A regional study of Bay of Bengal processes using radiation boundary condition in Modular Ocean Model

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Objectives of the present research

- Understand effect of different wind stress and solar radiation forcing in model
- Validate implementation of radiation open boundary condition with mass conservation and flux exchange
- Study effect of kpp vertical mixing scheme
- Understand heat budget in BOB region

Unique features of Bay of Bengal (BoB)

- River runoff from various tributaries during and after the monsoon period.
- Warmer SST which is observed in Bay of Bengal.
- Semi-annually reversing wind system causes a semi-annually reversing surface circulation.
- Monsoon and climate in vicinity of Bay of Bengal is mainly affected by ocean dynamics in the Bay of Bengal.
- Strong ocean structure variability due to wind reversal and fresh water flux.
- Availability of high solar radiation due the geographic location

[www.worldatlas.com]

Open boundary condition

- General Sommerfeld radiation equation: (Ref: Sommerfeld,1949)

$$\frac{\partial \eta}{\partial t} = -c\frac{\partial \eta}{\partial x} \text{ at } x = x_{boundary}$$

- Orlanski Radiation: (Ref: Herzfeld,2011)

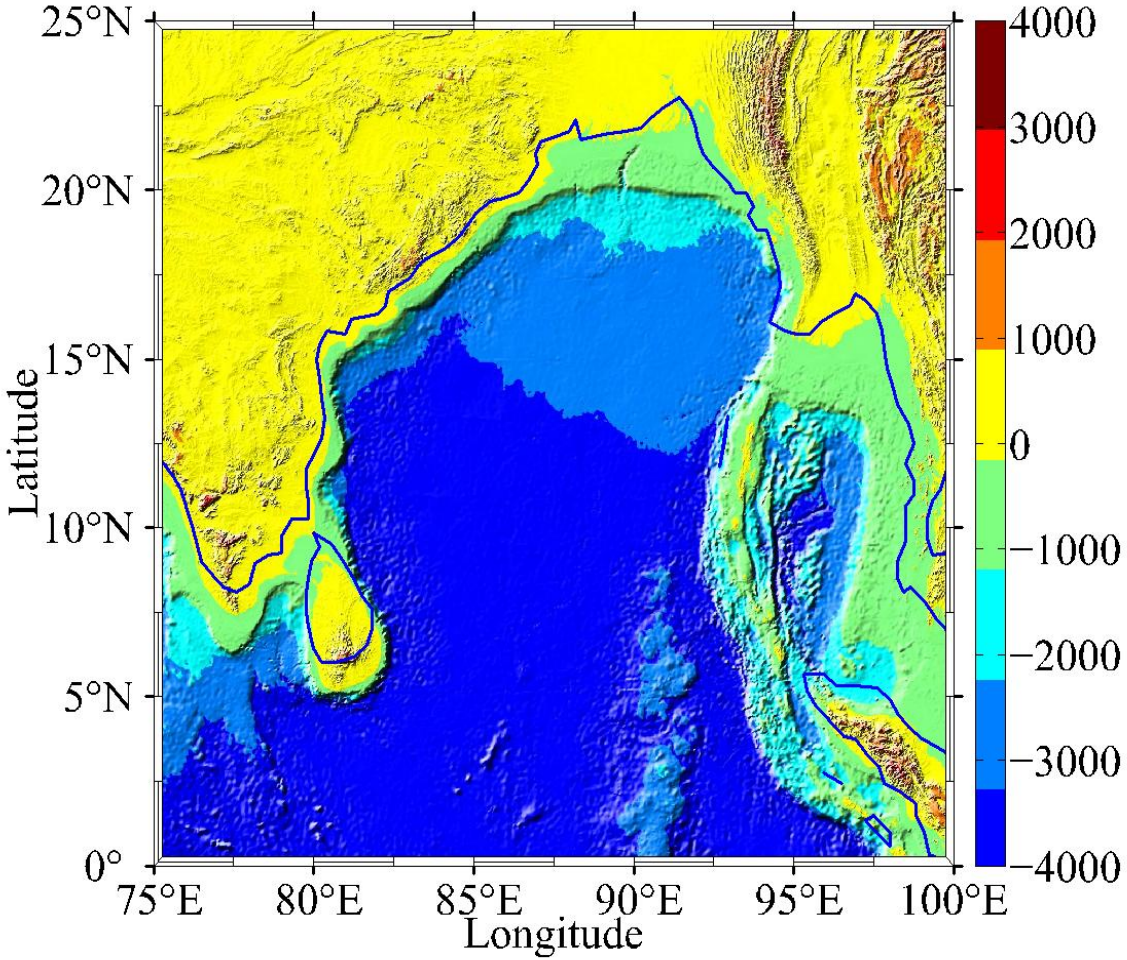
$$\eta(t+1, x_b) = \frac{(1-\mu)\eta(t-1, x_b) + 2\mu\eta(t, x_{b-1})}{1+\mu}$$

$$\mu = \begin{cases} 1 & \text{if } c \geq 1 \\ c & \text{if } 0 < c < 1 \\ 0 & \text{if } c \leq 0 \end{cases}$$

$$c = \frac{\eta(t-1, x_{b-1}) - \eta(t+1, x_{b-1})}{\eta(t+1, x_{b-1}) + \eta(t-1, x_{b-1}) - 2\eta(t, x_{b-2})}$$

Where, η is any variable
c is phase speed
x is space location
μ is dimensionless variable
t is time

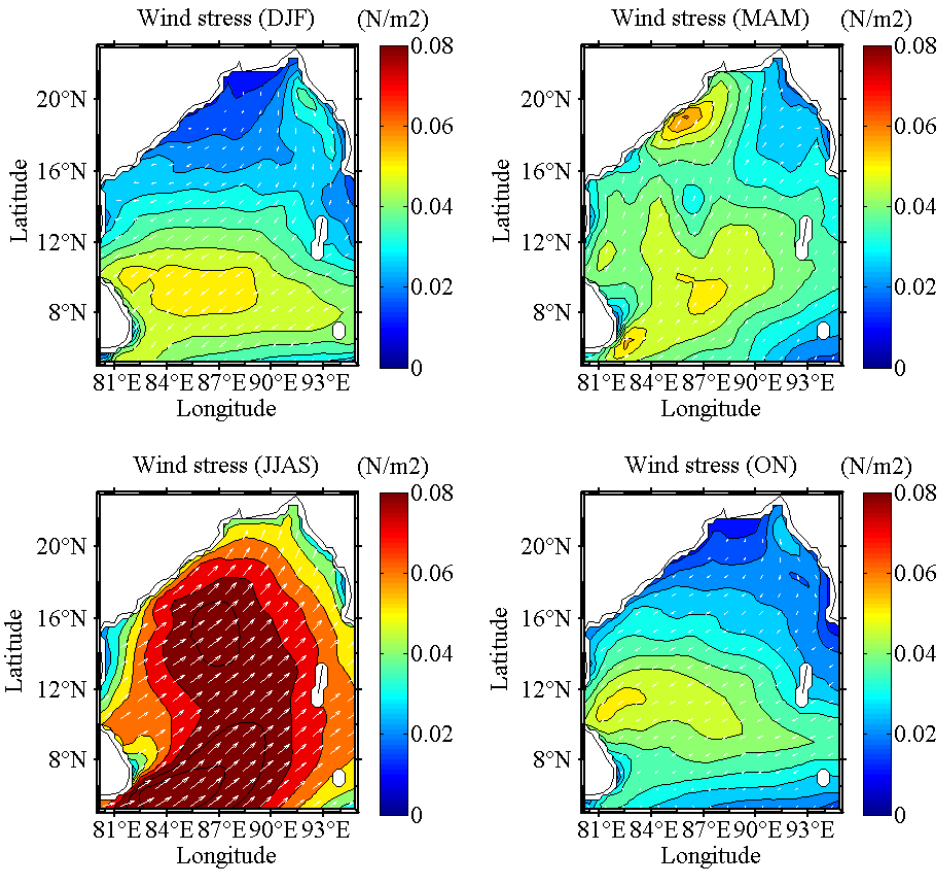
Model domain



- β plane approximation is used
- Horizontal grid resolution 1/4th degree
- Vertical grid resolution 1 m for first 60 m near surface
- Bathymetry with 2 minute resolution
- Laplacian and biharmonic horizontal mixing scheme
- Kpp vertical mixing scheme

Dataset

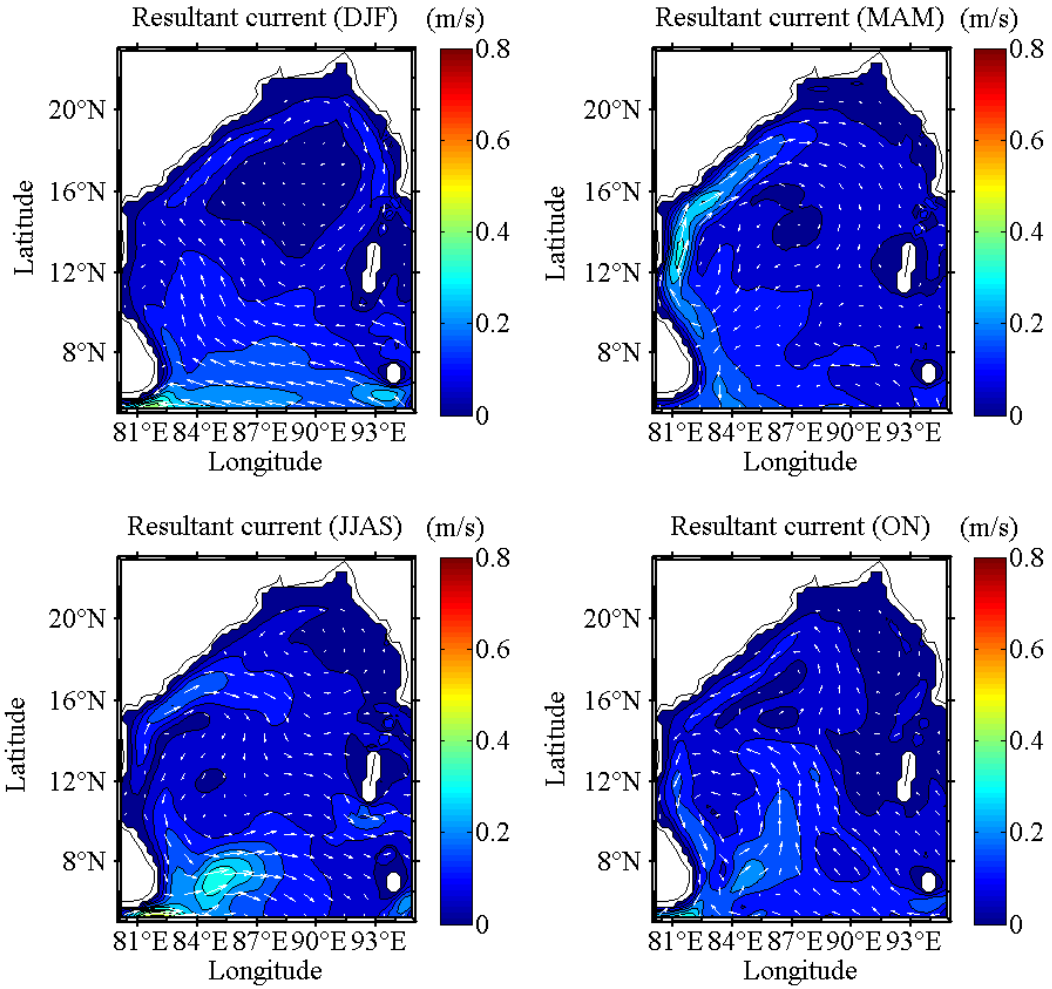
Variable	Frequency	Source
Wind Stress	Pentad	SODA
Temperature, salinity initial	Annual	WOA 2001
Temperature, salinity restore	Pentad	SODA
Surface height	Weekly	TOPEX
Shortwave radiation, Long wave radiation, Evaporation rate	6-hourly	WHOI
Rainfall	Daily	TRMM

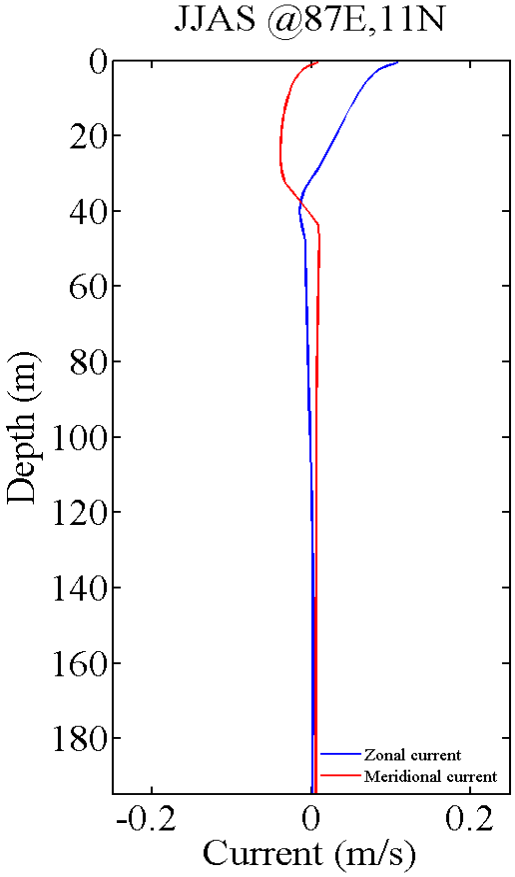


Wind stress input profile

- Data selected for duration of 2003 – 2012.
- Spin-up of 10 years implemented with climatology of data

Results:- Ocean current profiles

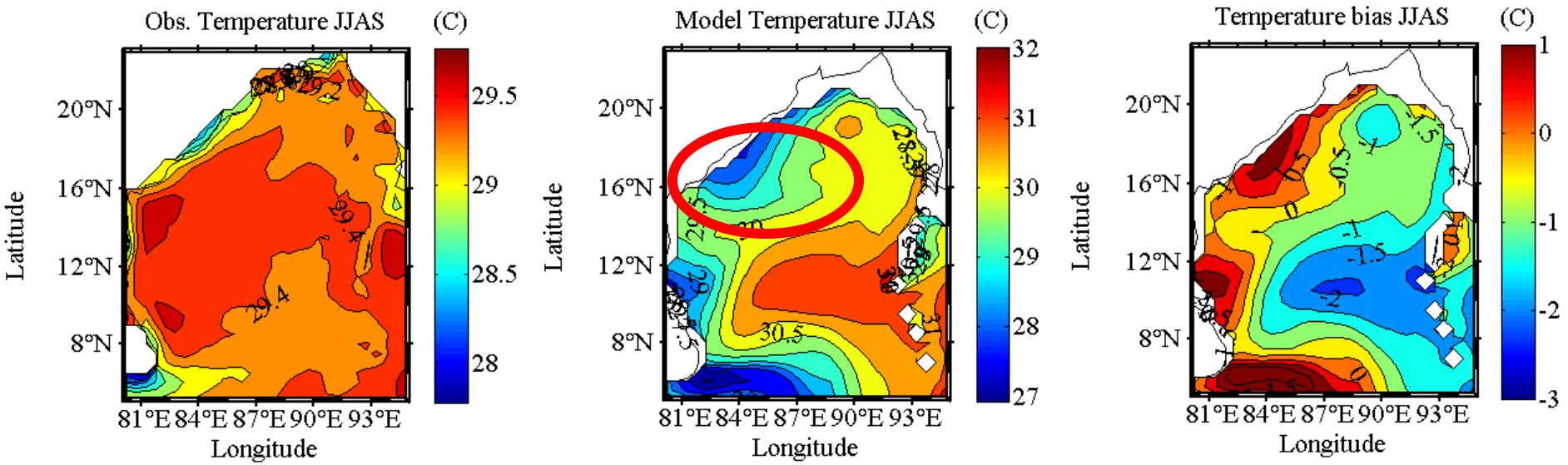




Vertical current profile

Spatial and vertical profile of currents shows similarity of current pattern with changing wind stress forcing and successful implementation of radiation open boundary condition

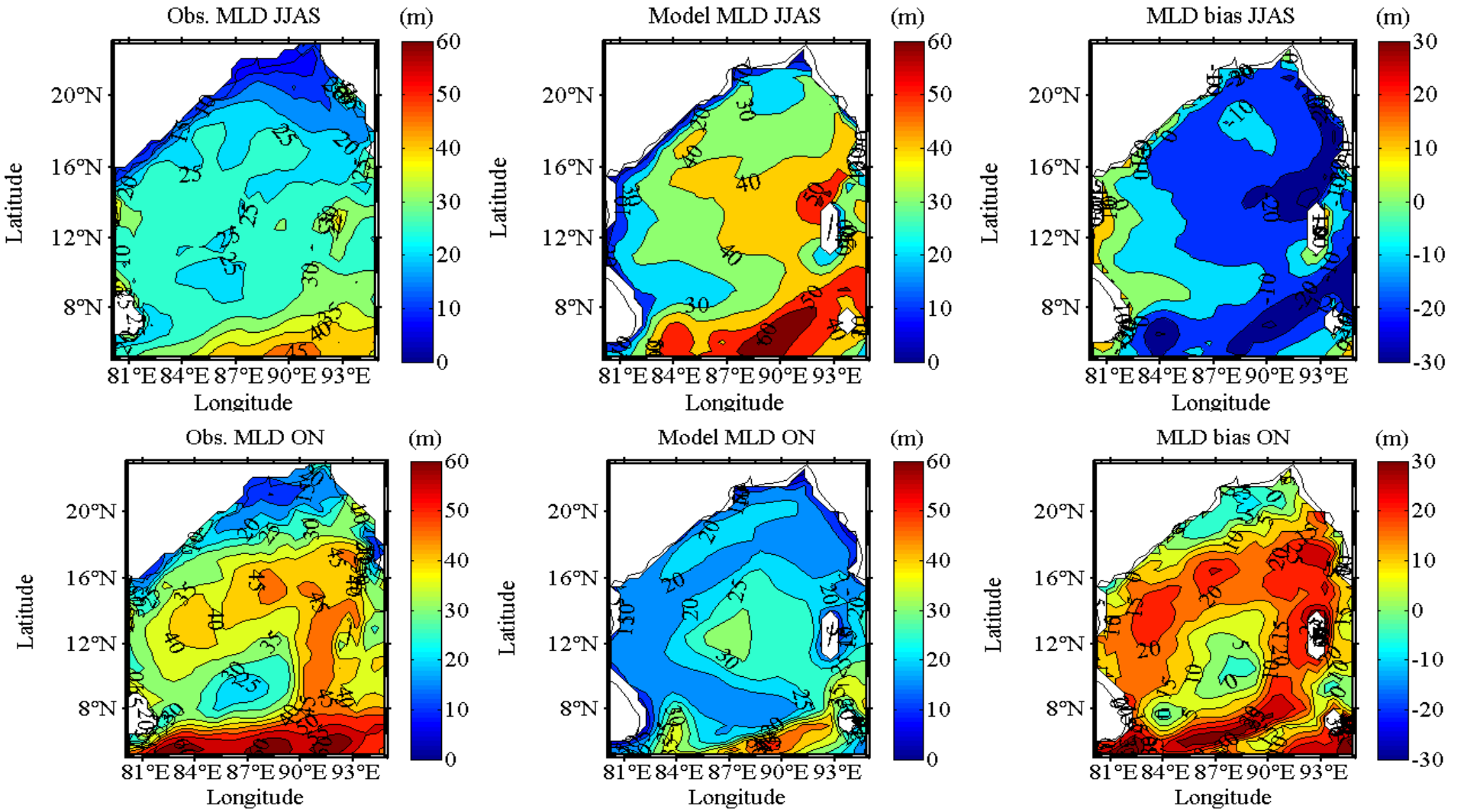
Sea Surface Temperature



- Small bias in (observation – model) simulation confirms good implementation of solar forcing and heat budget.

- Low temperature plume near east coast 16 N in JJAS (monsoon) season is observed in microwave SST data and missing in earlier sponge boundary simulation.

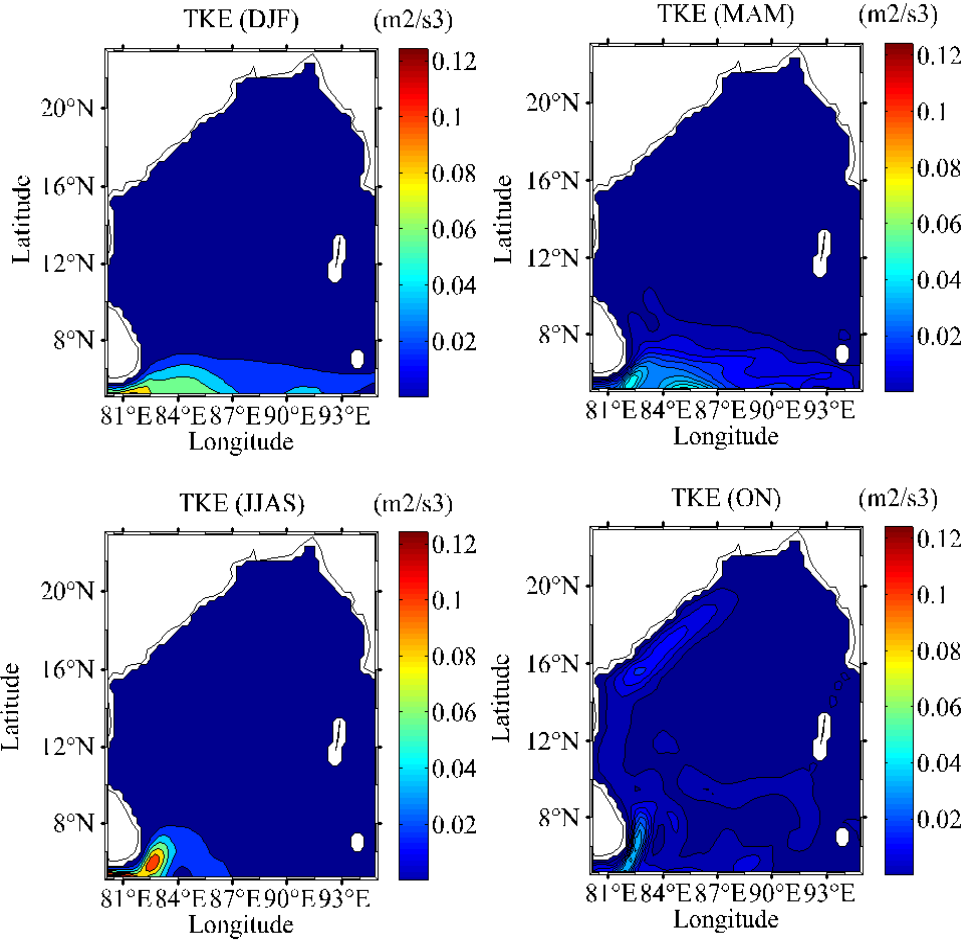
Mixed Layer Depth



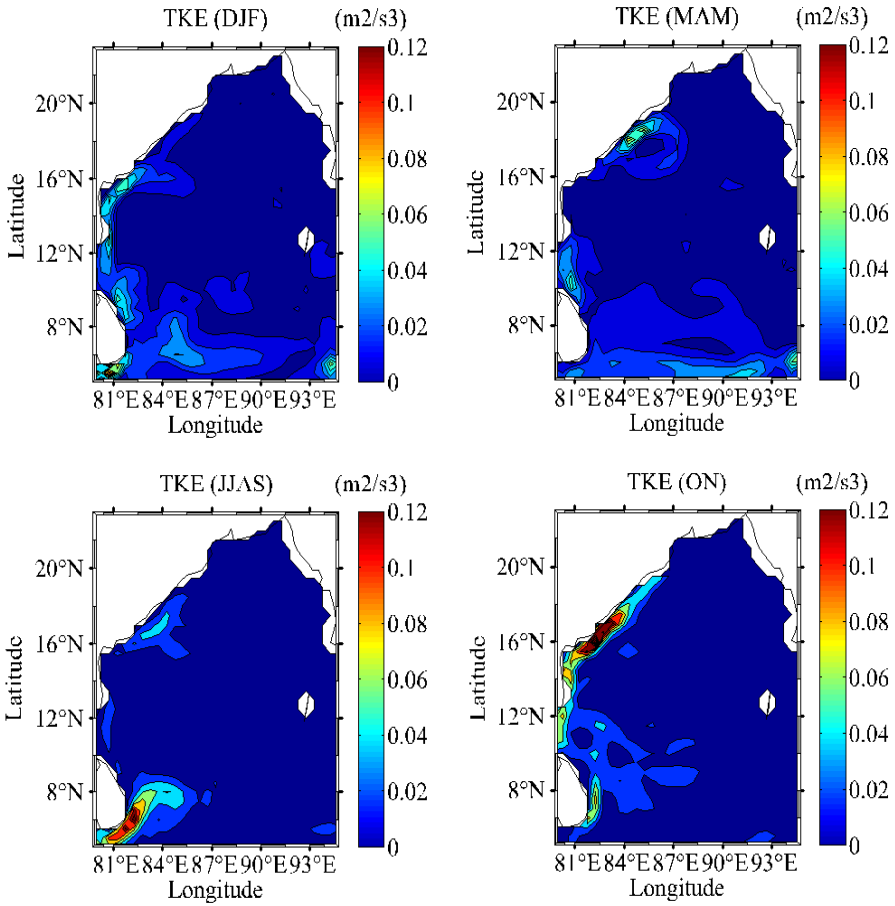
Low bias in MLD shows good implementation of kpp mixing scheme

Turbulent Kinetic Energy (TKE)

Model output (1/4 deg)



SODA data (1/2 deg)



TKE analysis comparison shows meaningful similarity in most of domain

Conclusion

- Open boundary condition is implemented successfully with wind shear and solar forcing for Bay of Bengal.
- Kpp vertical mixing scheme performs well for Bay of Bengal domain with radiation OBC.
- Implementation of KPP scheme enhances mixing in the upper ocean layers with more realistic thermocline formation and turbulent kinetic energy (TKE).
- The model is able to mimic the seasonal variability in the ocean currents enforced due to winds. The Sea Surface Temperature (SST) is in good agreement with SODA reanalysis data
- A plume like mesoscale feature in the SST plot is captured in the present study (that is also observed in microwave SST), but found to be missing in earlier BoB study with sponge boundary conditions.