Shallow-Water Tides from Multi-Mission Altimetry - a Case Study at the Patagonian Shelf

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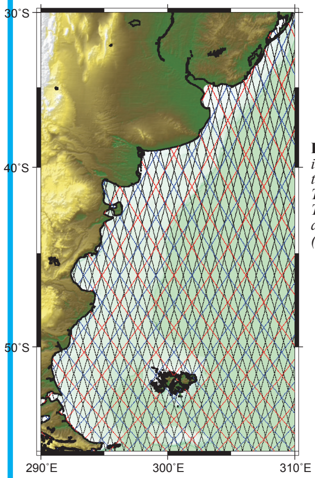


Fig. 1: *The area of investigation with the ground tracks of TOPEX/Jason1 (red), TOPEX-EM (blue) and of ERS/ENVISAT (black).*

Objectives

Global ocean tides models perform rather well in open ocean areas but tides in shallow-water are significant less well known. The capability to empirically estimate ocean tides from altimetry suffers from the large ground track spacing and the satellite repeat cycles leading to severe alias effects. The latter can be overcome only by rather long altimeter time series. We construct the longest possible altimeter time series by a multi-mission crossover adjustment and re-organise the data to facilitate time series analysis.

Without any smoothing a point-wise harmonic analysis is then performed with the TOPEX/Jason1 time series (13 years), the observation of TOPEX-EM over its shifted ground tracks (3 years), and the measurements of ERS-1/ERS-2/ENVISAT (13 years with some gaps). The length of these time series allow to de-alias and separate dominant tidal constituents. Single and dual satellite crossovers are used to further enhance the spatial resolution and to mitigate the alias problem. Results are compared with GOT00.2 and FES2004 and validated by improvements for GFO altimeter data.

Table 1. Altimeter mission data used for the present analysis

Mission (Phase)	Cycles	Period	Source	Replacements
TOPEX/Poseidon	001-481	1992/09/23-2005/10/08	MGDR-C AVISO	Chambers SSB correction, FES2004
Jason1	001-135	2002/01/15-2005/09/14	GDR-A PODACC	FES2004
ERS-1 (C & G)	083-101 144-155	1992/04/14-1993/12/20 1995/03/24-1996/04/28	OPR-V6 CERSAT	DEOS orbits, FES2004, pole tide, 1.5ms time bias
ERS-2	000-087	1995/04/29-2003/09/15	OPR-V6 CERSAT	DEOS orbits, FES2004, pole tide, 1.3ms time bias
ENVISAT	010-040	2002/09/30-2005/09/19	GDR ESA/CNES	FES2004
GFO	100-122	2003/01/01-2003/12/31	GDR NOAA	FES2004

Multi-Mission Crossover Analysis

For the altimeter data listed in Table 1 a common global crossover analysis for all contemporary altimeter systems has been performed to estimate complete time series of radial errors (for details see poster of Bosch on Multi-Mission Crossover Analysis). These radial errors have been corrected and ensure that time series of different missions can be consistently combined.

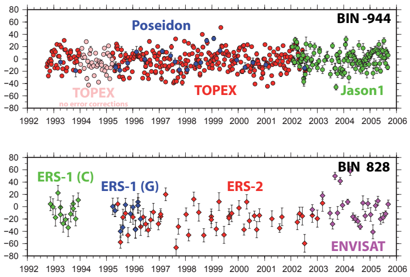
Data Reorganisation

The corrected altimeter data was then re-sampled into so called BINs, small along-track cells defined on nominal ground tracks in order to facilitate time series analysis. CLS01 mean sea surface height was subtracted and its slope has been used to refer all sea level anomalies to the centre of BIN.

Tidal Analysis

The Patagonian Shelf is one of the most extended shallow water areas on Earth. Amplitudes of the dominant semi-diurnal partial tides M_2 can reach values up to several metres. The bathymetry of the shelf is leads to significant resonance effects. The response method assuming a smooth admittance function may be problematic. We therefore used the classical harmonic analysis:

Fig 2:. *Time series of sea level anomalies (cm) for two BINS, located close to the coast (see right panel) on the ground tracks of TOPEX/Poseidon/Jason1 (Upper plot) and of ERS/ENVISAT (lower plot). Due to the radial error corrections a long and homogeneous time series can be constructed combining the data of different missions and phases. This facilitates to de-alias the dominant tidal constituents. Although the combined time series on the ERS track is less accurate and infrequently sampled it allows separation of M2 and N2.*



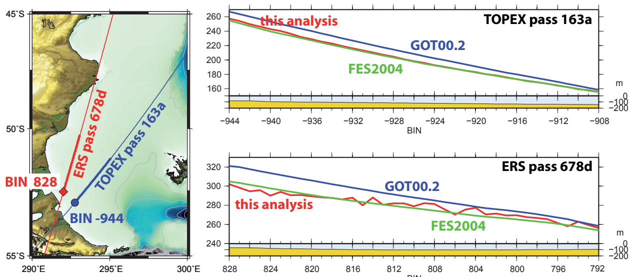


Fig 3: *Comparing M2 amplitudes (cm) derived by the present analysis (red) with the respective amplitudes of GOT00.2 (blue) and FES2004 (green). Note, the amplitudes of GOT00.2 and FES2004 differ by up to 10 or 15 cm. Along the ascending pass 163 of TOPEX/Poseidon (Upper plot) the results of harmonic analysis coincide rather well with the FES2004 model which differs from GOT00.2 by up to 10 cm. Similar holds for the descending pass 678 of ERS. The estimated amplitudes the analysis of the sea level anomalies at the BINS and of ERS/ENVISAT (lower plot).*

Residual Tides relative to FES2004

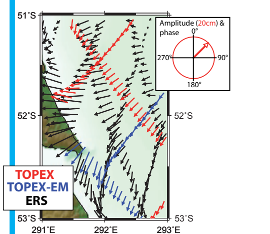


Fig 4: *According to the sampling characteristics the M2 tide could be estimated from TOPEX/Jason1, TOPEX-EM and the ERS/ENVISAT times series.*

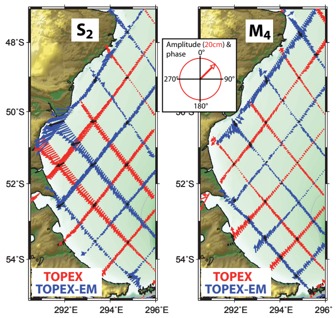


Fig 5: *The altimeter time series on both, the tracks of TOPEX/Jason1 (red) and the shifted tracks of TOPEX-EM (blue) allow to consistently resolve S2 and M4. The results on the TOPEX-EM tracks are however less accurate because only a three years time series is available.*

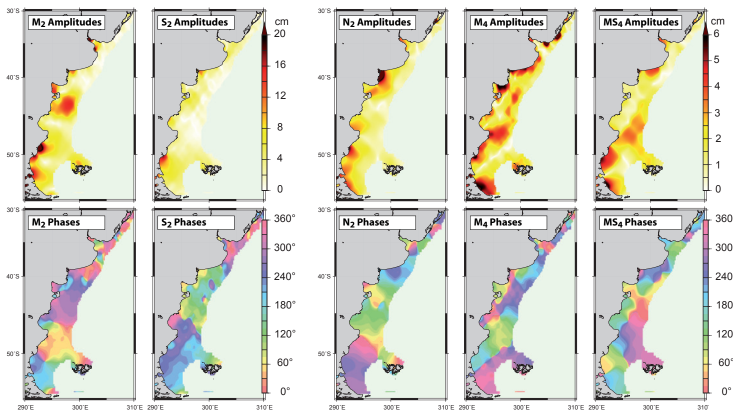


Fig 7: *Residual amplitude and phases for the five constituent analysed by multi-mission altimetry. Note the different scales used for the amplitudes of M2, S2 (left) and of N2, M4, MS4 constituents (right).*

Validation with GFO data

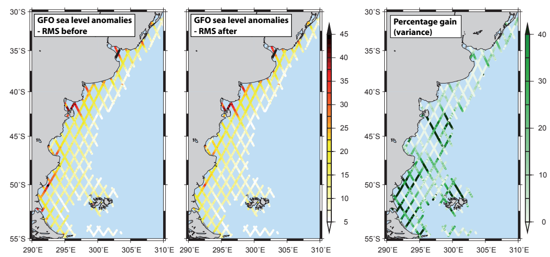


Fig 6: *In order to validate the result of our analysis the residual tides were taken to upgrade FES2004 and to compute and apply improved tidal corrections to the GFO altimeter data. The rms-scatter of sea level anomalies (cm) before and after this upgrade is shown left. The plot on the right illustrates the gain (in % of the variance) achieved through the empirical improvements of tides.*

Conclusions

- The global multi-mission crossover analysis is an essential step to construct consistent time series long enough to resolve dominant tidal constituents.
- The 13 years combined time series of TOPEX and Jason1 allows to de-alias nearly every constituent.
- The three years time series over the shifted ground tracks of TOPEX-EM is sufficient long to resolve S2 and M4.
- The combined time series of ERS-1, ERS-2, and ENVISAT allows separation of M2.
- Altimeter time series at crossovers mitigate the alias problem and were used to verify that amplitudes and phases along intersecting tracks are consistent with each other.

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