Tides beneath the Amery Ice Shelf from a finite element model

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Introduction

A finite element gravity wave model is used to simulate tides in the South Indian Ocean, one of the purposes being to provide tidal corrections for the satellite measurements. Since ice shelves have an important contribution in tidal energy dissipation, particular attention is given to the region of the Amery Ice Shelf (AIS). Thus we focus our attention on tides elevation beneath the shelf.

Comparisons of the four main tidal constituents have been made between the available data and the model prediction. We find good results for the diurnal tides, whereas semi diurnal tide amplitudes are overestimated beneath the cavity.

We obtain the same problems appear with the CADA results *(Padman et al., 2002).* Thus we discuss from the solutions which could be brought to improve the tidal results in the AIS region.

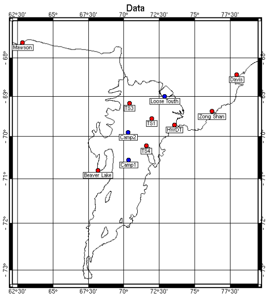
Available data for validation

Two types of elevation measurements:
- tide gauges (Davis, Mawson, Zhong Shan, Beaver Lake)
- GPS measurments(TS1, TS3, TS4, HWDT)

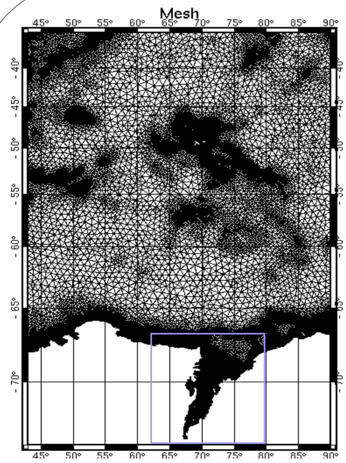
In addition, comparisons with the CADA00.10 model have been done on the blue sites and the Beaver Lake site.

Harmonic analysis have been done for each site, and the amplitude and phase for the four main tidal constituents (M2, S2, K1, O1) have been compared with model runs.

- Tide gauges and GPS measurements
- Sites for comparison with Padman model



Modelling



Model description

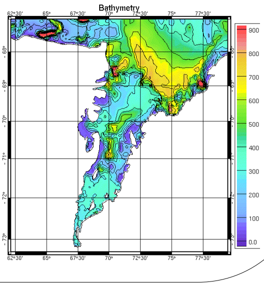
MOG2D (2D gravity wave model)
Lynch and Gray (1979) adapted by Greenberg and Lyard

- 2D barotropic
- Finite element resolution
- Hydrostatic pressure
- Shallow water equation

At the open boundary, the model is forced with the FES2004 solution (model global solution with data assimilation).
The bottom friction coefficient is doubled beneath the ice area.
We use 8 tidal constituents (M2, S2, K2, N2, K1, O1, Q1, P1) in the modelling.

Input data

The grounding line, bathymetry and ice thickness used have been updated by interpolating measurements done under the AIS (Ben Galton Fenzi).
The figure represents the water column thickness used for the modelling.



Model Validation

Bottom friction coefficient sensitivity

Model runs were carried out using three different bottom coefficients: 0.005 (the coefficient related to the seabed stress doubled), 0.006, 0.010.

→ No significant changes have been observed.

Tidal constituents comparisons

Amplitudes comparisons

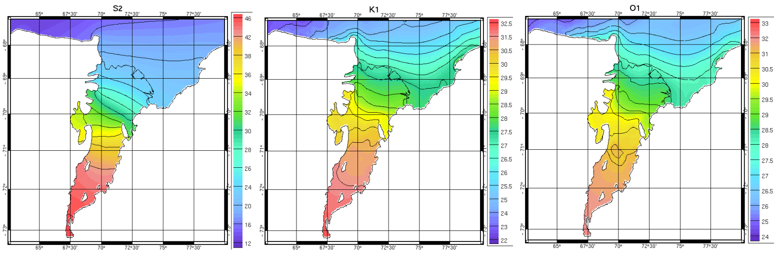
	Amplitude (cm)							
	M2		S2		K1		O1	
Location	M	O	M	O	M	O	M	O
Beaver Lake	30,9	24,9	36,0	26,2	30,1	28,5	30,5	29,7
Davis	20,4	20,2	20,3	17,7	27,6	27,6	28,3	28,6
Mawson	3,7	3,2	13,6	11,2	22,7	23,4	25,1	25,2
Zhong Shan	21,0	20,1	22,0	18,2	27,6	27,7	28,2	28,7
HWDT	22,9	18,6	25,0	17,8	28,3	31,0	28,9	28,3
TS1	23,8	22,0	26,4	22,1	28,1	29,5	28,8	29,3
TS3	22,7	21,8	25,3	21,6	28,0	29,4	28,8	30,0
TS4	27,9	24,5	31,8	25,4	29,6	30,7	30,1	31,4

- The differences between predicted and observed amplitudes are smaller in the open ocean than beneath the AIS.
- The amplitudes seem well simulated aside greater differences for the S2 constituent.
- The simulated amplitudes for the semi-diurnal constituents are larger than the observed amplitudes beneath the AIS. And this is worse for the data near form the grounding line.

Phases comparisons

- Largest phase errors are for the M2 phase at Beaver Lake and the S2 phase at TS1, TS3, and TS4 (lag between 21.2 and 24.8).
- Apart from those lags the amplitudes are well predicted.

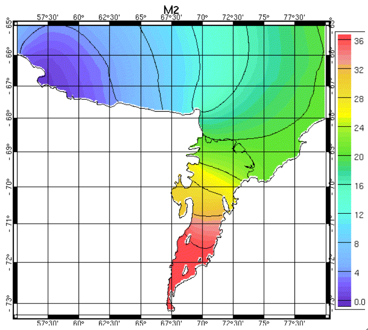
Tidal elevations



Amplitude and phase for the M2, S2, K1, O1 constituents.

- Amplification of the amplitudes beneath the AIS. This is emphasized for the semi-diurnal constituents.
- The structure of the M2 and S2 tides are similar.
- This is also the case for K1 and O1 constituents.

The amphidromic point for the M2 tide occur in the domain.



Discussion and perspectives

Comparisons with CADA

CADA description *(Padman, 2002):*
- grid less dense than the one used with MOG2D
- data assimilation : Beaver Lake, Davis, Mawson, HWDT in the region of interest

→ Differences between the two models

- The M2 amplitude is also not well predicted by the CADA model
- The amplitudes of the diurnal constituents are better predicted by MOG2D

	Amplitude (cm)							
	M2		S2		K1		O1	
Location	MOG2D	CADA	MOG2D	CADA	MOG2D	CADA	MOG2D	CADA
Beaver Lake	30,9	27,7	36,0	29,5	30,1	31,8	30,5	33,0
Camp1	30,6	28,0	35,5	29,7	30,2	31,8	30,5	33,0
Camp2	27,1	25,7	30,9	26,9	29,1	30,8	29,6	32,1
Loose Touth	21,2	21,5	22,7	21,7	27,5	28,8	28,4	30,2

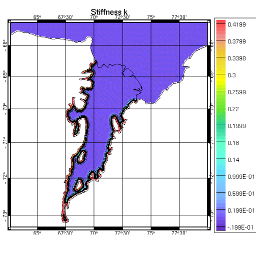
Perspectives

Both MOG2D and CADA modelling of the diurnal constituents amplitude are overestimated. The results can be improved by increasing the accuracy of the bathymetry and the model physics.

We project to add the numerical resolution of the elastic flexure in the grounding zone. The force due to the flexure will be implemented as fallows:

$$\vec{F} = \vec{\nabla} k\eta$$

with
- η the surface elevation
- $k = \sqrt{\frac{3}{2}\frac{\rho_w gE}{(1-\upsilon^2)h}}\, e^{-\lambda x}(\cos(\lambda x)+\sin(\lambda x))$, *(Holdsworth, 1969)*



Conclusion

We have presented tidal elevation results from a finite element model in the AIS region. We find that even if diurnal tides are well predicted, semi diurnal tide amplitudes are overestimated beneath the shelf. Similar results are find with the CADA model concerning the semi diurnal tides.

In order to improve the results in the AIS cavity we need to improve the model physics. A first step in this increasing is to add the modelling of the flexure mechanism in the grounding zone. It will reduce the tidal amplitudes nevertheless elastic flexure do not dissipate energy. Thus it could be interesting to model viscoplastic effects in the grounding line *(Lingle et al., 1981).*

When the tidal results will be improved, they could be used to remove tidal signal from satellite data collected over the AIS.

Acknowledgements

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