Geodetic survey of the freshwater front of the Ganges-Brahmaputra river plume in Bangladesh from CalNaGeo GNSS device

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Abstract

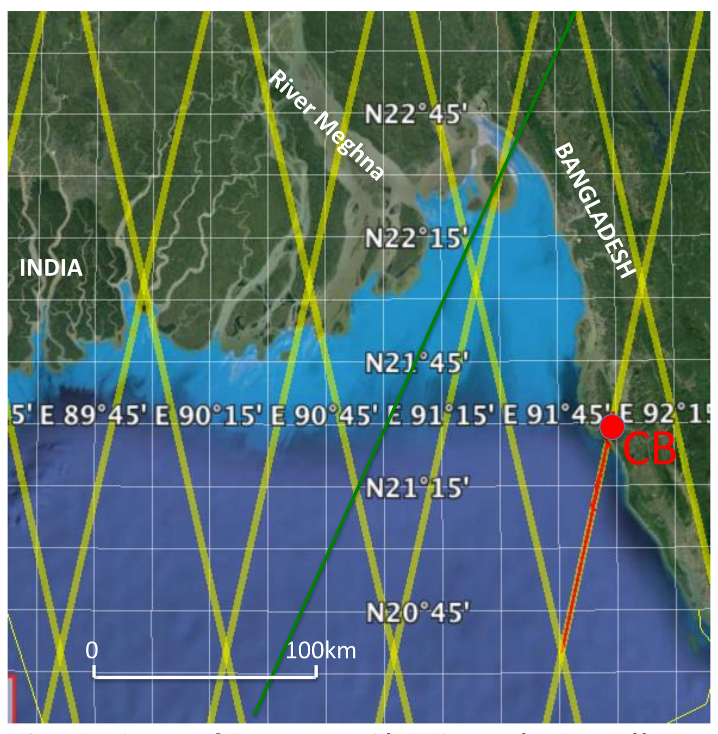

Fig. 1: Area of interest. AltiKA tracks in yellow, Jason track#53 in green, our CalNaGeo transect in red. Cox's Bazaar tide gauge is shown as red bullet.

The Bay of Bengal (**BoB**) is home to massive continental freshwater supply, provided by the Ganges-Brahmaputra-Meghna river system. During the summer monsoon season about 800 km^3 of freshwater flow through the Bengal delta into the northern BoB. The spatio-temporal evolution of this seasonal plume as well as the exact processes governing its dispersal in the open ocean remain largely unknown, due to the lack of in situ observations.

To shed light on this issue, we conducted a pilot experiment in the near-shore region of the northern BoB during the 2014 post-monsoon season, along **SARAL track#810 (Fig. 1)**. Our observational strategy is based on an original ship-borne towed GNSS device: **CalNaGeo (Fig. 2)**. This device is designed to measure the absolute sea surface height (**SSH**) within a few centimeters accuracy. Unfortunately, it was not possible to conduct the cruise during a SARAL overpass for validation of the SARAL measurements. However, our data are shown to capture efficiently multi-scale SSH variability, from horizontal scales of a few meters to tens of km.

We believe that our dataset evidences the signature of an hydrological front in the de-tided GNSS record, taking the form of a steric slope separating coastal (fresh) waters from off-shore (salty) waters. This experiment opens bright prospects for altimetry cal/val and tidal models assessment in under-observed areas.

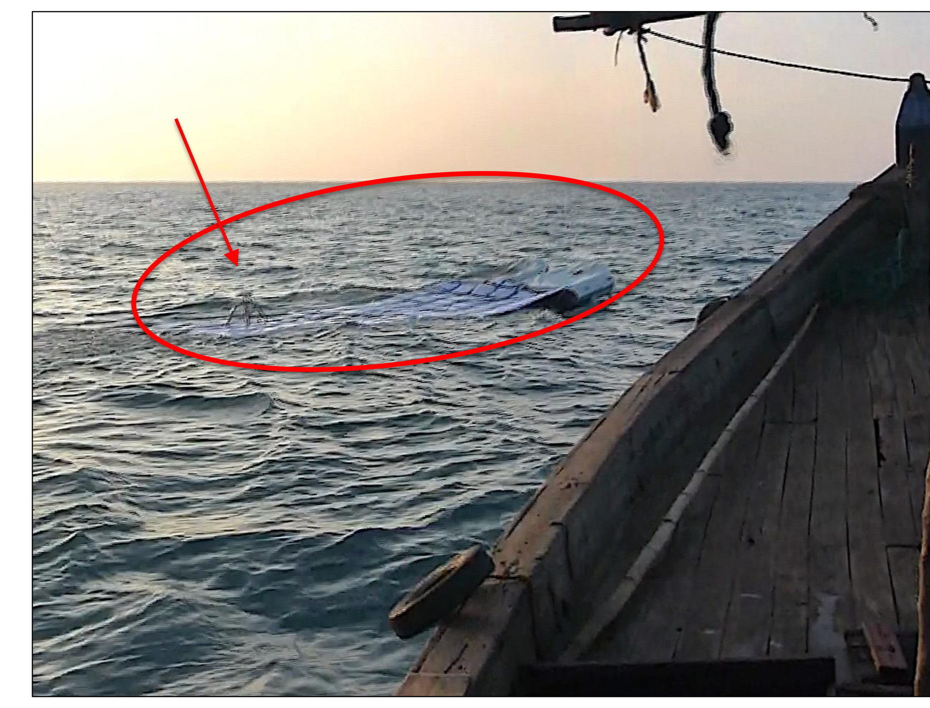

Fig. 2: Our observational device off the coast of Cox's Bazaar, Bangladesh, in November 2014. The CalNaGeo towed raft is highlighted in red. The arrow points to the GNSS antenna.

Geophysical context

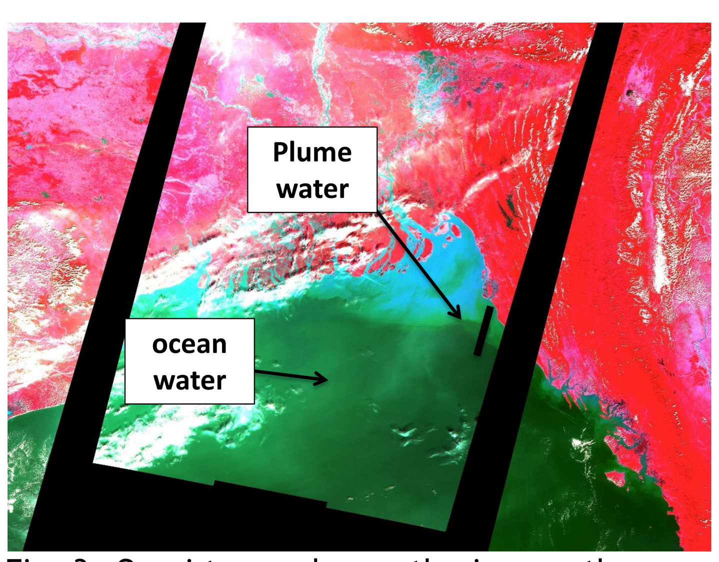

Fig. 3: Quasi-true color synthesis over the area on 11/11/2014, from PROBA-V satellite. CALNAGEO transect is marked in black.

Fig. 3 shows the sediment-loaded river plume (blueish) separated from open-ocean waters (green shades) by a tight hydrological front. CalNaGeo transect lies across this front. Expectedly, the plume is composed of low salinity waters. Ocean reanalyzes from Mercator PSY4V2R2 operational analysis suggest a similar frontal structure (**Fig. 4**). Such a salinity gradient would translate into a sharp density gradient.

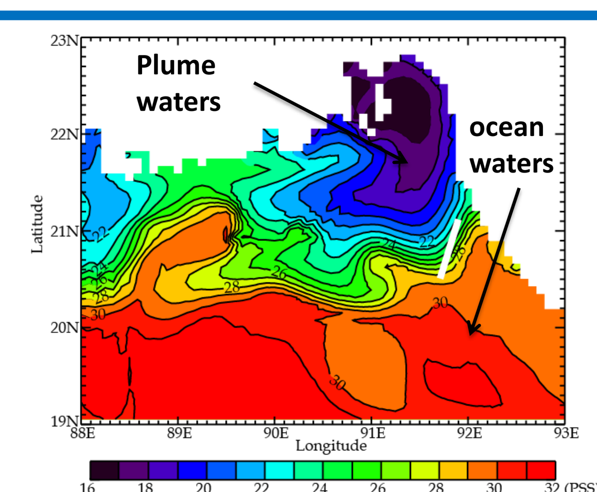

Fig. 4: Sea surface salinity on 9/11/2014. CalNaGeo transect is shown in white, right on the salinity front separating the river plume and open ocean waters.

Fig. 5 suggests the existence of such a frontal density structure, with a stair-like SLA in Jason-2 along-track data. The amplitude of the step (20 cm) would imply a 10-m thick pure freshwater plume at the shoreward edge of the track. This pattern is however highly intermittent in altimetry data (not shown), which puts into question the validity of altimetry in such a near-shore environment.

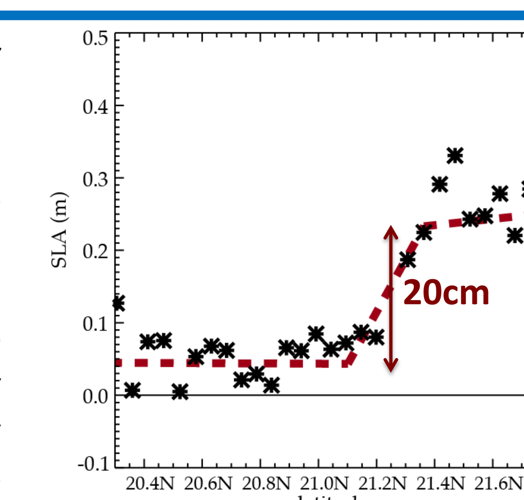

Fig. 5: SLA along Jason-2 track#53 on 10/11/2014 (from CTOH). This track passes 90km offshore our CalNaGeo transect (see Fig. 1)

Analysis of CalNaGeo SSH record

CalNaGeo sea level transect, thanks to its 1Hz sampling, reveals a broad temporal range of variability, from swell (a few seconds, **Fig. 6**) to tidal motions (a few hours, **Figs.7 and 8**) and beyond. The accuracy of CalNaGeo, estimated to a few centimeters by prior experiments (Fund et al., 2013), gives good confidence in the realism of the features we monitor.

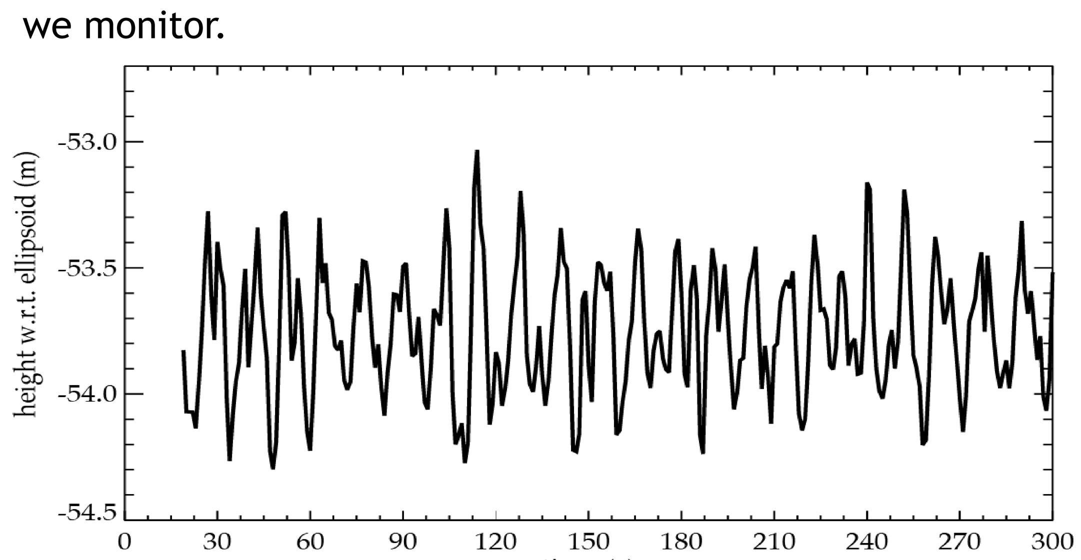

Fig. 6: Raw SSH measurements from CALNAGEO over 10min on 10/10/2014. Reference is GRS80 ellipsoid.

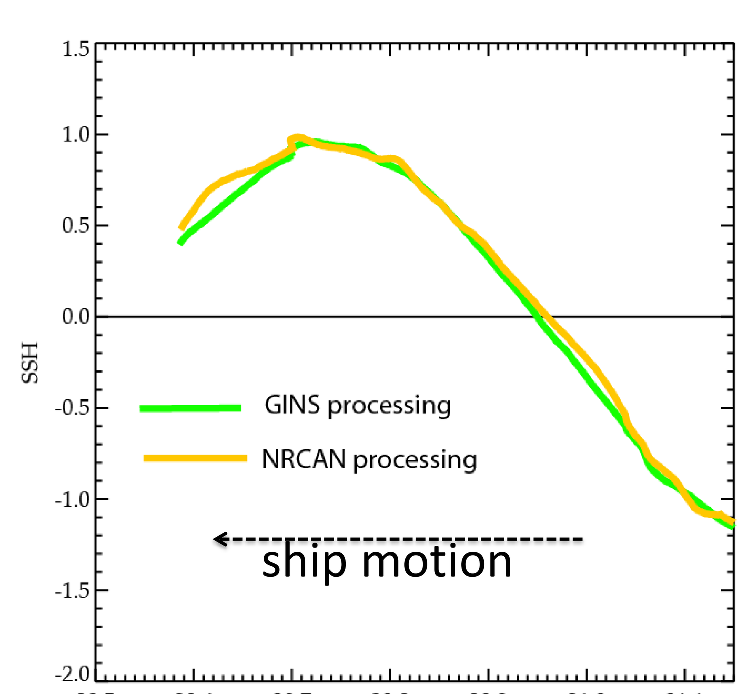

Fig. 7: SSH measurements from CalNaGeo after a 15min filtering (equiv. to ~2.5km), along the southward transect seen on **Fig. 1.** Reference is CNES-CLS2011 MSS.

Once we filter out the swell, our CalNaGeo transect reveals a clear signature of barotropic tide, as shown by comparing our record (**Fig. 7**) with the nearby tide gauge of Cox's Bazaar (**Fig. 8**). CalNaGeo measurements are processed by PPP (Precise Point Positioning) technique (Fund et al., 2013). The differences between the processing of CalNaGeo data by GINS-PC software (developed by CNES/GRGS; **Fig. 7**, green curve) and by NRCAN software (www.nrcan.gc.ca) (yellow curve) are typically centimetric, which further suggests the good signal-to-noise ratio of CalNaGeo measurements.

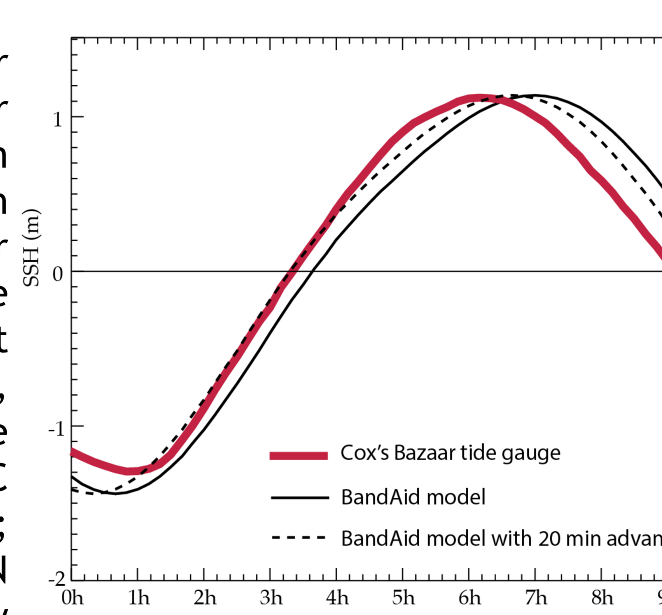

Fig. 8: SSH recorded by Cox's Bazaar tide gauge (in red) and simulated by Band-Aid model (black) during the same period as **Fig. 7.**

Steric slopes revealed by CalNaGeo

To investigate the steric effects expected in the river plume, we removed from CalNaGeo SSH the sea level predicted by two state-of-the-art tidal models: Band-Aid (Krien et al., 2016) and FES-2014 (Carrere et al., 2016). Band-Aid model was pre-processed by offsetting its predictions by 20min, to correct the phase lag observed against Cox's Bazaar tide gauge (**Fig. 8**). **Figure 9** displays the residuals we obtained along the ship track. They appear to differ greatly, with the BandAid-based residual reaching 40cm in amplitude around 20.7°N, and FES2014-based residual hardly reaching 10cm there. Both estimates, however, concur in a positive steric height anomaly, consistent with the presence of low salinity waters in the shoreward part of the transect. Although the intrinsic accuracy of the tidal models over our area, was estimated to about 20cm by Krien et al. (2016), the FES2014 is probably well constrained along our survey which follows a satellite ground-track, since altimetric data are included in the model. This level of accuracy is much worse than over most of the other coastal regions worldwide (Stammer et al. 2014), and this is known to result largely from the lack of knowledge of tidal dynamics (ocean bathymetry, bottom dissipation, etc.) in the shelf region of the Bay of Bengal.

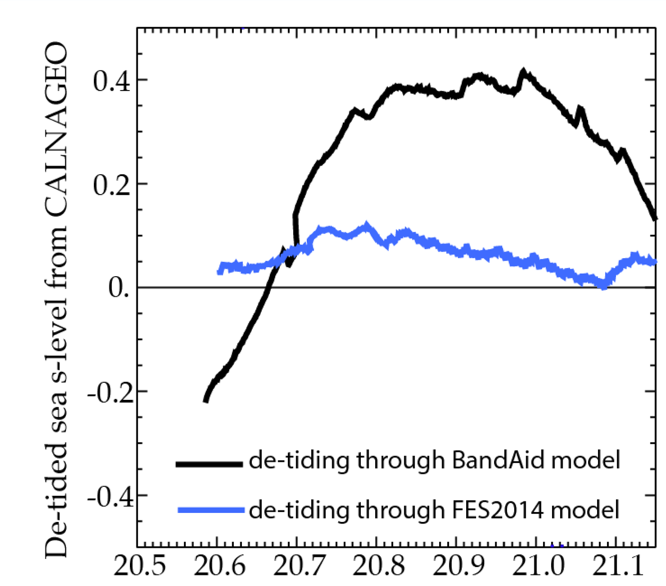

Fig. 9: CalNaGeo SSH residuals obtained after removing BandAid tidal heights (black) and FES2014 tidal heights (blue). BandAid model advanced by 20min was considered.

Conclusions

This study shows the feasibility of in-situ survey of absolute sea level height through CalNaGeo, a towed GNSS observational system. This device allows an accurate, multi-scale monitoring of the sea level slopes, including remote and under-equipped environments such as the far southern coast of Bangladesh.

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. Currently, the capability of our experimental system to monitor the meso- to sub-meso-scale sea level slopes associated with the river plume fronts is still hampered by the limited accuracy of tidal atlases available over our area. We expect to reduce this limitation through the approach presented in the poster by Ishaque et al. (this session).

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