Improved satellite altimetry for the observation of coastal ocean dynamics: a case study for the Northern Indian Ocean.

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Summary

The coastal currents in the Northern Indian Ocean are believed to play a prominent role in the heat and salt exchanges between Arabian Sea and Bay of Bengal. The objective of this study is to determine to what extent the sea surface height (SSH) variability (from intraseasonal to interannual) associated to these coastal processes can be observed with satellite altimetry. This study explores a newly released coastal altimetric dataset, obtained from a complete reprocessing of the Topex/Poseidon measurements using the MAP data processing (see Lyard et al.). We first present an objective method to derive geostrophic current from the raw SSH. Then we present the validation of the altimetric SSH against in situ observations. Finally we briefly analyze the observed variability of the East India Coastal Current (EICC) at various timescales.

1- Context and scientific issue:

Context

Over the last decade, altimetry has been shown to be a powerful tool to obtain a wealth of informations about the dynamics of the deep-sea ocean. The potential of this type of data for the coastal domain is very important but is currently unexploited. Indeed, near the coasts, the use of standard satellite altimetric products is challenging because the data accuracy decreases dramatically.

In the future, a new generation of altimetric missions will better fulfill the requirements of the coastal domain, among which the Indo-French Alti-KA mission. In parallel, we need improved post-processing chains for existing altimetric datasets for coastal purposes. This has led the MAP (Margins Altimetry Project) group to develop a new altimetric data processing approach in the coastal zone. Here, we have used the MAP altimetric data processing along the coasts of India.

See also:
Lyard et al. for details about the method.

Scientific issue

The coastal currents hugging the coasts of the Indian subcontinent, viz. the East India Coastal Current (EICC) along the western boundary of the Bay of Bengal and the West India Coastal Current (WICC) along the eastern boundary of the Arabian Sea, are believed to play a prominent role in the heat and salt exchanges between Arabian Sea and Bay of Bengal (Figure 1) (*Shenoi et al., 1999; Durand et al., 2006*). These salt transports have a major impact on the dynamics of the Northern Indian Ocean – Asian monsoon coupled system (*Masson et al., 2005*). Given that both the EICC and the WICC are poorly monitored, it is timely to ascertain their structure and variability at all timescales from intraseasonal to interannual. The question we want to assess here is:

➡ **Is altimetry a relevant tool to monitor the exchanges of heat and salt between the Arabian Sea and the Bay of Bengal?**

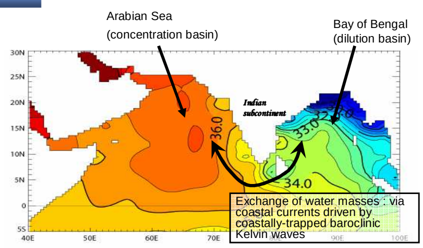

Figure 1 : Levitus Climatological Sea Surface Salinity (SSS).

2- Data and method:

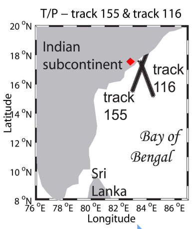

Figure 2 : Geography of the area. Topex/Poseidon coastal altimetric tracks 116 and 155 are shown (black lines). The diamond represents the location of Vishakhapatnam tide gauge.

An objective post-processing algorithm for coastal geostrophic oceanography

Based on alongtrack T/P altimetric sea level anomaly (SLA) data produced by the MAP procedure (Figure 2), we defined an automated method to compute smooth, realistic coastal currents. It is based on physical assumptions (geostrophy), on geophysical parameters (the Rossby radius of deformation), and on the common sense (realistic magnitude of the current).

1rst step: Cleaning the observed seal level data.

An upper limit (2m/s) is imposed on the geostrophic current derived from along-track SLAs. The resulting sea level profiles (Figure 3b) are significantly smoother, but still to noisy to be used for current retrieval (Figure 3c).

2nd step: Retrieval of the geostrophic current (see Figure 4).

Geostrophy can be applied only at scales larger than the Rossby radius of deformation Ro (~60 km in our area). Undesirable sub-mesoscale features in our dataset are filtered out by a simple polynomial fitting:

- **the length of the track is divided by Ro: it yields the maximal degree Dmax of the acceptable polynomial (here: 250km/60km=4 ; 4+1=5),**
- **the altimetric profiles are fitted (in the least squares sense) to polynomials of degree 0,…,Dmax,**
- **the lowest order polynomial that satisfies a given error threshold (2.5cm) is retained (Figure 3d),**
- **the geostrophic current is computed from this polynomial (Figure 3e).**

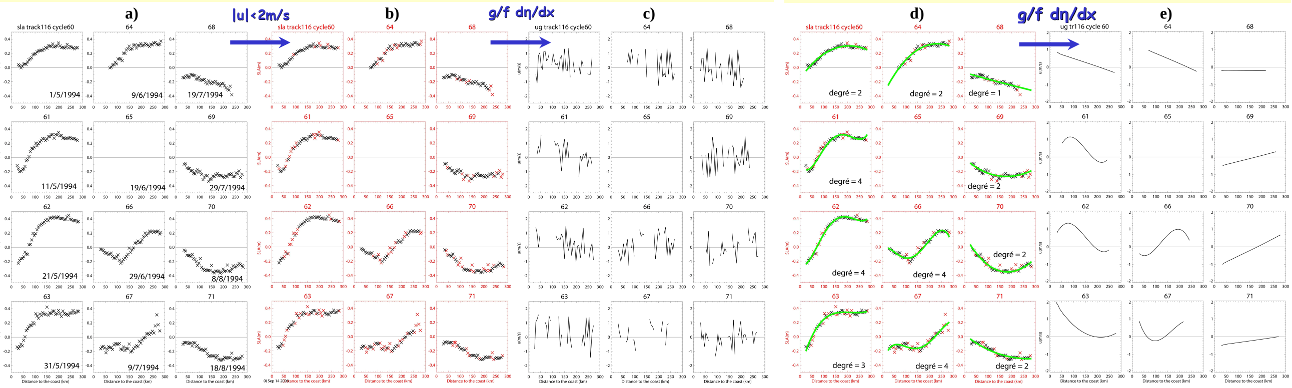

Figure 3 : Sequences of along-track data for track 116, during boreal summer 1994. One frame is shown for each cycle. The horizontal axis is the distance to the nearest shore, expressed in km. (a) The crosses represent the raw SLA provided by the processing (in m). (b) Same as (a), for the SLA data cleaned using the 2m/s threshold criterion. Flagged data are in red. (c) Geostrophic cross-track surface current deriving from (b) (in m/s). (d) Same as (b), superimposed on the polynomial least-square fit of the cleaned SLA profile (solid). The degree of the fitted polynomial is indicated. (e) Geostrophic cross-track surface current deriving from (d) (in m/s).

3- Validation and results:

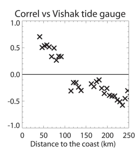

Figure 4 : Correlation between the monthly altimetric and the monthly Vishakhapatnam tide gauge SLA, as a function of the distance to the shore (km).

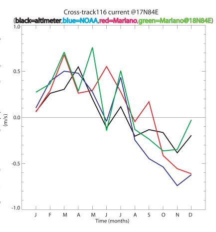

Figure 5 : Monthly climatology of ship drift data for NOAA product at 17°N,84°E (blue), for Mariano et al. [1995] product at 17°N,84°E (red), for Mariano et al [1995] product at 18°N,84°E (green) (m/s) ; currents have been projected in the cross-track116 direction. Corresponding monthly climatology of the altimeter-derived current at 17°N,84°E (black). Positive northward.

Comparison between altimetric and tide gauge SLA (Fig. 4).

The correlation with the tide gauge (TG) signal reaches 0.7 close to the shore and then decreases with the distance. This is a good result since only the shelf break area is expected to be dynamically consistent with the TG signal. The altimetric and TG datasets shares about 50% of their variance.

Comparison of the derived altimetric geostrophic currents with other current products (Fig. 5).

Very few direct in situ current data are available over our area, we have then used low-resolution (1°x1°x1month) historical shipdrifts climatologies (NOAA; Mariano et al.). For consistency, we have downgraded the spatial resolution of the along-track altimetric current estimates to 1°. The seasonal climatology of the various products, shows a good agreement between the shipdrifts estimates and the altimetric current: 1) a poleward-flowing EICC during the first semester, 2) a reversal occurring sometime during summer monsoon, 3) an equatorward-flowing EICC during the post-monsoon season, and 4) a reversal at the end of the year. Superimposed, we also see intraseasonal variations, linked with the high level of uncertainty in the shipdrifts velocity compilations.

Observed variability of the geostrophic current (Figure 6).

The altimetric dataset gives access to the spatio-temporal structure of EICC at a 10days temporal frequency, over the width of the current stream (250km–wide band). If, for example, we consider results for 1994, we observe a broad agreement with the climatological picture observed on Figure 5 with a band of 100km from the shore. We also notice a complete reversal during the post-monsoon season, from late August (cycle 24) to mid-October (cycle 28). The reason of this intraseasonal feature and its implications in term of mass transport still have to be determined. Another interesting feature is the current shear that exists between the section closest to the shore and the section further offshore during the first 8 months of the year, irrespective of the coastal current direction. This sheared structure of the along-shore current in the cross-shore direction is visible during many other episodes of the 10year period. The dynamical reason for this is unclear.

The time series of the 10 year-long record of EICC evolution (not shown) allows to realize the wealth of timescales at which the EICC varies, from interannual to intraseasonal. The characterization and complete analysis of its spectrum will be the next stage of this study.

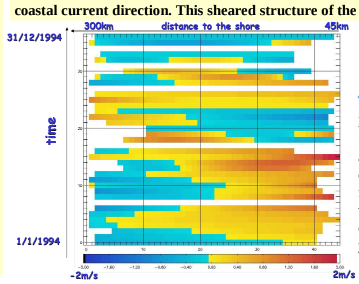

Figure 6 : Hovmuller diagram of the cross-track 116 altimeter-derived current for 1994, as a function of the distance to the shore and of the cycle number during the year (in m/s).

4- Conclusions and perspectives:

A novel method to derive the coastal geostrophic current from along-track satellite altimetric profiles is proposed. Based on the recently released MAP coastal altimetric data processing, the retrieved SLA as well as the current deriving from these SLA, have been validated at one privileged benchmark site in the Western Bay of Bengal. The validation was conducted to the extent of the available in situ data. We finally presented a glance over the wealth of information on the EICC variability (from intraseasonal to interannual timescales) that is contained in our dataset, at different time scales. A complete analysis of these results will be found in Durand et al. (in preparation for JGR). Beyond the Bay of Bengal case study, the generic character of our methodology thus opens a broad range of promising studies, typically in regions where the coastal surface circulation remains impossible to monitor via in situ measurements.