et al. (Met Office Exeter): Global-scale climate model sea surface temperature biases traced to cloud errors.
13. Théo Brivoal (Mercator Ocean international, CNRM): Using a simplified unidimensional atmospheric boundary layer model to assess the impact of the current feedback on the oceanic kinetic energy (KE) trends over the North-East Atlantic.
14. Guillaume Boutin (NERSC Bergen): Impact of wave-induced sea ice fragmentation on sea ice dynamics in the MIZ.
15. Torge Martin (GEOMAR Kiel): Ocean response to enhanced Greenland melting.

Session 3 Progresses in numerical modelling and model data analysis techniques

16. Stephen Griffies (NOAA/GFDL, Princeton - solicited): The vertical Lagrangian-remap method, hybrid vertical coordinates, and the prospect of eliminating the spurious mixing problem in ocean climate models.
17. Chris Roberts (ECMW – Reading): Impacts of ocean model resolution in the ECMWF coupled forecast model
18. Alex Megann (NOC Southampton): Tuning around z-tilde in a 1/4° global NEMO.
19. Mark Petersen (LANL – Los Alamos): E3SM: The Earth System Model of the US Department of Energy.
20. Sam Hatfield (ECMWF Reading): Mixed-precision ocean modelling at ECMWF.
21. Jean Sterlin (UC Louvain): Representation of melt ponds for global ocean circulation models.

22. Julien Le Sommer (IGE Grenoble, solicited) : Improving ocean model physics, numerical kernel and HPC : ongoing steps towards NEMO v4.2

Session 4 Understanding and modelling the ocean mixed layer and its heterogeneity

23. Christian Buckingam (Univ. Brest, sollicited): The Contribution of Surface and Submesoscale Processes to Turbulence in the Open Ocean Surface Boundary Layer.
24. Robin Waldman (CNRM -Toulouse): The mixed layer heat budget of extreme cooling events in a regional climate model of the Mediterranean region.
25. Paul Myers (Univ. Alberta – Edmonton): Evolving Labrador Sea Water Formation with changes in model resolution.
26. Daley Calvert (presented by Mike Bell, UKMO Exeter): Parametrisation of sub-mesoscale and Langmuir circulations.
27. Manon Gévaudan (LEGOS Toulouse) : Influence of salinity stratification on the western tropical Atlantic ocean climate.

Poster Session

28. Jan Klaus Rieck (GEOMAR Kiel): Simulating changes in Southern Ocean tracer uptake and ventilation: CO_2, CFC-12, and the role of mesoscale eddies.
29. Robin Waldman (CNRM Toulouse): A strong Arctic-driven centennial AMOC variability in the CNRM-CM6 climate model.
30. Afroosa Balkies Bai (INCOIS India): See-saw in the Indo-Pacific Oceanic mass: observations vs ORCA12.
31. Sebastian Wahl (GEOMAR Kiel): Sensitivity of Southern Ocean biases to coupling frequency and mixing in a coupled NEMO setup.
32. Bernard Barnier (IGE Grenoble): Modelling the impact of flow-driven turbine power plants on great wind-driven ocean currents and the assessment of their energy potential
33. Romain Caneill (University of Gothenburg, Sweden): Sensitivity of Oceanic Fronts to nonlinearities of equation of state investigated using Numerical Experiments
34. ALice Carret (LEGOS Toulouse): Forced and chaotic variability of interannual variability of regional sea level and its causes scale over 1993-2015).
35. Michael Dunphy (DFO Canada): High-resolution operational port modelling in Canada
36. Pierre Mathiot (UKMO – Exeter): Overflow representation at ¼ degree resolution
37. Charles Pelletier (UC Louvain): Ice shelf melt impact on the upper Southern Ocean heat content and its propagation using circumpolar Antarctic simulations.
38. Quentin Jamet (IGE Grenoble): Diagnosing eddy-to-small scale transfers in eNATL60.
39. Jean-Philippe Paquin (Environnement Canada, Dorval): Overview of the different ice-ocean prediction systems in operations & development at Environment Canada and their applications for Canada's Oceans Protection Plan.
40. Patrick Scholz (AWI Bremerhaven): AWI climate models: From global to regional scales and new features of FESOM2.0.
41. Olivier Narinc (IGE Grenoble): Forced and intrinsic variability of North Atlantic mode waters at interannual time scale.
42. Clément Bricaud (Mercator Ocean International): Overview of the first year of the NEMO global 1/36° configuration (ORCA36) development.
43. Pierre-Vincent Huot (Univ. C. Louvain) : Sensitivity of a coastal polynya to forcing resolution and ocean-atmosphere feedbacks.
44. Bruno Deremble (LMD – Paris): Mesoscale energy budget in a gyre.