Lagrangian interpretation of Aquarius surface salinity in the Bay of Bengal

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Introduction

Seasonal freshwater runoff into the Bay of Bengal (BoB) due to the Monsoon makes the Bay one of the freshest oceans and results in a large spatial gradient in sea surface salinity (SSS). Despite the societal importance of the BoB, few observational analyses of SSS variability have been carried out. The increased resolution of SSS observations available from the Aquarius mission provides a new opportunity for understanding the basic physical dynamics of the BoB and the role of the oceans in the hydrological cycle.

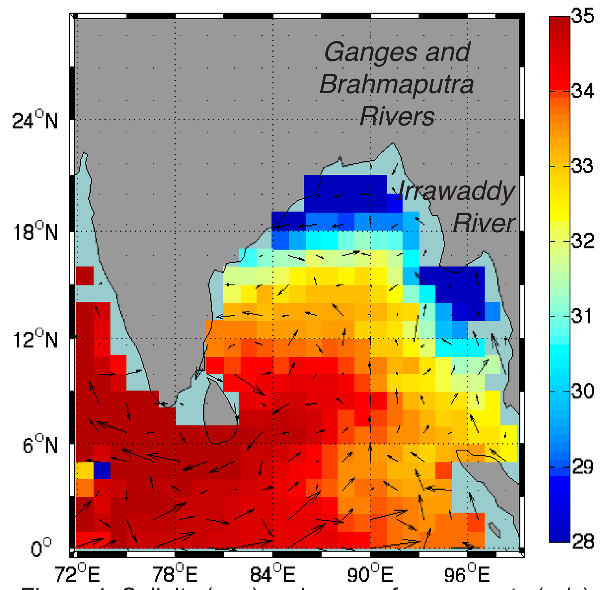


Figure 1. Salinity (psu) and sea surface currents (m/s). The plotted data is Mean monthly Aquarius gridded salinity and mean 5 day OSCAR velocity

Purpose

We seek to understand the processes underlying salinity variability in the Bay of Bengal, including

- What are the spatial patterns of salinity and how do they evolve seasonally?
- To what extent do advection, mixing, and surface fluxes cause observed changes in salinity?

Because of the known importance of mesoscale advection in this region,[5] we study processes in the moving frame of the ocean using Lagrangian modeling.

Salinity budget

$$\frac{DS}{Dt} = \frac{\partial S}{\partial t} + \nabla \cdot (\mathbf{u}S) = \kappa \nabla^2 S + \frac{E-P}{h} S + V$$

Sources and sinks

$\kappa \nabla^2 S$: Lateral mixing

$\frac{E-P}{h}$: Evaporation minus precipitation divided by mixed layer depth

V : Vertical mixing and mixed layer entrainment

Error calculations

At spatial scales of 9km or above (the Aquarius along-track resolution), Aquarius and a thermosalinograph from an ASIRI cruise observe the same gradients (Figure 2).

We calculate the error in the rates of change of salinity as a product of the salinity gradient and the time between satellite measurements. The error is greatest in the northern BoB, but the magnitude of the error is always less than the calculated rate of change of salinity.

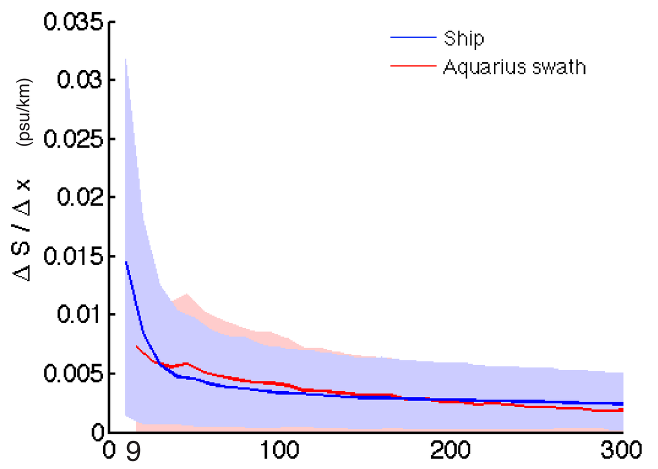
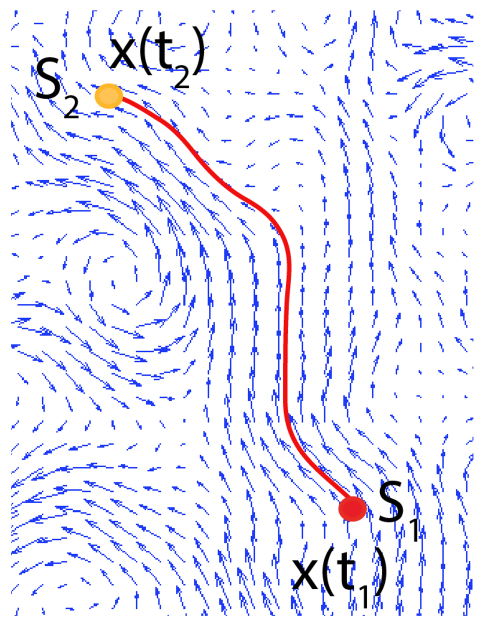


Figure 2. Mean and 95% confidence interval of salinity gradient (change in salinity along track over a set distance) v. distance

Methods

We tracked observed salinity from **Aquarius**[4] along water parcel trajectories calculated from satellite-derived surface geostrophic and Ekman currents (**OSCAR**).[1,3] This method assumes the surface layer is well-mixed. We estimate the material derivative using measurements of salinity at two time points along a single trajectory.

$$\frac{DS}{Dt} = \frac{S_2 - S_1}{t_2 - t_1}$$



We ascribed the observed changes in salinity to oceanic processes and surface fluxes using evaporation estimates from **OAFlux**[7], precipitation measurements from **GCPC** [NASA TRMM], **MIMOC** mixed layer depth,[6] and **Finite Time Lyapunov Exponent** estimates of horizontal strain.[2]

Results: Late Monsoon (Aug. - Oct., 2012)

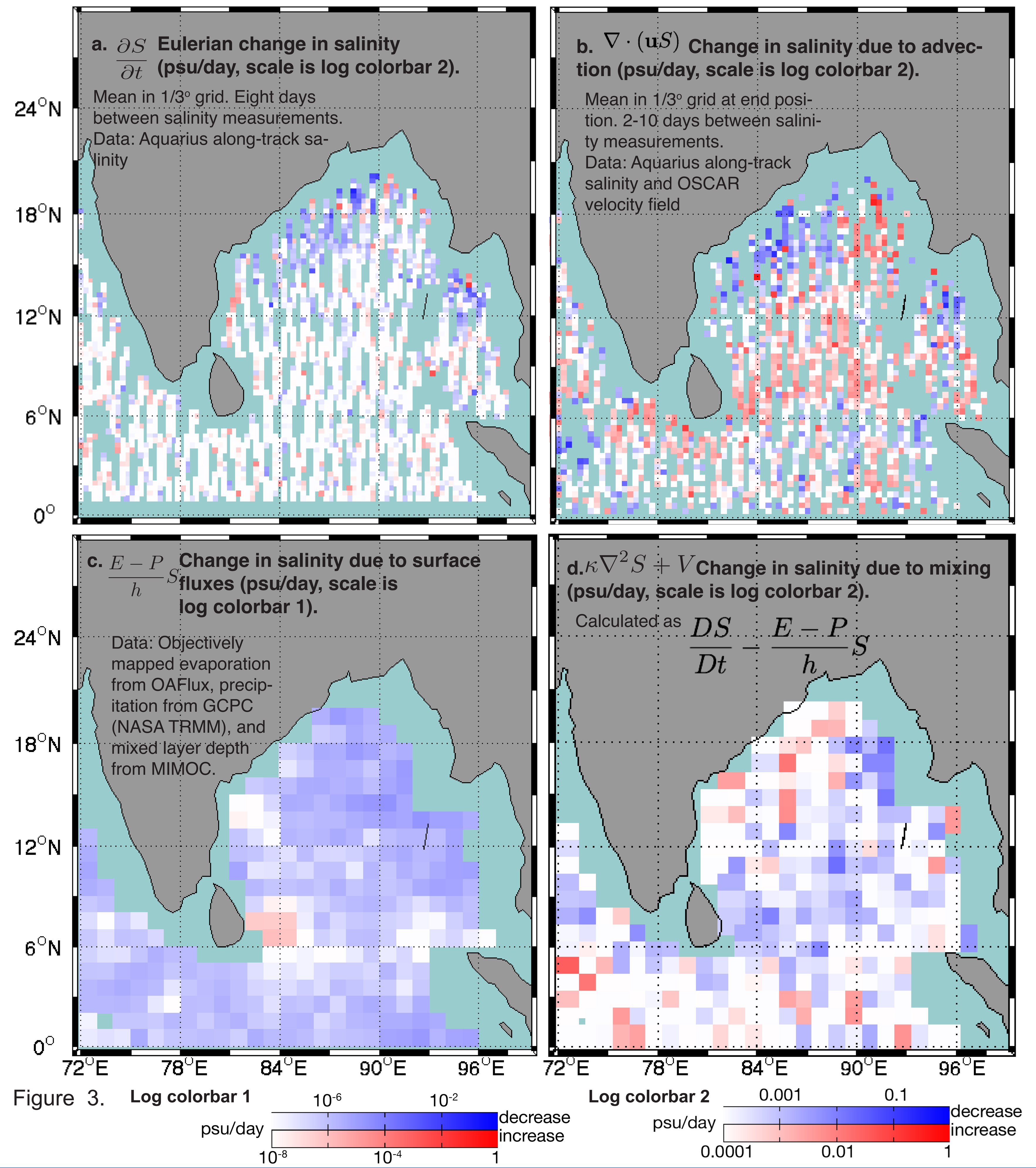


Figure 3.

Processes in a moving frame

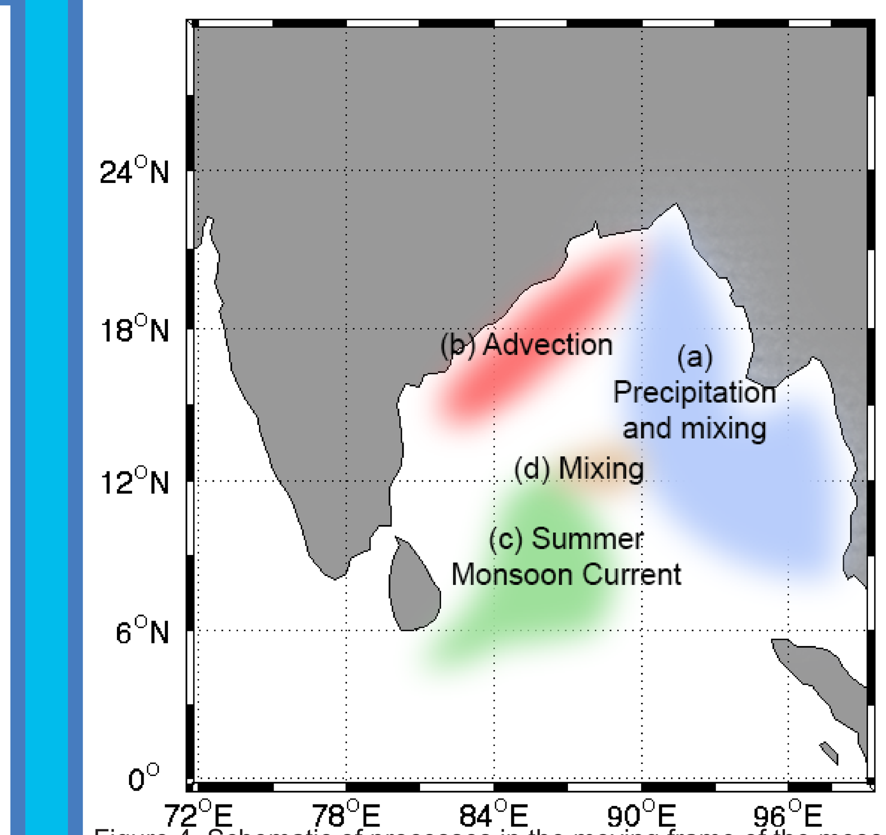


Figure 4. Schematic of processes in the moving frame of the meso-scale flow field

(a) High precipitation results in freshening of water entering the northeastern BoB from the south and west [Fig. 3c].

(b) During the summer monsoon, the narrow East India Coastal Current carries river run-off into the Bay. Water traveling down the western boundary of the BoB increases in salinity at a rate of 0.4 psu/day due to lateral mixing (note the high strain in this region [Fig. 5]) and Ekman-driven upwelling at the coast [Fig. 3b,d].

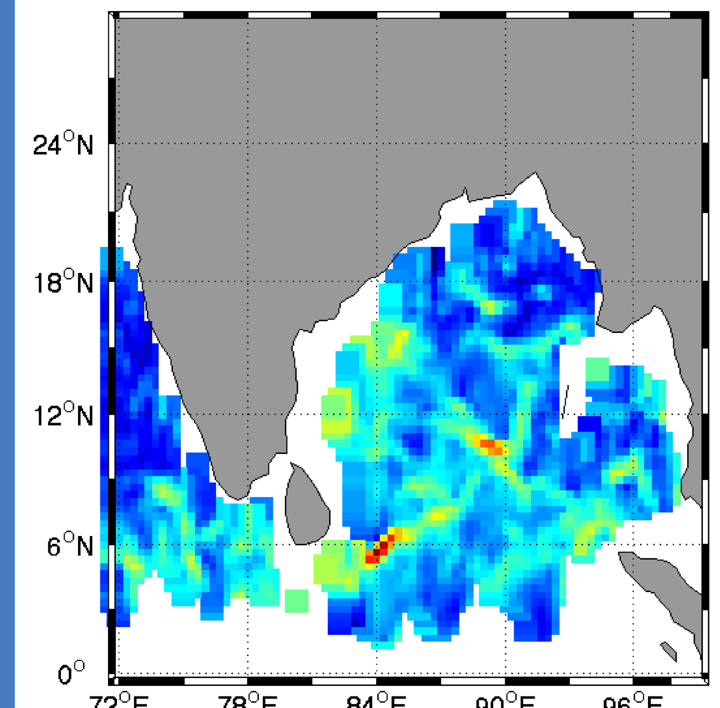


Figure 5. Strain rate calculated using FTLEs from OSCAR velocity fields for Aug.-Oct. 2012. Red colors indicate higher strain

(c) As water enters the BoB from the south and west, it appears to become fresher at a rate of 0.1 psu/day due to lateral mixing (diagnosed by high strain) and subduction below a fresh surface layer [Fig. 3d].

(d) Large salinity gradients and lateral mixing (diagnosed by high strain [Fig. 5]) result in high rates of change in salinity in a Lagrangian frame [Fig. 3b].

Conclusions

- Satellite along-track lateral salinity gradients are representative of ship-based measurements at spatial scales greater than 9 km.
- Surface fluxes are most important in the NE BoB, but rates of change due to surface fluxes are an order of magnitude smaller than advection and mixing across the whole Bay.
- The largests changes in salinity are due to advection, which is balanced by mixing. However, errors in these estimates are large compared to surface flux estimates.

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