An updated model of short-period Earth rotation variations deduced from altimetry-based elevations and barotropic currents

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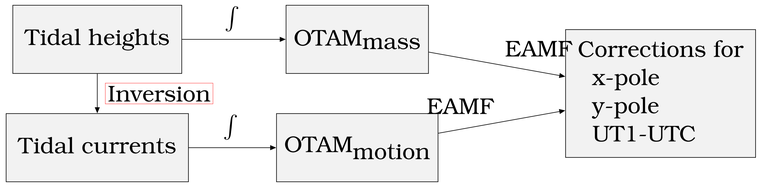
Abstract

A new high-frequency Earth rotation model is derived from the empirical ocean tide model EOT11a. The oceanic currents for nine major tides are derived using a simple, linearized hydrodynamic inversion approach. The model is validated using VLBI observations from 2011 to 2013 by comparing it with other models. There is no overall improvement in explaining the VLBI residuals, likely due to the small number of included tidal constituents. One possibility to include other partial tides is to interpolate ocean tidal angular momentum (OTAM) using admittance theory. The admittance function, however, not smooth for the mass term in the semi-diurnal range.

Derivation of ERP model

The derivation of an ERP model requires knowledge of both tidal heights and tidal currents. These two can be mapped to mass and motion terms of OTAM and subsequently to ERP corrections using *effective angular momentum functions* (*EAMF*)



Inversion

Ray (2001) proposed a linear inversion method to derive tidal currents from surface elevations. Simplified and depth-averaged shallow water momentum equations, supplemented by continuity constraints and no-flow boundaries form a linear equation system which can be solved iteratively using least-squares methods. Our computed volume transports and those from a reference tide model show a good agreement, making the algorithm a reasonable tool for the derivation of volume transports and motion terms.

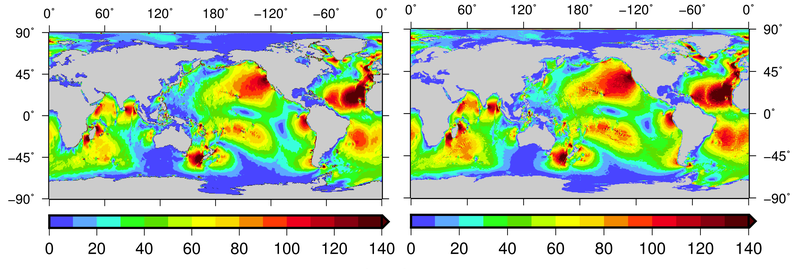


Figure: North volume transport amplitudes of M_2 from the inversion algorithm using EOT11a tidal heights (left) and from FES2012 (right). Units: m^2/s.

VLBI Validation

- 297 VLBI 24h-sessions from 2011-2013
- Analyzed using Vienna VLBI Software *VieVS*
- High-frequency ERP estimated a posteriori on time series
- Four a priori high-frequency ERP models were used:
  - FES2012 (reference): ERP model based on the hydrodynamic ocean tide model FES2012 (Finite element solution 2012)
  - IERS2010: Model recommended by IERS Conventions 2010
  - IGG Bonn: Empirical ERP model from Bonn University
  - EOT11a: ERP model based on the empirical ocean tide model EOT11a (tidal heights) plus oceanic currents derived using our inversion algorithm

The below figures show spectral differences of estimated ERP residuals, i.e. corrections to a priori models. For example, red values show: Spectrum of ERP_{FES2012} (reference) minus spectrum of ERP_{IERS2010}. Positive values indicate smaller estimates of the tested model (in our example: IERS2010) and, thus, more accurate a priori ERP values.

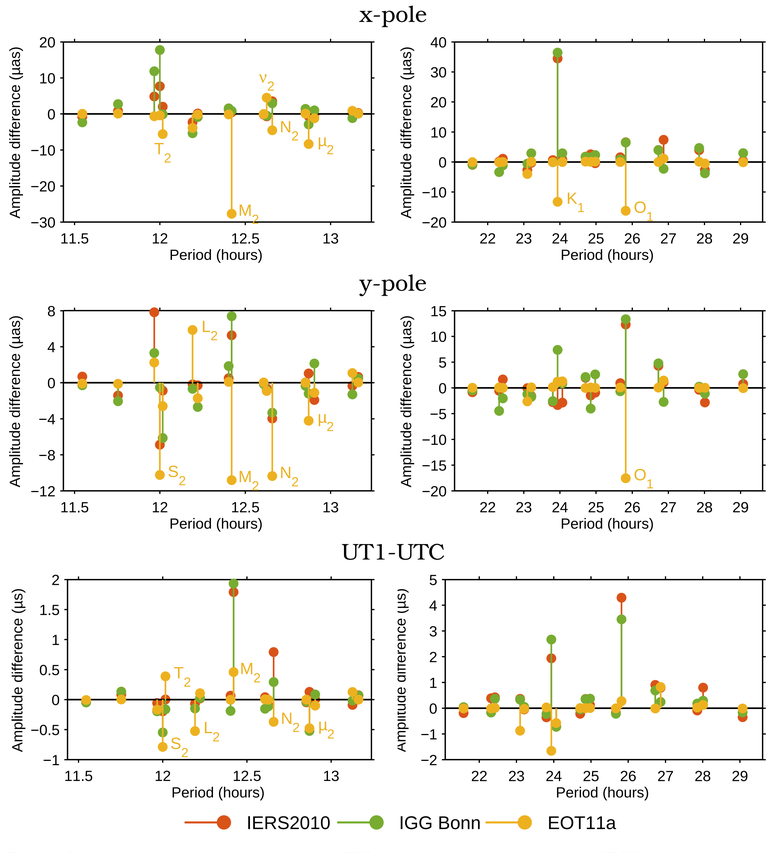


Figure: Differences of amplitude spectra of ERP residuals as computed from VLBI analysis.

Inclusion of minor terms

For our main comparison (mid column), model EOT11a was derived from only 9 major tides. Additional (minor) tidal constituents should be included in a precise ERP model. One possibility is to use admittance theory and interpolate ocean tidal angular momentum from known tides and known tidal potentials. This requires a smooth admittance (ratio of OTAM and tidal potential) with frequency. The below figures document the spectral behavior of the admittance using tidal heights and currents from FES2012. Units: 10^{25} kg s.

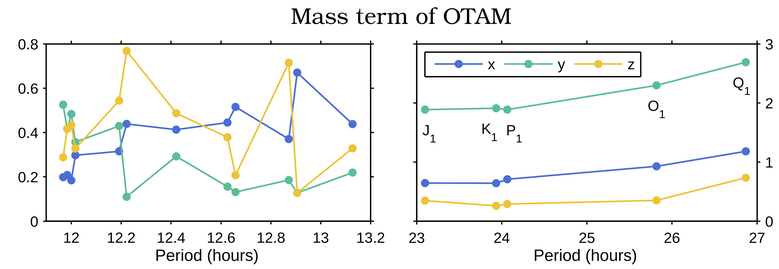


Figure: Admittance functions of OTAM in the semi-diurnal and diurnal range.

Diurnal tides show a much smoother OTAM variation with frequency and are, thus, well suited to be interpolated. The semi-diurnals show more variation, especially for the mass term.

Conclusion

The VLBI validation shows no overall improvement for the ERP estimation when using an empirical ocean tide model. However, the EOT11a model has been derived from only 9 tidal constituents. All other models contain far more: FES2012: 27; IERS2010: 71; IGG Bonn: 127. Additional tides should be therefore included in the ERP model. One possibility is to interpolate OTAM using the admittance approach. However, as shown above, not all components vary smoothly with frequency.

Reference: Ray, R. D. (2001). Inversion of oceanic tidal currents from measured elevations. J. Mar. Sys. 28, 1–18.

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