ALBATROSS: Improving bathymetry and ocean tide knowledge in the Southern Ocean

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Introduction

The knowledge about bathymetry and ocean tides is at the **crossroads of many scientific fields**, especially in the Polar regions, as it **has significant impact on the understanding of the coupled dynamical response of the ocean, sea ice and ice shelves system**, and on ocean and ice parameters derived from satellite measurements. Tides in the Southern Ocean strongly influence the whole global ocean (Fig. 1). Accurate and complete bathymetry information is crucial for tidal modelling, in particular under the Antarctic ice shelves.

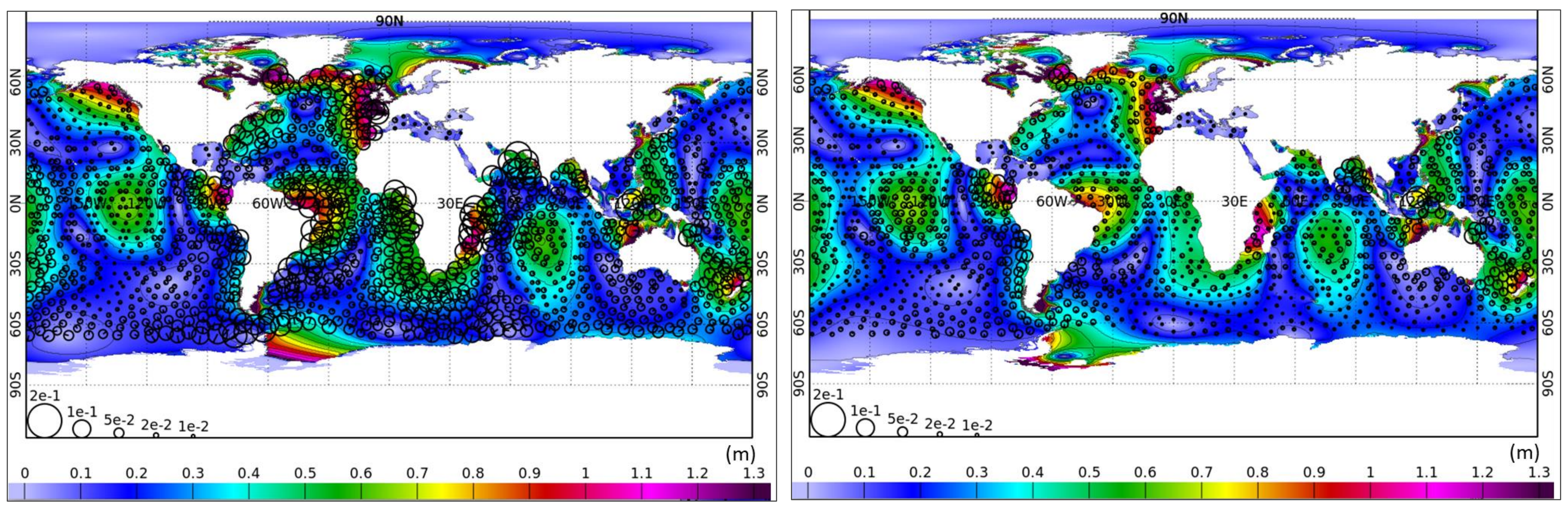


Fig. 1: Vector differences (m) on M2 between altimetry crossover points (deep ocean) and global tidal simulations based on GEBCO-2020 bathymetry (left) or Rtopo-2.0.4 bathymetry (right) in the Southern Ocean. Background: M2 amplitude (m) from the considered model simulation.

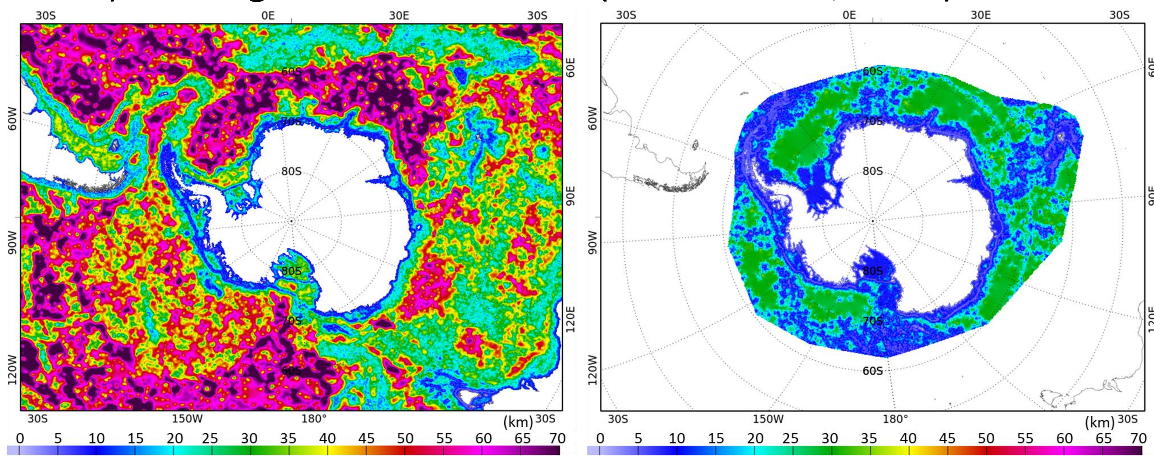
The ALBATROSS project (ALtimetry for BAthymetry and Tide Retrievals for the Southern Ocean, Sea ice and ice Shelves), led by NOVELTIS in collaboration with DTU Space, NPI and UCL, is funded by the European Space Agency in the frame of the Polar Science Cluster in the EO4Society Programme, with the objective to foster collaborative research and interdisciplinary networking within polar Earth Observation.

ALBATROSS is a 2-year project (2021-2023) with several objectives: First, to **improve the knowledge on bathymetry around Antarctica**, considering decade-long reprocessed CryoSat-2 datasets, innovative information on bathymetry gradient location through the analysis of sea ice surface roughness characteristics, and the compilation of the best available bathymetry and ice draft datasets in ice-shelf regions. Second, to **improve the knowledge on ocean tides in the Southern Ocean** through the implementation of a high-resolution hydrodynamic model based on the most advanced developments in ocean tide modelling, and data assimilation of tidal observations, including satellite-altimetry tidal retrievals in the coastal zone.

This paper presents insights about the strong relationship between the bedrock topography, the ice-shelf grounding line position and the ocean tides around Antarctica, highlighting areas where the tidal impact is particularly strong or variable, and where more data is needed to resolve discrepancies.

Tidal modelling setup

Tidal modelling strategy based on the TUGO-m hydrodynamic model, previously used for the development of global models such as FES2014 (Lyard et al., 2021) and regional tidal models (Cancet et al., 2018).



- High-resolution unstructured mesh grid
- Careful definition of the model extent (bathymetry features, tidal energy fluxes)
- Regional/local tuning of the model parameters

Fig. 2: Mesh resolution (km) of the FES2014 global model (left) and the ALBATROSS v1 regional model (right).

Tidal retrievals from satellite altimetry

Tidal harmonic constituents (amplitude and phase lag) computed from sea surface height time series combining CryoSat-2, ENVISAT, SARAL/AltiKa and Jason-suite observations in 0.5 x 3 degree bins.

CryoSat-2 data reprocessed with SAMOSA+ retracker for the 2010-2019 period, LRM/SAR/SARin combined (LRM from RADS).

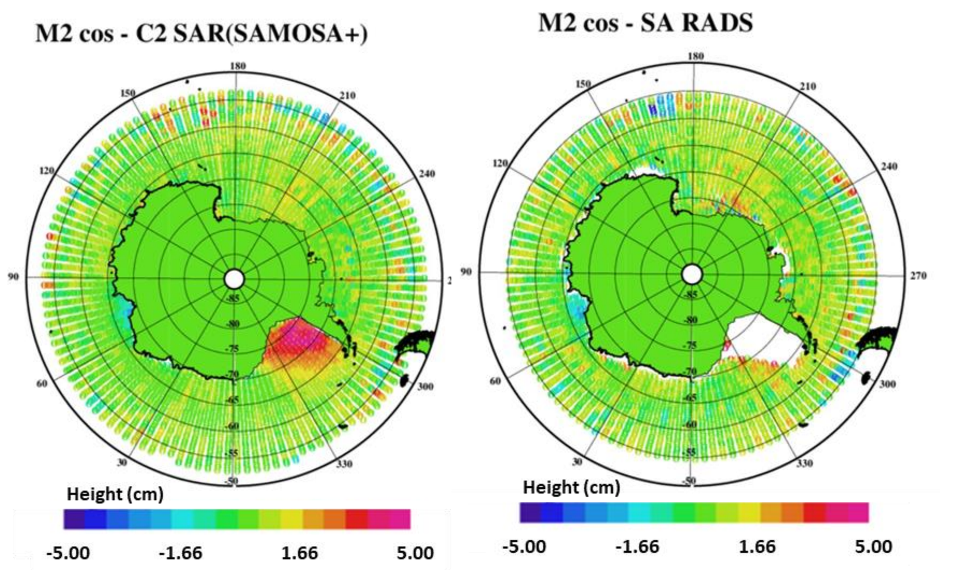


Fig. 3: M2 residual constituent from CryoSat-2 (left) and SARAL/AltiKa (right).

- ➢ **Strong tidal signal revealed by CryoSat-2** in the Weddell Sea, not observable before from satellite.
- ➢ **Very good agreement between CryoSat-2 and tide gauge data.** Good consistency with the model.
- ➢ CryoSat-2 can also help identify dubious in situ data.

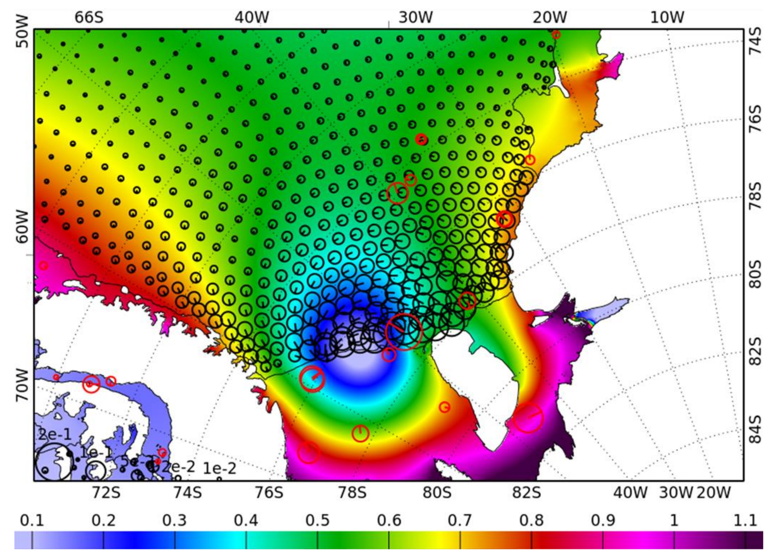


Fig. 4: Vector differences (m) on M2 between a regional ALBATROSS tidal simulation and CryoSat-2 altimetry data (black circles) and tide gauge data (red circles). Background: M2 amplitude (m) of the model in the Weddell Sea.

Bathymetry – work in progress

Open ocean

Use of the **most recently reprocessed CryoSat-2 data** (including SAR and SARin modes) in **DTU21 gravity field computation.**

- Bathymetry and gravity are correlated only on limited spectral bandwidth (20 to 100 km).
- Band-pass filtering and downward continuation of the ocean surface gravity to the sea floor, from DTU21 gravity field.
- Initial sea floor topography: BedMachine_Antarctica-2020-v2 (Morlighem et al., 2020) + RTopo-2.0.4 (Schaffer et al., 2019).

-> **New open ocean bathymetry produced.**

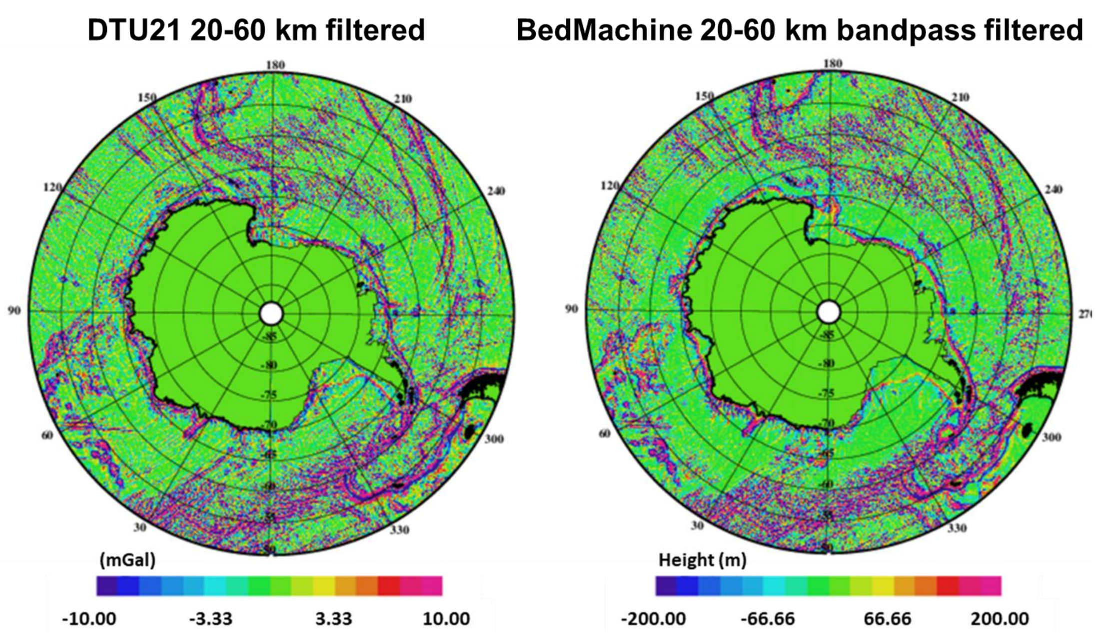


Fig. 5: DTU21 gravity field (left) and BedMachine+RTopo-2.0.4 bathymetry (right) band-pass filtered between 20 and 60 km.

Sea ice roughness and bathymetry gradients

Bathymetry controls ocean currents, temperature and sea ice presence. Locations of steep bathymetry act as hot spots of enhanced vertical heat fluxes mediated by tides and increased turbulence, and higher lead density correlates very well with steeper bathymetry.

→ Use of **sea ice surface properties to locate the bathymetry gradients**, based on a novel technique developed at ES_UCL using NASA MISR (Multi-angle Imaging Spectro-Radiometer) data to produce sea ice surface roughness maps.

-> On-going work: exploration of relevant statistics.

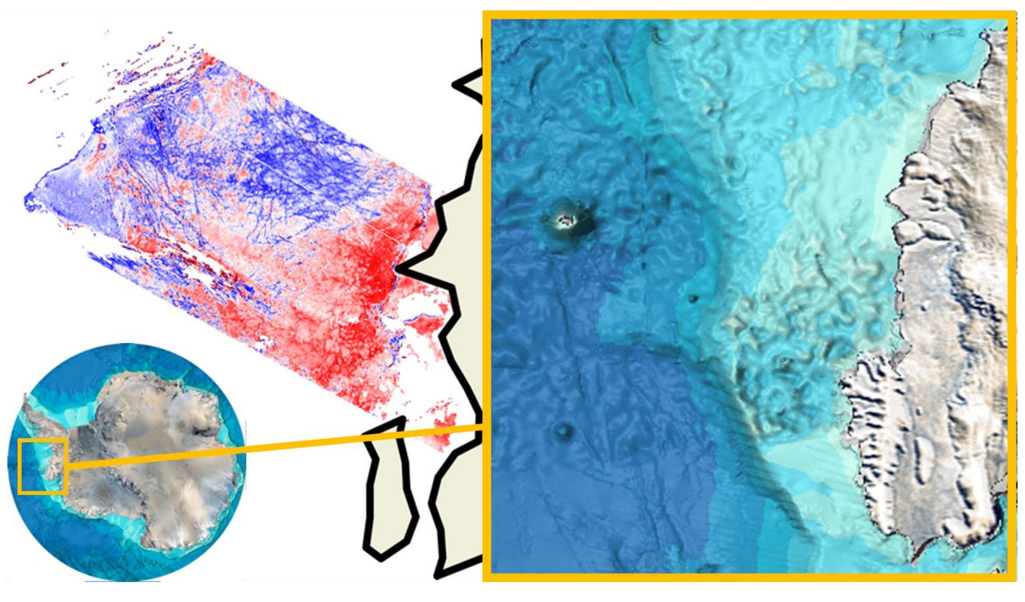


Fig. 6: MISR sea ice surface roughness (red to blue colors, left) and bathymetry features (right) close to the Antarctic Peninsula

Ice shelves, coastline and grounding line

Accurate information about grounding line location, bedrock topography and ice draft under the ice shelves is crucial to perform accurate tidal simulations.

-> Use of the tidal model to detect inconsistencies in those datasets.

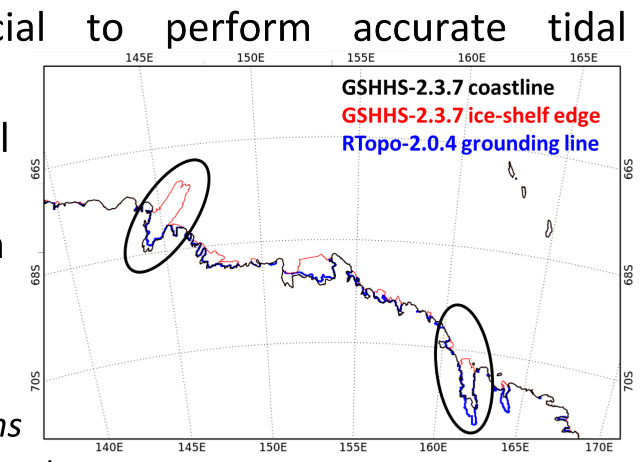
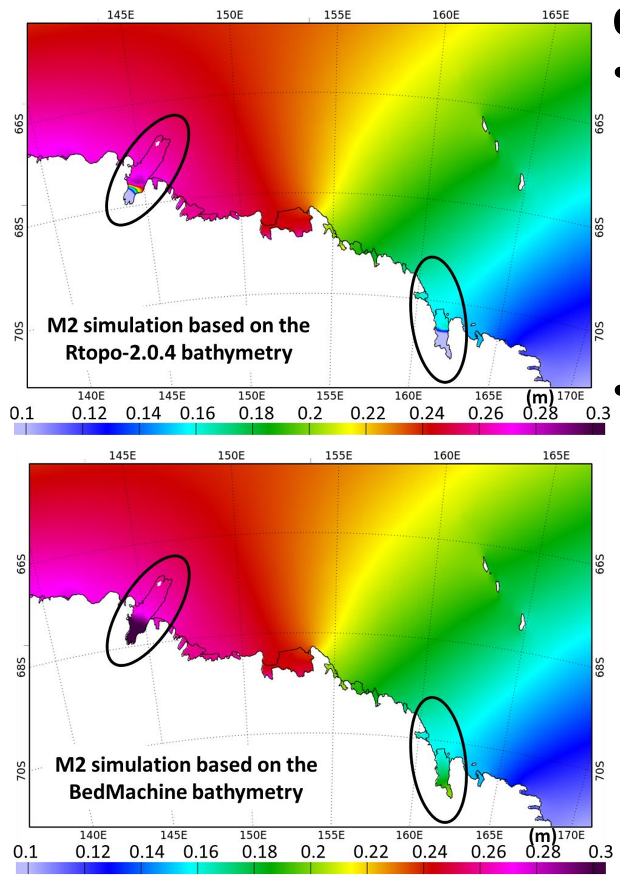


Fig. 7: Grounding line and coastline locations along the Antarctic coast.



On-going work:

- Updated masks for grounding line and coastline based on SAR interferometry, altimetry, and new Landsat-8 imagery
- Apply masks to improve ice-shelf bathymetry and draft

Fig. 8: M2 amplitude from tidal simulations based on two different bathymetry datasets. Areas of main discrepancies encircled in black.

CONCLUSIONS AND PERSPECTIVES

- **CryoSat-2 provides invaluable tidal estimates** in areas of the Southern Ocean not observed before, quite complementary to the scarce, coastal in situ observations.
- A **new open ocean bathymetry dataset** has been produced, based on CryoSat-2 data.
- On-going work to explore the links between sea ice specificities, tides and bathymetry features.
- On-going work to update and improve datasets of ice-shelf draft and bathymetry.
- The implementation of a **high-resolution regional tidal model with data assimilation** is underway.

References:

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