13th COASTAL ALTIMETRY WORKSHOP & COASTAL ALTIMETRY TRAINING
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ALBATROSS

ALtimetry for BAthymetry and Tide Retrievals for the Southern Ocean, Sea ice and ice Shelves

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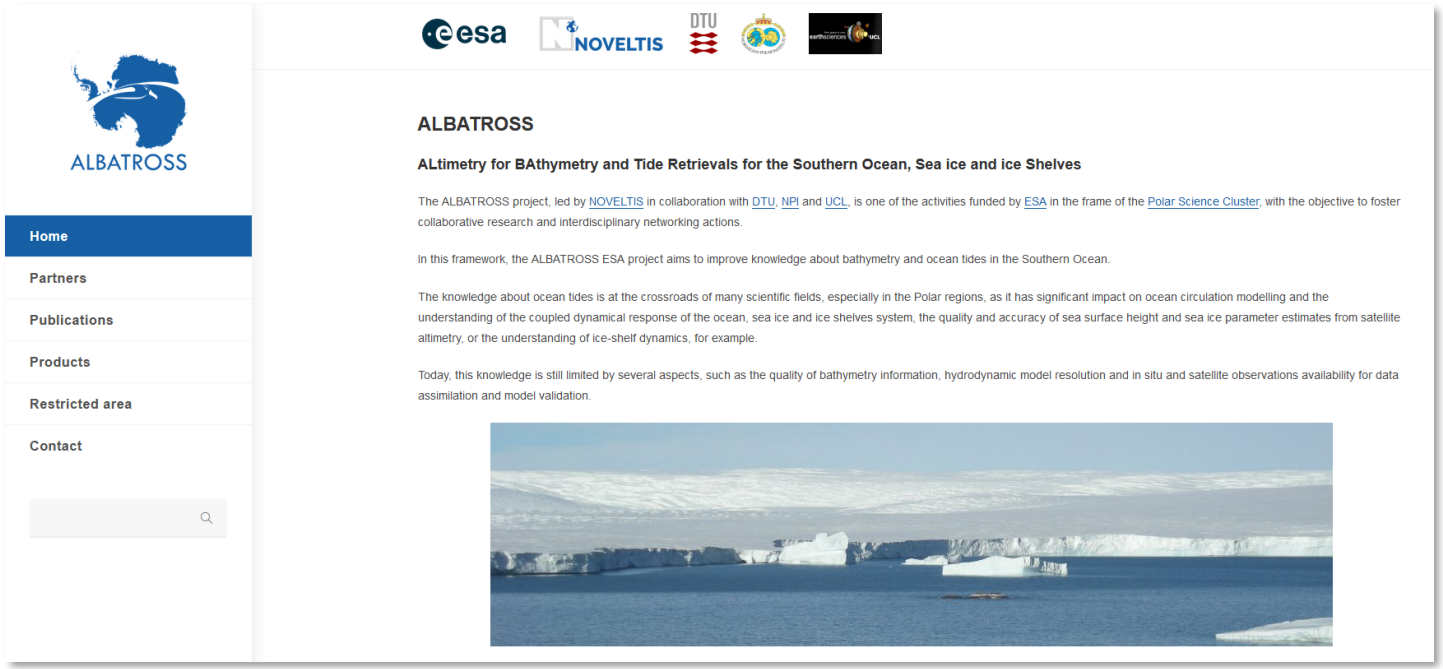
www.coastalaltimetry.org

ALBATROSS overview

- 2-year project (2021-2023)
- Funded by ESA in the frame of the Polar Science Cluster, EO4Society Programme

More details, documents, and products, ultimately:

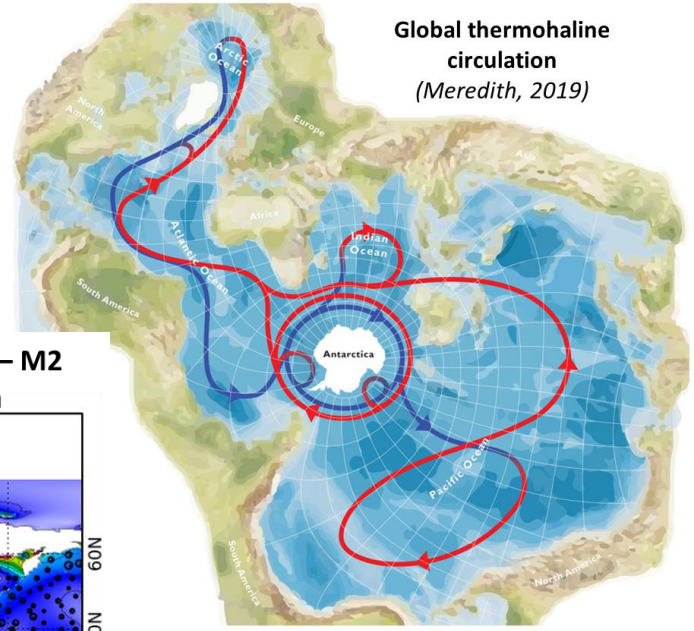
albatross.noveltis.fr



ALBATROSS overview

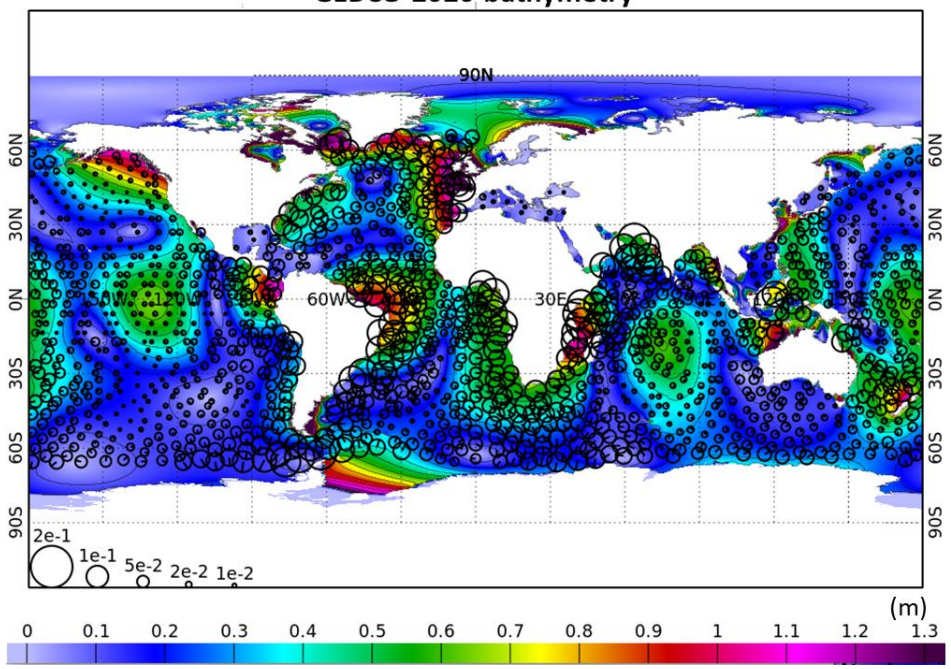
All oceans are connected in one global ocean where the **Southern Ocean plays a major role**.

Including for the ocean tides, with key role of large ice-shelf regions.

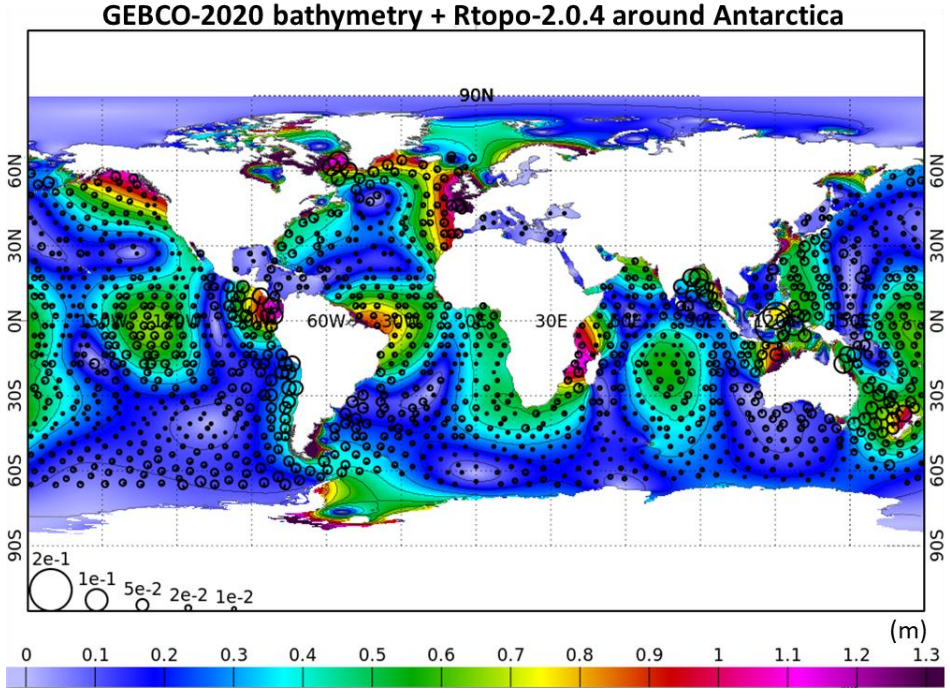


Global thermohaline circulation
(Meredith, 2019)

Vector differences to altimetry crossover points (deep ocean) – M2
GEBCO-2020 bathymetry

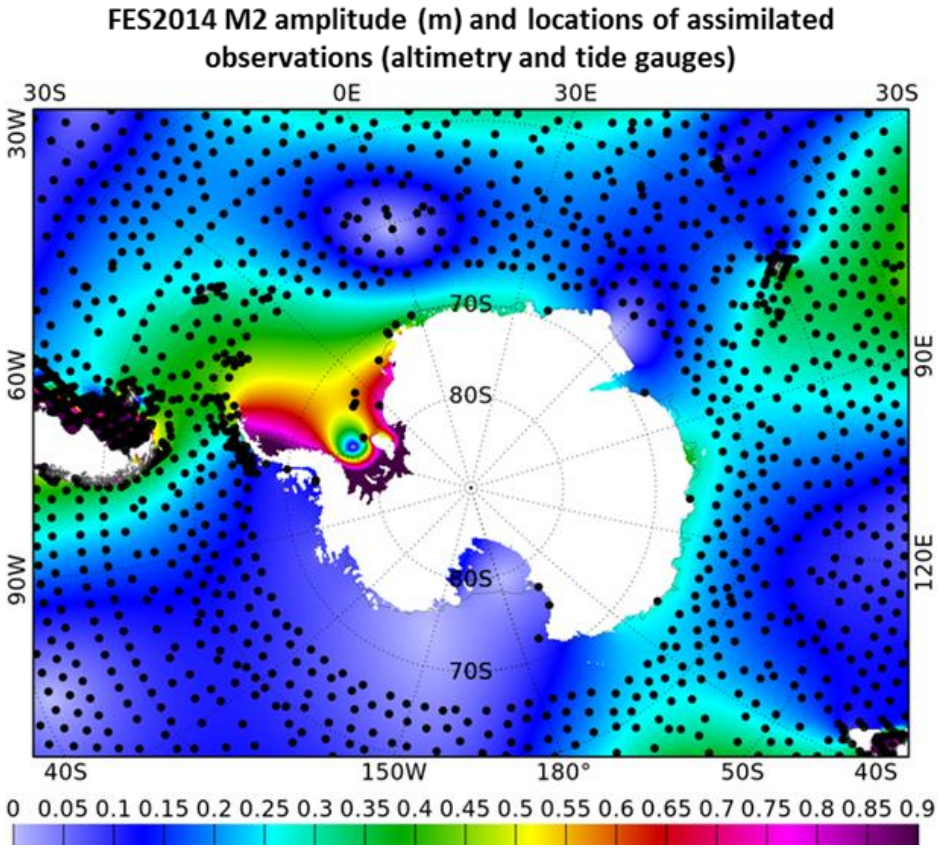


Vector differences to altimetry crossover points (deep ocean) – M2
GEBCO-2020 bathymetry + Rtopo-2.0.4 around Antarctica



ALBATROSS overview

- Knowledge on ocean tides in the Southern Ocean is still limited by several factors:
  - In situ and satellite observations availability and accuracy
  - Bathymetry quality
  - Coastline / grounding line location
  - Friction under the ice…

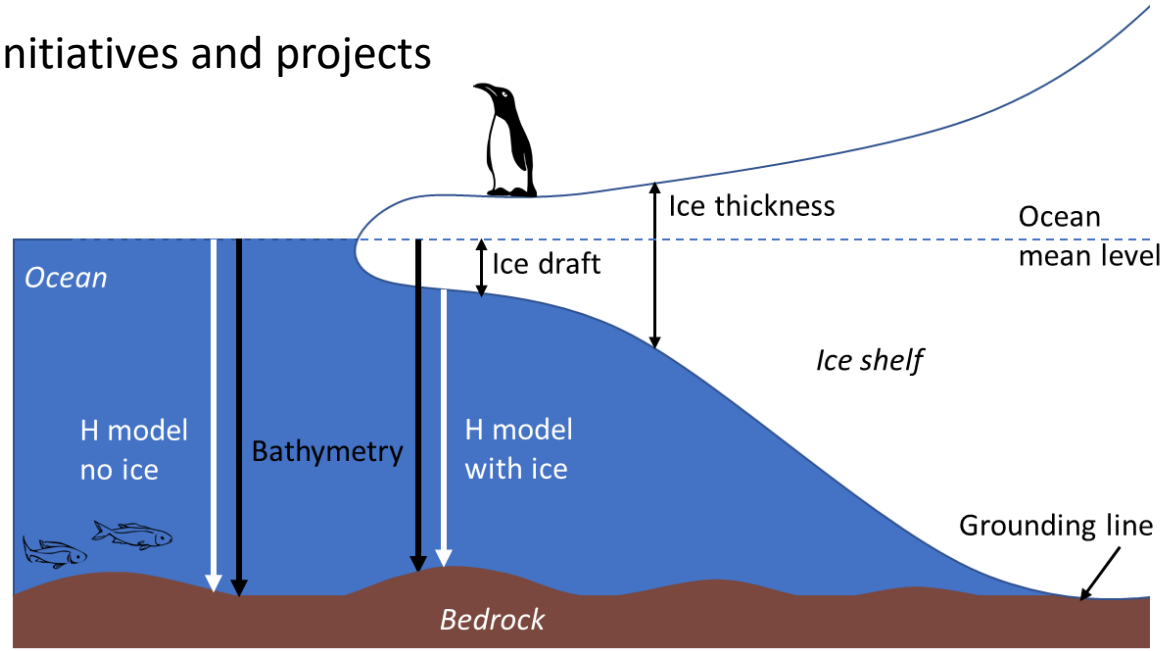


➔ **The ALBATROSS project aims to improve knowledge on :**

1. **Bathymetry around Antarctica**
2. **Ocean tides in the Southern Ocean (high-resolution hydrodynamic model)**

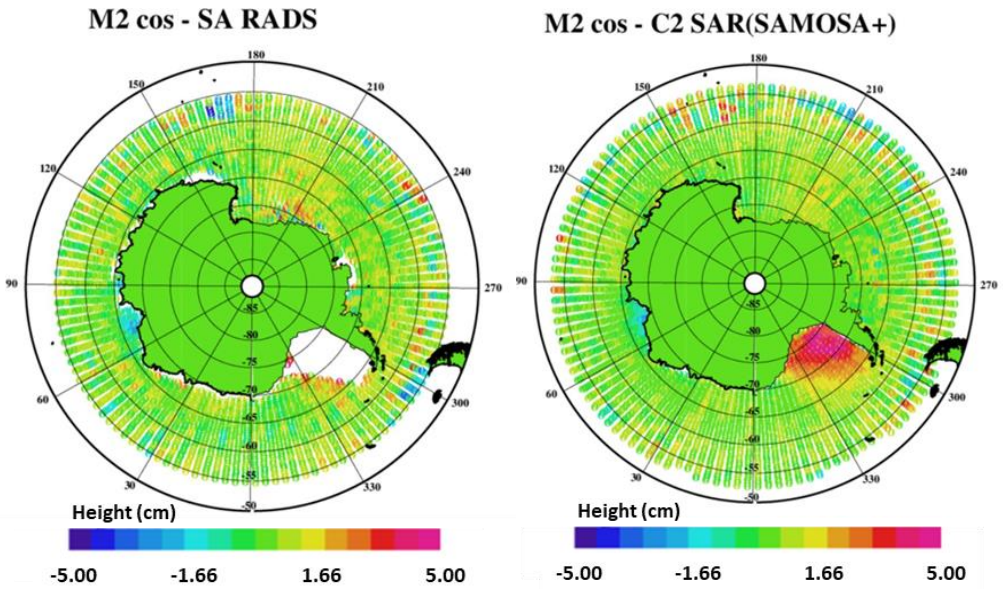
Objectives of the ALBATROSS project

- Use satellite observations to improve the bathymetry, the grounding line and the coastline information
- Explore linkage between sea ice roughness, bathymetry gradients and tides
- Retrieve tidal estimates from CryoSat-2 data
- Implement a new high-resolution tidal model with data assimilation
- Share information and knowledge with other polar science initiatives and projects



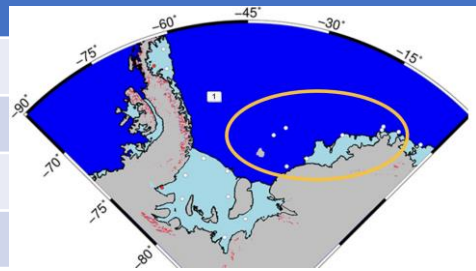
Tidal estimates from CryoSat-2 altimetry data (DTU)

- CryoSat-2 (2010-2019) SAR+SARin (>80% of the area) retracked with SAMOSA+ by ESA GPOD service
- CryoSat-2 LRM from RADS 1 Hz products
- Add other satellites when available and when it improves the solution (SARAL/ENVISAT/Jason-1/2/3)
- SLA averaged within 0.5 x 3 degree cells



Comparison to in situ stations from Zaron, King & Padman datasets

RMSVE (cm) 30 stations	FES2014	GOT4.10	CATS08	Zaron 2018	DTU22
M2	4.51	4.3	4.5	3.9	3.88
S2	4.43	8.8	7.6	6.8	2.76
K1	6.04	4.5	2.4	2.8	2.43
O1	6.69	5.6	1.2	2.1	2.61
8 selected stations					
M2	4.65				2.39
S2	4.62				2.69
K1	5.19				2.51
O1	6.01				2.44

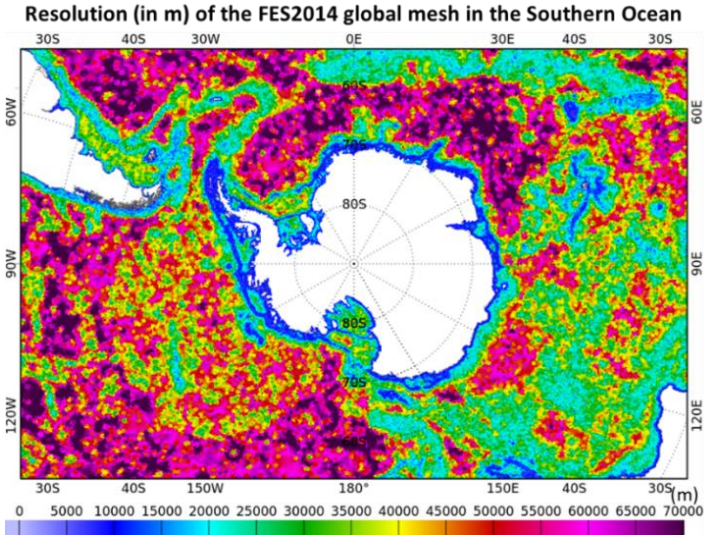


Extremely valuable new altimetry dataset to explore tides in the Southern Ocean, and for validation/assimilation into models

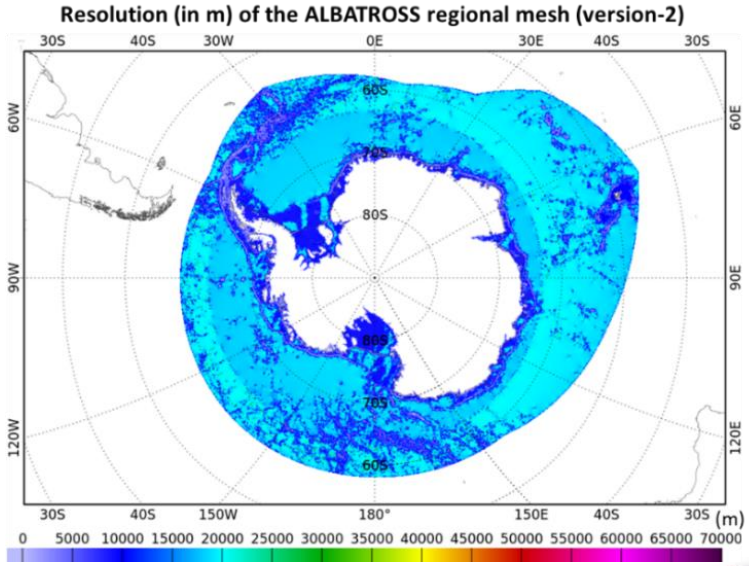
High-resolution regional tidal modelling (NOVELTIS)

Tidal modelling strategy based on TUGO-m hydrodynamic model (LEGOS)
Same approach as for the FES2014 and FES2022 global models

- High-resolution unstructured mesh grid
- Careful definition of the model extent
- Regional/local tuning of the model parameters to obtain the best tidal simulation
- Altimetry and tide gauge data assimilation to constraint the solution and to validate tidal simulations



Nb elements x 7



Bathymetry improvement – in the deep ocean (DTU)

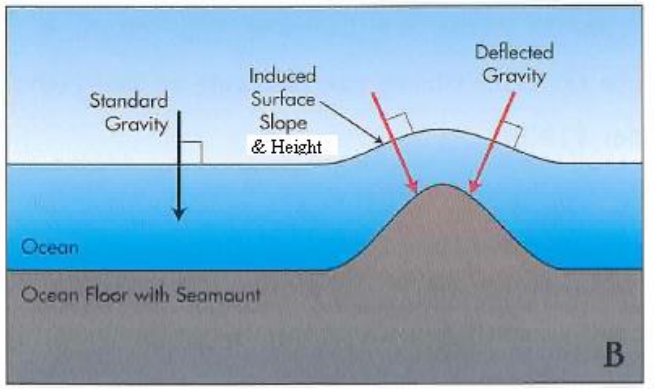
Bathymetry and gravity are correlated only on a limited spectral bandwidth (~20 – 100 km)

1 mGal gravity anomaly ~ 15 m bathymetry

$$H_p(x) = B_{long}(x) + S(x) \cdot G_{BP}(x) + B_{short}(x)$$

H_p : predicted bathymetry
B_{long} : a priori bathymetry (basis)
S : scaling factor to convert gravity to topography, in m/mGal
G_{BP} : band-pass filtered gravity

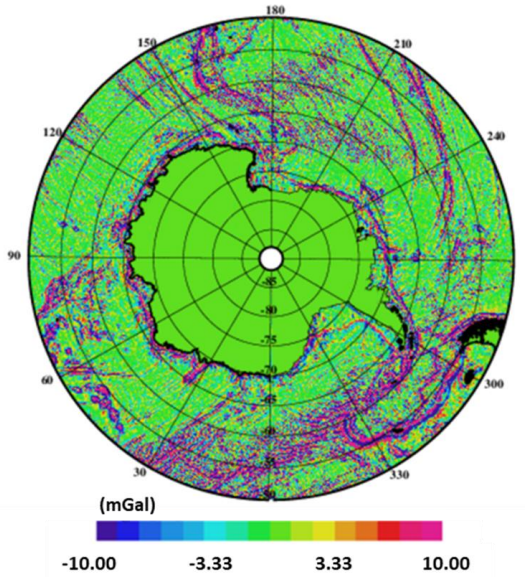
→ *Less effective in shallow waters*



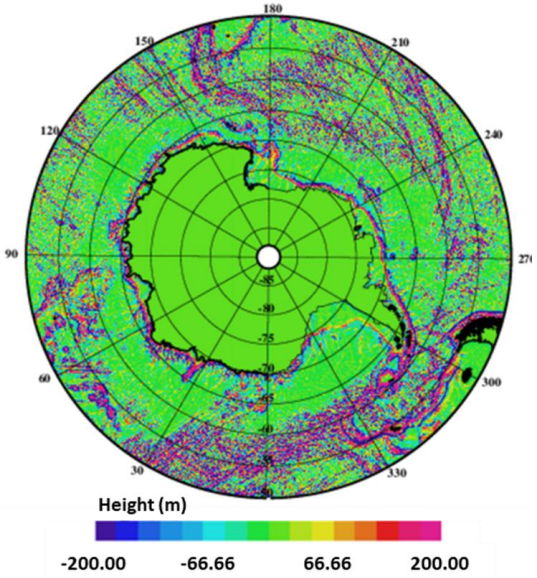
Prior bathymetry dataset: BedMachine_Antarctica-2020-v2 *(Morlighem et al., 2020)* + RTopo-2.0.4 *(Schaffer et al., 2019)* to cover the whole area of interest.

Combined with: DTU21 gravity field based on CryoSat-2 data reprocessed with SAMOSA+

DTU21 20-60 km filtered



BedMachine 20-60 km bandpass filtered

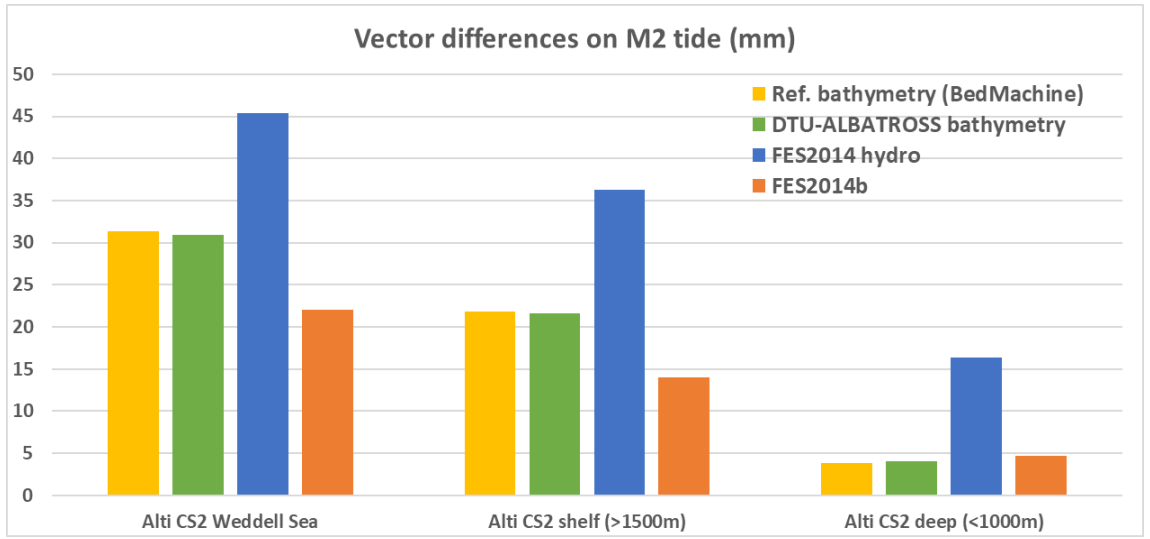


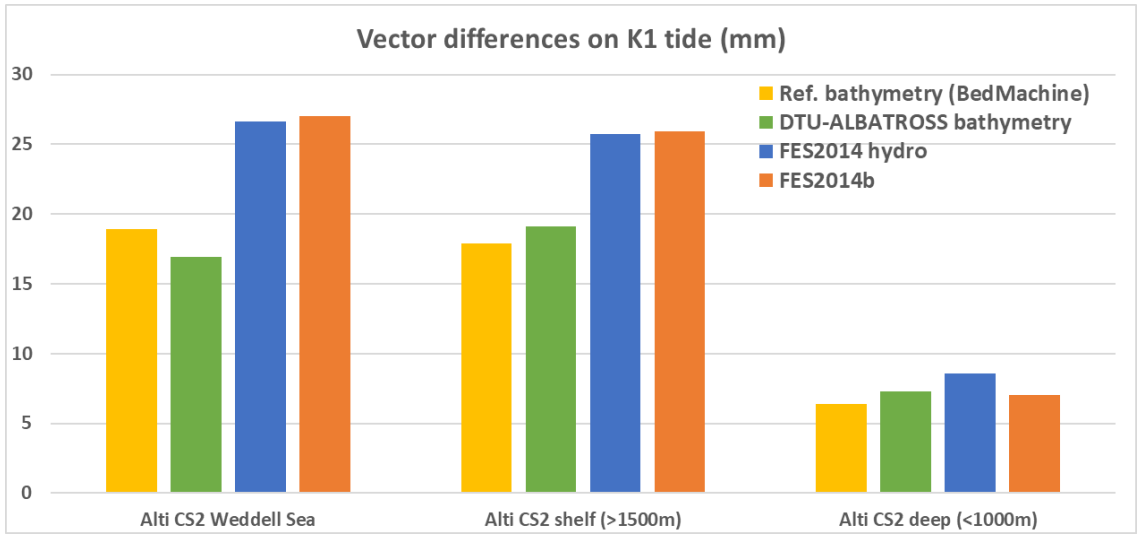
Bathymetry improvement – in the deep ocean (DTU)

Tested against 5.8 millions bathy observations (std 695 m), available down to 60°S only… and already ingested into BedMachine.

➔Local improvement observed but direct validation is quite limited due to lack of (independent) data

Diff (m) with surveys	mean	std	min	max
BedMachine	-32	235	2453	2678
DTU-ALBATROSS	-33	224	2453	2769





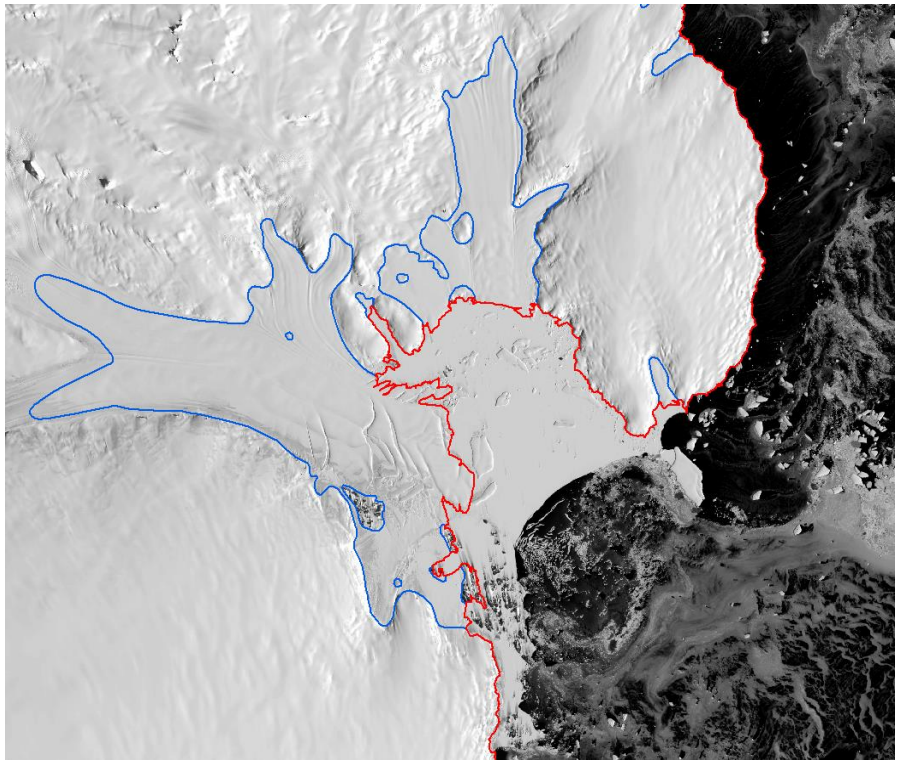
Hydrodynamic **tidal modelling** can be used as a **proxy to assess** the new **bathymetry model**

Ice shelves bathymetry, coastline and grounding line (NPI)

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

- Updated masks for grounding line and coastline, based on SAR interferometry, altimetry, and new Landsat-8/Sentinel-2 imagery
- Updated ice-shelf bathymetry and ice draft, based on recent bathymetry datasets.

A slightly updated version of the datasets is in prep. in collaboration with the Bedmap and SCAR-RINGS initiatives.

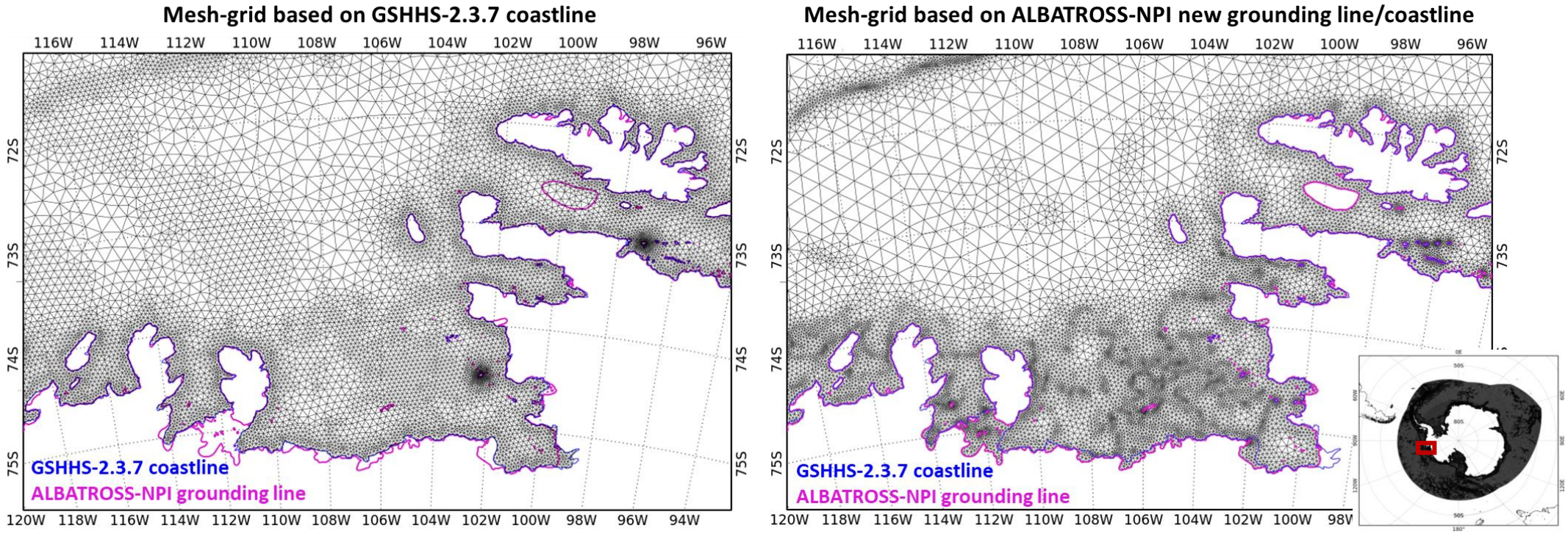


Combine coastline (red) with grounding line (blue), extraction of ice-shelf mask

Ice shelves bathymetry, coastline and grounding line (NPI)

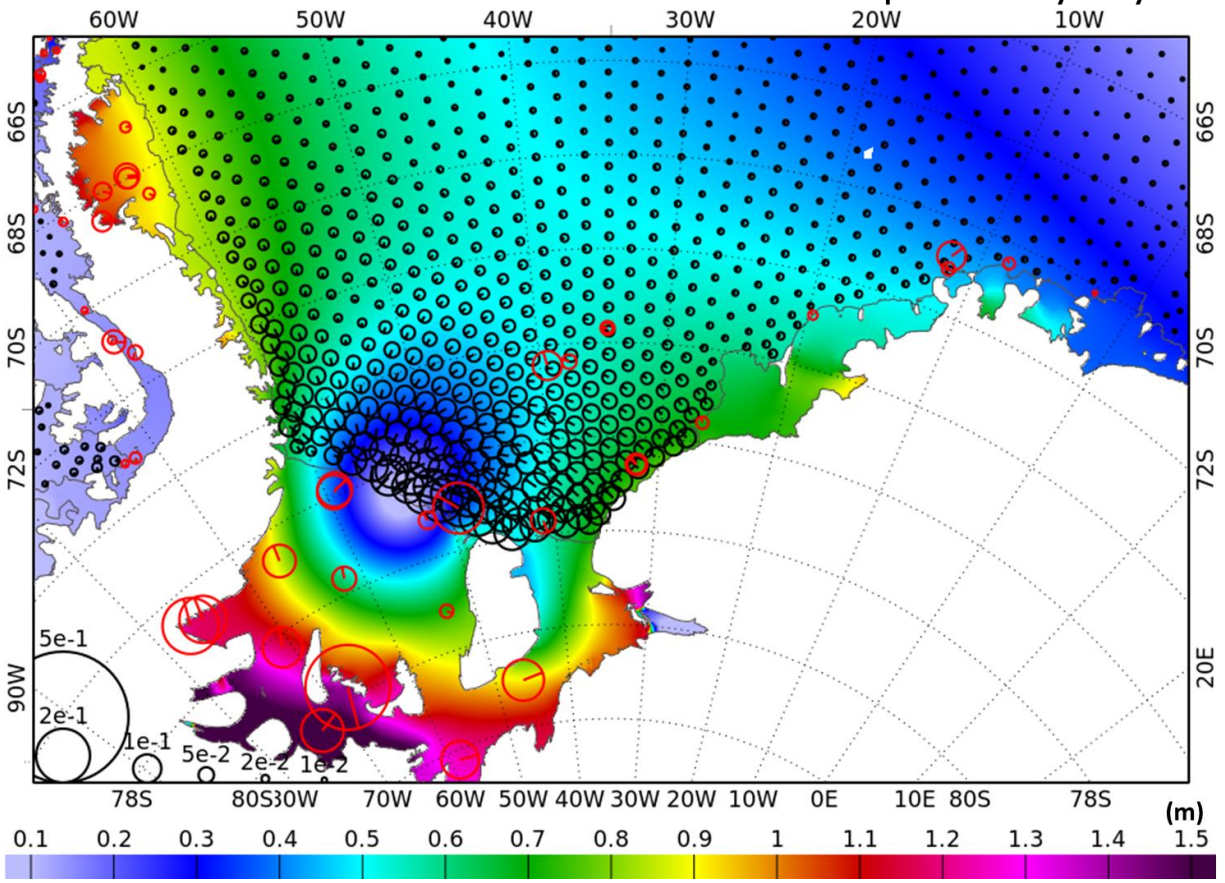
Accurate information about grounding line location, bedrock topography and ice draft under the ice shelves is crucial to perform accurate tidal simulations.

- New combined grounding line & coastline used as model grid land boundary, instead of GSHHG-2.3.7 coastline

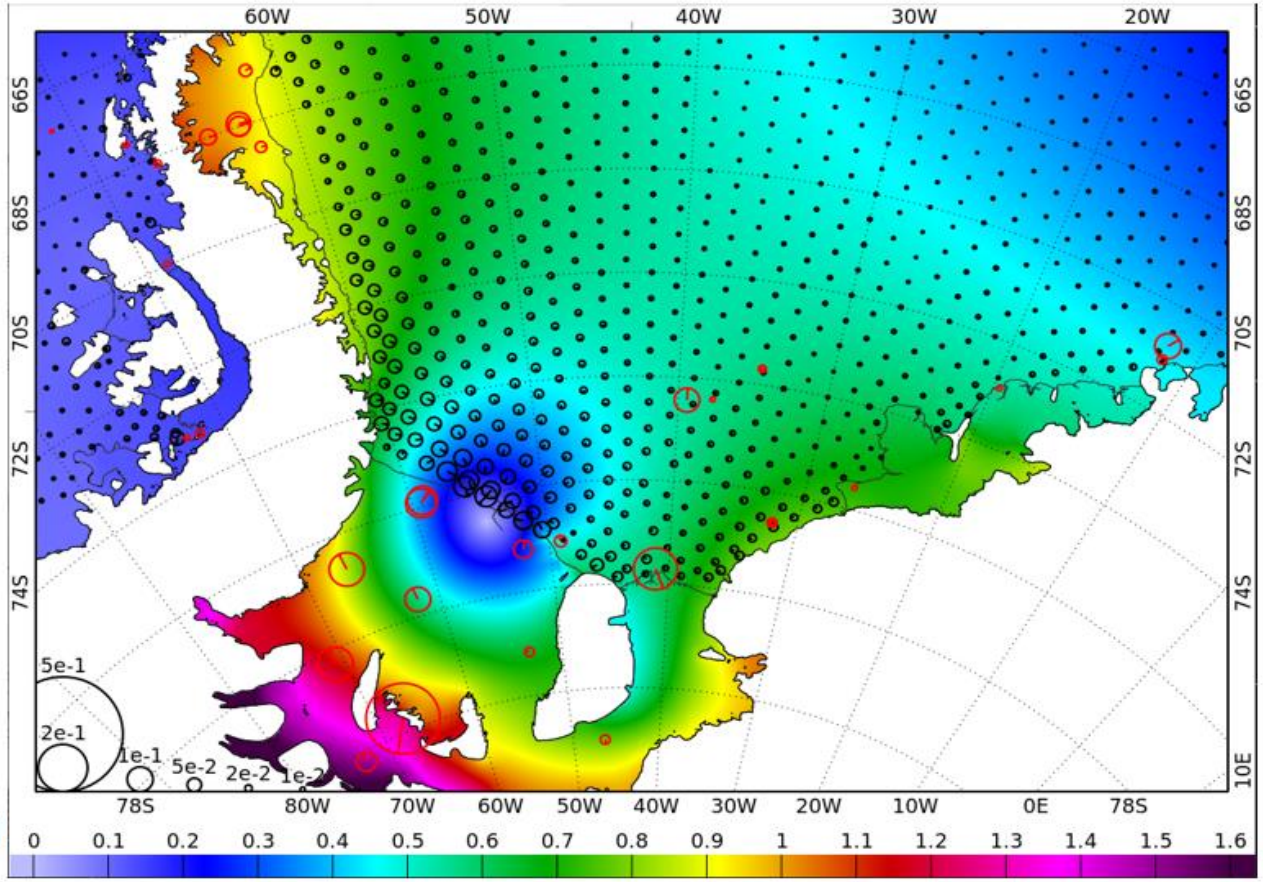


Tidal modelling based on the ALBATROSS bathymetry datasets

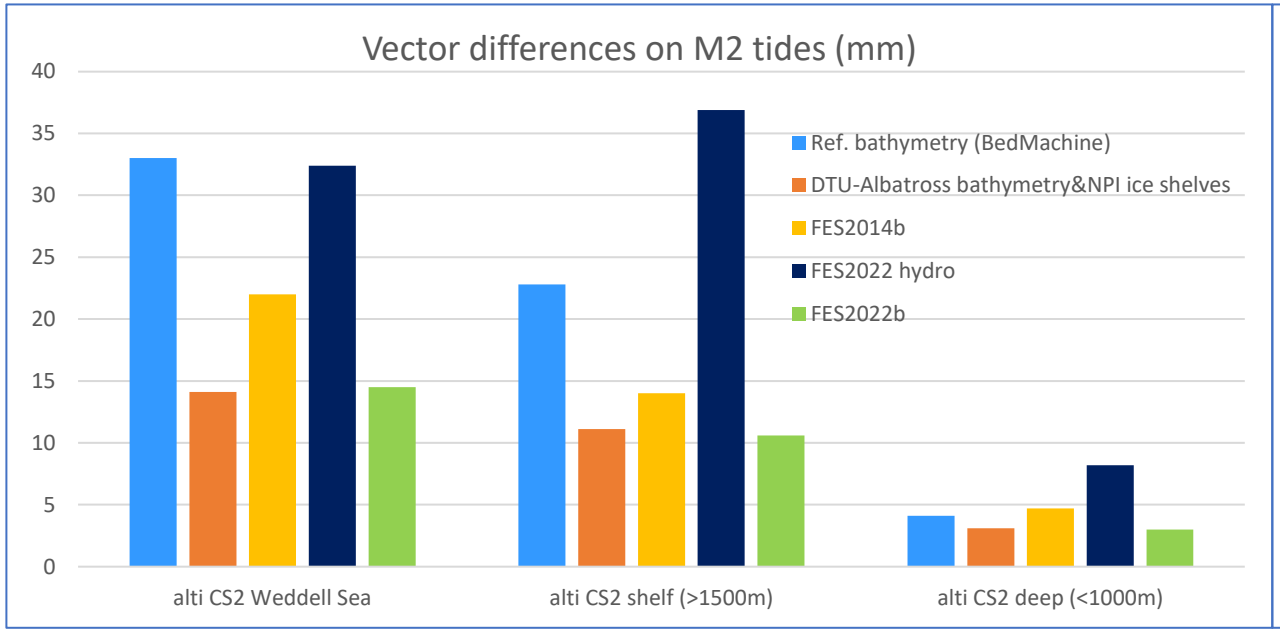
Vector difference on M2 (m) relative to CryoSat-2 data and in-situ data
ALBATROSS mesh based on GSHHS coastline – BedMachine+Rtopo-2.0.4 bathymetry

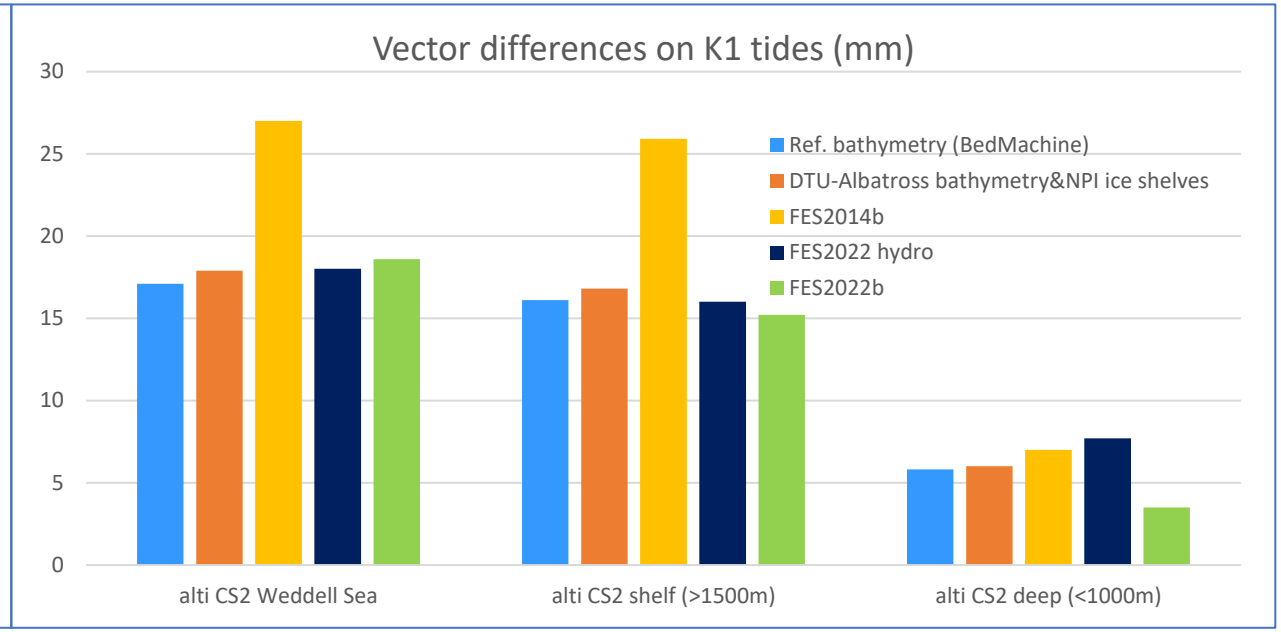


Vector difference on M2 (m) relative to CryoSat-2 data and in-situ data ALBATROSS mesh based on NPI&GlobalIslands coastline – DTU&BedMachine lower bathymetry&Ice shelves NPI



Impact of the bathymetry choice on the tidal simulation





Optimal combination of bathymetry models to be finalized, but already :

➔ Clear improvement when considering the new ALBATROSS bathymetry products fine-tuned (coastline & ice-shelf)

➔ Without assimilation, ALBATROSS hydrodynamic simulation (no data constraint) at the level of FES2014 (assimilated)!

Sea ice surface roughness and bathymetry gradient location (UCL)

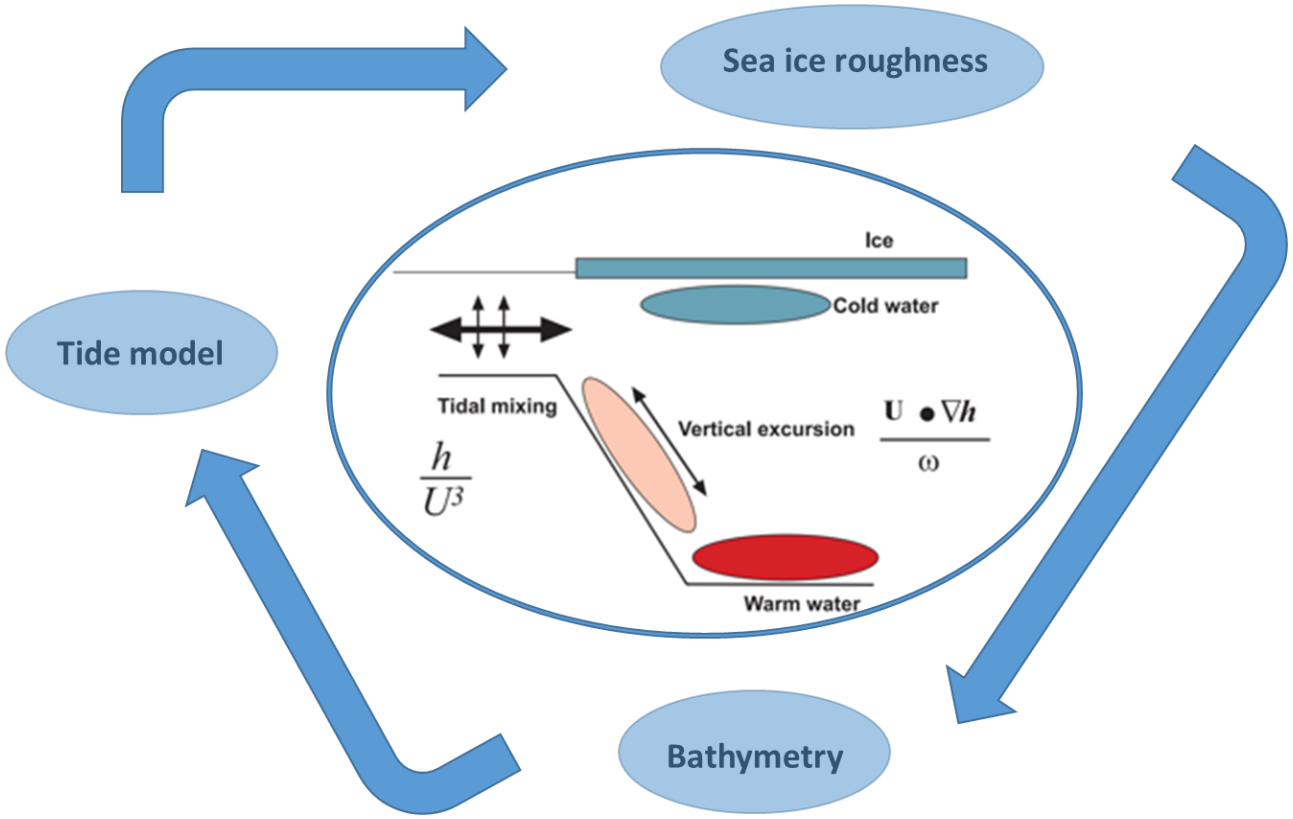
Bathymetry controls ocean currents, temperature… and sea ice presence

Seek a surface signature of bathymetry, in the sea ice roughness

- Steep bathymetry acts as hot spots of enhanced vertical heat fluxes mediated by tides and increased turbulence.

- Higher lead density correlates very well with steep bathymetry

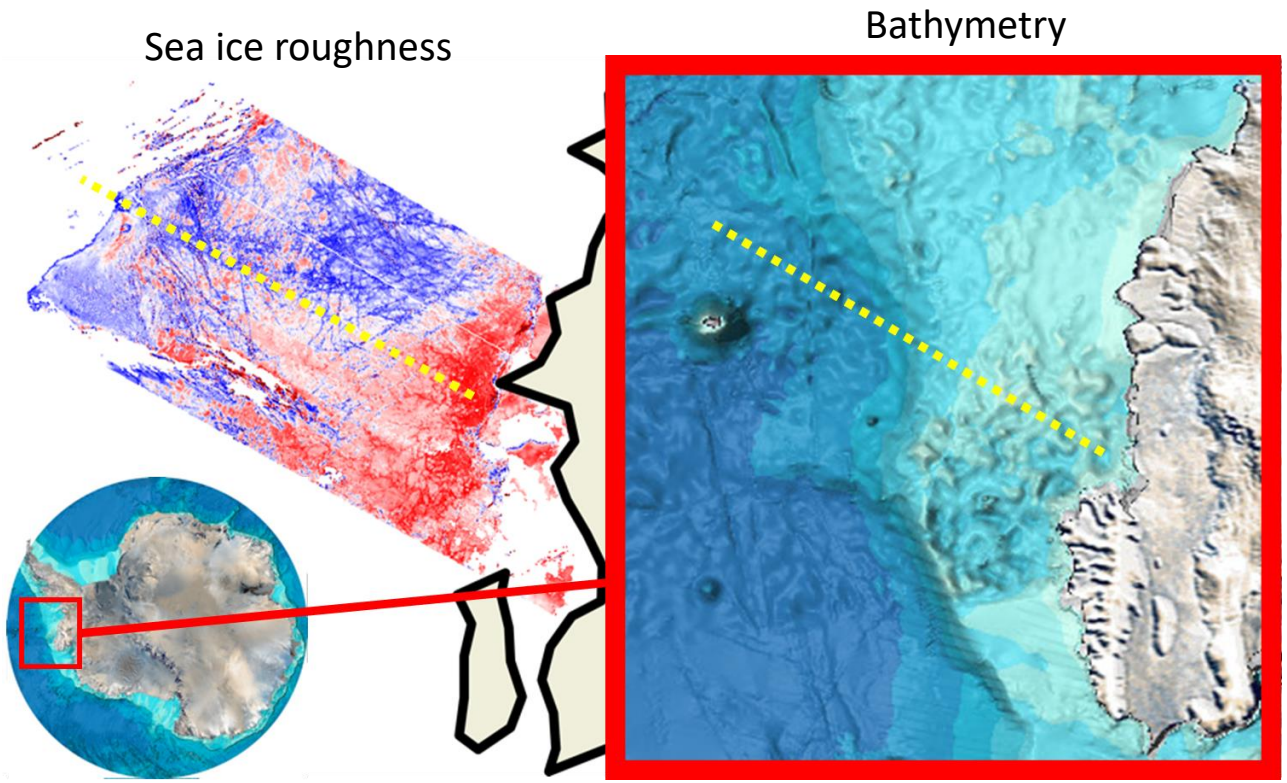
➔**Explore linkage between sea ice roughness, bathymetry and ocean tides**



Sea ice surface roughness and bathymetry gradient location (UCL)

Novel technique developed at ES_UCL using 20 years of NASA MISR (Multi-angle Imaging Spectro-Radiometer)

with Operation Ice Bridge airborne data for training



See Johnson et al., 2022 (accepted) for similar approach in the Arctic Ocean

Conclusions

- CryoSat-2 extremely valuable for tidal estimates and bathymetry retrievals
- New ALBATROSS products bring clear improvement
- Results on tidal simulations are very encouraging
- Main difficulty: independent validation (lack of in situ observations for bathy & tides)

Last steps

- Finalization of the regional tidal atlas (early 2023) : assimilation
- WP3 – Impact assessment (early 2023)
  - **In the ocean** (UCL) : Impact on the CryoSat-2 SSH and sea ice products (CryoSat+ Antarctic Ocean project)
  - **Ice shelves** (NPI): Impact on monitoring of Antarctic ice-shelf dynamics parameters

Planned outcomes

- Southern Ocean composite bathymetry
- Antarctic grounding line and coastline
- Sea ice surface roughness product
- Southern Ocean high-resolution tidal atlas

Interested in taking part in pre-release assessment (Feb.-March 2023)?
Please contact us!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