An inter-comparison of ocean tide loading estimates for Antarctica from models and GPS

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Introduction

The periodic redistribution of ocean mass due to ocean tides results in a periodic loading of the Earth known as ocean tide loading (OTL). Here we report on OTL on the Antarctic continent, comparing direct measurements from GPS data with estimates from several numerical tide models. Furthermore, we examine the effect of mismodelled OTL on altimetric measurements from ICESat.

Accurate estimates of OTL are required for the determination of accurate geodetic coordinate time series, altimetric height measurements and GPS estimates of precipitable water vapour. However, modelled values may be inaccurate where little input data is available for numerical tide models and/or coastline locations are poorly known. This is true for large portions of the circum-Antarctic seas and particularly so for the ice shelf regions where often little or no tidal data is available and coastlines may be incorrect by several tens of kilometres.

Model-GPS Differences

- GPS data processed using Precise Point Positioning (PPP; GIPSY-OASIS II) directly estimating the eight major diurnal and semi-diurnal constituents (K_1, O_1, P_1, Q_1, M_2, S_2, N_2, K_2) along with site coordinates and tropospheric zenith delay parameters
- Permanent and campaign GPS sites used with the IGS, SCAR and other institutes kindly providing data
- Independent OTL estimates from ~100-3000 days were combined using a Kalman filter, outliers removed and astronomical argument and nodal factors applied
- Model estimates were obtained from the SPOTL software using each of the TPXO.2, CSR3, FES95.2, FES99, NAO99, GOT00.2 and TPXO.6 global numerical tide models, plus the regional CATS02.01 and CADA00.10 models supplemented by TPXO.6 north of 60°S.
- Differences between the complex GPS and model estimates were computed according to (Figure 1):

$$S^2 = \sum_{n=1}^{8} \left| l_{GPS} - l_{Model} \right|^2$$

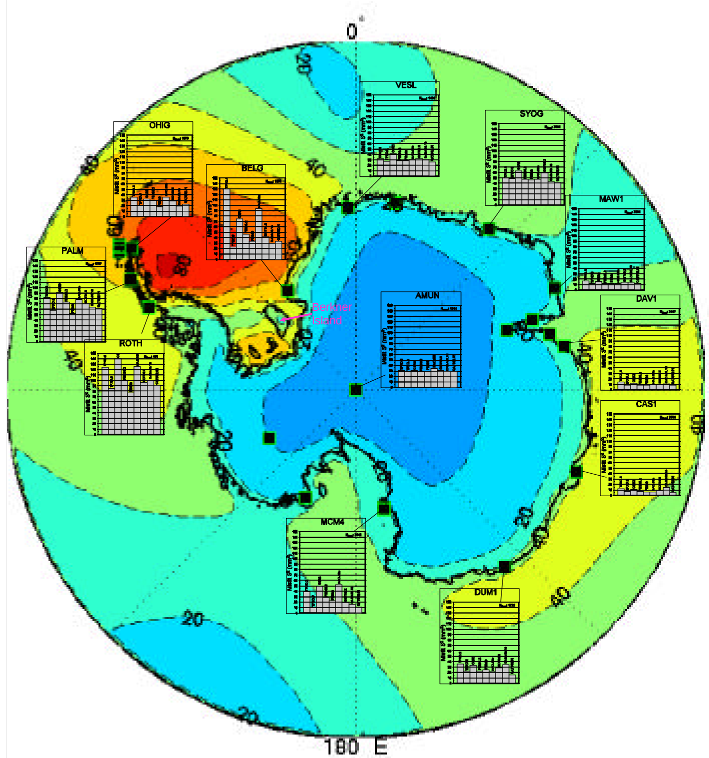

Figure 1: Contours show the sum of the four major OTL constituent amplitudes based on CATS02.01 (supplemented by TPXO.6 outside 60°S). Units are millimetres. This maximum is not reached in practice. Histograms show the level of misfit (S^2) between the GPS and model estimates. The black squares show the sites where >90 days of GPS data is available to us.

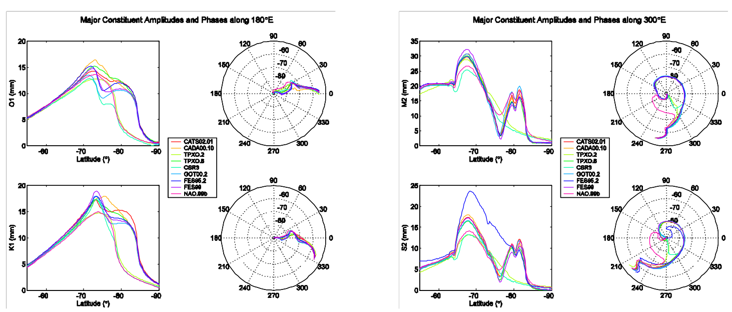

Figure 2: Model variation along longitudinal profiles for the two dominant constituents in each of the regions (K_1 and O_1 for longitude 180° - Ross Ice Shelf; M_2 and S_2 for longitude 300° - Filchner-Ronne Ice Shelf and Antarctic Peninsula).

OTL and ICESat

Laser Altimeter measurements from ICESat are affected by OTL. The model variability near the large ice shelves is significantly greater than in other regions (Figure 2). To test the *worst-case* scenario, we computed the differences in OTL estimates from FES99 and GOT00.2 for a non cross-over point on Berkner Is. (Figure 1) under the ICESat 91-day ground-track following the proposed 33-day on, 6-month off cycle. This produced a series of vertical rates depending on the chosen initial time of over-flight and the duration over which vertical rates were computed.

For the point tested we found vertical rates in the range ±2.4 mm/yr over the lifetime of the satellite, showing that until OTL can be verified in this region point measurements of ice thickness change may be biased at up to these levels. Temporal averaging at crossover points will reduce the bias, and with spatial filtering it may be negligible, although the degree of filtering required needs further investigation.

Conclusion

- Overall, the GPS OTL estimates fit best with TPXO.6, CATS02.01 and FES99
- Large misfits in West Antarctica suggest that tidal modelling is currently inaccurate in this region
- Model variability is greatest in the regions near the large Ross and Filchner-Ronne ice shelves where the coastlines are less well known and tidal observations are sparse.
- Unverified OTL model estimates may leave significant biases in the elevation time series derived from ICESat observations.

References

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