Estimation of the amplitude and variability of internal tides on the global ocean with multi-mission altimetry

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Abstract

Internal tides can have a signature of several cm at the surface with wavelength about 50-250 km for the first mode. The perspective of SWOT mission and high resolution ocean measurements make the correction of these small scale signals a challenge, as we need to be able to separate tides, even internal tides, from other oceanic signals.

Several studies have shown the interest of altimeters to estimate this internal tide signature at the surface (Ray and Mitchum 1996-1997, Carrere et al. 2004, Ray and Zaron 2011). In this study we use the global altimeter database prepared for assimilation in FES2012 tidal model to perform a new estimation of the internal tides signatures at the global scale, for several missions and for the four main tide frequencies (M2, N2, S2, K1). A tentative internal tides correction for altimetry has also been tested using these estimations.

1. Data used

We use the global altimeter database prepared within FES2012 project. Three long-term along-track altimeter time series have been harmonically analysed (TUGO tools from LEGOS):

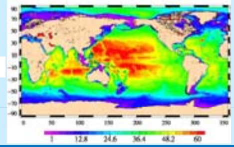
- TPJ1J2: 19 years
- TPNJ1N: 5.8 years
- E1E2EN: 17.5 years

CLS/CALVAL/PVA-2010 databases have been used, with some improvements:

- DAC_ERA_interim correction is used for TP mission
- A multi-missions orbit-error is used for ERS-EN missions

A specific along-track filtering is used to separate barotropic and baroclinic tides components; it is based on the estimation of the first baroclinic mode wavelength (Bessieres 2004) and on the typical scales of barotropic tides.

Filtering wavelength in nb of points along-track



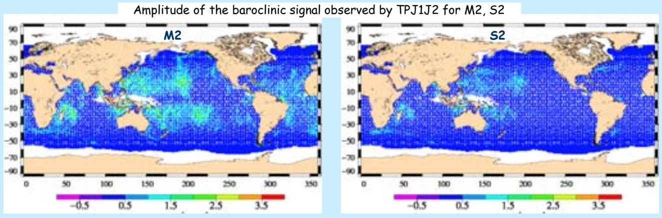
2. Observed baroclinic signal for TPJ1J2

Most of the alias issues have vanished in T/P-Jason reference altimeter series, allowing a better estimation of the amplitude and variability of the internal tide signal, phase-locked with the four main tide frequencies M2, N2, S2, K1. Table 1 shows that the amplitude of the S2, N2 baroclinic signal is about half the M2 signal; the variability of the baroclinic signal is weak but stronger in Indonesia and Madagascar regions. Signal to Noise ratio(S/N) is strong on large ocean regions for M2, with higher values than previous study (Carrere et al. 2004). Values are also strong for S2 on smaller areas (Madagascar, Hawaii, south Java, Atlantic). S/N is weaker for N2, but >2 in some regions, and even smaller for K1, due to lower amplitude of IW signal and stronger variability of K1 (K1-Ssa alias).

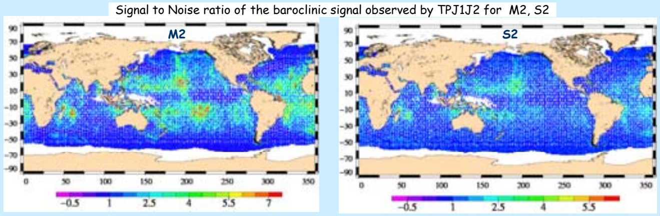
Table1: Amplitude and variability of the baroclinic signal M2, S2, N2 observed by TPJ1J2, on several time periods

TPJ1J2 M2/S2/N2	Mean	Standard deviation	Mean	Standard deviation
Units=cm	1992-1998/1996-2002		1996-2002/2002-2008	
Hawaii	1.0/0.6/0.4	0.3/0.2/0.2	1.0/0.6/0.4	0.3/0.3/0.2
Tahiti	1.1/0.4/0.4	0.2/0.2/0.2	1.0/0.4/0.4	0.3/0.3/0.2
Madagascar	0.9/0.7/0.5	0.4/0.5/0.5	0.9/0.6/0.4	0.3/0.3/0.2
Indonesia	1.0/0.7/0.6	0.8/0.8/1.1	0.9/0.6/0.5	0.6/0.5/0.8
Brazil	1.0/0.4/0.4	0.2/0.2/0.2	1.0/0.4/0.3	0.2/0.2/0.2
Gulf of Guinea	0.5/0.3/0.3	0.2/0.2/0.2	0.5/0.3/0.2	0.2/0.2/0.2
North East Atlantic	0.6/0.4/0.4	0.2/0.2/0.2	0.6/0.4/0.3	0.2/0.2/0.2

Amplitude of the baroclinic signal observed by TPJ1J2 for M2, S2



Signal to Noise ratio of the baroclinic signal observed by TPJ1J2 for M2, S2



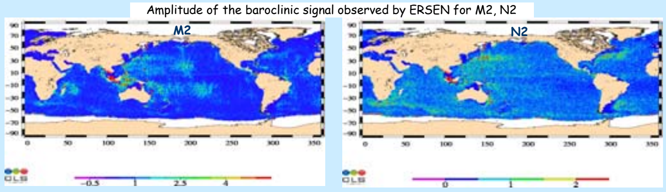
3. Other missions

TPNJ1N interleaved missions and ERS/EN missions still have some alias issues due to shorter temporal series and lower quality of data => results are more noisy but amplitude of main baroclinic tide is consistent with reference mission as seen on table 2 and right-hand figures. TPNJ1N data are missing in Indian ocean due to TPN problems but this has been improved in FES2014 database.

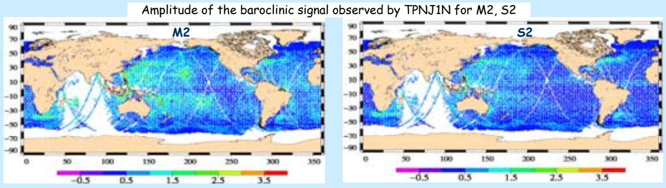
Table2: Amplitude and variability of the baroclinic signal M2, S2, observed by ascending tracks of TPJ1J2 and TPNJ1N.

M2/S2 Ascending tracks	TPJ1J2	TPNJ1N	TPJ1J2	TPNJ1N
	mean/*std* (cm)		mean/*std* (cm)	
Hawaii	1.02/*1.28*	1.12/*0.87*	0.57/*2.3*	0.64/*0.42*
Tahiti	0.96/*0.76*	1.14/*0.8*	0.4/*0.3*	0.6/*0.39*
Indonesia-Java	1.41/*4.54*	1.61/*4.81*	0.86/*4.42*	0.93/*3.04*
Brazil	0.90/*1.84*	1.0/*0.8*	0.41/*0.77*	0.59/*0.41*
Gulf of Guinea	0.58/*0.48*	0.63/*0.41*	0.3/*0.2*	0.41/*0.26*
North East Atlantic	0.47/*0.33*	0.55/*0.30*	0.29/*0.17*	0.44/*0.22*

Amplitude of the baroclinic signal observed by ERSEN for M2, N2



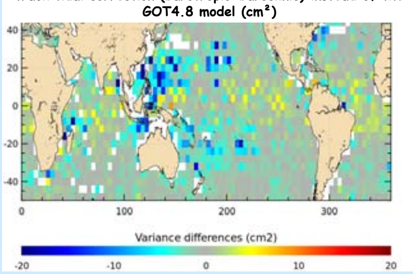
Amplitude of the baroclinic signal observed by TPNJ1N for M2, S2



4. Test of an along-track correction of internal waves

The along-track estimation of ocean tides are used to correct along-track TPJ1J2 residuals from barotropic tides and internal tides signatures on the global ocean.
The variance reduction obtained with this new correction and compared to the GOT4.8 barotropic tide model is estimated at crossovers on the Jason-2 period.
The SSH crossovers variance is reduced (several cm²) in the regions characterized by a strong and stable internal tides signal as shown on S/N figure above: Tahiti, Hawaii, west Pacific, south Java, Seychelles area … The reduction is less significant in the Atlantic ocean, likely due to some noise in the barotropic/baroclinic estimation …

Variance reduction at J2 crossovers when using the along-track tidal correction (barotropic+baroclinic) instead of the GOT4.8 model (cm²)



5. Conclusions and perspectives

Analysis made on FES2012 altimeter database shows very good S/N ratio for TPJ1J2 mission, particularly for M2 and S2. The analysis of other missions is still limited by aliasing problems, but an interesting IW signal is detected for M2 wave.

Using along-track analysis to detide J2 residuals from barotropic and baroclinic tidal components at once is a first step of a IW correction for altimetry and tests show interesting results. More validation results are described in the Poster "Internal Tides signature in frequency-wavenumber SSH spectra" from M. Orsztynowicz et al.

Altimeter database prepared for FES2014 is now available, and it should be used preferably for IW studies as it benefits from longer time series and better data processing.

As for coming SWOT and HR missions, the need is to correct all missions from IW signatures, next steps are: to test a purely baroclinic along-track correction for reference track and other missions, to combine altimeters IW measurements to map the IW signal, and hopefully to test the impact of using outputs from a global baroclinic tide model to correct IW signatures …

New frontiers of Altimetry – Lake Constance, Germany - October 2014
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