Minutes of the NEMO Sea Ice Working Group (SIWG) meeting

31st January – 2nd February 2017, Paris

Attendance:

Ed Blockley (co-chair)	Met Office, Exeter, UK
Martin Vancoppenolle (co-chair)	LOCEAN-IPSL, Paris, France
Helene Hewitt	Met Office, Exeter, UK
Jeff Ridley	Met Office, Exeter, UK
Danny Feltham	CPOM, Reading, UK
David Schroeder	CPOM, Reading, UK
Yevgeny Aksenov	NOC, Southampton, UK
Clément Rousset	LOCEAN-IPSL, Paris, France
Gurvan Madec	LOCEAN-IPSL, Paris, France
Claire Lévy (NEMO Project Manager)	LOCEAN-IPSL, Paris, France
David Salas	Meteo France, Toulouse, France
Gilles Garric	Mercator Ocean, Toulouse, France
Thierry Fichefet	UCL, Louvain-la-Neuve, Belgium
Olivier Lecomte	UCL, Louvain-la-Neuve, Belgium

Apologies:

Paul Holland	BAS, Cambridge, UK
Matthieu Chevallier	Meteo France, Toulouse, France
Dorotea Iovino	CMCC, Bologna, Italy

[Tuesday 31st January (pm)]

Introductions:
The meeting kicked off with a round-table of introductions to get to know everybody, where they worked and what they work on.

The meeting chairs, Martin & Ed, introduced the meeting and the NEMO Sea Ice WG more generally. An outline was provided of the discussions held at two smaller, ad-hoc meetings held previously in Paris (December 2015) and London (May 2016). The main recommendation of these previous meetings was that there could potentially be great benefits to increased collaboration on sea ice model development within the NEMO community. To explore this possibility a NEMO Sea Ice Working Group (SIWG) has been established and relevant experts within the European NEMO community invited to attend this first meeting.

Each group then were provided a 15 minute slot to present details about their existing NEMO sea ice use via a 5-slide template provided in advance by Martin & Ed. The presentation template included information on:

1) Science foci; models/configurations used
2) Recent and planned/upcoming model developments
3) Coupling methods for the ocean and atmosphere

4) Working practices (code management and pull-through to trunk)
5) Evaluation: what do they like and dislike about current setup; what is missing?

Presentations were given by: Ed Blockley (Met Office); Clément Rousset (CNRS/L'Ocean); Danny Feltham & David Schroeder (CPOM/Reading); Olivier Lecomte (UCL/LLN); David Salas (Meteo France/CNRM); Yevgeny Aksenov (NOC); Gilles Garric (Mercator Ocean/CMEMS – presented by Martin Vancoppenolle).

During a short coffee break Martin & Ed created a synthesis of the issues raised in the above presentations and summarised the areas where currently work is duplicated and/or where closer collaboration is possible.

The key points of this synthesis were:

- There is considerable sea ice expertise within Europe and many model developments are happening!
- Many of them are duplicated (i.e., all doing melt ponds and form-drag)
- The duplication does not only include the creation of developments but also the testing and incorporation into NEMO etc.
- Ocean-sea ice model coupling is duplicated three times within NEMO for each model (four times counting the moribund LIM2)
- There seems to be a bottleneck pulling developments through to final code owing to low level of resource at CNRS/Met Office and the fact that developments are not made according to NEMO coding practices or in the correct model/version
- Resource is generally low for the sea ice modelling groups (compared to say ocean or atmosphere)
- People were pleased with the way NEMO has worked (and does work) – particularly with reference to coding standards, testing methodologies and the scientific and technical robustness of the code
- It was identified that some of the working practices currently employed for sea ice development within NEMO could be improved and would benefit from coming more into line with the NEMO standards
- Having code in multiple repositories with multiple coding standards (i.e., CICE) is difficult and can cause technical overhead

These points were presented to the group and were agreed upon. In particular it was acknowledged that the European sea ice modelling community has a small amount of resource, both as a whole and individually, and that the present, fairly high level of duplication is hampering progress. It seemed to be well recognised that considerable reward could be obtained by working together better and in a coordinated fashion.

Future options:
Martin & Ed then presented and described four possible options for how we could work together in the future. The options were designed to be progressively more collaborative with each option being a subset of the next. The options presented were:

1) **Status quo:** keep the models as they are. This option could involve using the SIWG to provide increased communication between the groups or even disband the WG and keep the status quo entirely.

2) **Shared ocean-ice interface:** keep the 3 models separate as for the status quo but merge the sea ice model interfaces in the NEMO SBC code and work together to maintain this
3) **Shared dynamics:** maintain/use common sea ice model dynamics (2D) but not (1D) thermodynamics. This would involve porting the required CICE dynamics into NEMO/LIM - including B->C grid conversion - and would also include the merged NEMO SBC interfaces as in #2). Interfaces to use 1D solvers from CICE (DOE's Icepack) and GELATO would be kept in the code.
4) **Fully unified NEMO/European sea ice model:** All code would sit in the NEMO repository and the model would be renamed as a NEMO/European sea ice model. If people wanted an interface to the CICE Icepack solver could be kept.

The options were explained and questions answered about how they might work but without any in-depth discussion of any advantages or disadvantages.

[Wednesday 1st February]

The four options presented on the previous day were briefly recapped. It was agreed that this was a comprehensive list of possible options for the future of sea ice modelling within NEMO and that none should be added or removed.

Cross-model synthesis:
Before being able to accurately discuss the advantages and disadvantages of the four options it was decided that more information would be needed about the level of transition work required for the more collaborative options (namely #4 and #3). To better understand the work required a synthesis of the three sea ice models used within NEMO (LIM3/CICE/GELATO) was performed. The primary aim here was to identify the physics and/or capabilities available within at least one – but not all – of the 3 models that would be required in a prospective unified sea ice model. This summary of key/missing physics/capabilities is described in Table 1 below. Time estimates were provided as a guideline.

Table 1: A summary of model physics and capabilities currently available in some, but not all, of the sea ice models used with NEMO. This is essentially a list of capability that would need to be developed/ported/kept for a unified sea ice model.

Scheme	Description & notes	Time estimate
C-grid remapping for horizontal advection	The CICE scheme is B-grid and will need to be translated to C-grid. GELATO contains a C-grid version of the CICE remapping but it has a small conservation issue. However Gurvan Madec suspects that this is also the case for the CICE scheme around the north-fold (owing to non-square grid cells in the ORCA grids) and that this can be fixed. Furthermore Clément Rousset has developed a new scheme within LIM (UM5) that may be a suitable alternative to the CICE scheme. UM5 is fully conservative, having been written using the proper NEMO scale factor formulation, and is considerably faster than the existing LIM scheme.	**3PM**

EAP rheology	The Elastic-Anisotropic-Plastic rheology developed on the B-grid for CICE by the CPOM group would need to be translated onto the C-grid for use in a unified NEMO sea ice model.	**12PM**
Melt ponds	The Flocco and Feltham topographic melt ponds scheme is only available in CICE at present. It has been implemented in LIM with NEMO_3.1. These modifications are being implemented into the trunk by CNRS+UCL/LLN at present and is expected to be complete within the coming months.	**2PM** [underway]
Form-drag	The Tsamados et al. form-drag scheme is only available in CICE. However this is being included into LIM by UCL/LLN. The underlying Lupkes et al parameterisation extended by Tsamados et al. is also being included into LIM by Mercator.	**2PM** [underway]
HadGEM3 ice-atmosphere coupling	Presently the BL99 thermodynamic solver in LIM has not been modified to work with the semi-implicit coupling employed at the Met Office. This will need to be implemented before the sea ice model could be used within Met Office systems.	**3PM**
Modularity and 1D-2D splitting	It was noted that CICE has undergone a splitting exercise to separate 2D horizontal processes from the 1D thermodynamics. Such an activity is underway for LIM with only a couple of technical tasks required. This would be required for a partially integrated European sea ice model in option #3 and it was agreed should also be the approach adopted for a unified sea ice model in option #4.	**2PM**
[Sophisticated snow scheme]	It was identified that the current snow schemes available in LIM, CICE and GELATO are not very sophisticated and that neither would necessarily be preferred over another. UCL/LLN have recently developed a more sophisticated snow scheme at NEMO v3.1 that they are in the process of upgrading to v3.6 for inclusion in the trunk.	**[6PM]**
[Delta-Eddington radiation scheme]	Currently the delta-Eddington radiation scheme in CICE is the most sophisticated and the only scheme that includes internal scattering. It is not currently used within Met Office systems because it has not been adapted for use with the JULES coupling method. It is used by CPOM and NOC however. CNRS have plans to a new radiation scheme for LIM that is similar in functionality/sophistication to the CICE delta-Eddington scheme. This will most likely not be ready for 2 years or so.	

Pros and Cons:

The advantages and disadvantages of each of the 4 options were explored and documented. These can be found in Table 2 below. Given that options #1 and #2 are quite similar with respect to the transition work involved it was decided that these could be recorded together. Furthermore, although the pros and cons of the partially integrated option (#3) were assessed in comparison to the status quo (#1), it was decided that we should also directly compare options #3 and #4 to help people decide which was more attractive.

Table 2: Pros and cons for the 4 future sea ice model options considered. Comparison for option #4 made relative to option #3. For option #3 entries in *italics* are unique to option #3 whilst others would still be valid for #4 (relative to #1).

	#1 (status quo) and #2 (shared interfaces)	**#3 Shared horizontal dynamics (wrt #1)**	**#4 Unified sea ice model (wrt #3)**
Pros	• easy to implement • no transition cost • maintains model diversity • [#2 reduces some duplication c.f. #1]	• sharing horizontal physics is easier • 1D-2D split of model is warranted • common use of AGRIF for horizontal processes • common use of grid • share most of the HPC infrastructure and optimisation • *access to "Icepack" CICE1D column package* • reduced duplication	• open source • no external reliance • common use of full AGRIF • share all HPC infrastructure and optimisation • single repository • improved collaboration among NEMO users • full use of NEMO structural simplicity • contribution to NEMO simplification • net community expansion of developers is foreseen at 5-10 yr scale • political and scientific strategy alignment • alignment hopefully leading to an improved access to funding (EU etc.)

Cons	• maintains high level of duplication and maintenance
	• slows progress
	• reliance on external bodies
	• code in multiple repositories
		• transition cost :
		  ○ splitting 1D-2D
		  ○ inclusion of CICE 2D routines into NEMO
		• *work for 1D routines to work with AGRIF is duplicated*
		• *need to maintain interface with CICE*
		• potentially generates uncertainty in funding
		• *multiple repository + external reliance => long term cost*
			• largest transition cost
			• structural diversity loss
			• potential loss of collaborations with the US partners

Voting:

To assess the interest of the group for the four presented options a vote was taken. 7 votes were cast for option #4 and 2 votes were cast for "either **#3** or **#4**". There were no votes for option #1 or #2 and none for #3 outright. There were 3 abstentions - from the WG chairs (EB/MV) and NEMO Project Manager (CL).

Although the vote was unanimously in favour of option #4 – developing a pan-European sea ice model within NEMO – some words of caution were raised. In particular it was noted that,

although option #4 was the most preferable long-term solution, the transition period will be difficult and crucial to the success of the collaboration.
Concerns were also raised about losing contact with the CICE development groups in the US – particularly the "Icepack" 1D column package. It was agreed that it would still be possible to include an interface for CICE-Icepack within option #4.

Planning for a unified NEMO sea ice model:
Following the unanimous vote for the development of a fully unified sea ice model within NEMO the option was explored further to try and put some flesh on the bones. In particular the transition period was discussed with special focus on the inclusion of the key capabilities discussed above in Table 1.

It was agreed that changes should be made to the NEMO code after v4.0 because a number of code streamlining activities have been performed for this that would be advantageous (including NEMO SBC).

It was agreed that the transition period could be split into two phases.

- **Phase 1 (2017-2019**): contains all the key physics and capabilities required for all groups to be able to use a unified NEMO sea ice model and, at the least, replicate their current level of sophistication. One key requirement to be included in phase 1 is that the functionality in question needs to either be already fully tested and implemented within one of the existing sea ice model code bases or for this to be planned within the next 6 months.
- **Phase 2 (2019+)**: contains more of a wish list for the longer-term development of a communal sea ice model. For now, phase 2 includes the developments that will be ready (e.g. quality controlled) in the next two years. Further refinement of what Phase 2 will be must be dealt with in line with the long-term strategy development.

In practice, Phase 1 would start from the validated NEMO trunk around June, by renaming the LIM_SRC directory to reflect the new name chosen for the unified sea ice model. Then all the functionality listed in Table 1 not currently available within LIM3 would be incorporated into the new model.

Phase 1 (i.e., years 1-2) would be crucial to the success of a unified NEMO sea ice model and will need careful planning (see below). Phase 2 meanwhile (years 2-5) will not need such prescriptive planning at this stage. In order to better plan the work required for Phase 1, individual developments were discussed and PI's were identified and allocated to each activity as described in Table 3 below.

Table 3: Planned activities and responsible parties for NEMO sea ice model phase 1 implementation

Activity	Task details	Those responsible (PI in bold)	Notes
Remapping	• Making GELATO C-grid remapping scheme conservative and porting to NEMO/LIM. • Perform comparisons with Clément's UM5 scheme	**David Salas** Clément Rousset (Yevgeny Aksenov) (Gurvan Madec)	

Anisotropic rheology	• Translating EAP rheology from B-grid in CICE to C-grid in NEMO	**Danny Feltham**	Funding required for CPOM involvement
JULES coupling	• Modify existing LIM3 BL99 thermodynamic solver to work with HadGEM3 coupling	**Ed Blockley** Martin Vancoppenolle	
AGRIF	• Finalise LIM3 AGRIF capability	**Clément Rousset** Martin Vancoppenolle	Underway and expected for NEMO v4?
Modularity	• Complete the splitting of 2D horizontal processes from 1D vertical processes	**Clément Rousset** Martin Vancoppenolle	Underway and expected for NEMO v4?
Form-drag	• Implementing Tsamados et al. scheme into LIM3	**Thierry Fichefet** (with CPOM consultation)	
	• Implementing Lupkes et al. scheme into LIM3	**Gilles Garric**	
Melt ponds	• Re-Implementation of Flocco & Feltham topographic melt pond scheme in LIM3 (update from a 3.1 branch)	**Martin Vancoppenolle** Olivier Lecomte	Underway and expected for NEMO v4?
Diagnostics	• Create a synthesis of requirements for future diagnostics differentiating between those we would like and those that are already present functionality for at least one of the models.	**Ed Blockley**	

Phase 2 developments were scoped and listed as shown below. Although the partner organisations involved in the developments are listed, no official PI's have yet been allocated for phase 2 activities. There could well be other items added, in the line of the design of the long-term NEMO development strategy document.

- LLN snow scheme (UCL/LLN)
- Multiple tracer framework (CNRS)
- Maxwell-Elasto-Brittle rheology (UCL/LLN)
- Delta-Eddington style radiation scheme (CNRS)
- Topographic melt pond scheme improvements (CPOM)
- Form-drag scheme improvements (CPOM)
- Frazil-ice formation scheme (CPOM)
- MCO – multi-category ocean mixing scheme (UCL/LLN)
- MIZ dynamics with waves and FSD (NOC & CPOM)
- Interfacing with wave models (NOC)

Naming:
To recognise the significance of the unification of sea ice models within NEMO, and the

collaboration involved, it was agreed that the unified sea ice model should have a new name. The name should reflect the fact that this is the NEMO sea ice model and/or a collaborative European collaboration. Several possible names and acronyms were considered but none were considered perfect and so the naming of the new model remains to be determined. Working group members are encouraged to send any sensible ideas they might have to the working group chairs.

[Thursday 2nd January (am)]

Future of the NEMO Sea Ice Working Group (SIWG):
The next steps for the SIWG were discussed. It was felt that the group served a useful purpose and should be kept as a NEMO working group. One of the primary functions of the group would be to oversee the transition period whilst the new NEMO sea ice model is being created from the existing LIM3, CICE and GELATO models.

Claire Lévy raised the issue that the next NEMO DevCom meeting will be the "Enlarged Developer Committee" meeting to be held in Barcelona in early April and that this would be a useful forum to discuss the outcomes of this meeting. At present there is nobody to represent sea ice at this meeting.

It was agreed that Ed Blockley would attend the NEMO DevCom in Barcelona (3rd-6th April 2017). Ed's primary function there would be to:

1) Report on the activity, discussions and decisions made at this NEMO SIWG meeting and represent the views of all those who contributed;
2) Invite comments from the rest of the NEMO community to feedback to the SIWG.

A report of the SIWG meeting will be created and this will form the basis of Ed's report to DevCom. This will be drafted by Martin & Ed and then circulated for comment and iteration.

The "ice" section of the NEMO strategy document will need to be updated to reflect the plans. Although this is a 5-year planning document, it was agreed that we will aim to focus details on the next 2 years (i.e., our phase 1). The plans for 2019 onwards meanwhile would remain a little less detailed and will be updated at a later date as the transition progresses.

It was noted that the NEMO ice section contains more than sea ice as it includes ice- shelf cavities, ice-sheet coupling and icebergs. The NEMO SIWG would not take over ownership of these sections of the document. Responsibility for these would remain unchanged from the status quo.