High resolution tidal modeling in the Arctic Ocean: needs and upcoming developments

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Introduction

The Arctic Ocean is a challenging region for tidal modeling, because of its complex and not well-documented bathymetry, together combined with the intermittent presence of sea ice and the fact that the in situ tidal observations are rather scarce at such high latitudes. As a consequence, the accuracy of the global tidal models decreases by several centimeters in the Polar Regions. In particular, it has a **large impact on the quality of the satellite altimeter sea surface heights** in these regions (ERS1/2, Envisat, CryoSat-2, SARAL/AltiKa and the future Sentinel-3 mission).

Better knowledge of the tides would improve the quality of the high latitudes altimeter sea surface heights and of all derived products, such as the altimetry-derived geostrophic currents, the mean sea surface and the mean dynamic topography. In addition, **accurate tidal models are highly strategic information** for ever-growing maritime and industrial activities in this region.

NOVELTIS and DTU Space are currently working on the development of a regional, high-resolution tidal atlas in the Arctic Ocean. In particular, this atlas will benefit from the assimilation of the most complete satellite altimetry dataset ever used in this region, including Envisat and SARAL/AltiKa data up to 82°N and the CryoSat-2 reprocessed data between 82°N and 88°N. The combination of all these satellites will give the best possible coverage of altimetry-derived tidal constituents. The available tide gauge data will also be used either for assimilation or validation.

This poster presents the deficiencies and needs of the global tidal models in the Arctic Ocean and the on-going work to develop an improved regional tidal atlas in this region.

Performances of global tidal models in the Arctic Ocean

Evaluation of the global tidal models vs tide gauges: vector differences for the M2 wave

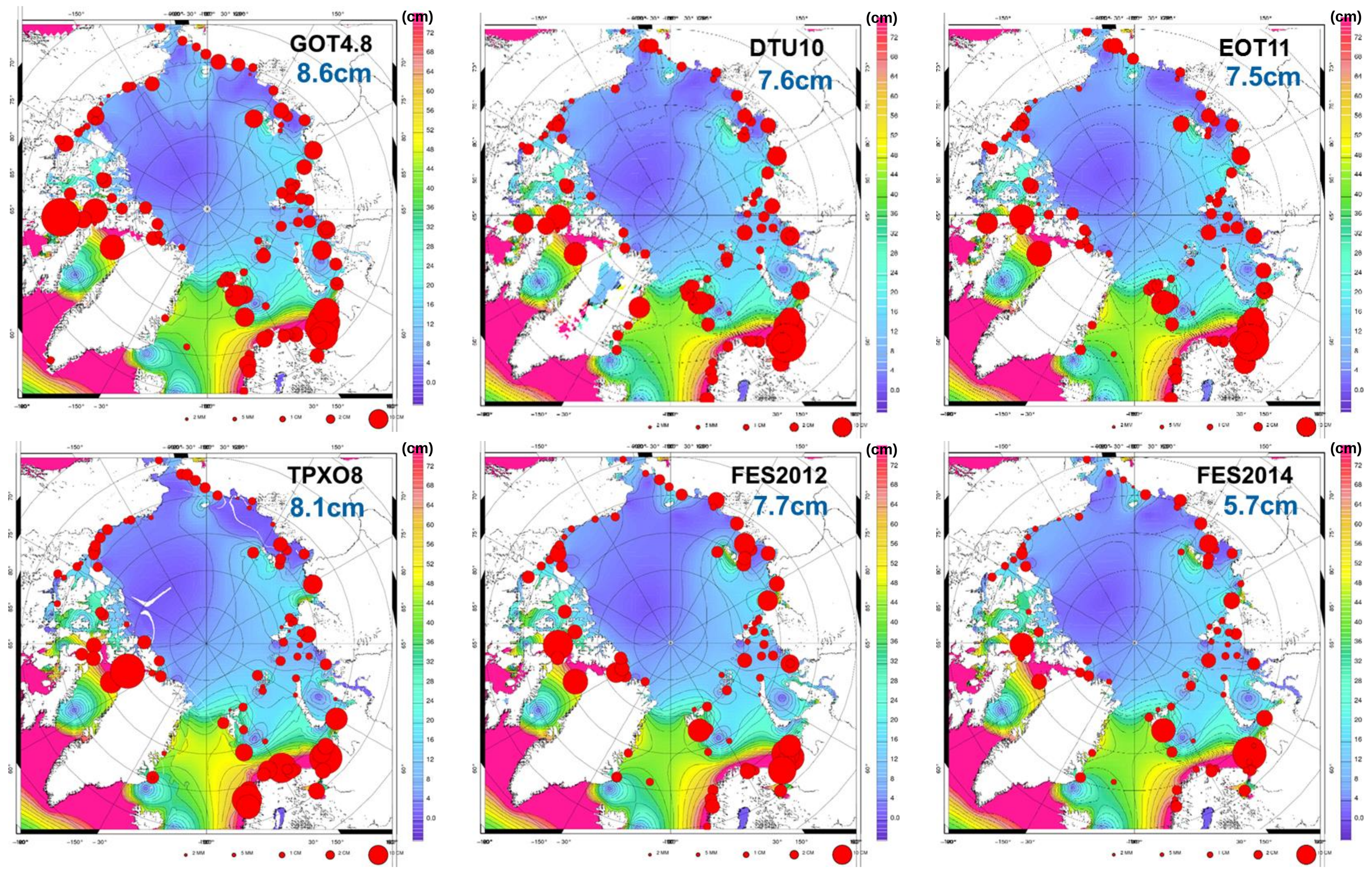

***Figure 1:** Amplitude (in cm, color) of the M2 tidal wave for various global tidal models and vector differences to the tide gauges (red dots)*

- Largest errors in the areas of largest tidal amplitude, as expected
- The performances are quite similar: 7.5-8.5cm of mean vector difference vs TG
- Except for FES2014 (5.7cm) explained by the assimilation of the tide gauge database.

➔ **Means of improvement: regional tidal modeling with finer mesh resolution.**

Regional tidal modeling methodology

The tidal modeling strategy is based on the **TUGO hydrodynamic model** and the **Kalman ensemble assimilation method**. It was previously used for the implementation of global models such as FES2004 (*Lyard & Lefèvre, 2006*), FES2012 (*Carrère et al, 2012*) and FES2014, and for the development of regional models (*Cancet et al, 2012*).

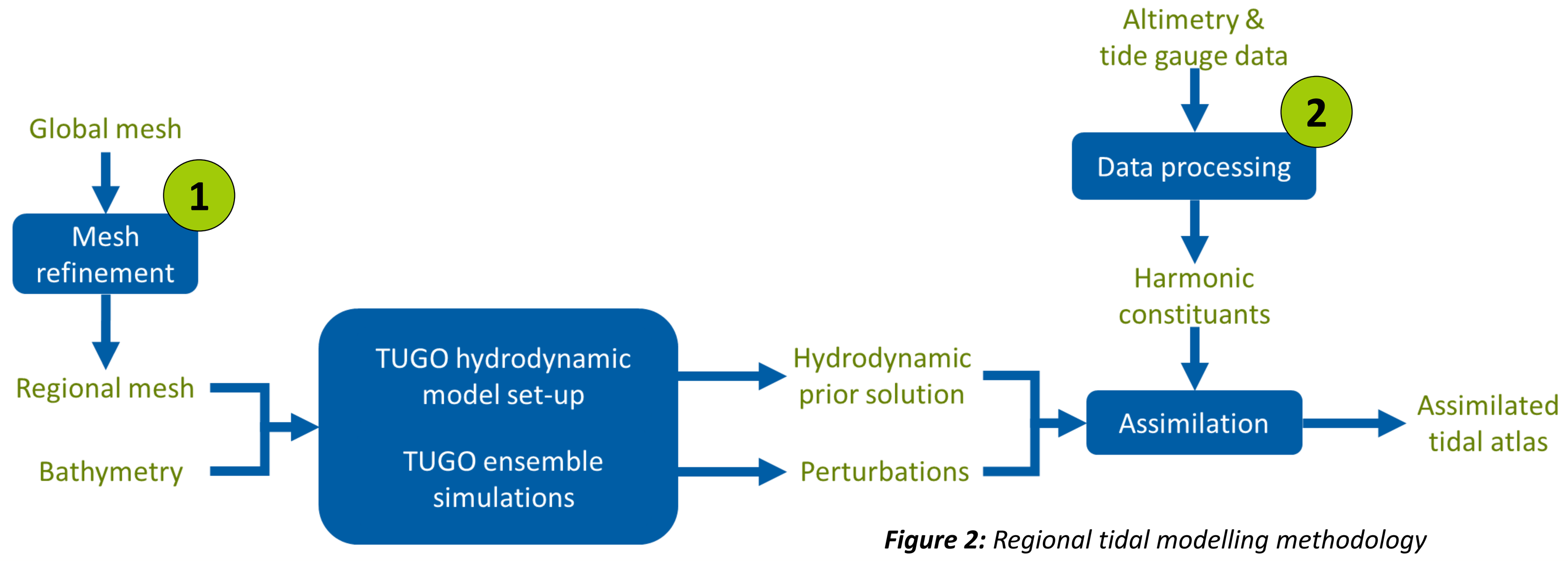

***Figure 2:** Regional tidal modelling methodology*

1 Preparation of the hydrodynamic model set-up: Mesh refinement

Strategy:

- Starting from a global unstructured mesh with a resolution ranging between 15 km at the coast and 80 km in the open ocean.
- Local mesh refinement with resampling of the coastline : 2-5 km at the coast, ~20 km in the open ocean, increase of the resolution on bathymetry gradients.

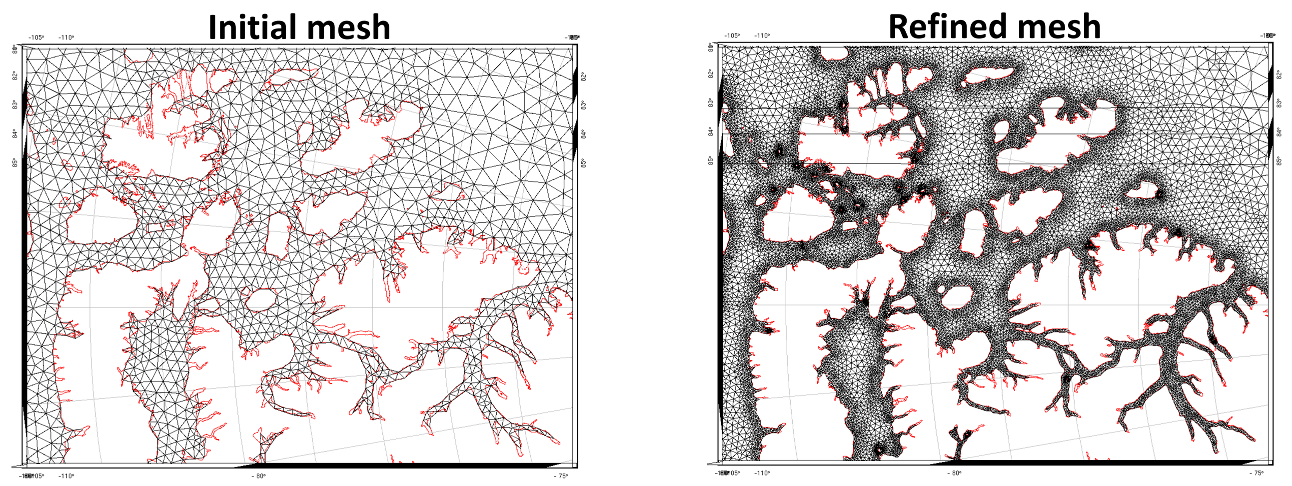

***Figure 3:** Extracts of the unstructured initial and refined meshes in the North-West Passage (Canadian Archipelago)*

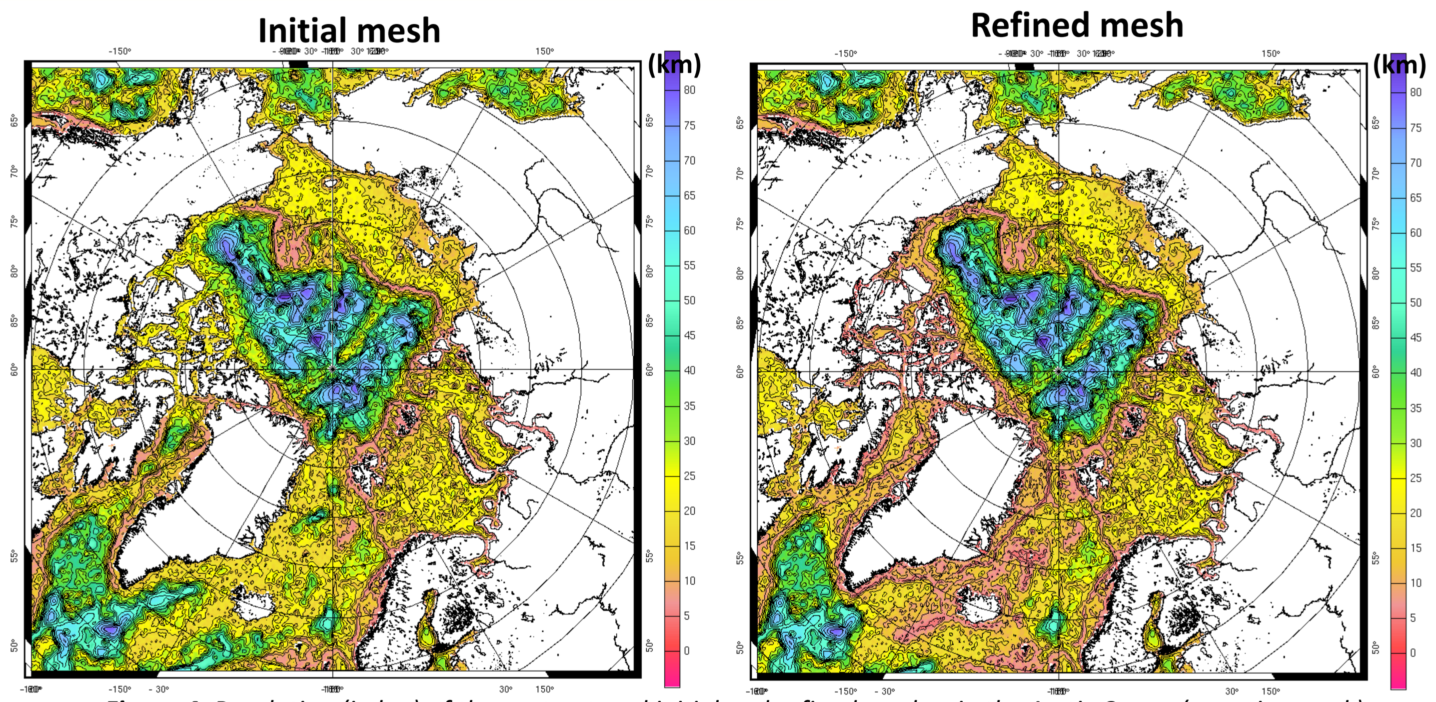

***Figure 4:** Resolution (in km) of the unstructured initial and refined meshes in the Arctic Ocean (on-going work)*

2 Altimetry data processing in the Arctic Ocean, in preparation of the assimilation

Data Processing

- CryoSat-2 data in LRM and SAR mode (2010-2014) and Envisat data (2002-2010) are included in the analysis. C2 LRM+ENVISAT from RADS, SAR retracked using primary peak retracker.
- An Arctic grid of 1°x3° (optimal based on experiments) were used with the response method to determine sin and cosine values for each grid cell and for each major constituent incl 4 shallow water constituents.
- The determination of the tidal constituents were performed in a remove/restore methodology where FES2004 is removed prior to tidal prediction and subsequently restored to obtain the final tidal signal.
- Satellites observe the residual geocentric tide, the tidal components are corrected by 8%.
- A first evaluation against tide gauges were performed to validate the altimetric derived harmonic constituents.

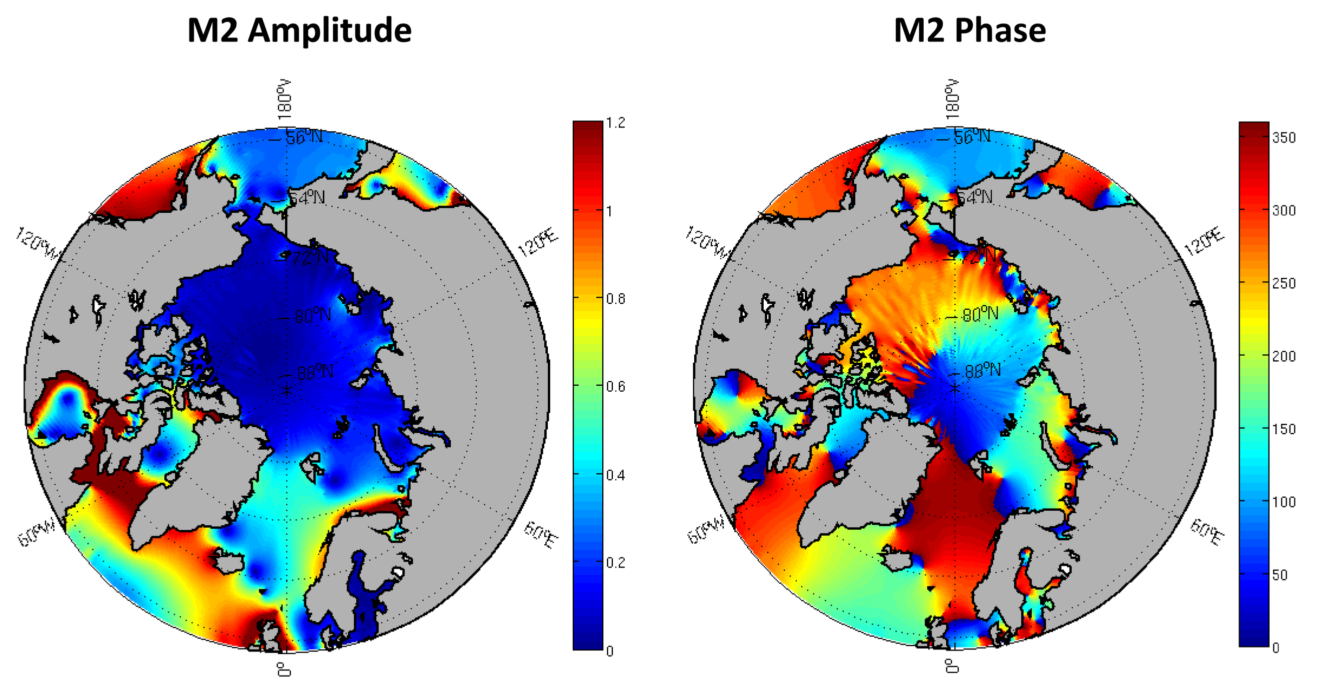

***Figure 5:** Amplitude (in m) and Phase (in deg) for M2 from altimetry (1 x 3 degree boxes)*

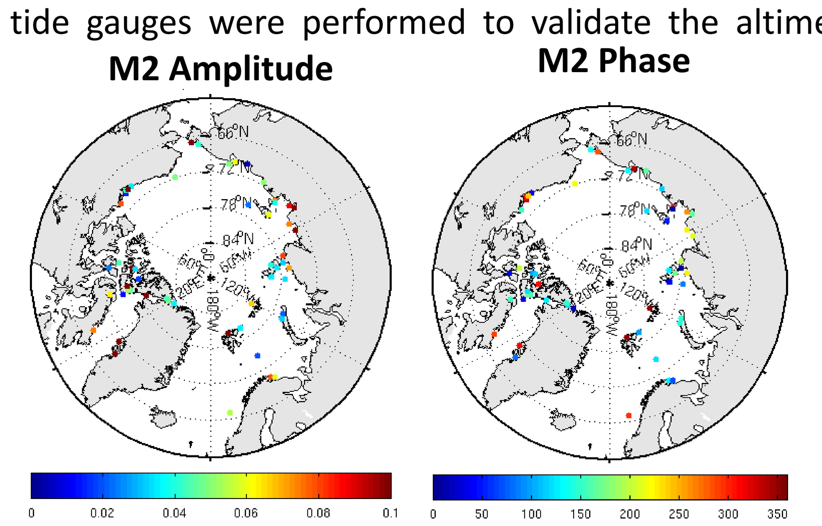

***Figure 6:** Residuals between the new model and tide gauges for amplitude (in m) and phase (in deg) of M2*

Results:

- Model validation using tide gauges in the Arctic is ongoing.
- We need to include SAR-in data as most coastal regions is within the SAR-in mask for Cryosat.
- Some phase fluctuation are seen close to 88N due to a very small amplitude of M2.

NEXT STEPS

This tidal atlas in the Arctic Ocean is expected to be released by the end of the year 2015. The next steps in the implementation are:

- To complete the mesh refinement over the whole region ;
- To set up the hydrodynamic model (wave drag parameter, bottom friction coefficient,…) ;
- To run the assimilation process, using the altimetry data processed by DTU Space.

Lyard, F., F. Lefèvre, et al. (2006). "Modelling the global ocean tides: a modern insight from FES2004." Ocean Dynamics 56: 394-415.

Carrère, L., Lyard, F., Cancet, M., Guillot, A., & Roblou, L., FES2012: A new global tidal model taking advantage of nearly twenty years of altimetry, Proceeding of the 20 Years of Progress in Radar Altimetry Symposium, Venice, Italy, 2012.

Cancet, M., Lyard, F., Birol, F., Roblou, L., Lamouroux, J., Lux, M., Jeansou, E., Boulze, D., Bronner, E., Latest improvements in tidal modeling: a regional approach, Proceeding of the 20 Years of Progress in Radar Altimetry Symposium, Venice, Italy, 2012.