NEMO prospective at Mercator-Océan

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"NEMO for ocean forecasting and reanalysis systems".

This document is not Mercator Océan's precise workplan but a list of suggestions of what should be tackled considering the known model deficiencies and possible evolutions of our operational systems. The "scientific prospective for Operational Oceanography" being in progress in the French community, Mercator Océan's directions for NEMO developments will consequently adapt to new objectives. At the time of writing this document, the exact target resolution of the future global operational system is being discussed. It is however expected that:

i) the new system will push the results into a fully eddy-resolving regime which is only partially the case with the actual global 1/12° ORCA grid. Considering in addition the possible evolution towards probabilistic ensemble forecasts, this put a strong constrain on the efficiency of new code developments.

ii) there will be a need for an increase of the horizontal/vertical resolution over French shelves (including French overseas territories) and/or in specific regions such as narrow straits or overflows regions.

1 INCREASE RESOLUTION: FROM GLOBAL MESOSCALE TO REGIONAL SUBMESOSCALE

1.1 Numerics

Needs : improve the resolution and/or the effective resolution of NEMO, increase regionally the resolution, simulate at global scale eddies, meanders, fronts … and smaller scale structures as river plumes, filaments, small eddies … Improve interaction with boundaries. Relax some approximations: Boussinesq/hydrostatic (quasi non hydrostatic would be a fairly easy first step) and study their effects in eddying simulations.

1.1.1 HORIZONTAL GRID

- **AGRIF must be fully operational whatever the chosen numerical option**: For instance, whatever the free surface option: filtered/split- explicit in "one"

or “two-ways”; It should handle different choices of vertical coordinates in parent/child grids.

- **Enable the use of AGRIF with other components: sea-ice and BGC model.**
- **AGRIF and MPP** (parallelization optimization)
- Unstructured (vs actually rectangular) refinement near coasts (thanks to AGRIF capabilities ?) and/or vertically near the bottom.
- Online coarsening for BGC model or sea-ice model.
- New global grid, Tool to build/tune new grids.

1.1.2 *VERTICAL DISCRETIZATION*

- The generalized coordinate framework must allow the **use of combined partial cells and s-coordinates.** Diffusion operators (isopycnal, iso-level, geopotential) as well as hydrostatic pressure gradient computation should be updated accordingly.
- **A full working z~ coordinate** (Leclair & Madec, 2011) is a strong need to minimize numerical dissipation, especially to move to global, climate, forward tide modeling.

1.1.3 *NUMERICAL SCHEMES*

- **High order** time-space **numerical schemes**. We encourage the development of new numerical schemes in order to improve time stepping accuracy or increase the effective spatial resolution. The current horizontal effective resolution in Mercator’s operational systems is around seven times the grid size which can be improved if one refer to the work done elsewhere (it seems reasonable to expect five times or less). Limiting the implicit numerical diffusion in the model, which is the main focus here, should allow for instance the explicit simulation of tides without excessive numerical erosion of water mass properties (cf work on arbitrary lagrangian coordinates by Leclair and Madec, 2011).
- New temporal scheme for biogeochemistry.
- Relax some approximations: Boussinesq/hydrostatic (quasi non hydrostatic would be a fairly reasonable first step) and study their effects mainly for reanalysis purposes and in fully eddying simulations.
- Treatment of lateral boundaries in particular for Coriolis terms should be clarified (in light for instance of the recent work of Ketefian and Jacobson 2009).

1.2 Parameterizations/additional physic

- **Tides:**
  - Explicit global tidal modelling. Need for internal wave drag parameterization accounting for explicitly resolved internal waves. Need for simple as well as maybe more elaborate SAL parameterizations.
  - Mixing induced by unresolved internal waves.
- **Wave coupling:** implement relevant terms outside littoral zone.

2 INTEGRATED SYSTEM

Needs: NEMO needs to be interface with other component of the earth system (atmosphere, sea ice, land, biogeochemistry) with several degree of complexity depending of its application.

2.1 Online coupling with atmospheric boundary layer model:

Needs : Evolution of the NEMO surface module including an atmospheric boundary layer which can allow a coupling with wave model and can provide better resolution and higher frequency of atmospheric forcing.

- Including online Wave model coupling
- **Surface forcing: toward high resolution/high frequency ocean atmosphere coupling.**

2.2 Coupling with land (hydro) models (improvement of runoffs module):

Needs : At global as at local scale interaction of the ocean with land take place in river mouth. Heterogeneity of the data (from observations, satellite or insitu and models, for physics and biogeochemistry) have to be take into account in the runoff module (robustness, flexibility, …)

- Prepare an interface for dedicated objectives and different origins (model, data, and climatology).
- Prepare the model to get more real volume fluxes from hydrological models constrained by SWOT.
- Handle runoffs with nutrients and temperature (and salinity).
- Coupling with river estuaries models.

2.3 Coupling with sea-ice

Needs : LIM is identified as the standard sea ice model, adaptation and evolution of this component for representation of high resolution and high frequency phenomena and interaction with Ice shelves, Iceberg …

2.3.1 ICEBERGS MODEL :

- full explicit model implemented in NEMO
- Impact of the stream flow near the coast.

2.3.2 ICE CAPS AND ICE SHEETS INTERACTIONS:

- Fluxes (freshwater) signal from satellites in real time? Systems able to handle fast modification of coastlines.
- Ice shelves model : be able to represent explicitly increasing exchanges between ice shelves and upper layers of the ocean
- Rheology more adapted tor high resolution flows: granular scheme?
- Representation of land fast ice.
- Towards a general shift to multi-category sea ice models with prognostic salinity, melt ponds, snow model etc… Need to develop assimilation scheme to handle different categories over one grid mesh.

2.4 Coupling with oceanic biogeochemistry

Needs : PISCES is identified as the standard biogeochemistry model, adaptation and evolution of this component for representation of higher frequency phenomena as the diurnal cycle and the tide toward a shelf modelisation of the biogeochemistry processes including interaction and input of the rivers.

2.4.1 BIOGEOCHEMICAL PROCESSES:

- Impact of biogeochemistry on physics.
- Diurnal cycle.
- Develop upper trophic level in PISCES for operational applications?
- Coupling PISCES with tides.
- High frequency forcing from physics for biogeochemistry.
- Sedimentary module.

3 OTHERS

3.1 Model/observation operator

Needs : Even if the assimilation topics is outside the NEMO prospective, the use of NEMO for operational oceanography is linked to assimilation scheme and/or the comparison between model output and observations. Interface between NEMO and observation dataset has to continuously evolved to take into account new type of observation and especially high frequency and high resolution observation.

- Adaptation of observation operator to use GRACE/SWOT/gliders/radar HF/BGC data.
- Availability of a shared observation dataset (among consortium developers) compatible with Model/observation operator.

3.2 NEMO environment

Needs : NEMO has to keep a "readable" code to be shared by the operational and the research community, new versions of NEMO have to be regularly (but not every year) updated that include new options and cleaning in the code. The NEMO user interface has to be developed and improved.

- New reference configuration including new data set for bathy, forcing,…
- Optimization of MPP, IO, in NEMO
- **Suppress obsolete options**
- **Interface to setup a relocatable system**