# A Comparison of GPS, VLBI and Model Estimates of Ocean Tide Loading Displacements: Globally and in Antarctica

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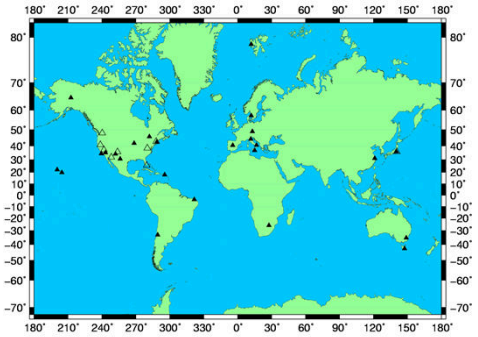
## Introduction

Harmonic ground displacements at principal diurnal and semi-diurnal tidal frequencies have been previously measured using the GPS (e.g. Schenewerk *et al.* 2001; Allinson *et al.* 2004; King *et al.* 2005) and VLBI (e.g. Petrov and Ma 2003).

We compute up-to-date GPS estimates of **Ocean Tide Loading Displacements** (OTLD) for a global selection of sites (Thomas *et al.* 2006), and compare our measurements with the VLBI measurements of Petrov and Ma (2003), and also with estimates computed from five modern global ocean tide models - FES2004, NAO99b, CSR4, GOT00, TPX06.2 - convolved through Green's functions.

## GPS estimation strategy

- 25 International GNSS Service (IGS) GPS stations identified with co-located VLBI stations used by Petrov and Ma (2003) (maximum allowed GPS-VLBI separation of 10km, typically ~100m).
- 24 hour GPS data collated for 11 year period 1994.0 to 2005.0



All triangles:- VLBI stations used by Petrov and Ma (2003)

Dark triangles:- 25 co-located GPS and VLBI stations used in this study

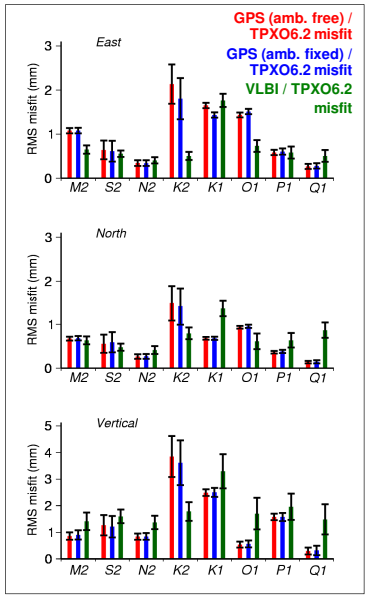
- Three-dimensional OTLD (sine and cosine parameter in each of E,N,V components) estimated daily at semi-diurnal (M2, S2, N2, K2) and diurnal (K1, O1, P1, Q1) tidal frequencies, using a GPS strategy similar to that employed by Allinson *et al*. (2004) and King *et al*. (2005) :
  - GIPSY-OASIS II GPS software (JPL) used in Precise Point Positioning mode (Zumberge et al, 1997) - with an elevation cutoff of 7° and a sampling interval of 300 seconds.
  - Solid Earth tide models implemented according to the IERS Conventions 2003.
  - Tropospheric zenith delays and gradients modelled as random walk parameters - process noise of 10.2mm/√(hr) and 0.3mm/√(hr).
  - Carrier phase ambiguities fixed to integer values in 4-6 station clusters – an ambiguity free and an ambiguity fixed solution.
  - Daily estimates of OTLD stacked in a Kalman filter and nodal corrections added.

## GPS, VLBI & Model Comparison

- Global RMS misfits computed - per constituent, per component.
- e.g. for M2 vertical component and TPXO6.2 model:

$$\left(\frac{1}{25}\sum_{n=1}^{25}\left(\mathrm{GPS}_{\mathrm{M2,vert.}}-\mathrm{TPXO6.2}_{\mathrm{M2,vert.}}\right)^2\right)^{1/2}$$

- Formal 1 sigma errors are propagated into misfits.
- Patterns in global misfits are very similar for the 4 other global models tested – FES2004, NAO99b, CSR4, GOT00.2.
- The only notable difference between model misfits is a reduced GPS / model misfit for the N2 vertical component for the NAO99b model.

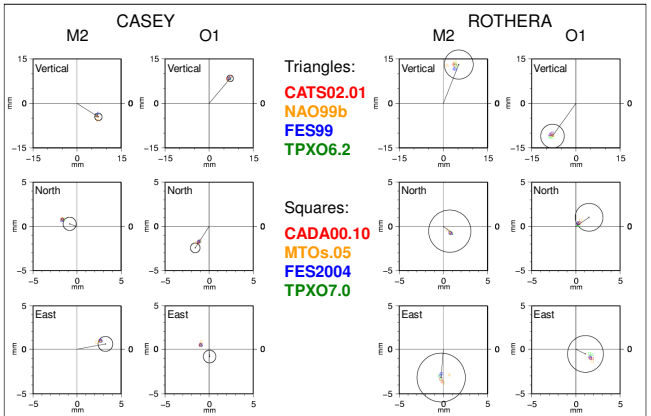



## Conclusions

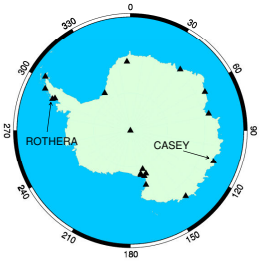
- Overall, GPS and VLBI data are similarly useful in determining OTLD estimates at diurnal and semi-diurnal frequencies - in both vertical and horizontal directions.
- GPS is capable of estimating the important vertical OTLD with accuracy equal to or greater than that achieved from VLBI, for 7 out of 8 principal diurnal and semi-diurnal constituents – the exception being the K2 constituent.
- The fixing of GPS carrier phase ambiguities to integer values has very marginal benefit on the accuracy and precision of GPS OTLD measurements.
- GPS is capable of distinguishing between the modelled OTLD at a 95% confidence level for certain individual sites and in certain components / constituents.
- Overall, the fit of modelled OTLD estimates to both GPS and VLBI measurements is similar for the five ocean tide models tested, and therefore we can not distinguish between the models at a global scale.

## Case Study: OTLD in Antarctica

- Additional models tested include TPXO7.0 and regional models (supplemented with TPXO6.2) CADA00.10, CATS02.01, AntPen04.01 and MTOs.05.




Example phasor plots showing GPS (black vector, 95% error ellipse) and modelled OTLD at M2 and O1 constituents, for Antarctic sites Casey and Rothera.




- We can distinguish between models at **a few** site / constituent / component combinations at 95% confidence - e.g. at Casey, M2 East component, we disagree with the MTOs.05 estimate of OTLD.
- We can rank models regionally and for the continent – TPX06.2, MTOs.05, FES2004, CADA00.10, CATS02.01 generally give good overall agreement with GPS OTLD.
- Overall, perhaps we have reached limits of GPS measurement of OTLD (for now!) – we are down to the level of needing to resolve remaining GPS systematic biases.

**References**

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