SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	2019………………………………………………………..……
Project Title:	Improvement of the barotropic tide in the 1/12° global ocean NEMO model ……………………..……
Computer Project Account:	spfrmore……………………………………………..……
Principal Investigator(s):	Yves Morel, Benoît Tranchant, Loren Carrere ………………………………………………………..……
Affiliation:	LEGOS/CNRS and CLS………………………………..……
Name of ECMWF scientist(s) collaborating to the project (if applicable)	………………………………………………………..…… ………………………………………………………..……
Start date of the project:	January 2019……………………………………….……
Expected end date:	December 2020……………………………….……

Computer resources allocated/used for the current year and the previous one

(if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)			4100000	2806831
Data storage capacity	(Gbytes)			2450	54

Summary of project objectives (10 lines max)

The main project objective is the implementation of a new barotropic tide solution in the global 1/12° NEMO ocean model in order to ensure an accurate barotropic tide without disrupting the eddying general circulation. To do so, different solutions have to be tested. The first, classical, one is to modify/improve the tide dynamics in the model (bathymetry, bottom friction, tide loading and tide dissipation via internal tide generation). The second solution is through assimilation of data coming from the “state of the art” tide model FES2014. Providing an accurate global barotropic tide atlas is an essential step before doing realistic simulation of baroclinic tides. The NEMO model (Nucleus for European Modelling of the Ocean (https://www.nemo-ocean.eu) is a platform for ocean modelling developed by a European consortium. This project will use the global configuration at 1/12° named MFC-GLO used in CMEMS that explicitly solve the barotropic tides from an astronomical tide potential.

Summary of problems encountered (10 lines max)

As mentioned above, our project is based on the global configuration at 1/12° named MFC-GLO used in CMEMS and it is a time-consuming configuration especially since we explicitly solve the barotropic tides at a high resolution.

In addition, the XIOS software used for the parallel I/O failed with such huge configuration and we spend most of our initial quota to deal with this issue. Note that this behaviour is not specific to ECMWF HPC and has also been observed on other HPC platform (Bull/Météo France).

Summary of plans for the continuation of the project (10 lines max)

- Up to now, initial conditions were coming from climatology. In order to have more realistic conditions, the next step will be to test an initial condition coming from an existing model solution (ORCA12: January 2014).
- Test the bottom stress harmonic analysis with the ORCA12 configuration and compare results with FES2014 (state of the art tide model).
- The global tide energy budget should be systematically estimated in order to quantify the generated energy but also those propagated and dissipated by the model.
- Improvement of the tidal dissipation by tuning the bottom friction and by implementing a specific wave drag parameterization.

List of publications/reports from the project with complete references

- Evolution and optimization of NEMO code used in CMEMS-MFC-GLO: global barotropic tide simulations - Quarterly report – Q2 May 2019, CLS-ENV-NT-19-0177.
- Evolution and optimization of NEMO code used in CMEMS-MFC-GLO: global barotropic tide simulations - Quarterly report – Q1, February 2019, CLS-ENV-RP-19-0050

Summary of results

If submitted **during the first project year**, please summarise the results achieved during the period from the project start to June of the current year. A few paragraphs might be sufficient. If submitted **during the second project year**, this summary should be more detailed and cover the period from the project start. The length, at most 8 pages, should reflect the complexity of the project. Alternatively, it could be replaced by a short summary plus an existing scientific report on the project attached to this document. If submitted **during the third project year**, please summarise the results achieved during the period from July of the previous year to June of the current year. A few paragraphs might be sufficient.

Bathymetry from FES2014.
Starting from the existing LEGOS database, the optimization of the domain's bathymetry (bathymetry, shoreline and land-sea mask) has been carried out in certain key areas for tidal wave propagation (such as cavities under the ice, or areas subject to resonance), based on the most recent bathymetric data available to the community.

The FES2014 bathymetry (bathymetry used to compute the global FES2014 tidal atlases) at 1/16° has been interpolated on the NEMO grids ¼° and 1/12°.

This new bathymetry for both interpolated resolution (¼° and 1/12°) has been tested and following the harmonic analysis, it seems to give better results for the K1 tide: results are given on Figure 2, that shows the surface tidal elevation complex differences at crossing points between Topex/JASON1/JASON2 and the model for two different bathymetries, ORCA and FES2014. It also shows that better results are obtained with the higher resolution grid ORCA12 compared to ORCA025, regardless of the bathymetry.
For the M2 tide, the results are not as good as expected and it comes probably from the fact that the new interpolated bathymetry is (i) too noisy at this resolution and/or (ii) that the tide solution is very sensitive to topography of small areas/bays within which errors can spread to large scales, see Figure 3. As for K1, the horizontal resolution at 1/12° gives better results than at ¼°.
Nevertheless, M2 solution is better in some regions such as in Indonesian seas where tides are crucial to better understand/describe the oceanic circulation, see Figure 4: on this area, the improvement is explained by the better quality of the FES2014 bathymetry thanks to many in situ dataset. Note that the tuning of the bottom friction dissipation should help improving this result for M2 wave.

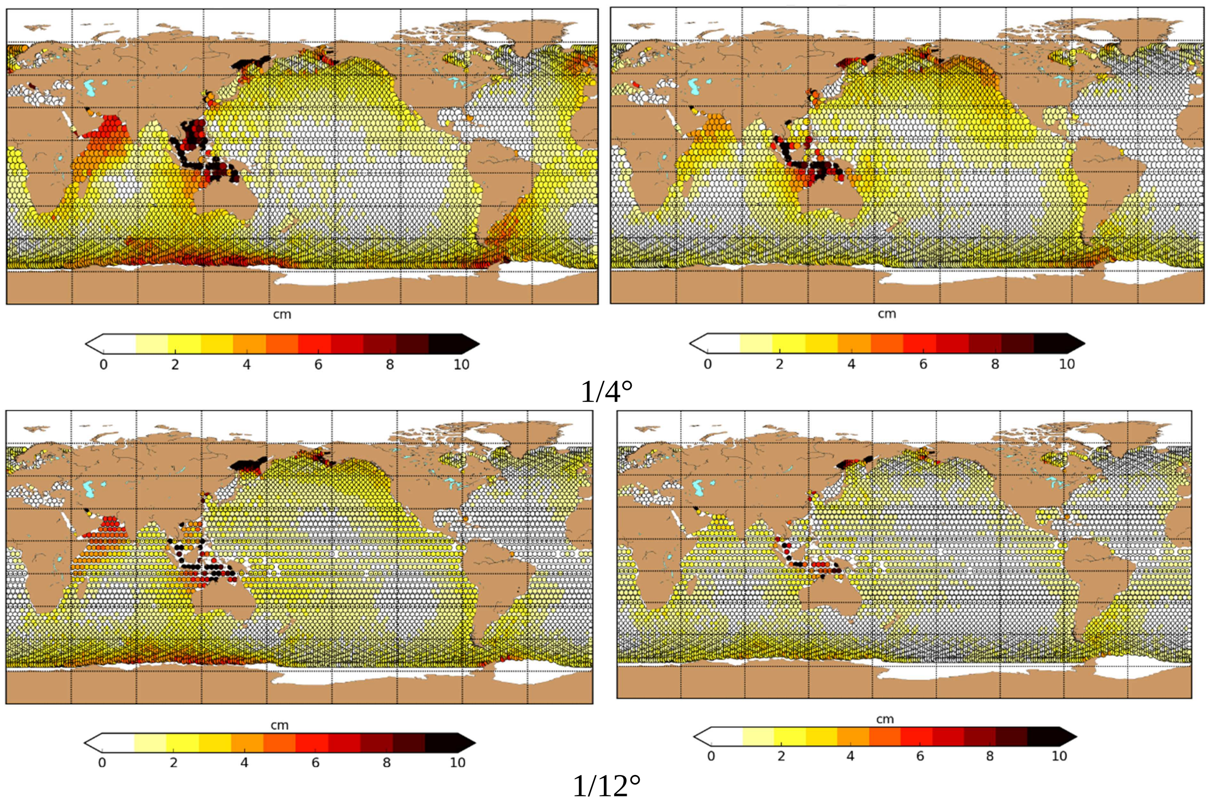

Figure 2: Surface tidal elevation complex differences (cm) at crossing points between TPX/J1/J2 and Model for the K1 tide: (top left) native ORCA025 bathymetry, (top right) Interpolated FES2014 bathymetry on ORCA025, (bottom left) native ORCA12 bathymetry, (bottom right) Interpolated FES2014 bathymetry on ORCA12.

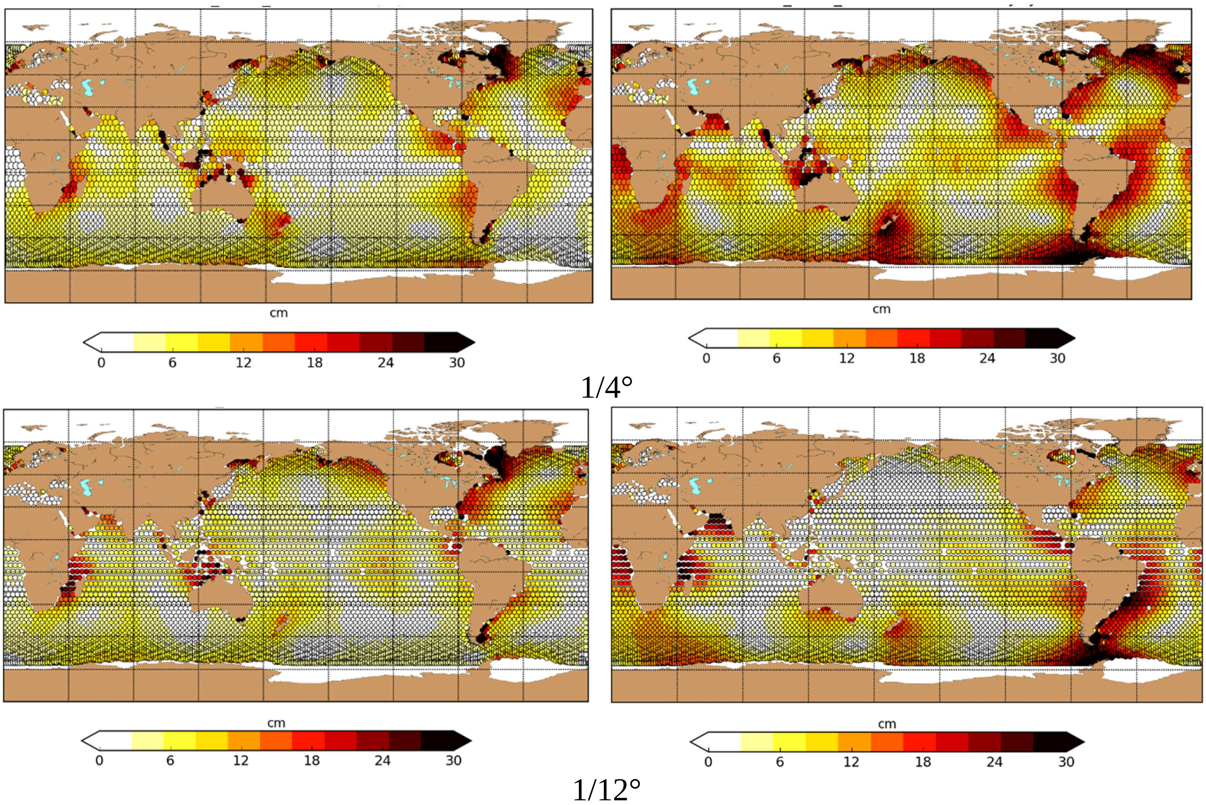

Figure 3: Surface tidal elevation complex differences (cm) at crossing points between TPX/J1/J2 and Model for the M2 tide: (top left) native ORCA025 bathymetry, (top right) Interpolated FES2014 bathymetry on ORCA025, (bottom left) native ORCA12 bathymetry, (bottom right) Interpolated FES2014 bathymetry on ORCA12.

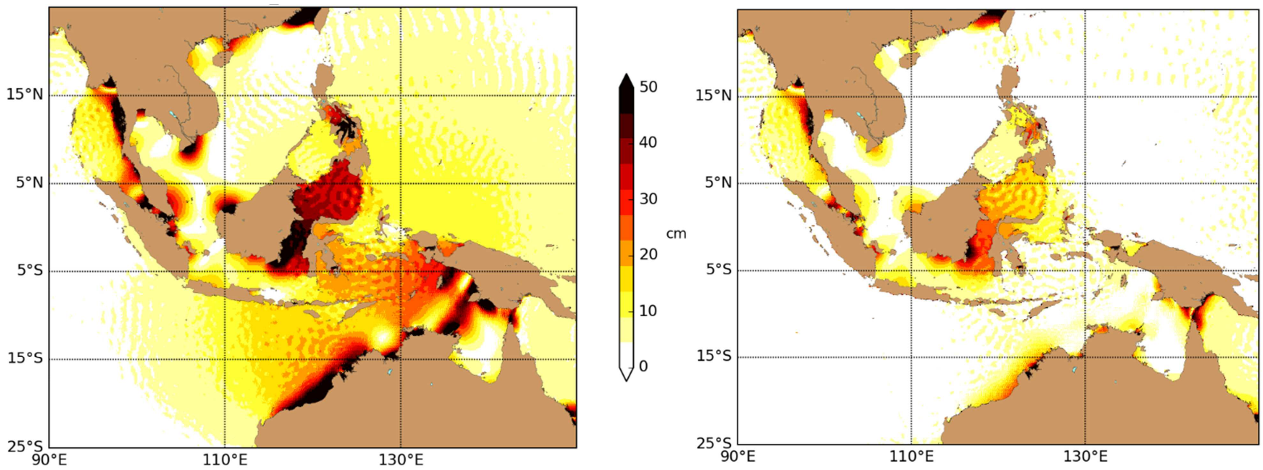

Figure 4: Surface tidal elevation complex differences (cm) between FES2014 and NEMO Model for the M2 tide: (left) native ORCA12 bathymetry, (right) Interpolated FES2014 bathymetry on ORCA12.

Energy budget

Internal tide generation is an important source of dissipation of the barotropic tide.
For this purpose it is important to follow a global energetic approach of the system in order to separate accurately the barotropic and the baroclinic energy and to estimate the transfer between them. Figure 5 illustrates the transfer of energy between barotropic and baroclinic tides (M2+K1) for two different bathymetries at 1/12°. It particularly shows that the largest differences are

localized in the Atlantic Ocean. Note also that the total energy conversion can be diminished/augmented up to 25% depending on the bathymetry field used.

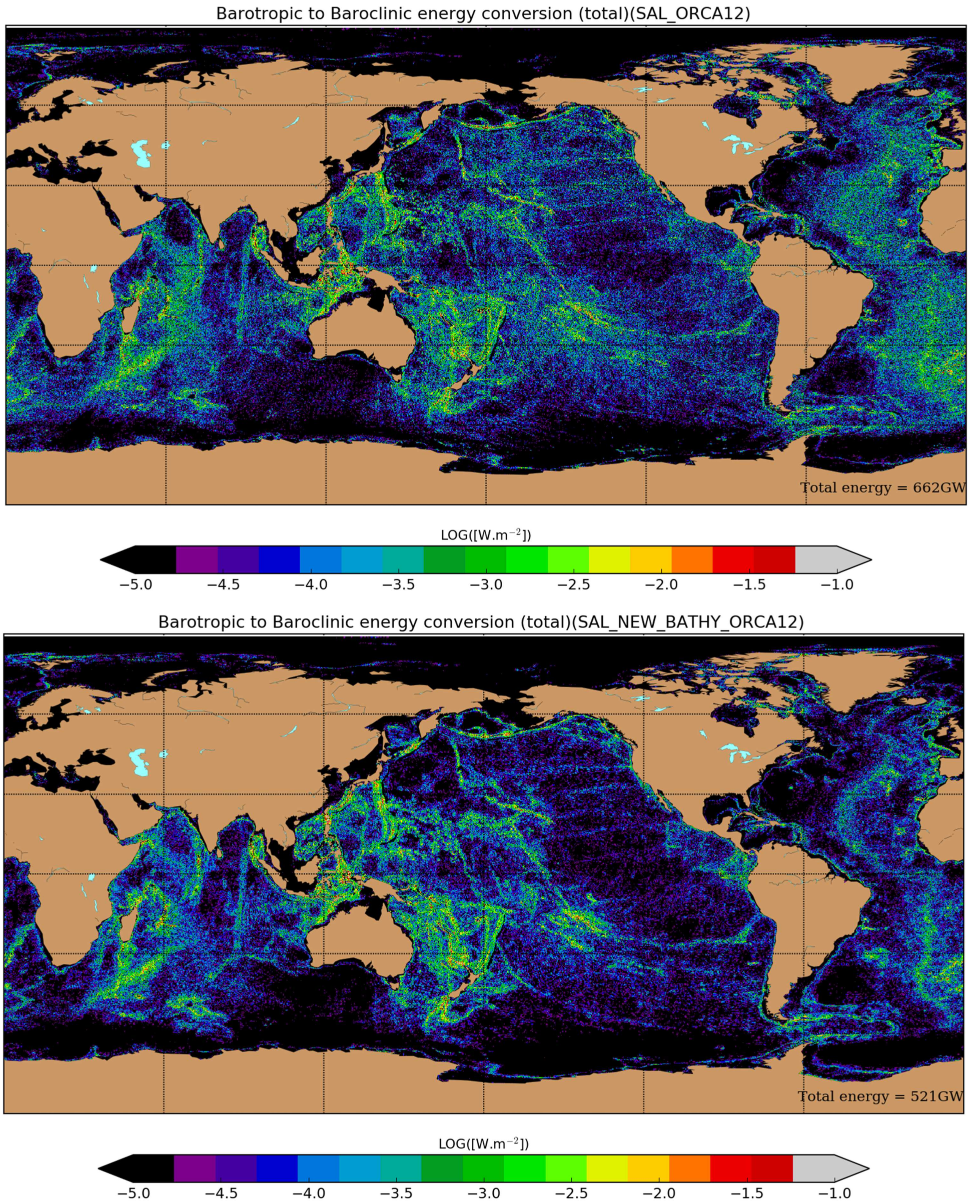

Figure 1: Energy conversion (barotropic to baroclinic) for M2 and K1 for the NEMO bathymetry (up) and for the FES2014 bathymetry (bottom). The total energy conversion is mentioned.