High-resolution Simulations for the Bay of Bengal Mean Features: Sensitivity to River Input and Wind Forcing

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Abstract

The sensitivity of the Bay of Bengal (BoB) mean features (thermohaline and circulation) to two climatological winds forcing (weaker COADS and stronger QuikSCAT) and two representations of river inputs (river inflow with seasonally varying estuarine salinity or with zero salinity) is investigated, using an eddy-resolving ROMS setup.

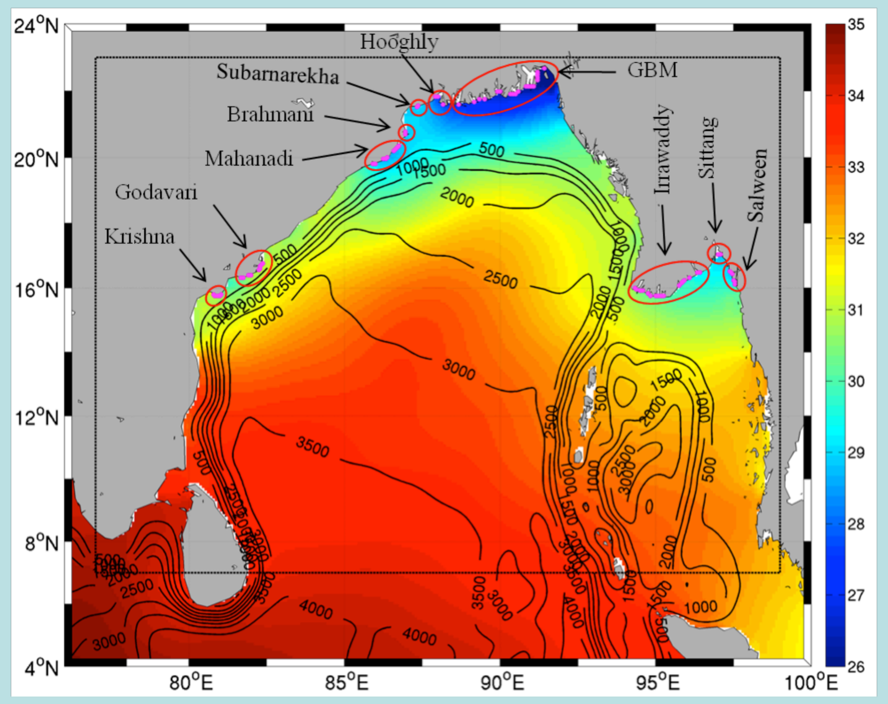


Figure 1: The modeling domain overlaid with the climatological annual salinity in psu (color background). Contours represent the model bathymetry values in meters. Dotted black lines represent the boundary of the domain of analysis. Magenta points along the coastal boundary are the locations of the point sources for river input.

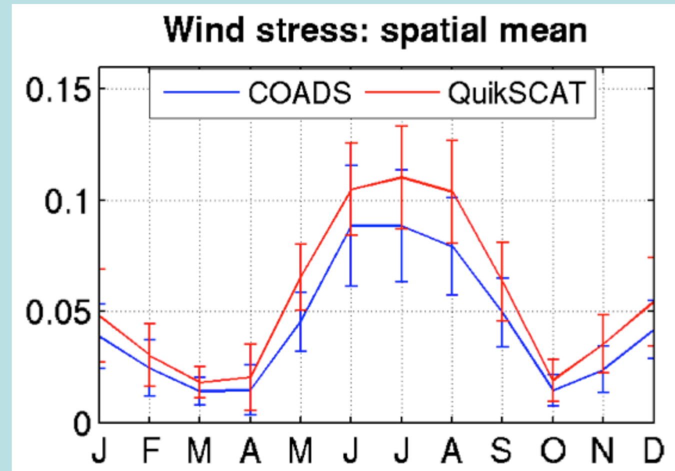


Figure 2: Seasonal cycle of the domain-averaged wind stress magnitude (dynes cm^{-2}) from COADS (blue line) and QuikSCAT (red line). Bars on the lines represent the standard deviation. The COADS winds are weaker than the QuikSCAT winds all throughout the year; the difference is especially large during the monsoon months (JJA).

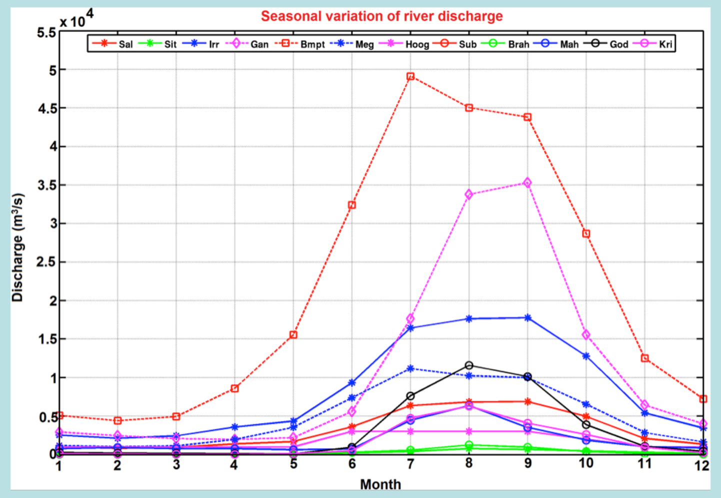


Figure 3. Seasonal cycles of discharges from all the rivers. Name of the rivers in the legend are (from left to right) Salween, Sittang, Irrawaddy, Ganges, Brahmaputra, Meghna, Hooghly, Subarnarekha, Brahmani, Mahanadi, Godavari and Krishna. (From Jana et al., 2015)

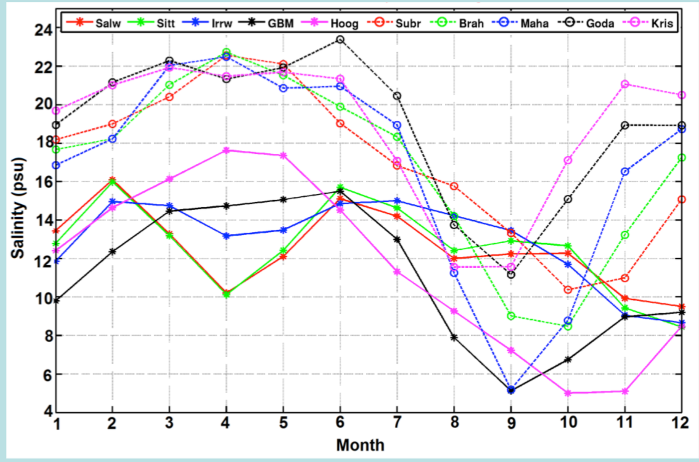


Figure 4. Seasonal cycles of salinities at the river mouths. River abbreviations are similar to those in **Figure** 3. (From Jana et al., 2015)

Approach:

A set of four different simulations (each 15-year long) using two winds forcing and two river inputs are compared and contrasted.

Numerical Experiment	Wind forcing (Monthly Climatology)	River input Salinity parameterization
CRS	COADS	River input with seasonal salinity
QRS	QuikSCAT	River input with seasonal salinity
CRZ	COADS	River input with zero salinity
QRZ	QuikSCAT	River input with zero salinity

Table 1: Summary of the main modeling simulation experiments

The sensitivities are analyzed in terms of the surface circulation, thermohaline structure, freshwater plume dispersion, and the coastal upwelling along the western boundary during late spring/ summer. All simulations reproduce the main features of the Bay; however, magnitudes and variabilities depend on forcing conditions. The major mean effects of winds and river inputs are found mostly limited to the upper 50 m of the water column in a domain-average sense, with deeper and stronger influence in the northern BoB. Some key results are shown in the middle and right panels.

Key Results

- The stronger QuikSCAT wind-induced enhanced mixing lowers (enhances) the upper ocean temperature (salinity), weakens the near-surface stratification. Moreover, stronger winds enhance eddy activity, strengthen the springtime Western Boundary Current (WBC) and enhance coastal upwelling during spring and summer along the east coast of India.
- The fresher river input reduces the surface salinity and hence enhances spreading and intensity of the freshwater plume, stratification, and barrier layer; however, its impact on SST is negligible. The lower salinity simulation prefers an eddy-dominant springtime WBC, and enhances the freshness, strength, and southward extent of the autumn East India Coastal Current (EICC) core with plume water inhibition by about 10% over the domain.
- The stronger QuikSCAT winds during the summer monsoon do not favor the spreading of the freshwater plume but rather reduces its spatial extent due to erosion of the freshwater buildup due to enhanced mixing.

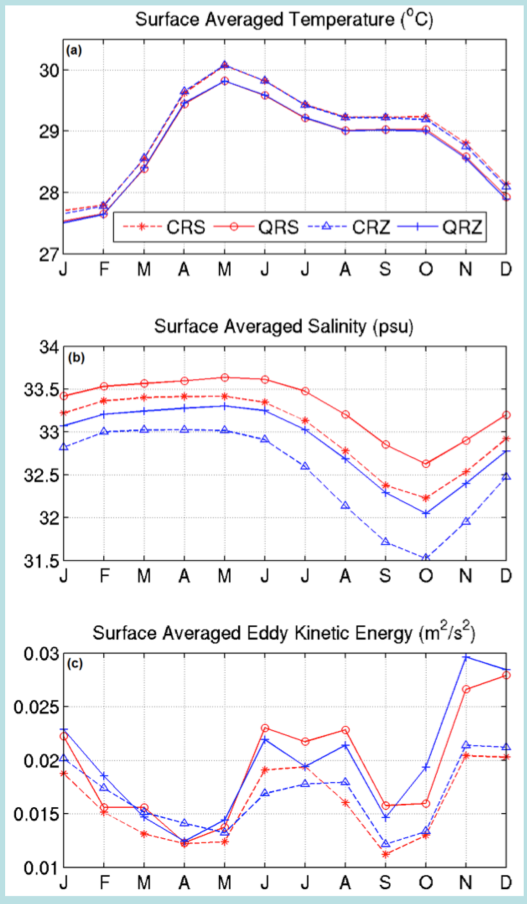


Figure 5: Surface averaged temperature, salinity and eddy kinetic energy from all four simulations. Our findings show that the EKE is primarily wind-driven during the year and modulated by buoyancy forcing with a reducing effect in summer and enhancing impact in autumn and winter.

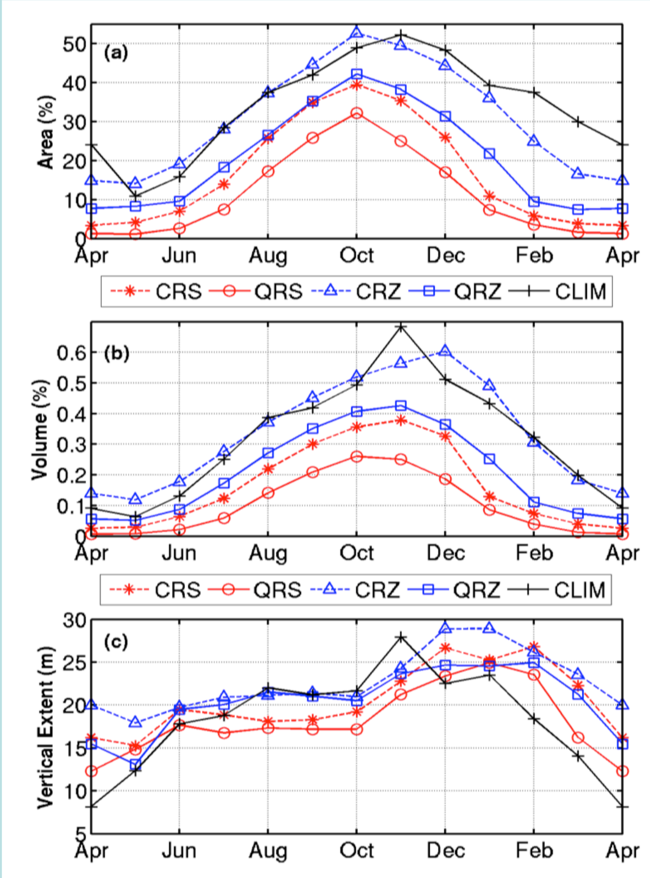


Figure 6: Seasonal evolution of (a) area, (b) volume, and (c) vertical extension of the freshwater plume region (as defined by the 32.5 psu contour in 3-D). Note the 1-month lag in reaching the peak value for volume coverage from area coverage and then for mean vertical extent from the volume coverage.

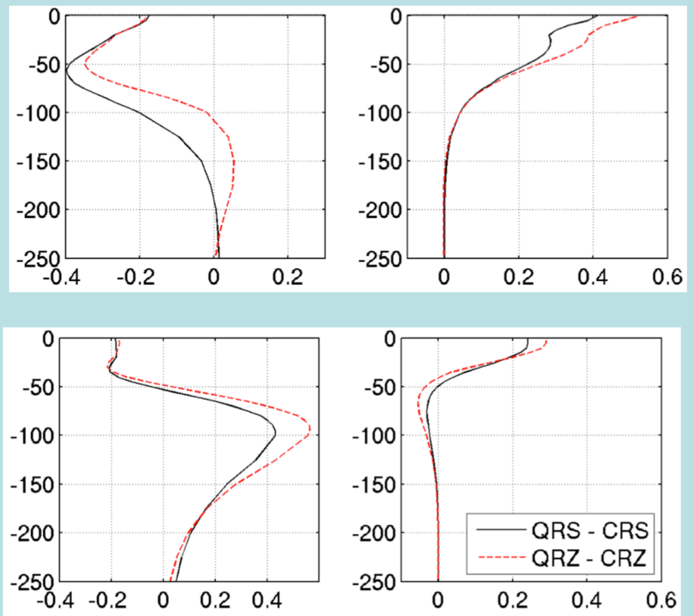
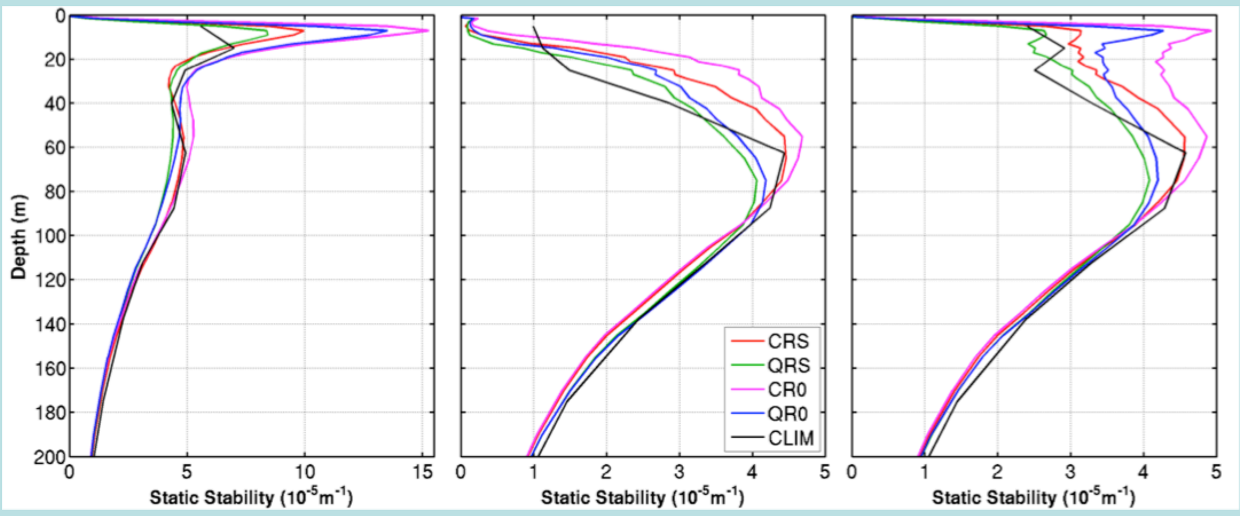


Figure 7 (Left): Sensitivity to different wind forcing of the simulated temperature (°C) (left column) and salinity (psu) (right column) fields in the northern (top row) and southern BoB (bottom row). Difference (QuikSCAT – COADS) for the two buoyancy conditions (zero and seasonal salinity) are shown. Note that the effect of stronger winds (QuikSCAT) is felt (i) deeper for temperature than for salinity, and (ii) has different responses in the upper 200 m of the southern Bay than in the northern Bay. See text for details.

Figure 8 (Below): Comparison of vertical profiles of mean static stability during July through October, averaged over the (a) northern BoB (north of 15°N), (b) southern BoB (south of 15°N) and (c) entire BoB (right), between climatology (NIOA), and the four simulations.



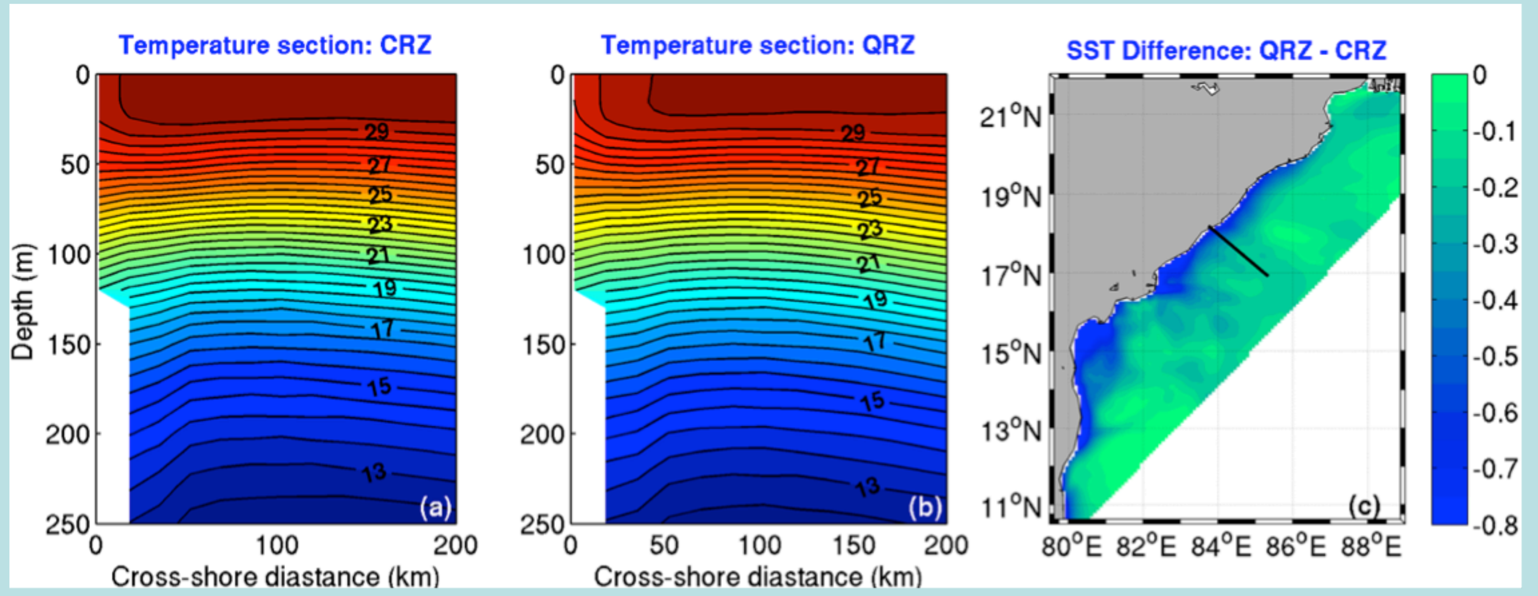
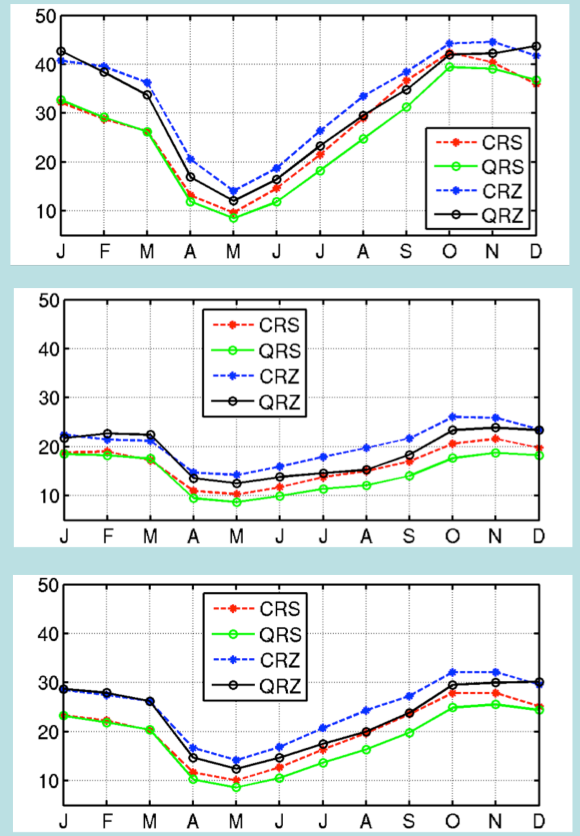


Figure 9: Signature of coastal upwelling: vertical sections in the temperature (°C) fields of the (a) CRZ and (b) QRZ fields; and SST difference (c) between CRZ and QRZ. The black line near 18°N in (c) denotes the location of the cross-shore section, which is similar to Leg E of Shetye et al. (1993). All the fields presented here are the average of Jun-Aug fields.



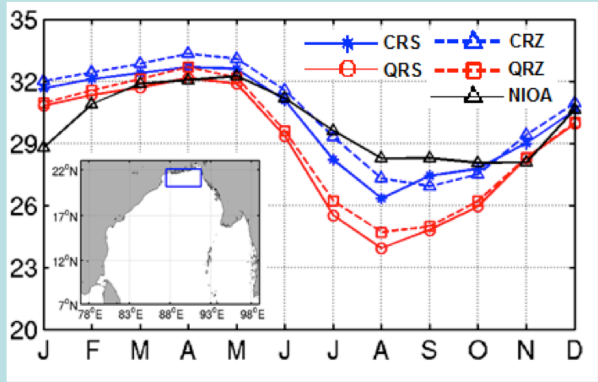


Figure 10: Annual cycle of SSS (psu) averaged over a Box (blue box in the inset plot) near the mouth of GBM for the four simulations, compared against that from the NIOA climatology. For consistency, the computations are carried out on NIOA grid and land mask. Note that both of the zero salinity runs significantly underestimate the seasonal cycle of climatology during June through October

Figure 11 (Left): Annual cycles of barrier layer thickness (BLT) in m averaged over (a) northern BoB, (b) southern BoB and (c) entire BoB from CRS, QRS, CRZ and QRZ. Note the higher seasonal range exhibited in the north compared to the south and over the entire BoB. See text for other details.

Conclusion

- Our sensitivity results can provide a useful realization for high-resolution simulations in the Bay of Bengal. Future studies should surpass the skills presented here through improved parameterizations; more accurate river discharges and tidal forcing; and advanced multiscale and multivariate data assimilation of temperature, salinity, SSH, etc. and adaptive data collection.
- More accurate river discharge models will help resolve coastal and shelf circulation, shelf-slope exchanges, and cross-shelf transport, which are all important for understanding the impact of climate change on the coastal ecosystem and fisheries at large.
- Results presented here with sensitivities to strong/weak winds and river buoyancy forcing could be helpful to diagnose the corresponding inter-annual variability. A systematic study to understand the sensitivity of the model results to vertical resolution by varying vertical resolution and keeping high horizontal resolution has not been done yet for the Bay. Recent simulations (Lermusiaux et al., 2017) show that such effects can be significant.

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