Impact of sea surface salinity on tropical cyclone intensification in the Bay of Bengal: preliminary satellite observations and ocean modeling results

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Background

- The Bay of Bengal (BoB): fresh surface from rainfall and rivers
  (Sengupa et al. 2006, Varkey et al. 1996; Howden and Murtugudde 2001) .

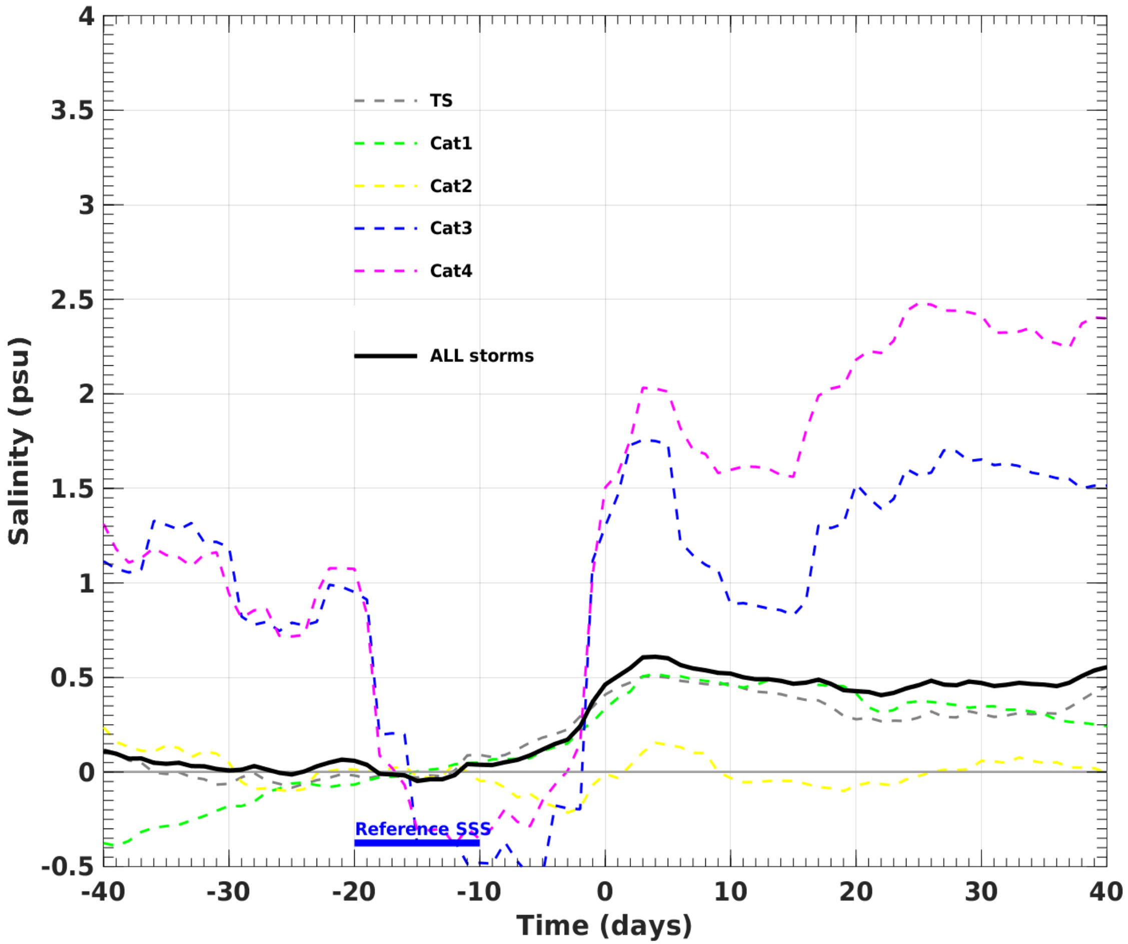
- Fresh upper ocean and salinity barriers: inhibit TC-induced cooling & favor TC intensification
  (Neetu et al. 2012; Balaguru 2012; Androulidkis et al. 2016).

- Surface freshening shoals mixed layer, and nutrient input from rivers may enhance near-surface chlorophyll
  (Narvekar & Kumar 2014).

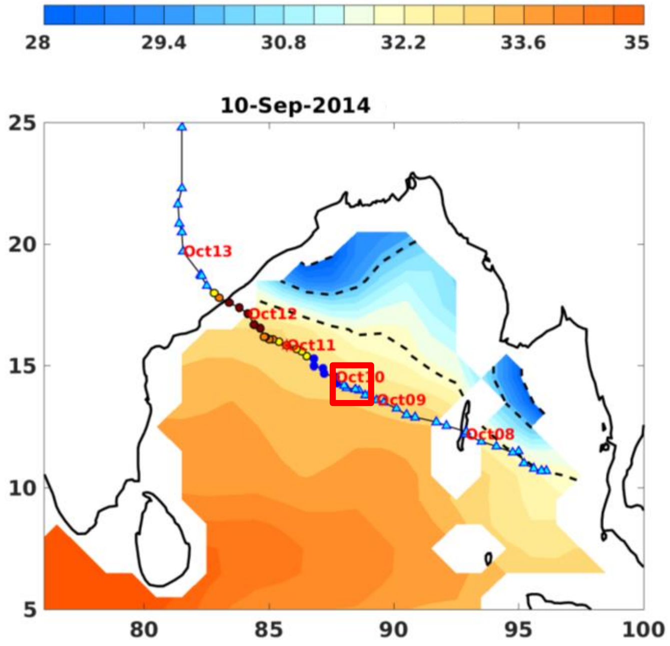
- We investigate the impact of SSS on: TC-related SST change and TC intensification in the Bay of Bengal.

After average BoB TC: salinity increases

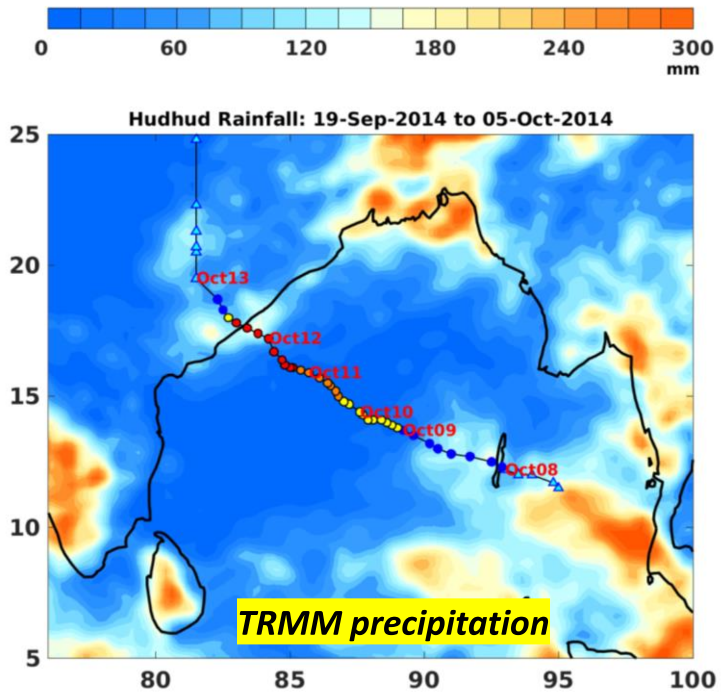
Intense BoB TCs: dramatic (> 1psu!) precursive SSS decrease, subsequent SSS increase

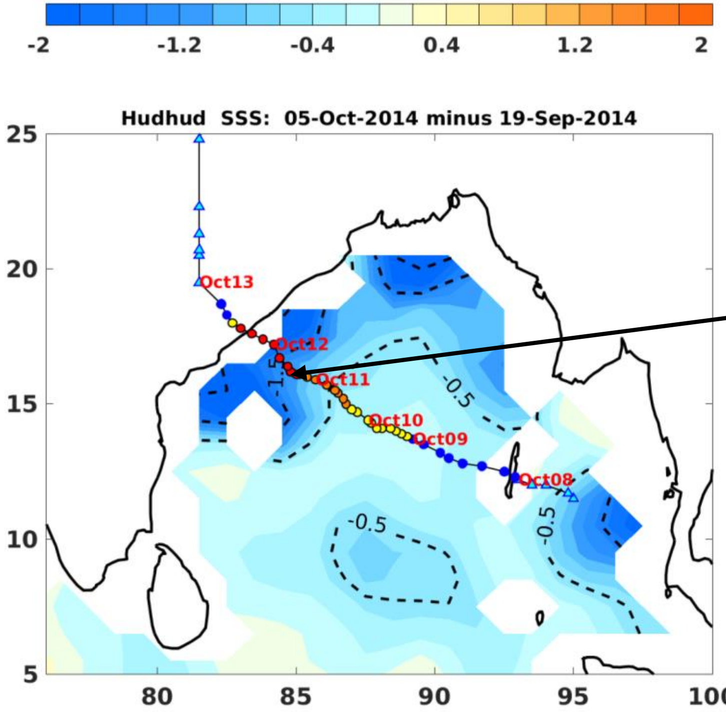


- The Lagrangian composite of the SSS anomaly for all the TCs in BoB from 2011 to 2017.
- The SSS anomaly is averaged over a 2^{o} x2^{o} region centered over each TC track position.
- During -20 to -5 day before TCs passed over, mean sea surface salinity anomaly decreases from 1psu to -0.5psu.
- ***Aquarius and SAMP Satellite SSS (7/8 day running mean)***



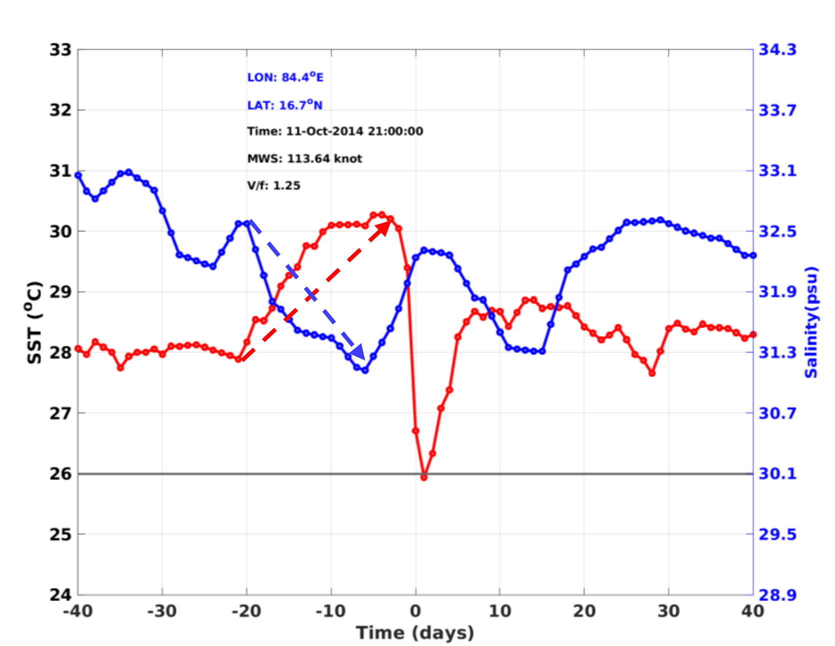
Extremely Severe Cyclonic Storm Hudhud (2014)





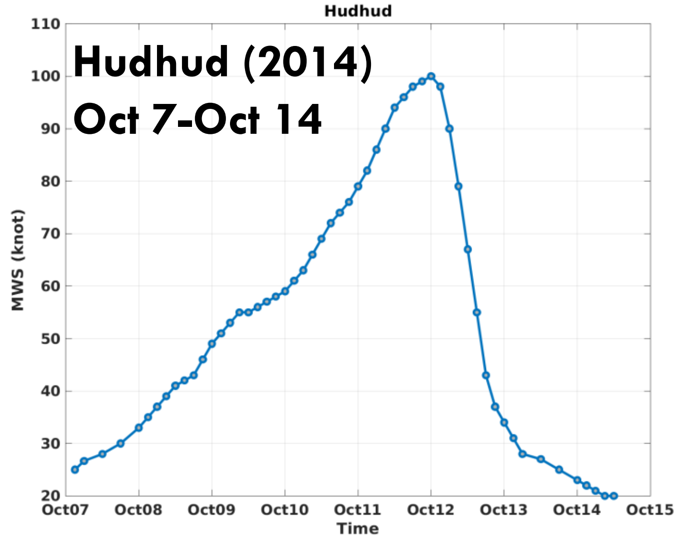
Hypothesis: The fresher surface salinity before TC Hudhud results from river runoff.

Tropical Rainfall Measuring Mission (TRMM) TMI SST

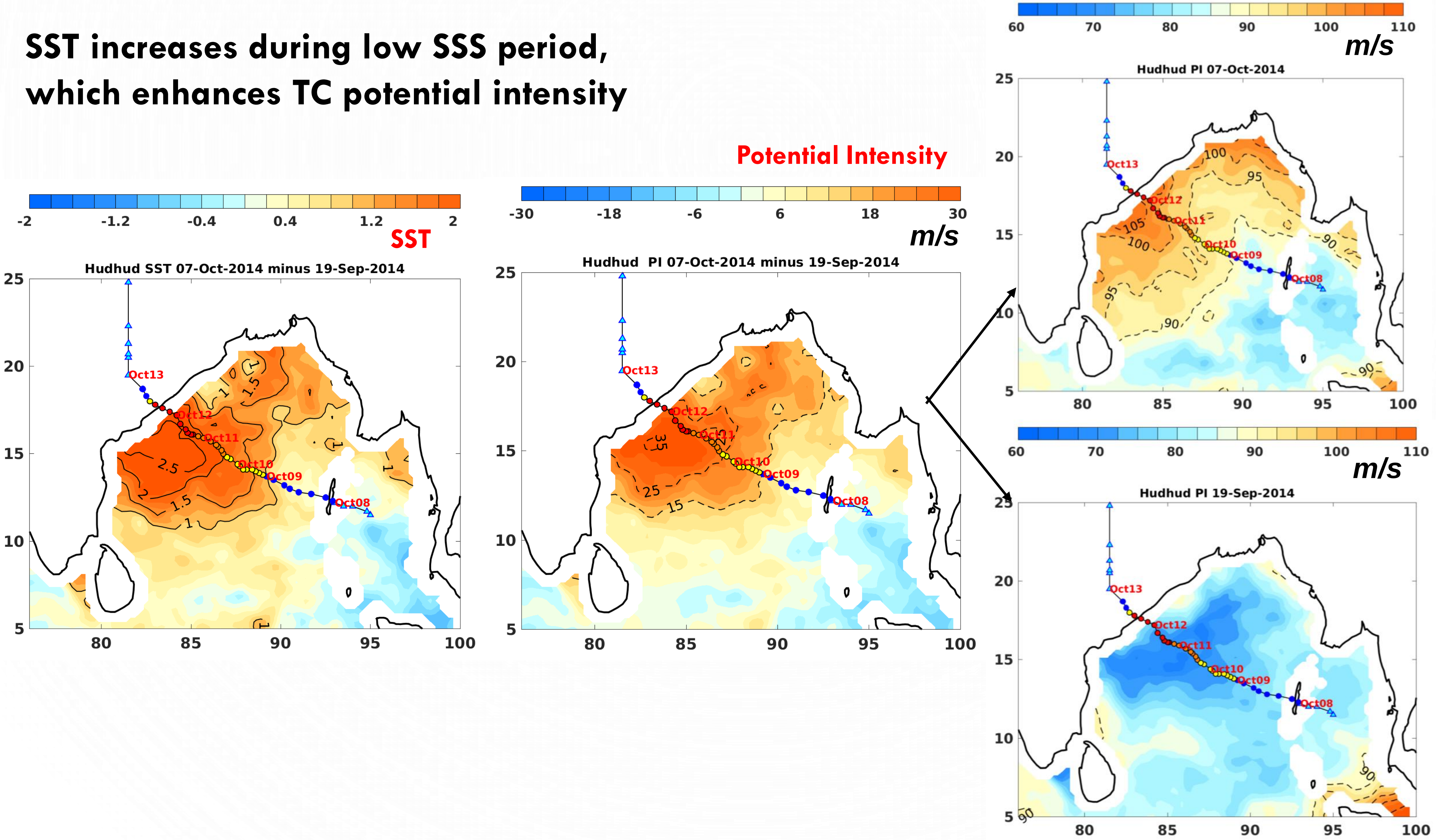


SSS and SST evolution before & after Hudhud pass over (84.4°E 16.7°N).

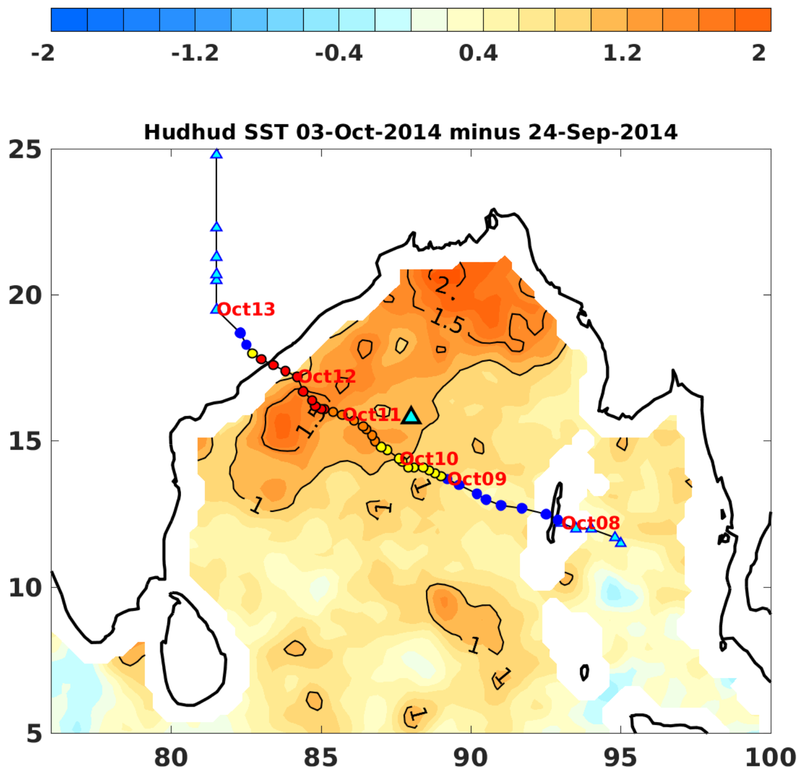
SSS drops while SST increases from 28 to 30 °C

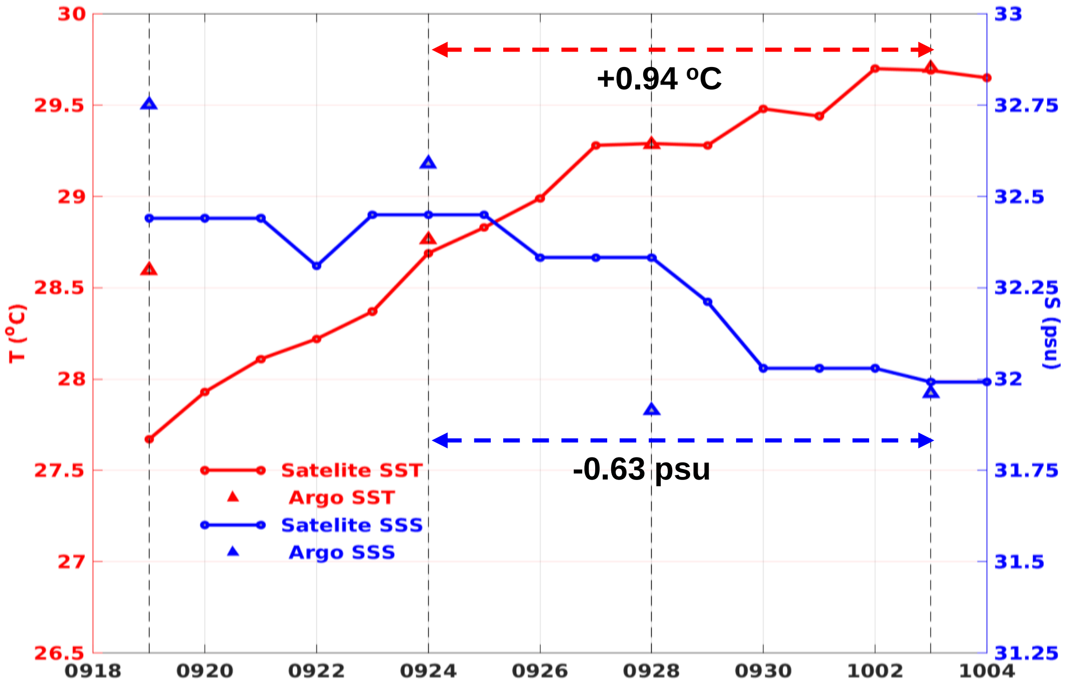


SST increases during low SSS period, which enhances TC potential intensity

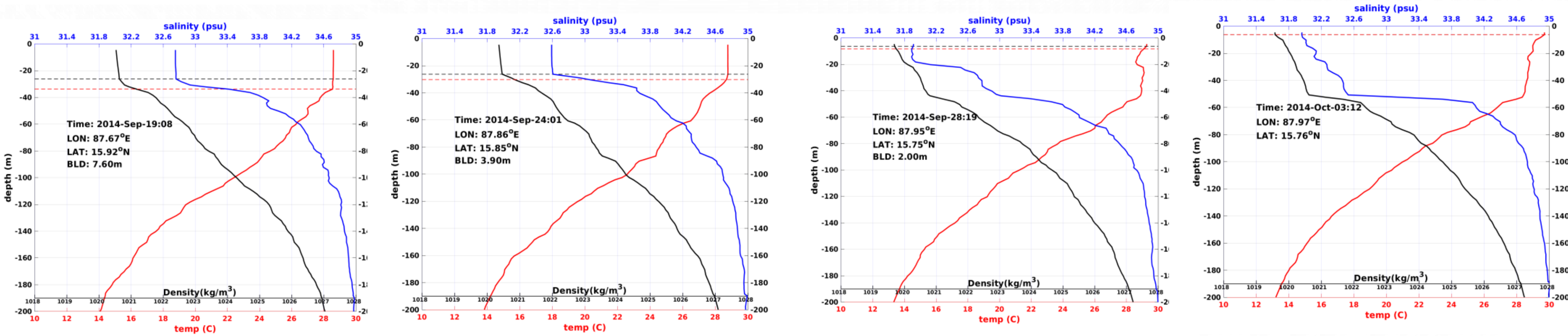


Satellite SSS&SST agree well with the Argo data.





MLD: 26.23 26.29 6.3 6.19m



The influence of MLD on SST change:

Shoaling MLD : 1) makes the heat flux more effective in increasing the SST. (Rao et al 2011)

2) increases penetrative radiation beneath Mixed layer, which decreases SST (Thangaprakash et al 2019)

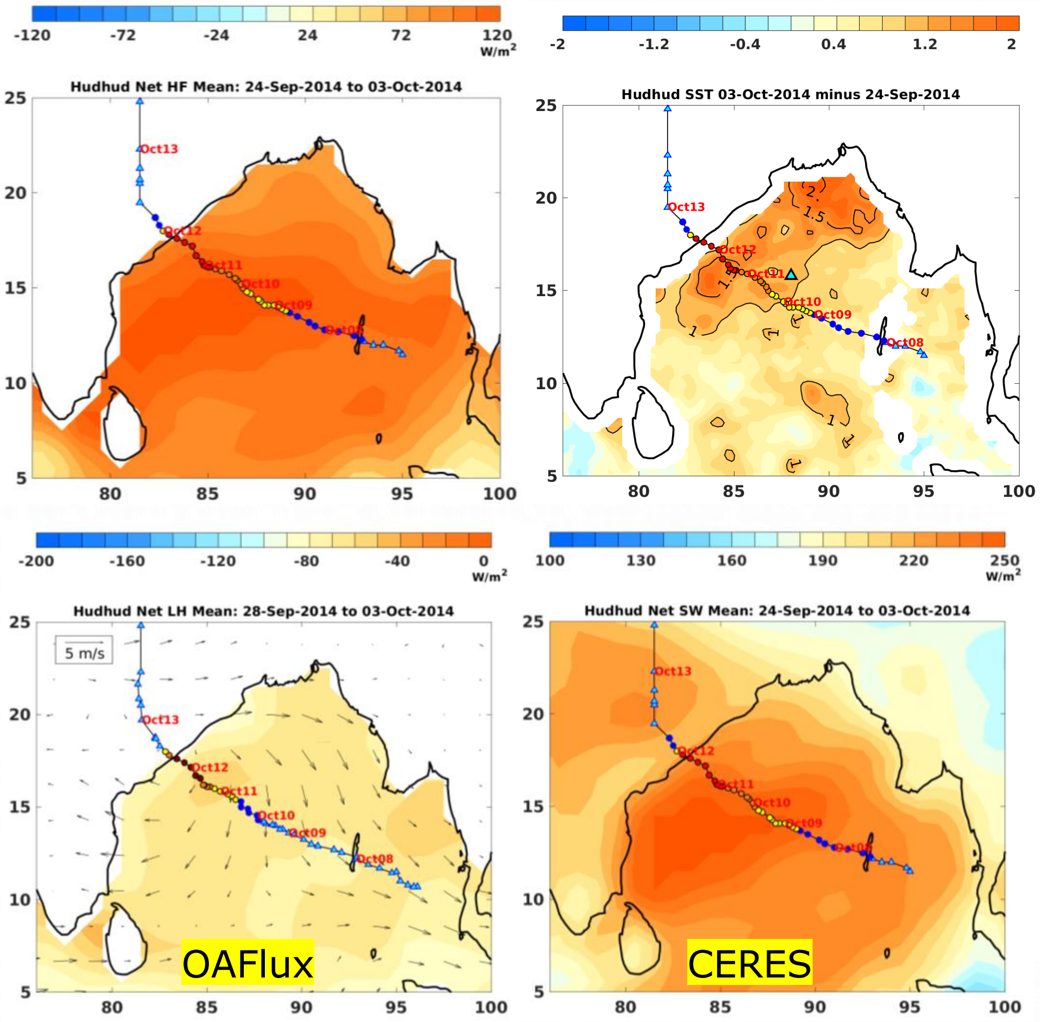
$$\rho C_p H_0 \frac{\partial SST}{\partial t} = Q_{eff} + \text{Advection} + \text{Mixing}$$

$$Q_{eff} = Q_{net} - Q_{pen}$$

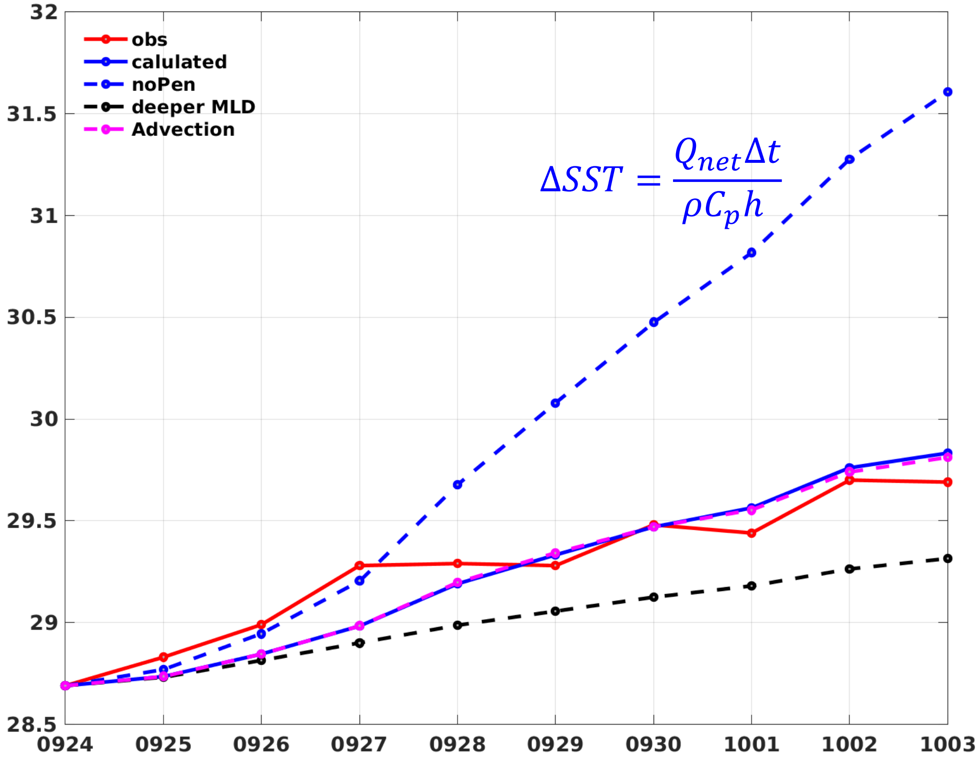
$$Q_{pen} = Q_{sw} e^{-\frac{H_0}{\zeta}}$$ (Paulson and Simpson, 1977)

ζ is the attenuation depth

The Shallowing of MLD explained half of the SST increase from Sep24 to Oct03.



$$\text{Mixing} + \text{Advection} + (Q_{net} - Q_{pen}) = \rho C_p H_0 \frac{\partial SST}{\partial t}$$

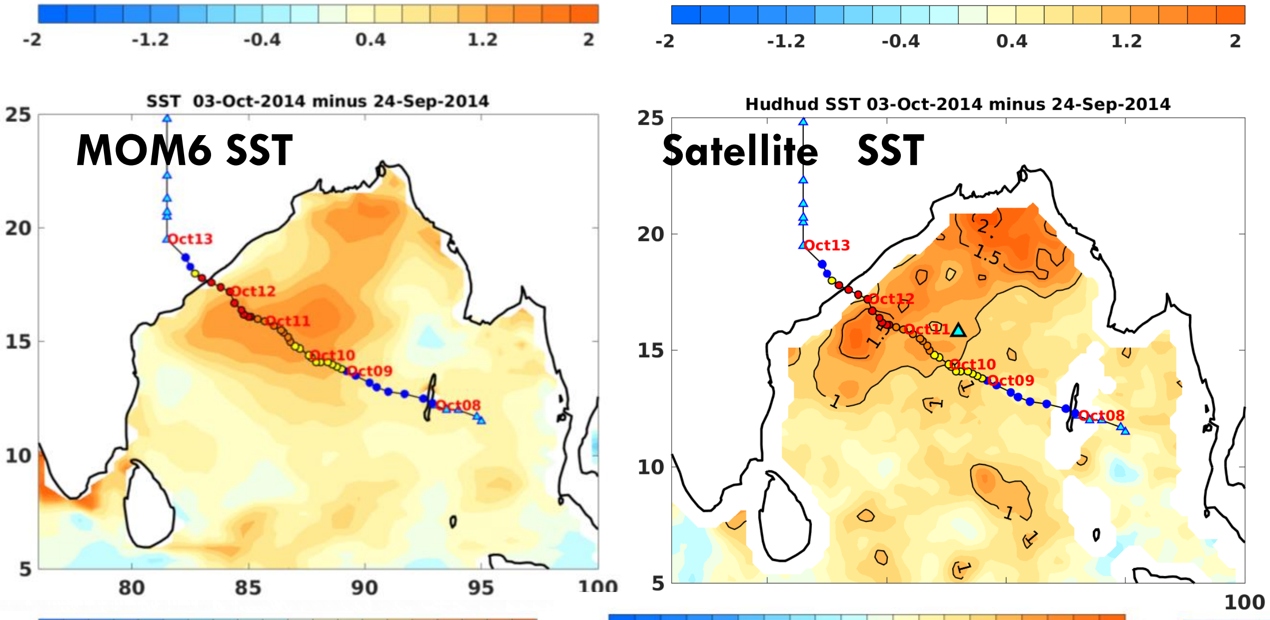


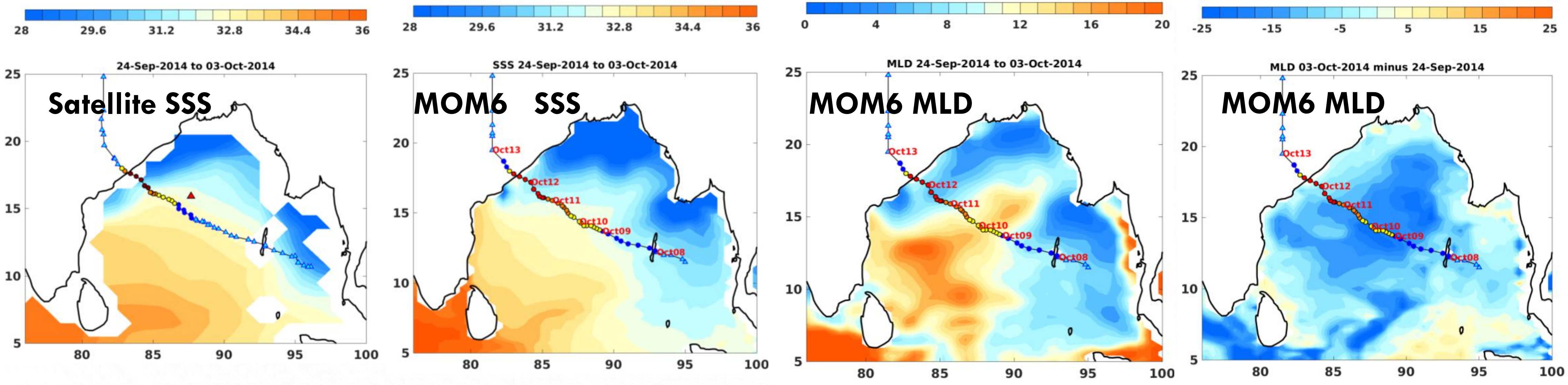
The Mixed Layer depth from Sep24 to Oct03 is linearly interpolated with Argo mixed layer depth on Sep 24,28 and Oct03, which are 26.29, 6.3, 6.19m, respectively.

GODAS *u v* currents in mixed layer is used.

MLD is assumed to be 26.29m constantly.

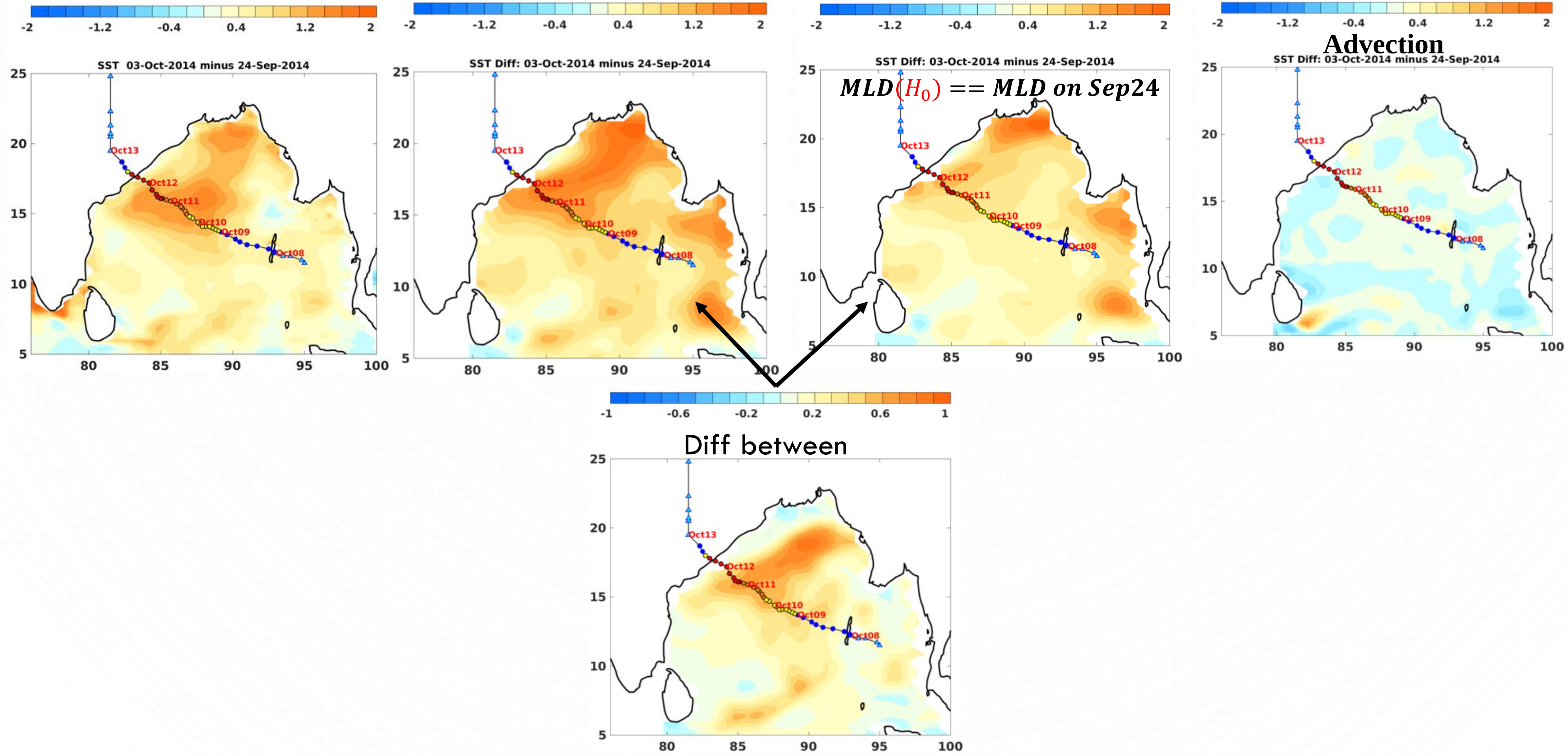
MOM6
Resolution: 0.5°x0.5°
Forcing: JRA-55
1958-2017





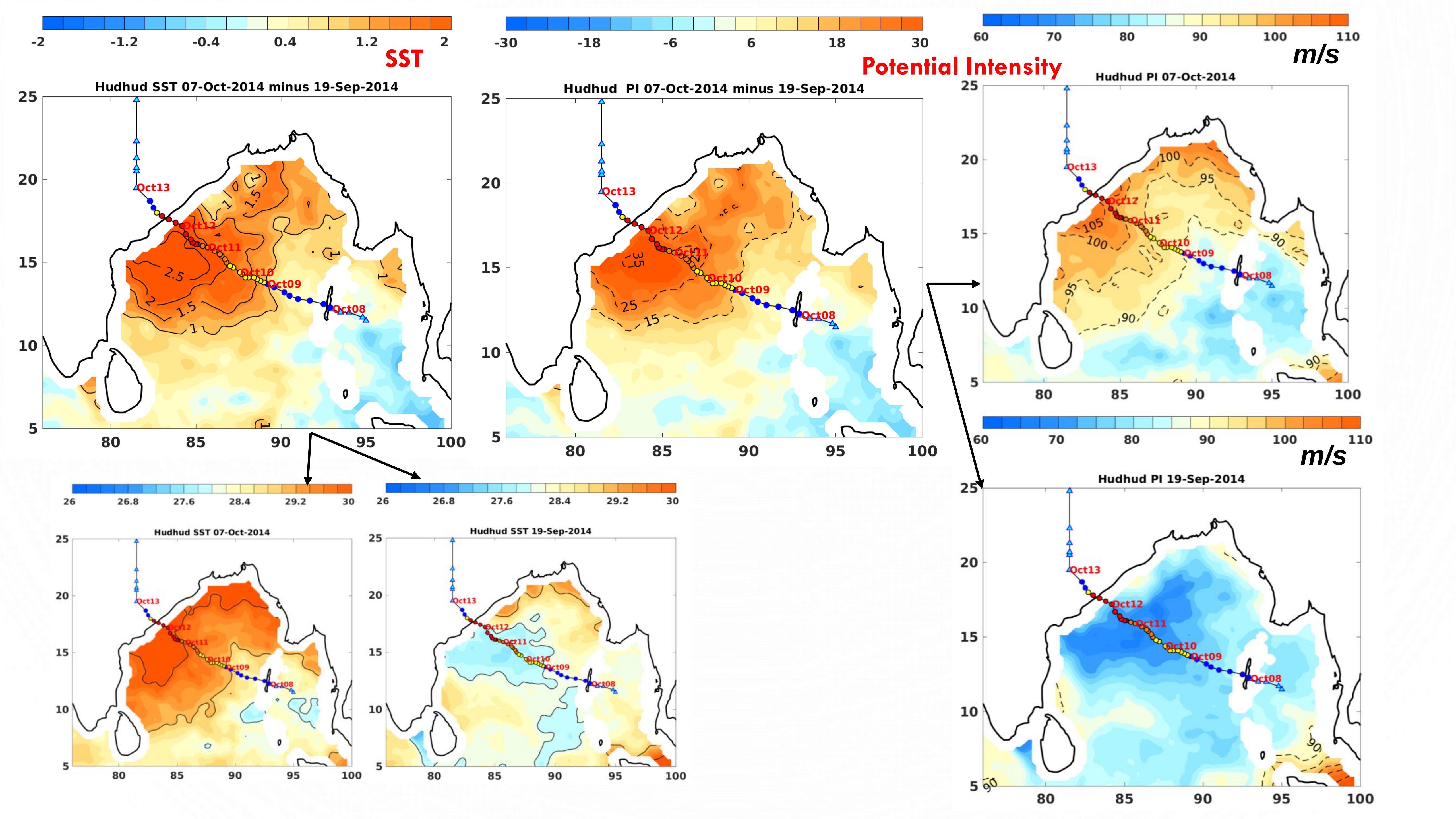
The shallowing of MLD explained half of the SST increase in the northwest of the BoB.

$$\boxed{\rho C_p H_0 \frac{\partial SST}{\partial t} = Q_{eff}} + \text{Advection} + \text{Mixing}$$



CONCLUSIONS

- SST in the BoB increased 2°C during low SSS period before TC hudhud, which enhanced the potential intensity and provided a favorable ocean condition for TC intensification.
- The salinity induced shallowing of MLD explained half of the SST increase before TC Hudhud was generated.


SST
Potential Intensity
m/s
Hudhud SST 07-Oct-2014 minus 19-Sep-2014
Hudhud PI 07-Oct-2014 minus 19-Sep-2014
Hudhud PI 07-Oct-2014
Hudhud PI 19-Sep-2014
Hudhud SST 07-Oct-2014
Hudhud SST 19-Sep-2014
Oct08
Oct09
Oct10
Oct11
Oct12
Oct13

$$\rho C_p H_0 \frac{\partial SST}{\partial t} = Q_{eff} + \text{Advection} + \text{Mixing}$$

$$Q_{eff} = Q_{net} - Q_{pen}$$

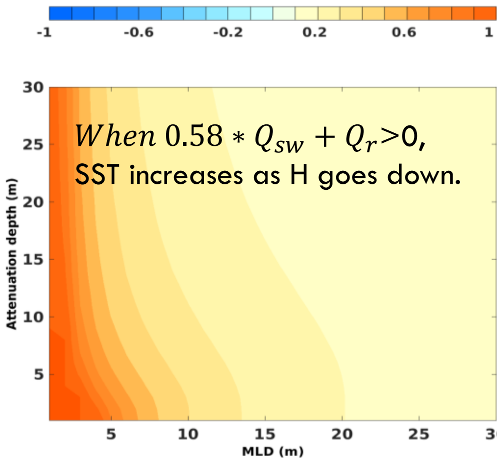
$$Q_{pen} = Q_{sw}(1-\alpha)e^{-\frac{H_0}{\zeta}}$$

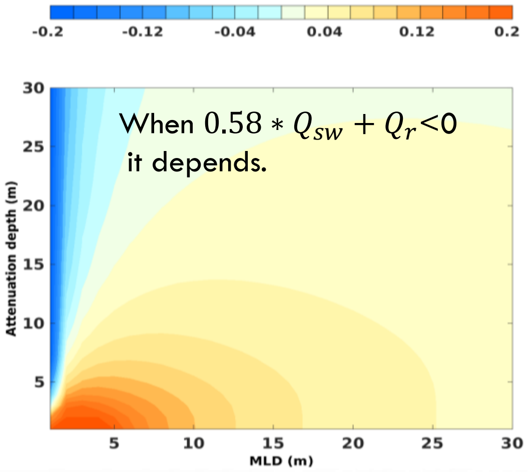
(Paulson and Simpson, 1977)

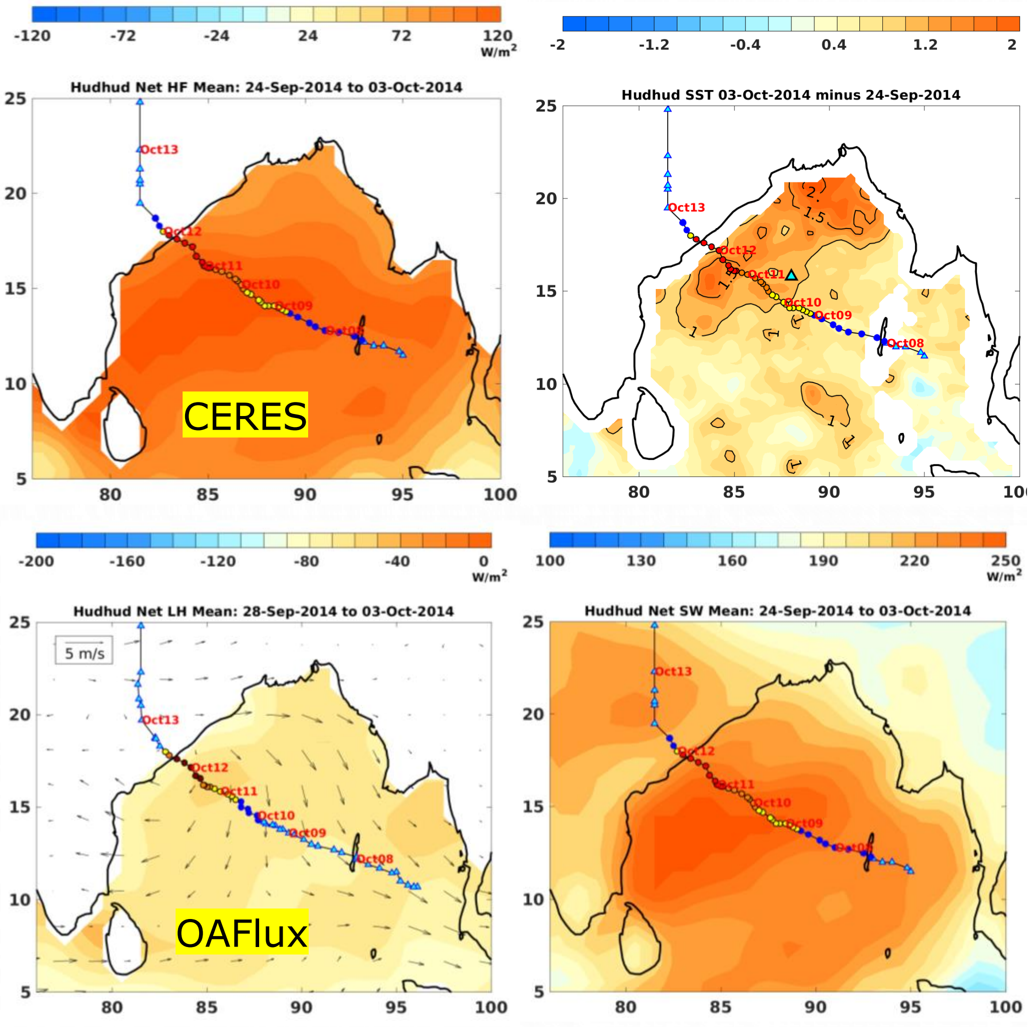
$$Q_{sw}\left(1 - 0.42e^{-\frac{H_0}{\zeta}}\right) + Q_r = \rho C_p H_0 \frac{\partial SST}{\partial t}$$

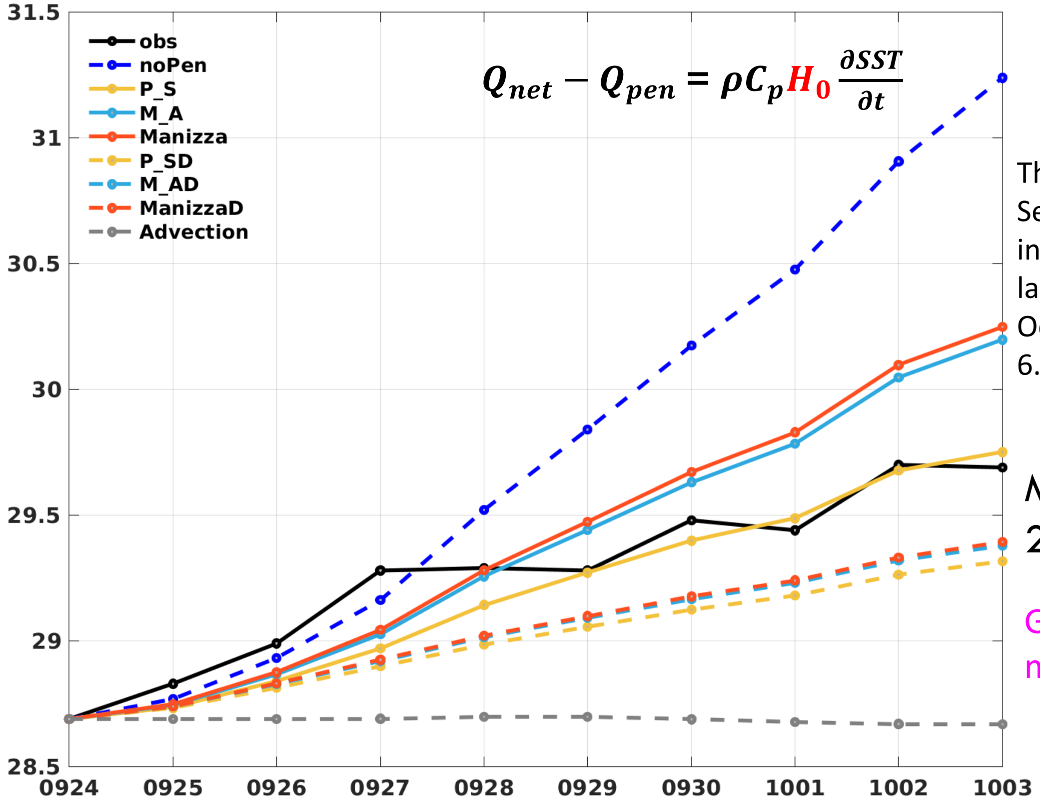
$$Q_r = Q_{lw} + Q_{lh} + Q_{sh}$$

α =0.58 is the fraction of incident sunlight (mainly red and infrared) absorbed in the upper ~2 m; ζ is the attenuation depth of visible wavelength bands , i.e., the 1/e-folding depth for subsurface radiation.









The Mixed Layer depth from Sep24 to Oct03 is linearly interpolated with Argo mixed layer depth on Sep 24,28 and Oct03, which are 26.29, 6.3, 6.19m, respectively.

MLD is assumed to be 26.29m constantly.

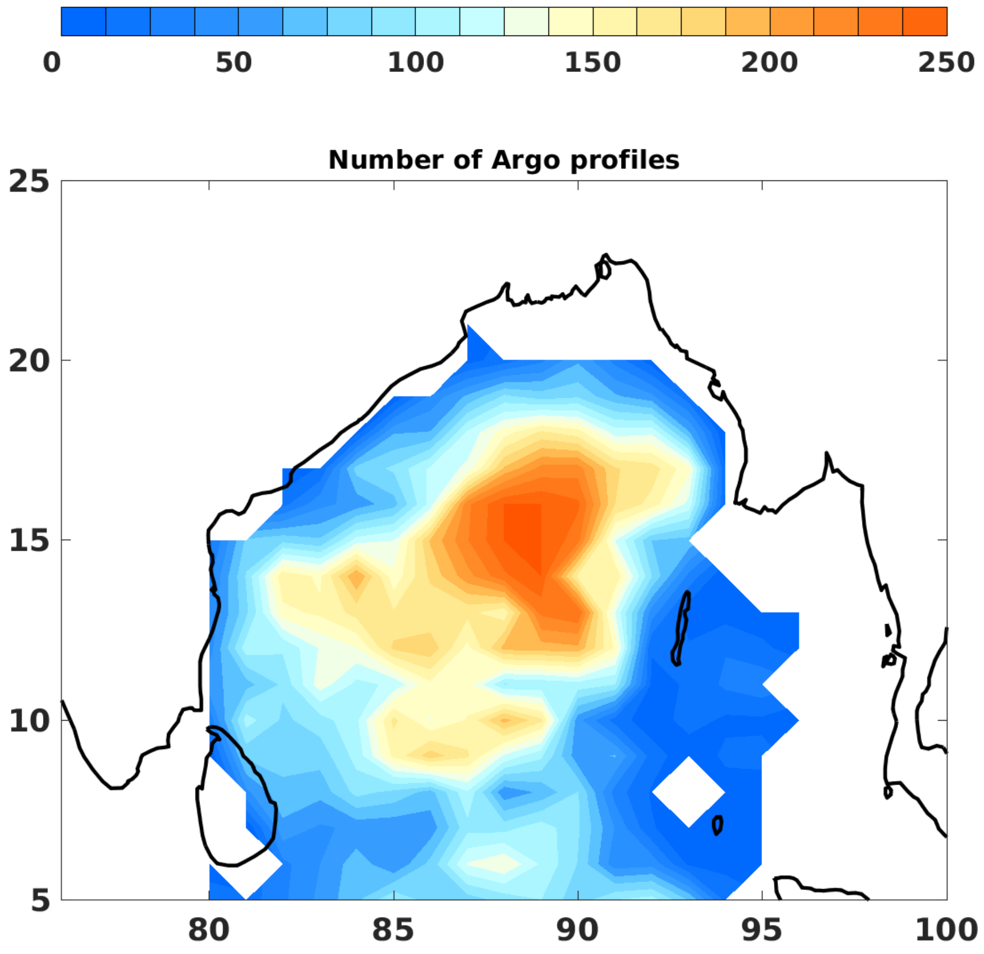
GODAS *u v* currents in mixed layer is used.

Penetrative radiation below the mixed layer is estimated by
P_S (Paulson and Simpson 1977)
M_A (Morel and Antoine 1994)
Manizza (Manizza et al. 2005).
Chlorophyll a from Ocean Color CCI data

The Shallowing of MLD explained half of the SST increase from Sep24 to Oct03.

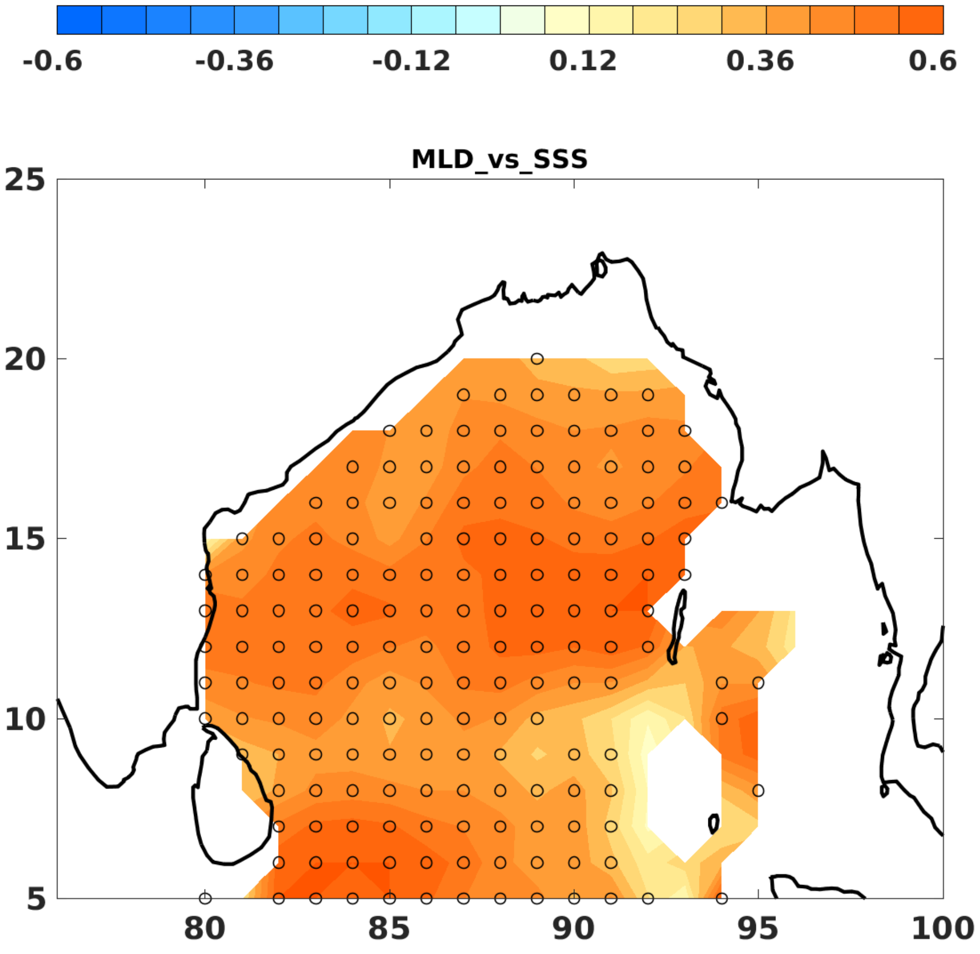
Argo data from 2003 to 2018

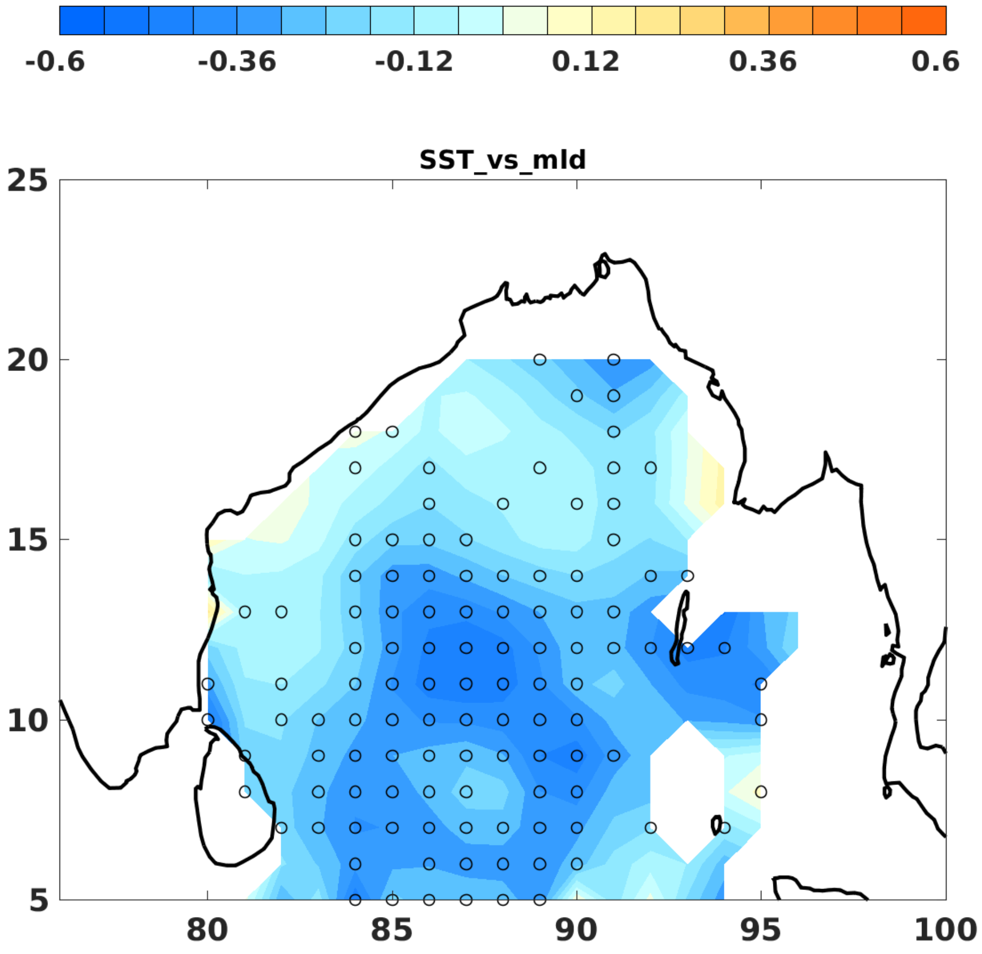
- All Argo profiles from 2003 to 2018 in bob are collected. **Maximum=353.**



Correlation coefficient between SSS and MLD

- MLD is positively correlated with SSS at 95% significance level.

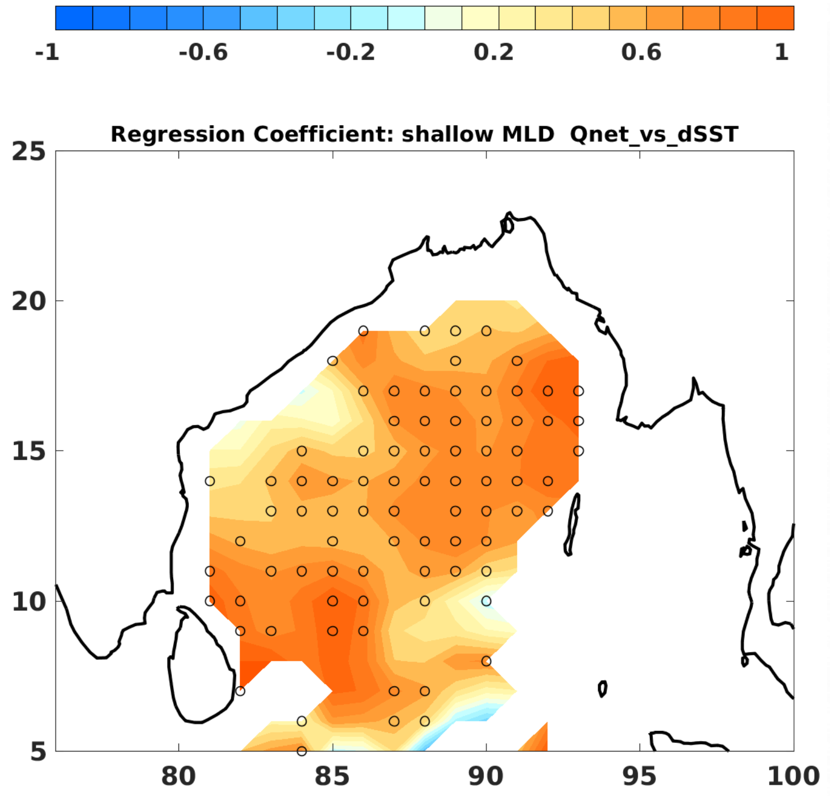


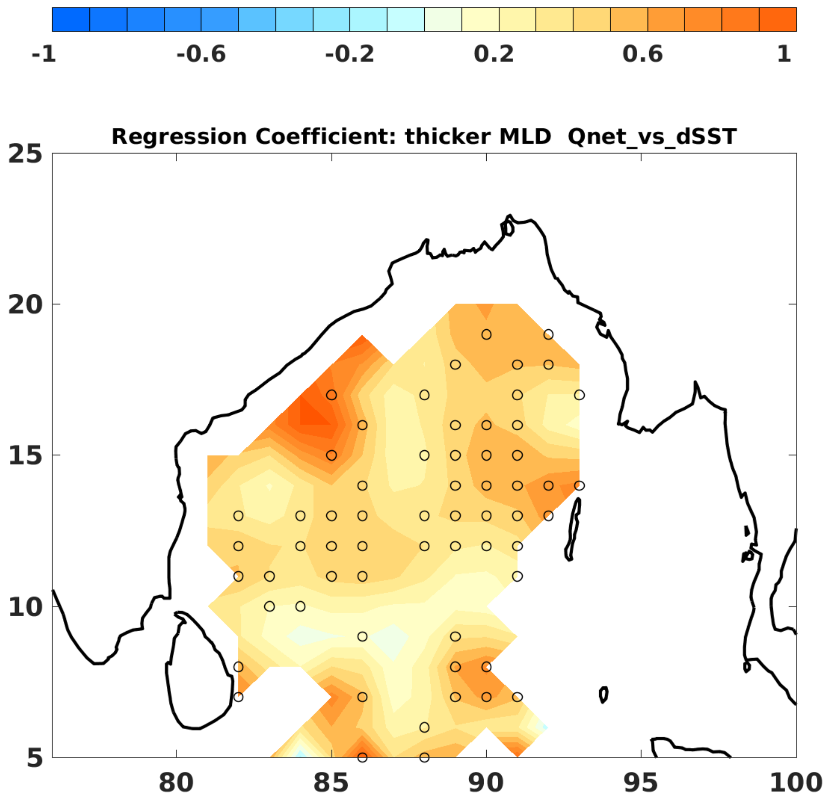


$$\underbrace{Q_{sw}\left(1-0.42e^{-\frac{H_0}{\zeta}}\right)+Q_r}_{X}+Advection+Mixing=\underbrace{\rho C_p H_0\frac{\partial SST}{\partial t}}_{Y}$$

Wind speed <10m/s;

Two groups: 1. MLD < mean(MLD) –2/3*std(MLD)   Shallower MLD
2. MLD > mean(MLD)+2/3*std(MLD) Deeper MLD





For shallower MLD, the heating of SST is more effective.

CONCLUSIONS

- SST in the BoB increased 2°C before TC hudhud, which provided a favorable ocean condition for TC intensification.
- The salinity induced shallowing of MLD explained half of the SST increase before Tropical cyclone Hudhud was generated.
- The MLD in BoB is dominated by Salinity. For shallower MLD, the heating of SST is more effective.

Background

- The Bay of Bengal (BoB) is the freshest region in the Indian Ocean. The fresher surface salinity largely results from oceanic rainfall and from the huge river discharges. (Sengupa et al. 2006, Varkey et al. 1996; Howden and Murtugudde 2001) .

- Recent studies suggest that the freshening of the ocean surface induces upper ocean stratification and salinity barriers, which inhibits the tropical cyclone (TC) induced cooling and favors TC intensification (Neetu et al. 2012; Balaguru 2012; Androulidkis et al. 2016).

- On the other hand, the upper ocean stratification induced by freshwater would decrease the mixed layer depth and the nutrient input from adjoining rivers may enhance the surface chlorophyll (Narvekar & Kumar 2014).

- In this study, we will investigate the impact of sea surface salinity on SST change and TC intensification in the Bay of Bengal.