Questions to consider in the NEMO Development strategy 2017-2021

First draft : 7 July 2016, Mike Bell and Julien Le Sommer; to be updated by the members of NEMO Developers Committee.

The aim of these notes is to identify the issues that should be considered in the new version of the NEMO Development Strategy intended to be completed in summer 2017.

The proposed structure of the document is laid out in the table below. The chapters, their titles and order may evolve:

Chapter	Title	Contributors
1	Introduction	Claire Lévy and writing group
2	Target applications for NEMO by 2020.	Julien Le Sommer
3	HPC performance constraints	HPC group members
4	Future evolutions of NEMO ocean kernel.	Mike Bell and Gurvan Madec
5	Ocean dynamics component of NEMO	Julien Le Sommer and Mike Bell
6	Toward locally higher effective resolution: AGRIF	Jérôme Chanut and AGRIF WG
7	The assimilation and ensemble component of NEMO	Pierre-Antoine Bouttier and Dan Lea + ASSIM WG
8	The ice components of NEMO	Ed Blockley and Martin Vancoppennolle
9	Air sea interface and surface boundary layer physics	Laurent Brodeau and Gurvan Madec
10	The biogeochemical component of NEMO: TOP and its interface	Olivier Aumont and Tomas Lovato
11	NEMO validation and range of user support	Andrew Coward

As for the previous exercise, the purpose of each chapter is to identify area of consensus and remaining points of debate in order to guide the development of NEMO by 2021.The strategy should be based on careful assessments of the relevant scientific literature. In some instances it would be useful for reviews of the state of play to be described in more detail in a supplementary document to be linked to the strategy document.

Chapter 3 is new. It is introduced early in the document to emphasize its potential impact on other sections. Chapter 9 is new. It is introduced because of the specific needs and the specific expertise required; it will also reduce the scope of Chapter 5.

The assimilation section (Chapter 7) now also encompasses the modelling of uncertainty (ensemble considerations, stochastic closures).

There is another aspect of strategy: How to foster a vibrant community developing and using NEMO. This was not covered in the previous strategy document. Chapter 11 could consider ways of doing it.

1. Introduction

This chapter will give a brief explanation of the process, with a summary of the main conclusions from the previous strategy (e.g the simplification strategy, approach to enhanced resolution).

2. Target applications for NEMO by 2020.

This chapter will include a list of priority applications, their anticipated frontiers and the factors that currently limit the quality of our simulations; for example:

- What are the drivers for evolution from the point of view of the applications ?
- What are the main factors that limit the use of NEMO for higher resolution solutions (km range) in forced configurations: HPC, processes, sub grid physics, air-sea interactions ?
- Will we require non-hydrostatic capabilities ?
- Will we need to represent very intricate coastlines ?
- How important is the representation of tidal motions and internal tides for operational applications ?
- Are the sill overflows currently limiting the quality of climate simulations?
- Is there evidence that the level of implicit numerical mixing is limiting climate simulations ?
- …

3. High Performance Computing constraints :

This chapter will include an analysis of the target machine architectures for NEMO applications, of the actual performances / bottlenecks, of the relevant performance metrics and of the proposed ways forward by 2021. Contributions are expected from the HPC working group.

- Are the standard NEMO configurations (e.g. ORCA025) making effective use of the existing HPCs ? If not what are the main limitations ?
- What are the proposed strategies to improve NEMO's HPC performance
- How do we expect NEMO performance to scale in future ?
- How do we expect to use future HPC resources (e.g. larger ensembles, more model complexity, more use of multi-grid / parallel in time methods) ?
- What performance do we need for the future
- Do we expect to need flexibility to organize the code differently for different applications on HPC machines ?
- How can we improve model portability ?

4. Future evolutions of NEMO ocean kernel

This chapter will include an analysis of the current status of the code, of the future needs and of the proposed ways forward with respect to the core discretization and algorithms used in NEMO.

- A brief summary of the approach being implemented or planned for the time integration scheme and our use of higher order advection schemes.
- A brief summary of the energy diagnostics instrumentation of NEMO kernel.
- Is implicit numerical mixing still a major issue in our models ? Are we able to control it ?
- GFDL has made a lot of progress on hybrid z-level / isopycnal (ALE) coordinates. Do we need that approach as well as z-tilde ? Is that feasible ?
- A summary of new knowledge on relevant properties of triangular and hexagonal grids using finite volume and finite element methods (based on GungHo research)
- Are we able to control the routes for energy conversions in our models ? (do our discretisations avoid spurious modes of instability ?)
- How to use demonstration cases for guiding the choices wrt the evolutions of NEMO kernel ?
- …

5. Ocean dynamics component of NEMO

This chapter will include analyses on the required evolutions of NEMO-OPA in terms of explicit or parameterized representation of ocean physical processes in NEMO. The proposed evolutions should be in phase with the target applications. Relevant questions may include :

- *regarding explicitly represented ocean physics.*
    - how realistic are explicitly represented physical processes in the range 1-50km ?
    - what are the main limitations for an accurate representation of tidal motions ?
    - to what extent is internal wave dynamics affected by the code numerics? is the code adapted to represent energy exchanges between balanced and unbalanced dynamics ? (note overlap with previous chapter)
    - how can we instrument the code in order to accurately monitor the energy pathways in specific configurations ?
    - …
- *regarding parameterized ocean physics.*

  This encompasses mesoscale and sub-mesoscale eddy closures (momentum, tracers); interior and boundary mixing (note overlap with chapter 9);
    - status of closures included in NEMO and in the literature.
    - strategy with respect to scale aware closures.

- interaction / dependence of closures wrt code numerics
- rationale with respect to LES-type (Large Eddy Simulation) vs RA-type (Reynolds Averaged) closures (valid pointwise or valid statistically)
- rationale with respect to deterministic versus stochastic closures.
- is there a general framework that we should try to follow for enforcing the overall consistency of closure (cf Eden's work, Young's work) versus adhoc closures.
- how to monitor the impact of closure on energy cycles ?
- …

6. Toward locally higher effective resolution: AGRIF

This chapter will provide guidelines on the evolution and integration of AGRIF within NEMO. This will mostly be based on the current conclusions of AGRIF working group. Relevant questions may include :

- a critical assessment of the complexity and maintainability of the system (together with HPC issues). What are the maintenance costs expected to be ?
- what are the steps towards allowing communication between AGRIF nests ?
- can AGRIF solve the overflow problem ?
- to what extent could grid coarsening (e.g. for BGC variables) be reimplemented with AGRIF (mother grid)?
- …

7. The assimilation and ensemble components of NEMO

This chapter will provide guidelines as to the evolution of the NEMO component used for data assimilation and confrontation with observation. This also cover tools and methods for modeling/propagating model uncertainty. Contributions are expected from NEMO-ASSIM working group. Relevant questions may include :

- what are the future evolutions and ways forward for NEMO-TAM ?
- is NEMO-OBS adapted to handle dense 2D observations (geostationary ocean colors, wide-swath altimetry)
- what tools could be provided for better modeling the propagation of model uncertainty (ensembles, stochastic approaches, …) ?
- …

8. The ice components of NEMO

This chapter will provide a roadmap for the evolutions of cryospheric components and interfaces of NEMO. This includes : sea ice, iceberg and ice-shelves cavities. Input on sea-ice are expected from the WG on sea ice.

9. Air - sea interface and ocean surface boundary layer physics.

This chapter is a new chapter that will cover questions related to dynamical and thermodynamical exchanges at the air-sea interface. Relevant questions will for instance cover :

- ocean / atmosphere coupling interface,
- forcing of ocean component : bulk formulae, representation of atmospheric boundary layer processes.
- ocean/wave coupling interface
- sub-grid closure for ocean surface boundary layer (OSBL) processes :
    - coupling of lateral / vertical parameterizations in the OSBL
    - evolution of TKE/GLS closure, OSMOSIS closure ?
    - parameterization of spatially heterogeneous sub grid convection
- …

10. The biogeochemical component of NEMO: TOP and its interface

This chapter will cover questions related to the BGC components of NEMO. Relevant questions could cover

- genericity of the coupling interface
- how to improve the orthogonality between OPA and BGC components (eg : sedimentation)
- status of the coarsening capacity (see also chapter 6)
- rationale as to the trade off between complexity and cost.
- rationale regarding the representation of BGC model uncertainty and the use of stochastic closure for BGC (see also chapter 7)
- …

11. NEMO validation and range of user support

This chapter will cover questions related to the user uptake of NEMO model. To a large extent, relevant questions are covered by the activities of the Robustness / Config Manager WG. Relevant question may include :

- how to use demonstration cases in the development and validation processes ?
- how to foster the use of NEMO by a vibrant community of dynamicists in order to get an external perspective on the current limitations and possible evolutions of the code ?
- how to foster the maintenance of NEMO model configurations by NEMO users (and not by the system team)
- how to distribute the pre-processing / post-processing tools useful to work with NEMO?
- …