The Effect of Bay of Bengal Freshwater Flux on Indian Summer Monsoon Rainfall in a Coupled Column Model

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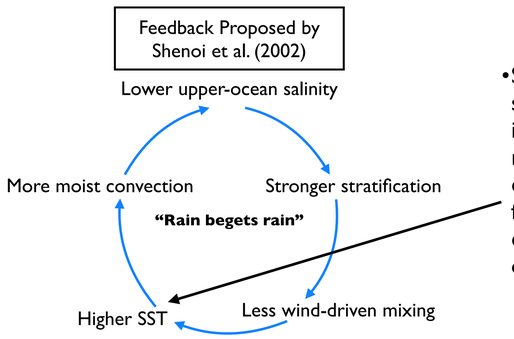
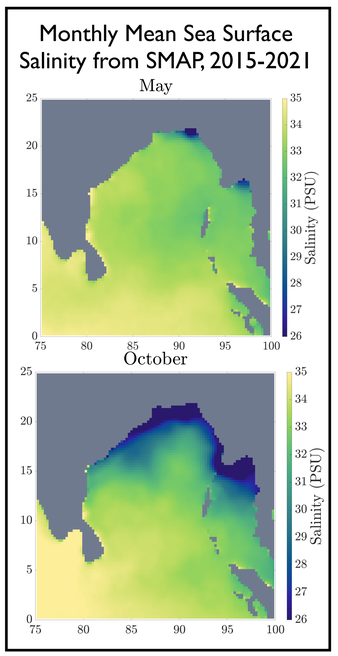
1: Background - Freshwater in the Bay of Bengal

- Summer monsoon rainfall and freshwater runoff into the Bay of Bengal spreads as a fresh surface layer that creates shallow mixed layers in the northern and central Bay.
- Shallow mixed layers may allow for more rapid response to surface forcing which modulates the SST available to drive heat flux to the overlying atmosphere. Shenoi et al. (2002) proposed the resulting positive feedback loop shown below.



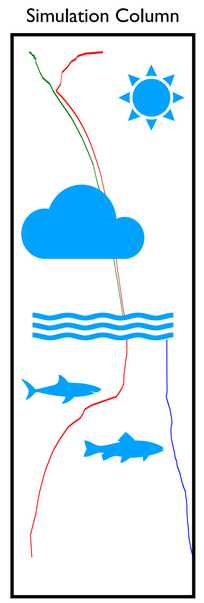
- Subsequent modeling has shown that freshwater input does not necessarily result in higher SST, but it does increase latent heat flux to the atmosphere. So does the feedback still operate?

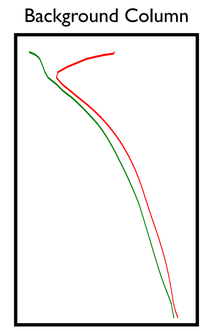


- We are investigating the effect of freshwater forcing on monsoon precipitation in a coupled single column model representing the Bay of Bengal.

2: Method - A Coupled Single Column Model

- We alternate atmosphere and ocean timesteps with a coupling timestep of 2 hours.
- Atmosphere: MIT single column model (Emanuel 2010)
  - Interactive radiation, parameterized convection (Emanuel and Živković-Rothman 1999), and parameterized layer clouds (Bony and Emanuel 2001)
- Surface fluxes: Bulk formulas (Soon: COARE3.5)
- Ocean: PWP column model (Price et al. 1986)
  - Applies surface forcing and computes mixed layer depth and mixing based on static stability and Richardson number criterion
  - Freshwater forcing is prescribed at each timestep to restore toward a chosen mixed layer salinity

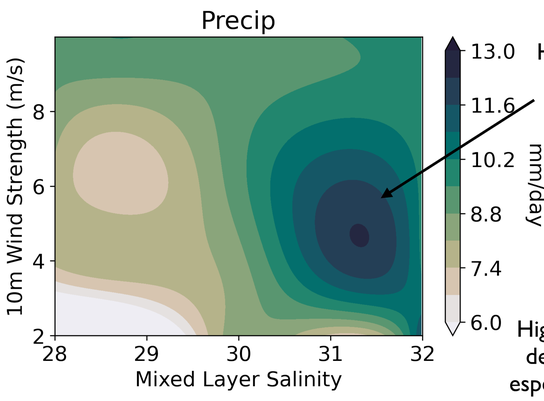




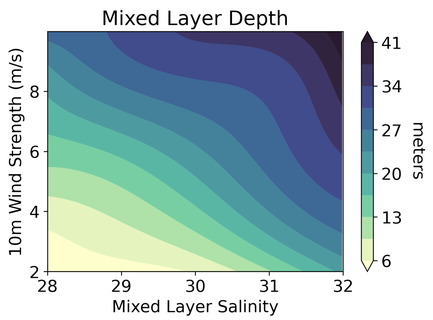
- Weak temperature gradient approximation: Atmospheric temperature profile is nearly constant in the tropics due to the fast gravity wave speed (Sobel et al. 2001).
- Implemented via coupling to a background column via linear gravity waves (Kuang 2008)
- Background column obtained from radiative-convective equilibrium over fixed 28 degree SST

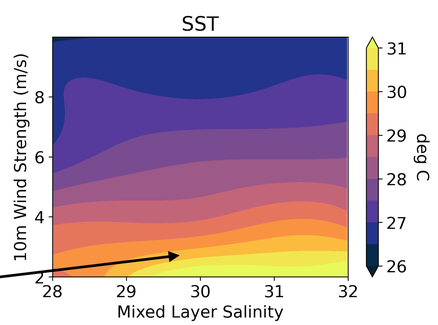
3: Results of Freshwater Forcing Simulation

- Initial profiles (pre-monsoon state) from May 2015 Argo and ERA5
- 16 week run to simulate summer monsoon season
- 5-day freshwater forcing timescale to restore to chosen mixed layer salinity
- 25 runs to fill 2D parameter space
- Plots show median value over final week of run



Higher precipitation occurs for deeper mixed layers with sufficient warmth and wind

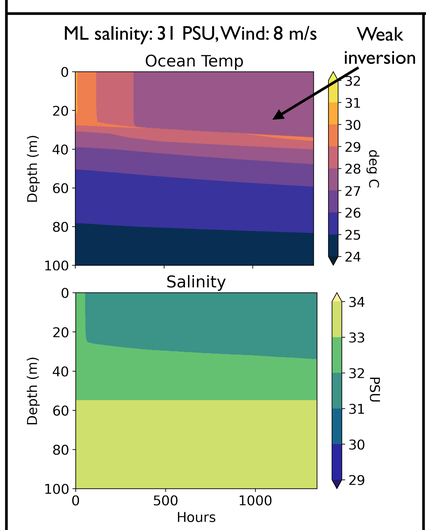


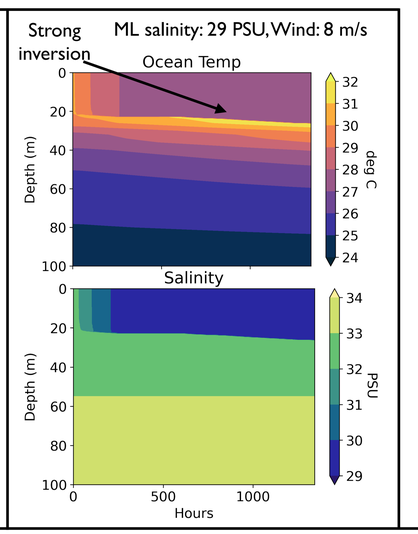


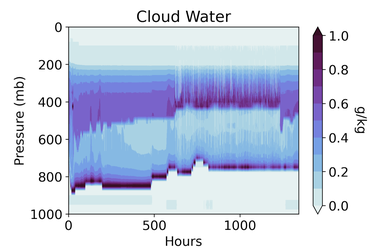
Higher SST occurs for deeper mixed layers, especially for low winds

4: Discussion and Future Work

- Strong freshwater forcing shoals the ocean mixed layer so that shortwave flux penetrates below and creates a temperature inversion. This results in a lower SST and less precipitation, which prevents the feedback mechanism of Shenoi et al. (2002) from operating in these cases.
- For the feedback mechanism to be effective, the salinity-controlled mixed layer must be deep enough to capture most of the incoming shortwave flux, but shallow enough to maintain a small heat capacity.







- Strong low- and mid-level clouds significantly modulate incoming and outgoing radiation in many model runs.
- Future work: We plan to compare the Bay of Bengal and Arabian Sea using separate single column experiments. To what extent do their freshwater inputs influence their difference in rainfall?

Primary References

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