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Altimetry-derived ocean tides in the Arctic: a Foxe Basin case study

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Introduction

- Cryosat-2 presents a suitable time-series of data for tidal analysis in the higher latitudes and has resulted in improvements in modelling of tides in the higher latitudes (Zaron 2019, Andersen et al 2023).

- Efforts have also been made to provide increased coverage from in-situ measurements.

- The Foxe Basin (**Figure)** is a historically challenging region for both tides and satellite altimetry, due to the sea-ice coverage for most parts of the year and NO in-situ measurements

- This forum discussions presents a focused study on the Foxe Basin in an attempt:

    1. To better characterise the tides of the region
    2. To evaluate the impacts of different factors such as sea ice and bathymetry on resultant tidal estimations.

Figure 12.1. Map of Foxe Basin.

Tides in Foxe Basin: Historical View and Problem

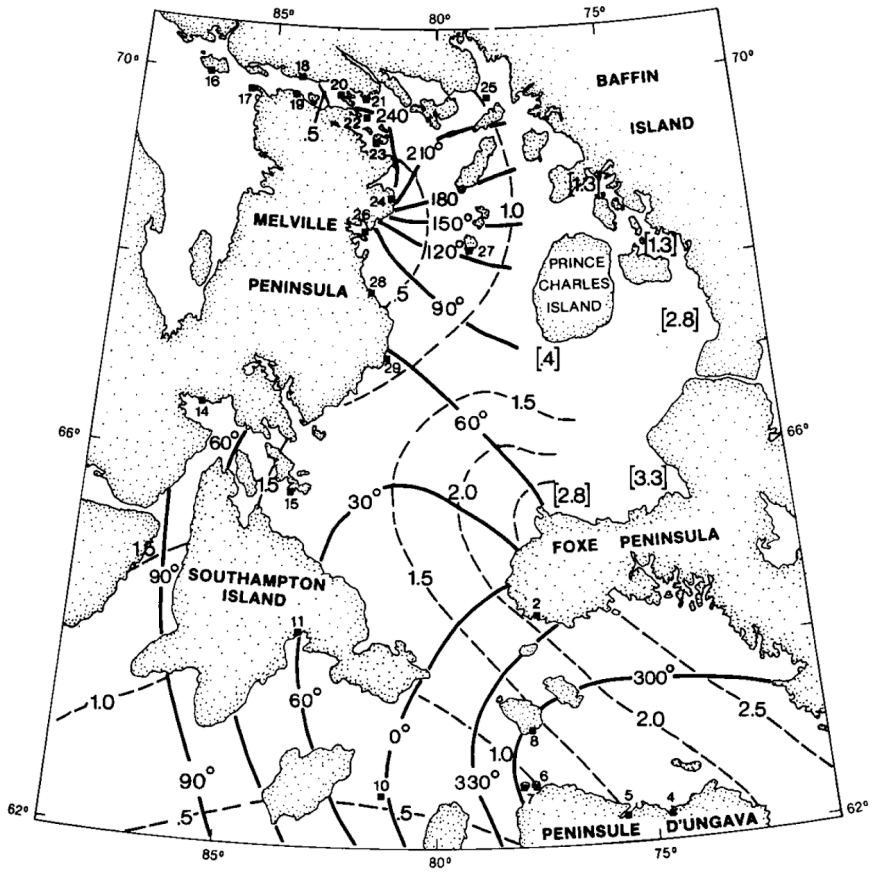
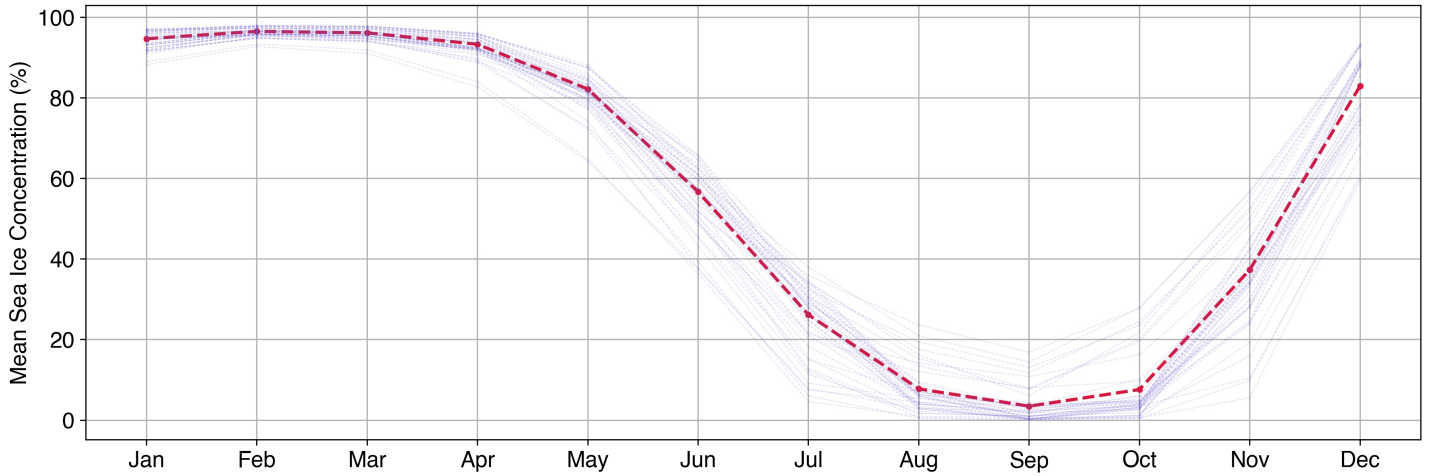


Figure 12.7. M_2 co-tidal chart for GMT + 4 hr time zone. Co-phase (deg.) represented by solid lines and co-amplitude (m) by dashed lines. Smaller numbers indicate station numbers whose data (Table 12.1) is used to plot chart. Large numbers in square brackets are reported tidal amplitudes (no phases).

- **Figure (left).** M_2 tide amplitude and phase. Taken from Prinsenberg, S. J. (1986).
- **Figure (below)**. Mean sea ice concentration across the Foxe Basin (red) and latitudinal variability (blue). From Copernicus Marine Service for the 1994 to 2020.

- Sea ice is crucial based on the used satellite altimetry data, which can retrieve SLA data used in the tidal analysis only where there is no sea ice or within ice leads.



What do the models say?

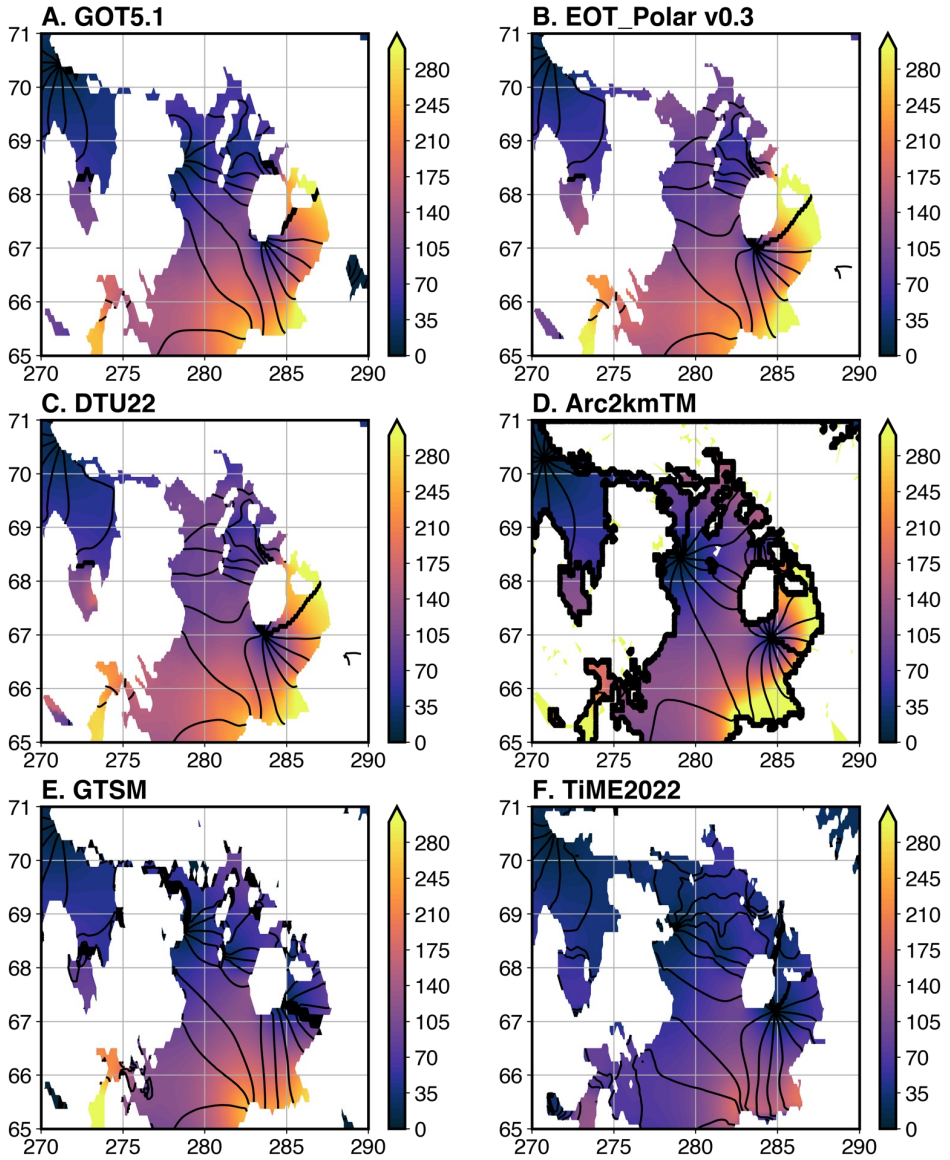


Figure. M_2 for 6 models, three semi-empirical and three numerical models. EOT (Hart-Davis et al 2021 updated), GOT (Ray 1999 updated) and DTU (Andersen et al 2023) all include Cryosat-2.

- The three numerical models (Arc2km (Howard and Padman 2021), GTSM (Veenstra et al *in prep*), TiME (Sulzbach et al 2021)) all use different bathymetry products in this region.
- The three empirical models show significantly larger tidal amplitudes compared to GTSM and TiME2022.
- Arc2km in terms of amplitudes matches more with the data-constrained models.
- The phase structure matches well between the empirical models, especially EOT and DTU (which use the same Cryosat-2 data processing).
- The numerical models have quite big differences in the phase.

Bathymetry differences

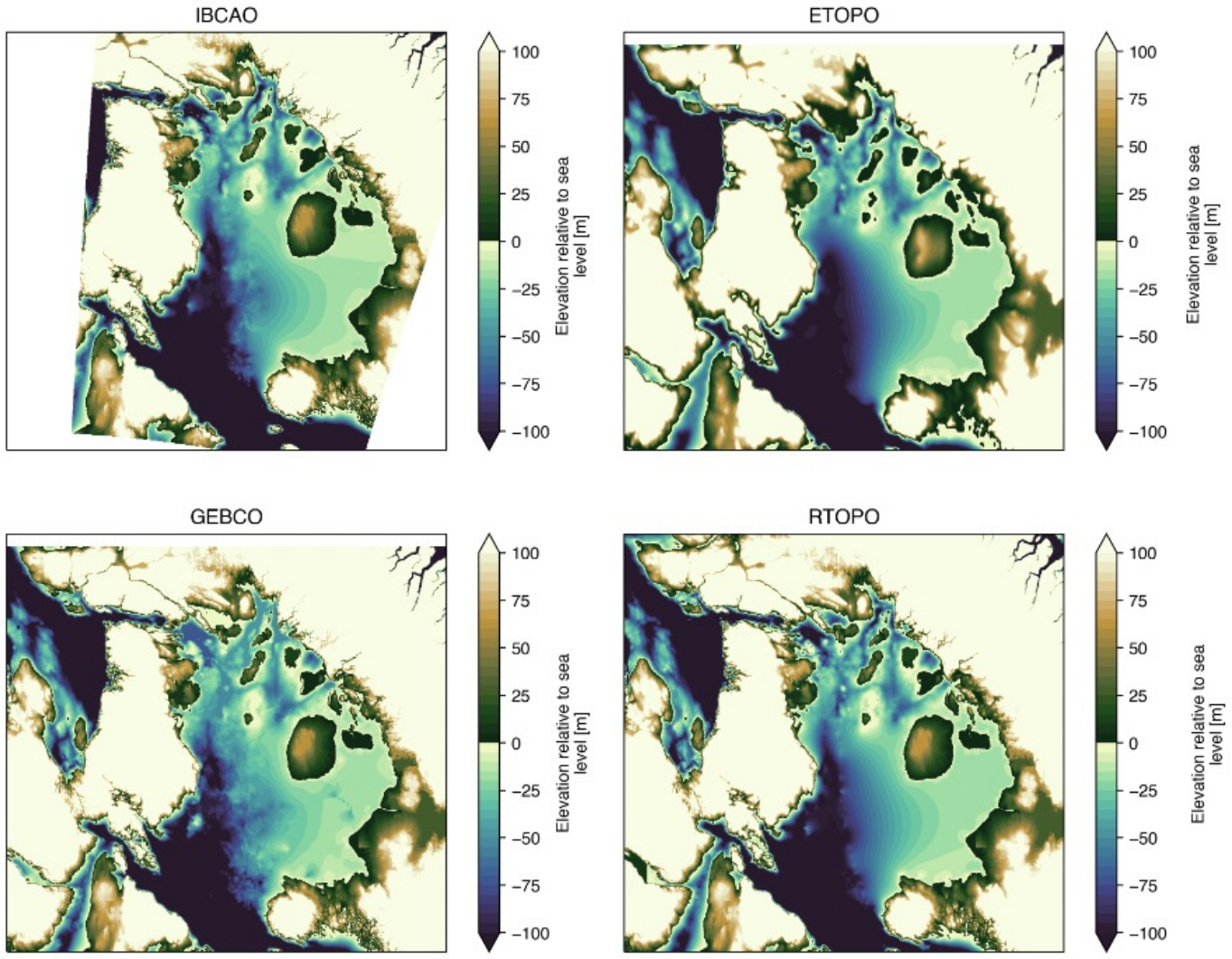


Figure. Four different bathymetry of the Foxe Basin

- Arc2kmTM uses GEBCO14
- GTSM uses GEBCO2019 which incorporates the IBCAO dataset
- TiME2022 uses ETOPO.
- Eastern part of Foxe Basin, which shows high amplitudes from altimetry, has a very shallow bathymetry.
- The bathymetry products presented here vary considerably, also on the shallow eastern part of the basin.

Sea Ice Dampening?

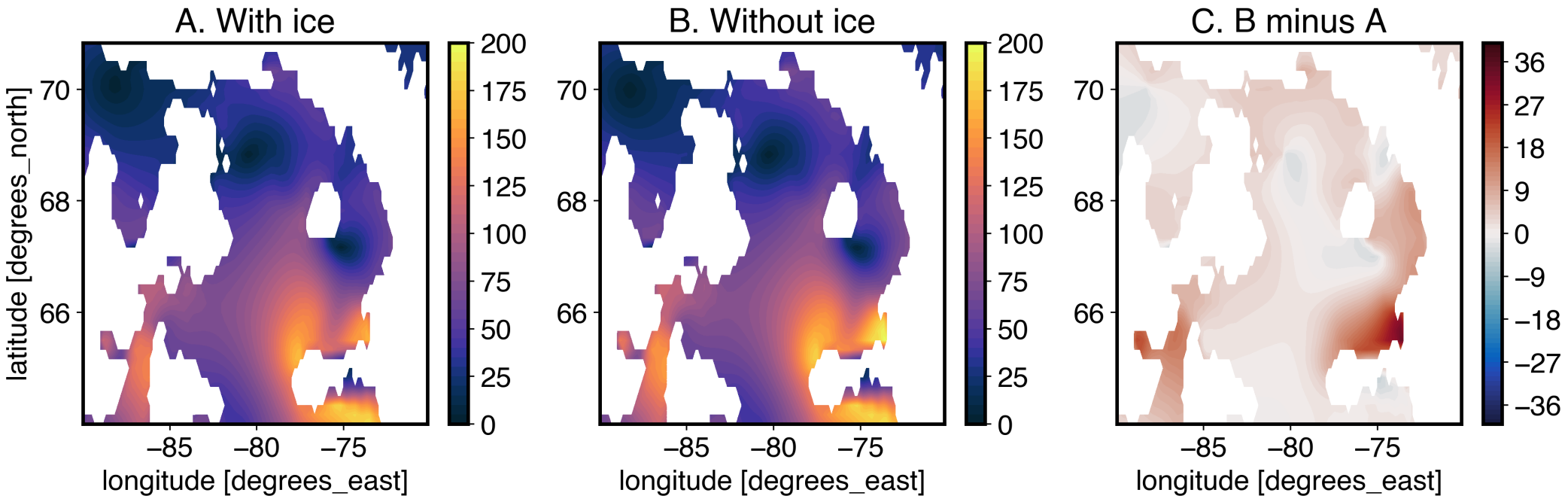


Figure. The TiME model was run here with and without ocean tides and compared here for the M_2 amplitude. Model run by Roman Sulzbach (GFZ)

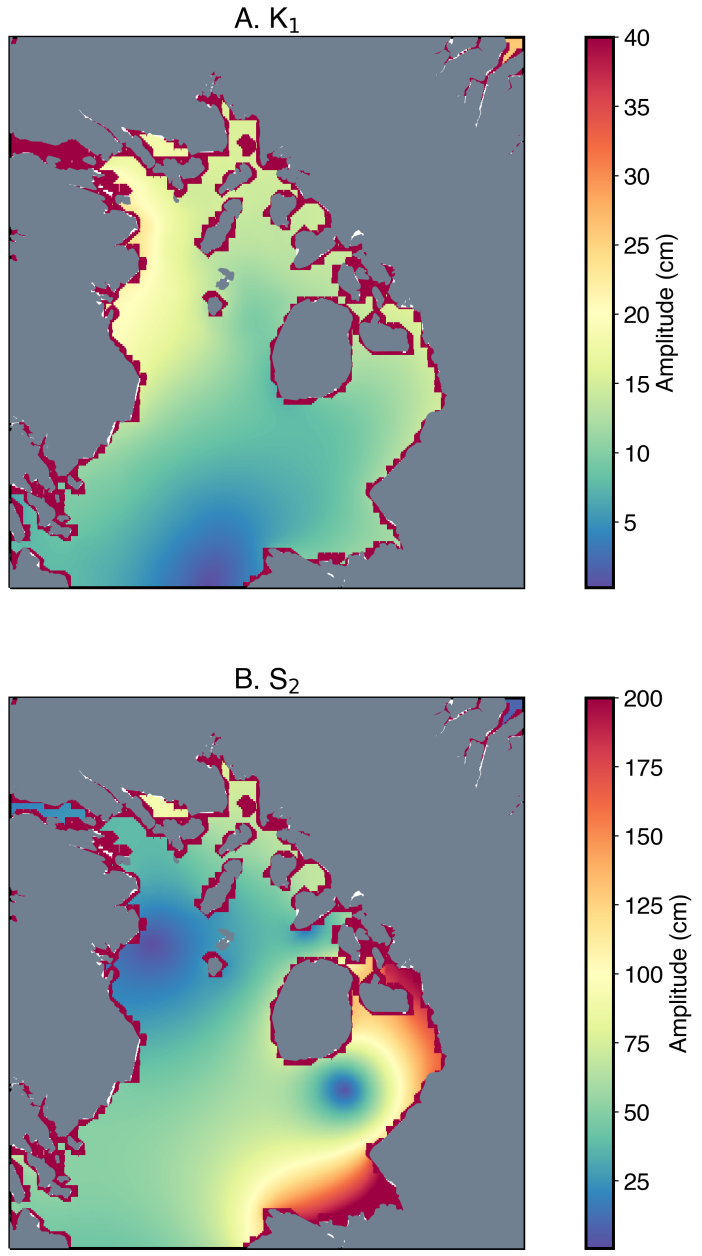
- This was done as the data-constrained models are of course only making estimates when there is no ice. So the amplitude differences in this case changing by >30 cm can explain SOME of the differences between the models.

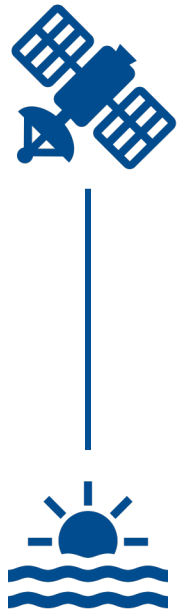
- But the bathymetry differences / inaccuracies are likely also driving significant changes.

Conclusions

Figure. Arc2km model amplitudes for the S_2 and K_1 tides.

- The Foxe Basin presents a challenge for modern day tide models due to both sea ice for empirical models and bathymetry products for numerical models.
- Despite Cryosat-2 showing significant insight into the higher latitudes, this region also highlights difficulties in estimating tides in the higher, sea ice covered latitudes.
- This region has relatively large tides, with the M_2 being shown to exceed 300 cm while the S_2 exceeds 200 cm in parts of the basin.
- Identifying which model or which approach is most suitable for this region is not easy, due to no in-situ measurements being found on the eastern part of the Foxe Basin which has the highest tides.
- Research will continue.





Thank you! Questions?

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