Summary of meeting to discuss introduction of 2-level-time-step (2LTS) schemes into NEMO

4 July 2018

Present: Andrew Coward, David Storkey, Gurvan Madec, Mike Bell

Agreed notes to be copied to: Jerome Chanut, Claire Levy, Julien le Sommer

The **aim** of the meeting was to discuss Gurvan's ideas for introducing 2LTS schemes into NEMO and start to build a plan for distributing the work (consistent with the IMMERSE proposal).

These notes describe:

- some algorithmic developments that need to be made before the longer time-step "promised" by the 2LTS schemes can be realised in practice
- the options for development and their pros and cons
- proposed re-organisations of the code in the trunk
- development of an RK3 prototype branch
- an initial list of code components that need to be considered
- a list of tasks and who could do them

Algorithmic developments

The adaptive, where necessary implicit, vertical advection scheme of Shchepetkin (2015) is needed to avoid vertical advection breaking CFL at hot spots. Andrew will implement this with assistance from Gurvan.

Because the time steps of the 3D fields and the depth integrated flow differ, the bottom friction on the two flows can differ significantly, particularly when the friction is calculated implicitly. Jerome has developed a technique which greatly improves their consistency (it works by doing a better job in projecting the profile of the drag onto the depth integrated velocity).

There are somewhat similar issues with the consistency of the drag between the upper ocean and sea-ice. These will need to be tackled in consultation with the SI^3 team when they have established the new code properly as they could have major implications for the modularity of the sea-ice and ocean codes.

Options for development

Developments to the trunk: The algorithmic developments noted above should be introduced into the trunk when they are ready. Some re-organisations of the code should also be introduced if: they are expected to have no impact on the results; they can be applied to the whole code and will not break any of the functionality tested by SETTEE; it is clear that they are the best approach to take.

Developments to branches: Some (further) prototyping of RK3 on the core dynamics is expected to be valuable. The changes in such branches will not be applied to the whole code and would break the SETTEE tests. This exploratory code will have a short shelf-life.

Gurvan has developed ideas for developing a code that can support both 2LTS schemes and a Modified Leapfrog (MLF) scheme. This approach would allow results from the MLF option in the new coding framework to be (bit-?) compared with those from the old framework. Including the MLF option would complicate certain aspects of the implementation. Gurvan is not convinced that including an MLF scheme would be worth it. This needs more thought.

Re-organisations of the code

The meaning and calculation of rn_dt, rdt and r2dt need to be adjusted to make their meanings clean for the 2LTS and MLF schemes (Gurvan)

The main routines in TRA and DYN calculate the RHS of the tracer and momentum equations. Instead of incrementing ta or (ua,va) they should increment pRHS which should be an argument (intent in/out) of the subroutine.

The time dependent arrays (stored within OCE), including the e3 arrays, should have an additional index for their time-level. The dimension of this index normally would be 3 for MLF and 2 for 2LTS. Its name needs to be chosen carefully. The index (or for MLF in some routines the two indices) of the time-level(s) to be used to calculate the RHS need to be passed as input argument(s) to the DYN and TRA routines. A beneficial side-effect of this approach will be to allow the swap at the end of time-steps to be achieved simply by swapping the indices; this will reduce cache memory usage. Gurvan has prototyped passing both input and output time dependent arrays into the DYN and TRA subtroutines and concluded it was a nightmare.

Gurvan and Dave will develop some examples of (templates for) the pRHS and time-level index code. It would be useful to discuss these with the NEMO System Team before working through their implementation.

We (ruefully) agreed that the vector invariant momentum equations are a dead end. The impact of using the flux form of the momentum equations on standard ORCA025 and ORCA0083 configurations needs to be examined (Dave). The impact of Gurvan's re-formulation of the Coriolis term (f calculated at T points) could be tested at the same time with relatively little additional work. The vector invariant form should then be removed (Gurvan).

The following **additional** ideas would be valuable but are not (strictly speaking) part of the 2LTS work:

TRA should calculate the thickness weighted tracer tendencies. This is conceptually cleaner and will avoid nugatory multiplications and divisions by metric terms. Similar steps could be taken with the momentum equations if the flux (rather than the vector invariant) formulation is standard.

Options to allow NEMO to be run either as a pure barotropic or a pure baroclinic model would be useful.

Development of an RK3 branch

Gurvan will develop a prototype RK3 branch. Do the tests to be done need to be clarified (e.g. tests to ensure AGRIF will be OK)?

Initial list of code components to be considered

One of the main difficulties is to avoid breaking the following functionalities. The people mentioned are well placed to assist :

AGRIF – Jerome (AGRIF should be OK if the swap of time-levels is done right at the end of the code and the split-explicit time-steps are required only on the last sub-step of the RK schemes).

Boundary data – Dave

Passive tracers – Christian Ethe

Obs operator – Matt Martin

Sea-ice – Martin Vancoppenolle (major changes expected later)

Task List

ID	What	Who	Assisting	When
A1	Adaptive implicit vertical advection	Andrew	Gurvan	2018
A2	Consistent bottom stress	Jerome	Gurvan	2018
A3	Consistent ice-ocean stress		Gurvan	Later
T1	Impact of FF momentum on standard configurations	Dave	Mike	2018
T2	RK3 parameter exploration	Gurvan ?	Florian	?
T3	RK3 split-explicit	Gurvan		
O1	rn_dt	Gurvan		Summer 2018
O2	pRHS	Dave	Gurvan	2018 ?
O3	Time index	Dave	Gurvan	?

O2 and O3 might be tackled as one task.