Estimating tidal constants in the near-shore domain from Jason1-2-3 archive: a case study for the northern Bay of Bengal

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Introduction

The shoreline of the Bengal delta (Bangladesh and India) is a macrotidal area (over 4 m), with a broad (200 km) and shallow shelf (**Fig. 1**). It is also home to marked variability of the water level, with frequent cyclonic surges and flash floods. Despite profound implications of the water level variability on the society and economy of the 150 M inhabitants populating the near-shore region, the characteristics of the ocean tide is poorly observed and understood in this region. Only two tide gauges provide public data to GLOSS database (**Fig. 1**). Numerical tidal models also do not perform well in this region, compared to the rest of the tropical oceans. This stems, among others, from the lack of knowledge of the bathymetry of the shelf region.

As part of the BAND-AID project (http://belmont-bandaid.org), we present an attempt to curb this lack of knowledge, by making use of along-track spaceborne altimetry. We consider standard products (GDRs) for the whole Jason1-2-3 archive, as well as re-processed (PISTACH and DGFI/TUM) Jason-2 products. We apply harmonic analysis to these datasets, with minimal editing criterion prior to analysis. We compare our estimates to state-of-the-art, publicly available altimetric tidal constants (from CTOH) and from the most recent numerical models (FES2014 and BAND-AID/SCHISM)

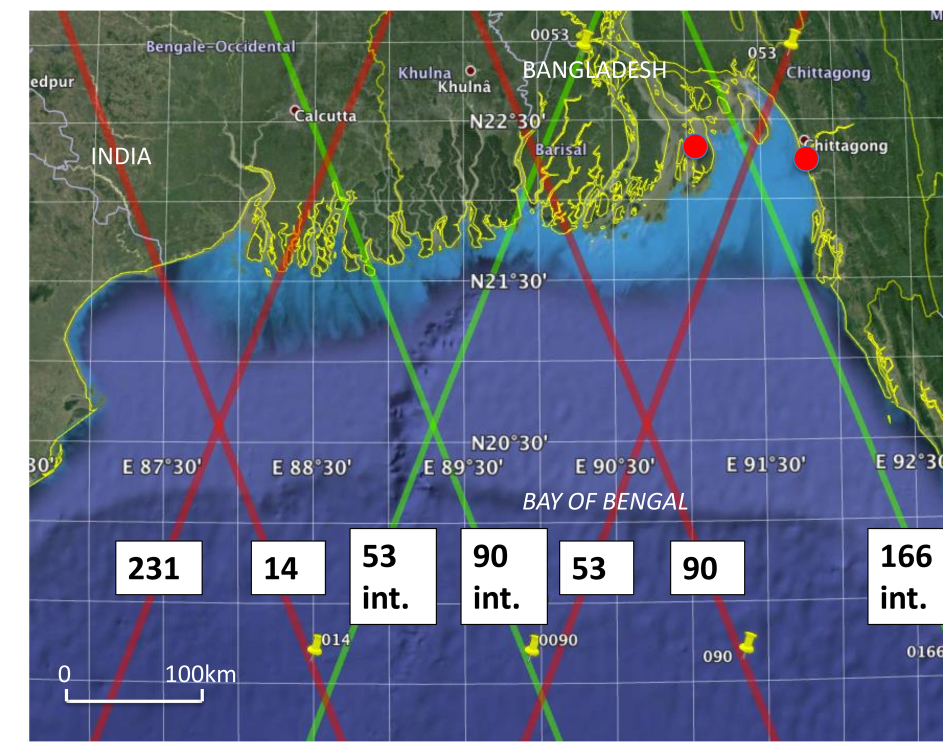

Fig. 1: Our area of interest. Jason nominal tracks in red, interleaved tracks in green. The two tide gauges available in GLOSS database are shown as red bullets.

Altimetry data and processing

We first considered Jason1-2-3 GDRs products (retrieved from AVISO, ftp://avisoftp.cnes.fr/AVISO/pub) at 20Hz sampling rate. We considered 4 tracks of nominal orbit (#14, 53, 90, 231) and 3 tracks of interleaved orbit (#53, 90 and 166). We computed the sea surface height as follows:

ssh = alt - (range_ku + geoid_egm08 + model_dry_tropo_corr + model_wet_tropo_corr + iono_corr_gim_ku + solid_earth_tide + pole_tide + load_tide_sol2 + sea_state_bias_ku + inv_bar_corr)

The resulting SSH is displayed on Figure 2 for all cycles, for the example of track#14.

We also considered Jason2 PISTACH (ftp://ftp.aviso.oceanobs.com/pub/oceano/pistach) and DGFI/TUM products over the four nominal tracks (also at 20Hz). These consist of tailor-made along-track products, dedicated to the coastal ocean. We considered three different retracking algorithm of PISTACH database (ocean3, red3 and ice3). We applied the same equation as above to compute ssh.

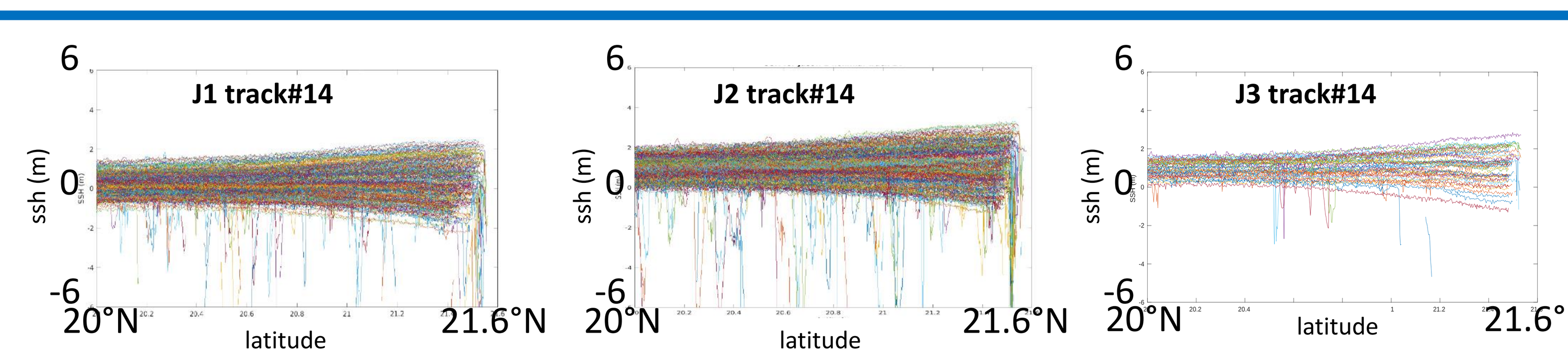

Fig. 2: SSH along track#14 from GDRs, for Jason1 (left), Jason2 (centre) and Jason3 (right).

We simply processed these raw SSH records by retaining all measurements lying within a reasonably acceptable range, that varies from track to track, and from mission to mission (typically we retain the interval [-2.5m,+2.5m]). On these cleaned data, we apply the harmonic analysis software « altimetry-detidor » (Allain, 2016)

Analysis of our altimetric tidal constants

Figure 3 presents a representative sub-set of our tidal analyses. We compare the various altimetric estimates we obtained with CTOH reference product (available on ftp.legos.obs-mip.fr/pub/altimetrie_regionale/TIDAL_CONSTANTS/) as well as with two most recent tidal models: FES2014_hydro (Carrère et al., 2016) and BandAid-SCHISM (Krien et al., 2016).

It is seen that our estimates allow to significantly extend shoreward the coverage of the previously published altimetric constants from CTOH. In particular, the extended coverage of our estimates allows to evidence the models' biases, in the domain where the model-to-model discrepancies are maximal.

Interestingly, the tidal constants obtained from the various products (GDRs, PISTACH with its three different retracking algorithms and DGFI/TUM) appear quite consistent with one another, with typical discrepancies generally inferior to the model-to-model differences, both for amplitude and phase of the major constituents. They also cover broadly the same spatial domain.

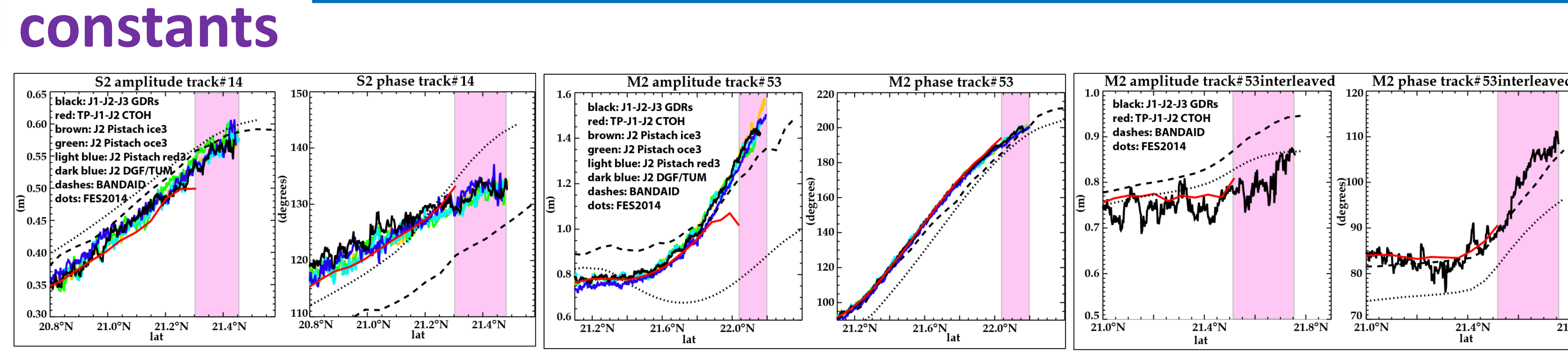

Fig. 3: Amplitudes and phases retrieved along track#14 for S2 constituent (left), for track#53 for M2 constituent (centre) and for track #53 interleaved for M2 constituent (right). We show the estimates from GDRs, from Pistach (3 different retracking algorithms), from CTOH, from DGFI/TUM, and from the two numerical models (FES2014-hydro and BANDAID-Schism). The pink stripe features the extent of the coastal domain where we get additional coverage compared to CTOH product.

Expectedly, in the offshore part of the tracks (typically beyond 50km from the coast), our estimates are consistent with the previously published altimetric tidal constants from CTOH.

We performed additional tests where we discarded one or several Jason missions from our dataset, or where we included Topex/Poseidon GDRs in our dataset. These tests showed that our estimates remain robust, both for amplitude and phase of the major tidal constituents (M2, S2, K1, O1), for all tracks (not shown).

Estimating tide from near-shore altimetry

Figure 4 displays the spatial coverage of CTOH along-track tidal constants, as well as the additional stretches produced in the present study. It is seen that our basic approach allows extending the coverage shoreward, by typically half-a-dozen to one-dozen kilometers (depending on the track considered). **Table 1** summarizes the spatial gain we achieve.

Jason track number	Number of kilometers of extra virtual stations added in this study
14	14 km
53	13 km
90	3 km
231	5 km
53 interleaved	27 km
90 interleaved	10 km
166 interleaved	3 km
total	75 km

Table 1: Additional along-track coverage of tidal constants produced in the present study.

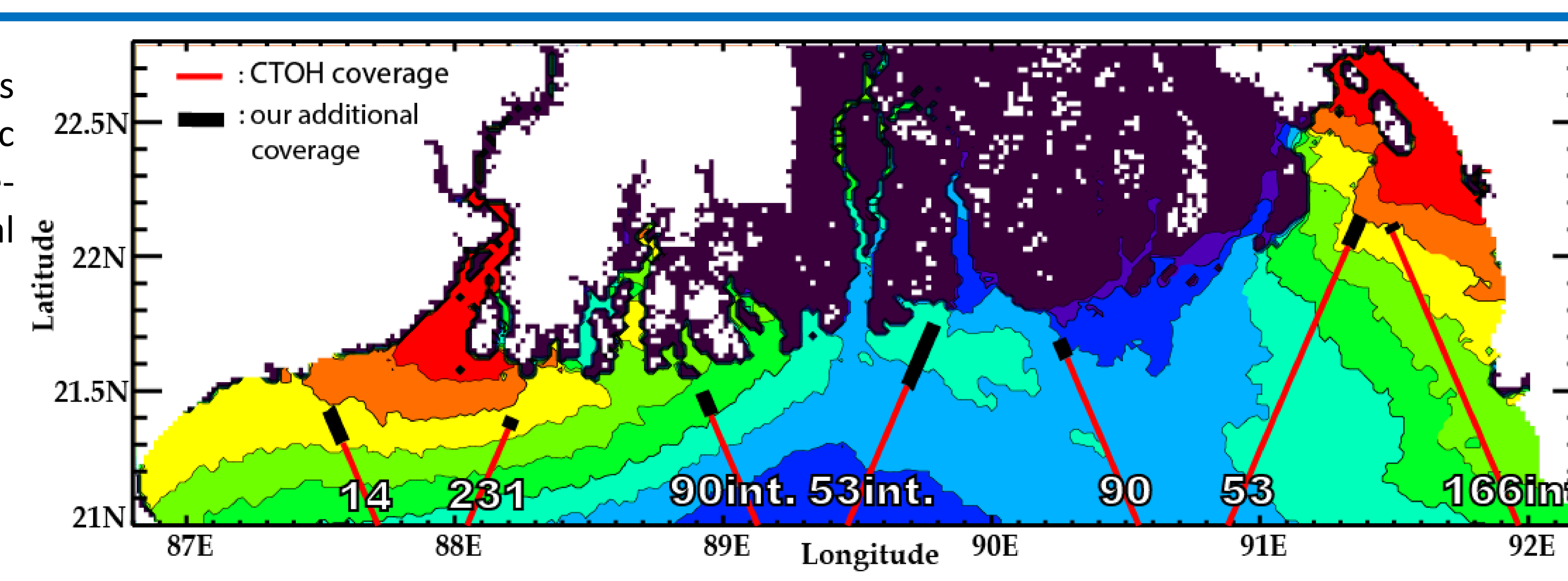

Fig. 4: Coverage of along-track CTOH tidal constants (red) and additional coverage of our estimates (black). The background features M2 amplitude (from BAND-AID model).

Conclusions

Our analyses allow to extend shoreward the coverage of standard altimetric tidal constants by about 10km (depending on the track considered, within the Bay of Bengal). This implies that the editing strategy applied routinely in the standard altimetric products, though probably suited for the offshore domain, is too stringent for the coastal ocean. The consistency between our various estimates implies that the choice of the set of altimetric corrections or retracking algorithm is not quite instrumental in the estimation of tidal constants in the coastal domain: our estimates remain robust.

The observational coverage of our altimetric tidal constants estimates, extended towards the shore, opens promising prospects for the tidal modeling community, as it corresponds to the coastal strip where the various tidal models solutions diverge most from one another.

Our study opens up bright prospects for both thematic and cal/val activities of the future high-resolution nadir and swath altimetric missions (Sentinel-3 and SWOT), in a key-region of the tropical freshwater cycle.

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