Modulation of wind work by surface current: eddy energetics and mixed layer stratification in the Bay of Bengal

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MISO-BoB Meeting
APL/Univ. Washington, Nov 8-9, 2018

Motivation

- Among the factors affecting the BoB SST and air-sea flux are the mesoscale circulation and ML stratification.
- Models often show too strong (long-live) eddy activity and weak stratification.
- Relative Wind (RW) effect (i.e., surface current-wind interaction) affects the wind work and thus these processes.

$$\frac{d\vec{K}_e}{\partial t} = -\frac{1}{\rho_0}\vec{\nabla}\vec{u}'\cdot p' - \frac{g}{\rho_0}\langle \rho' w' \rangle + (-\vec{u}'\cdot(\vec{u}'\cdot\vec{\nabla}\vec{U})) + \frac{1}{\rho_o}\langle \vec{u}'_{sfc}\cdot\vec{\tau}' \rangle$$

EPE→EKE (BC)

MKE→EKE (BT): influenced by $\frac{1}{\rho_o}\langle \vec{u}_{sfc}\rangle\cdot\langle\vec{\tau}\rangle$

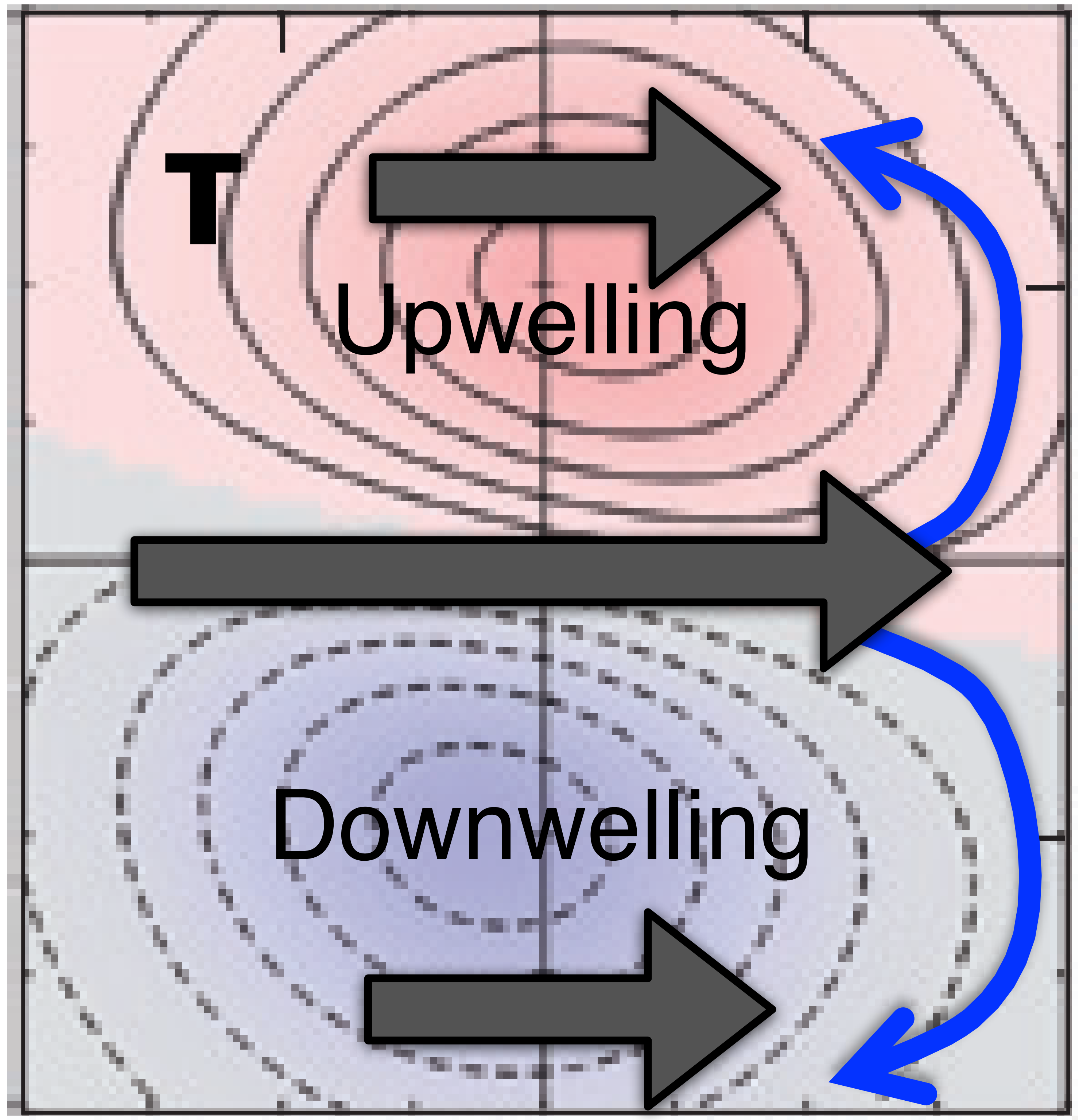
eddy wind work

where $\tau = \rho_a C_D(U_a - U_o)^2$

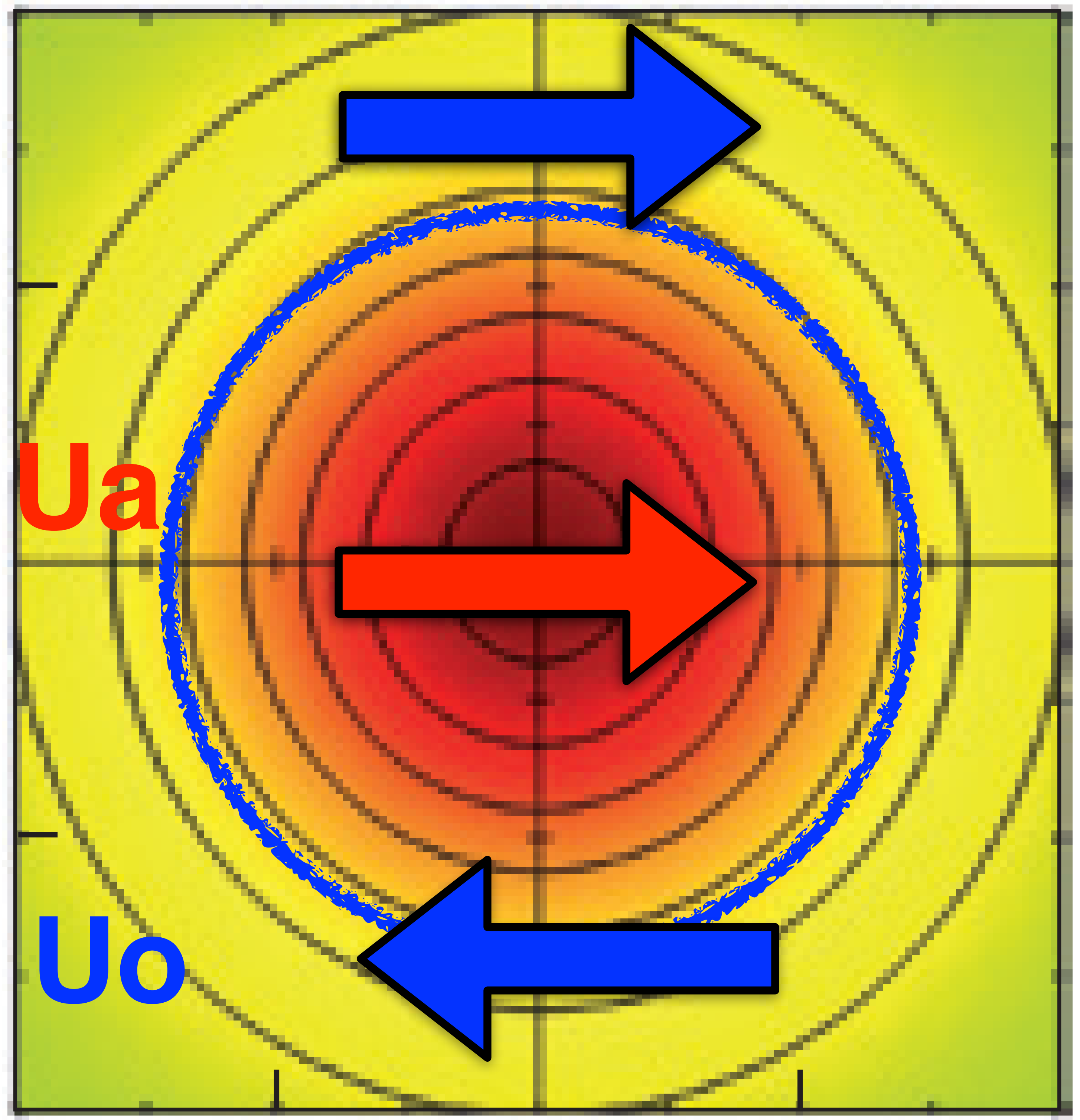
RW effect is an essential part of eddy-wind interaction

Bulk formula for wind stress $\tau = \rho_a C_D(Ua - Uo)^2$

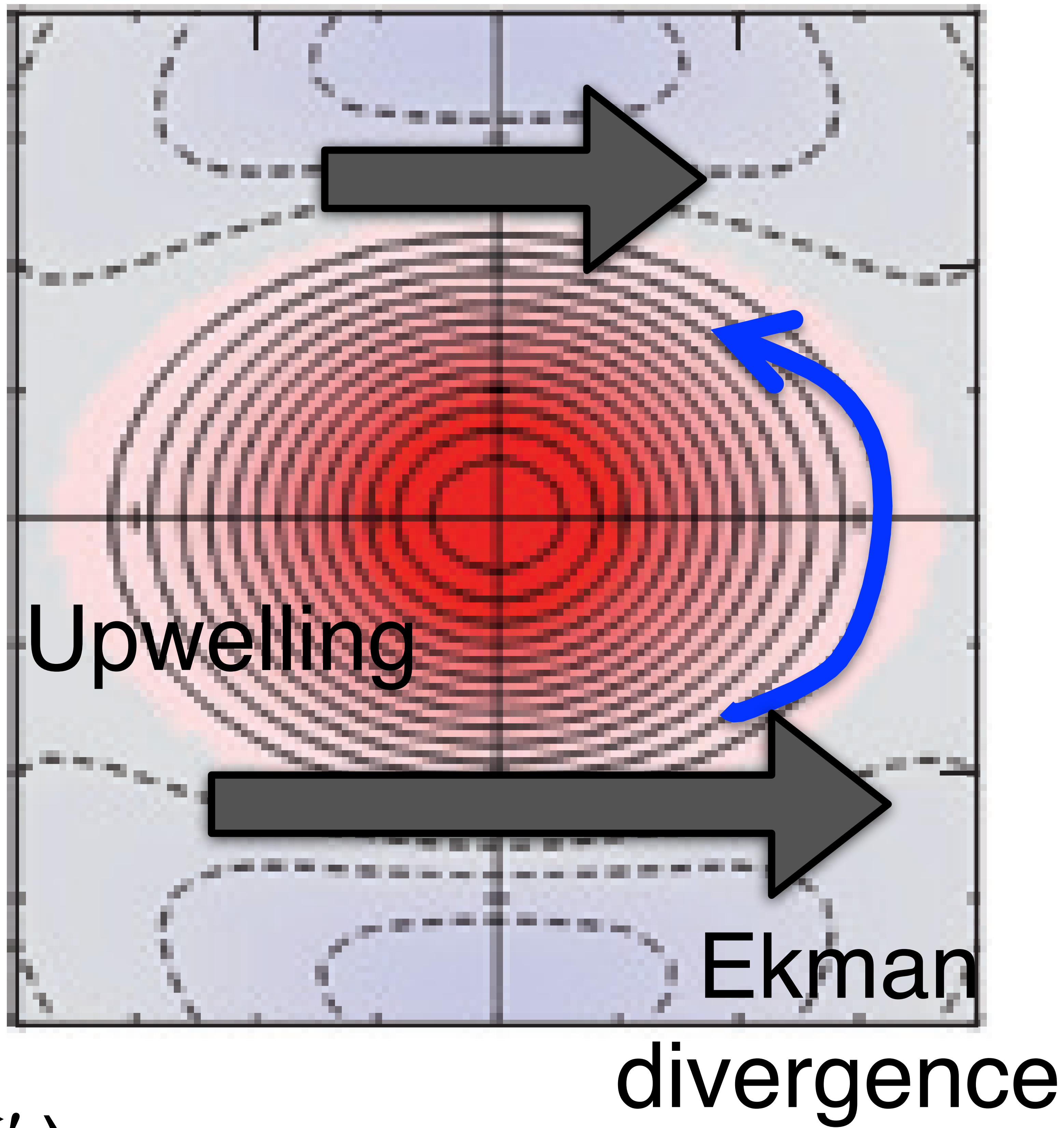
SST-wind coupling



Anticyclonic eddy



Current wind coupling



Current-wind coupling modifies the wind work ($\vec{u}'_{sfc} \cdot \vec{\tau}'$)
and Ekman velocity ($W_e = \frac{1}{\rho_o} \nabla \times \frac{\tau}{(f+\zeta)}$)

Chelton 2013; Seo 2017

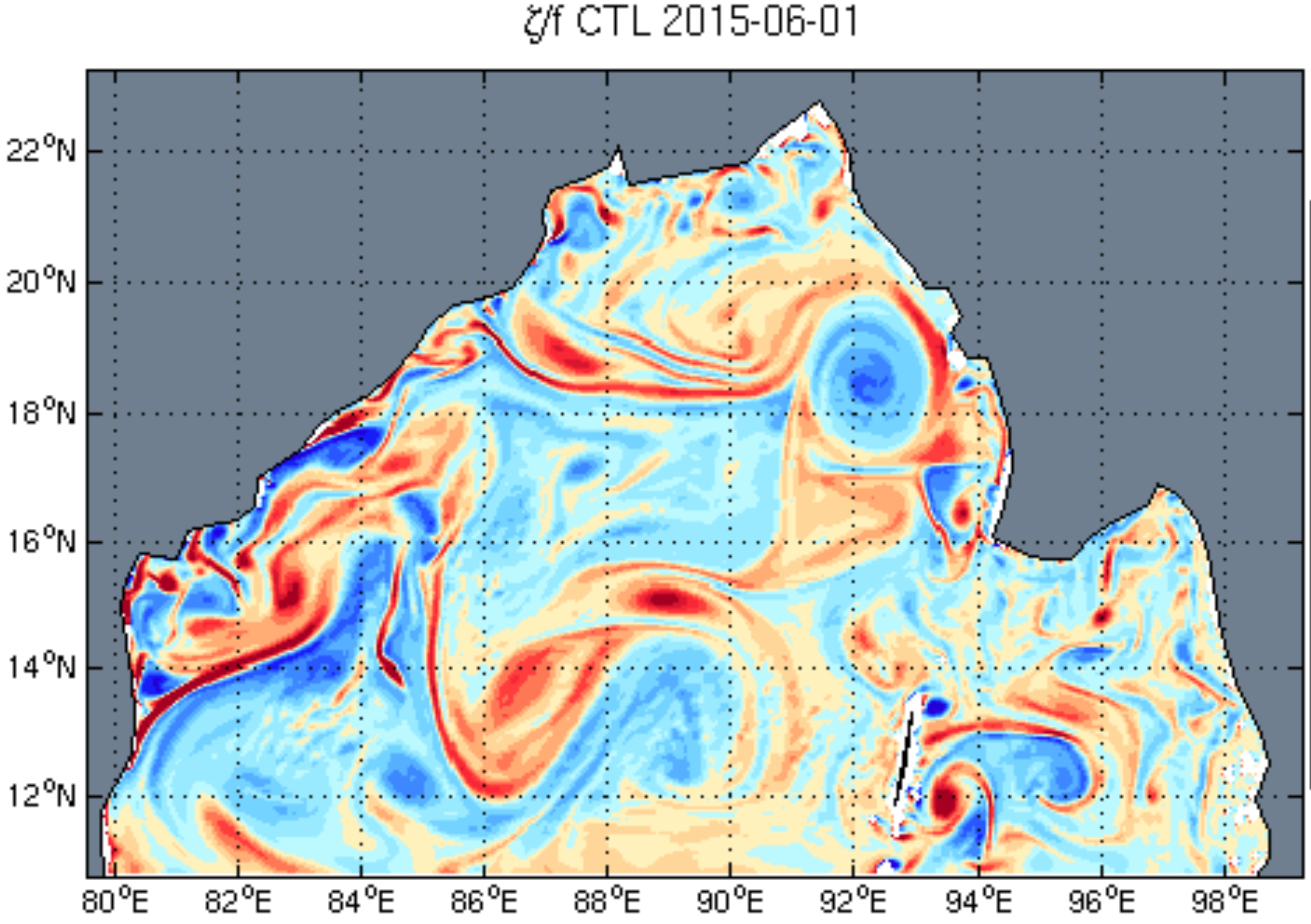
SCOAR Regional coupled model

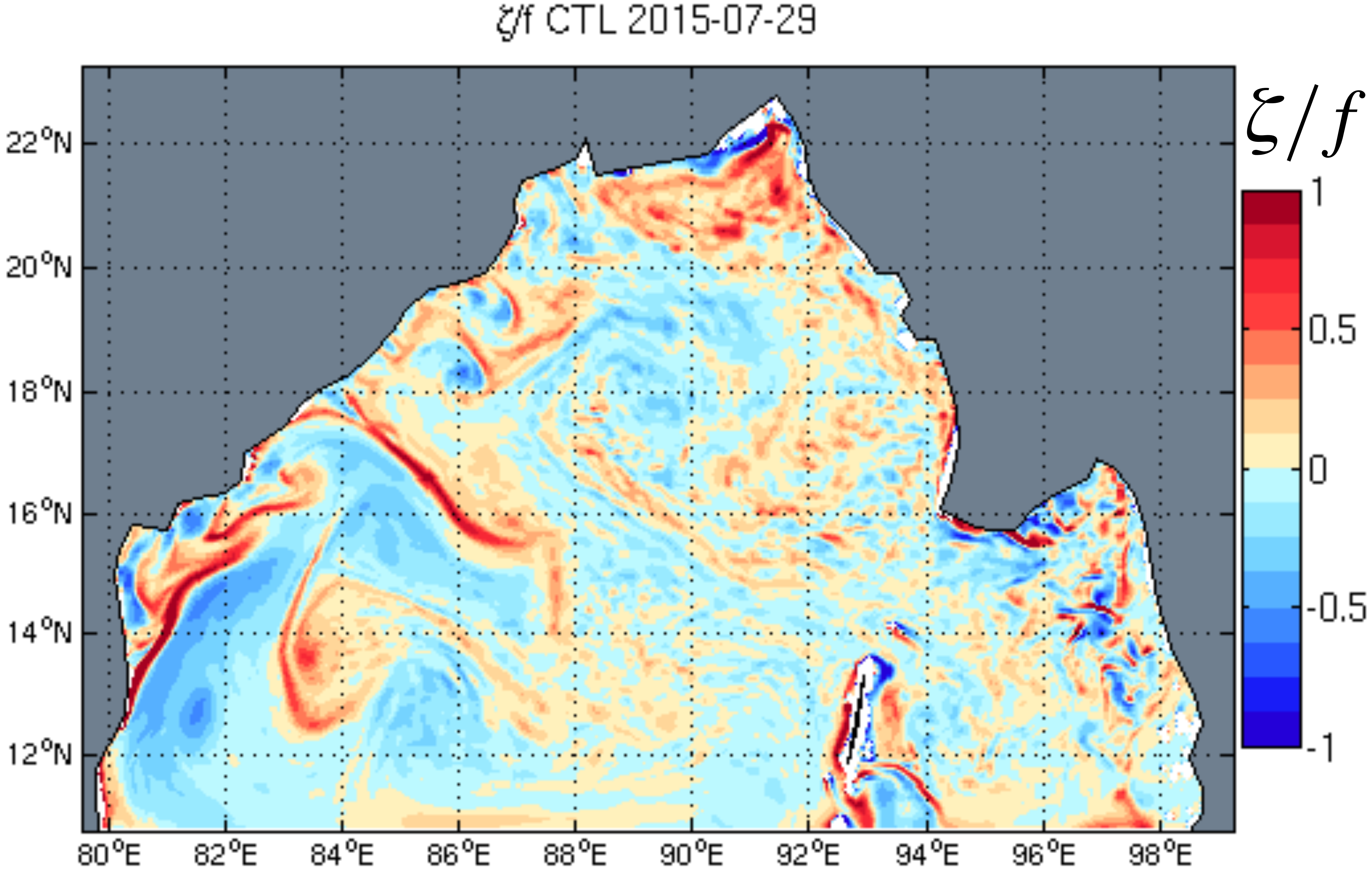
https://hseo.whoi.edu/scoar
Seo et al. 2007, 2014; 2016

- 5-km ocean (ROMS) & atmosphere (WRF)
- 9 summer integrations (2006-2015)
- WRF: ERA-Interim
- ROMS: SODA (forced w/ ERA-I)

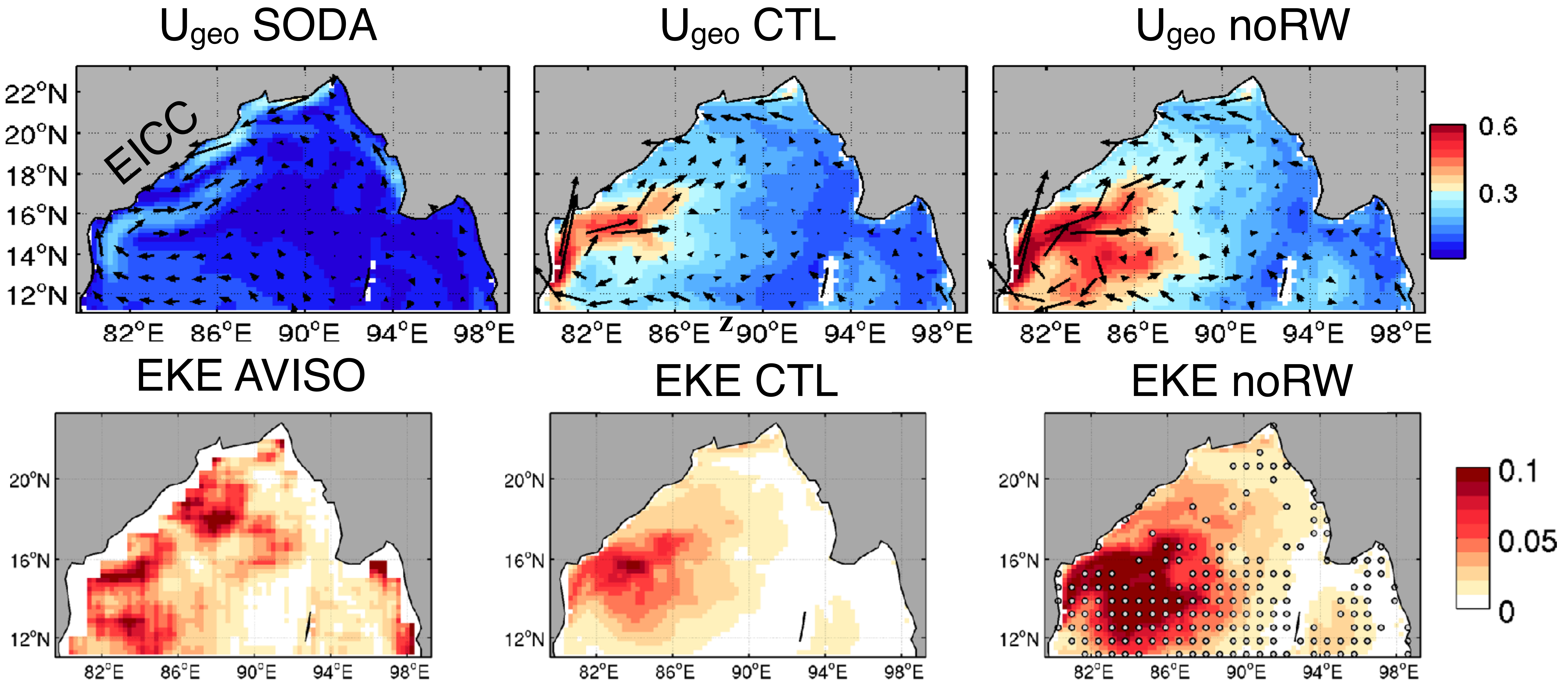
CTL $\boxed{\tau = \rho_a C_D (Ua - Uo)^2}$

noRW $\boxed{\tau = \rho_a C_D Ua^2}$





Simulated geostrophic current and eddy kinetic energy



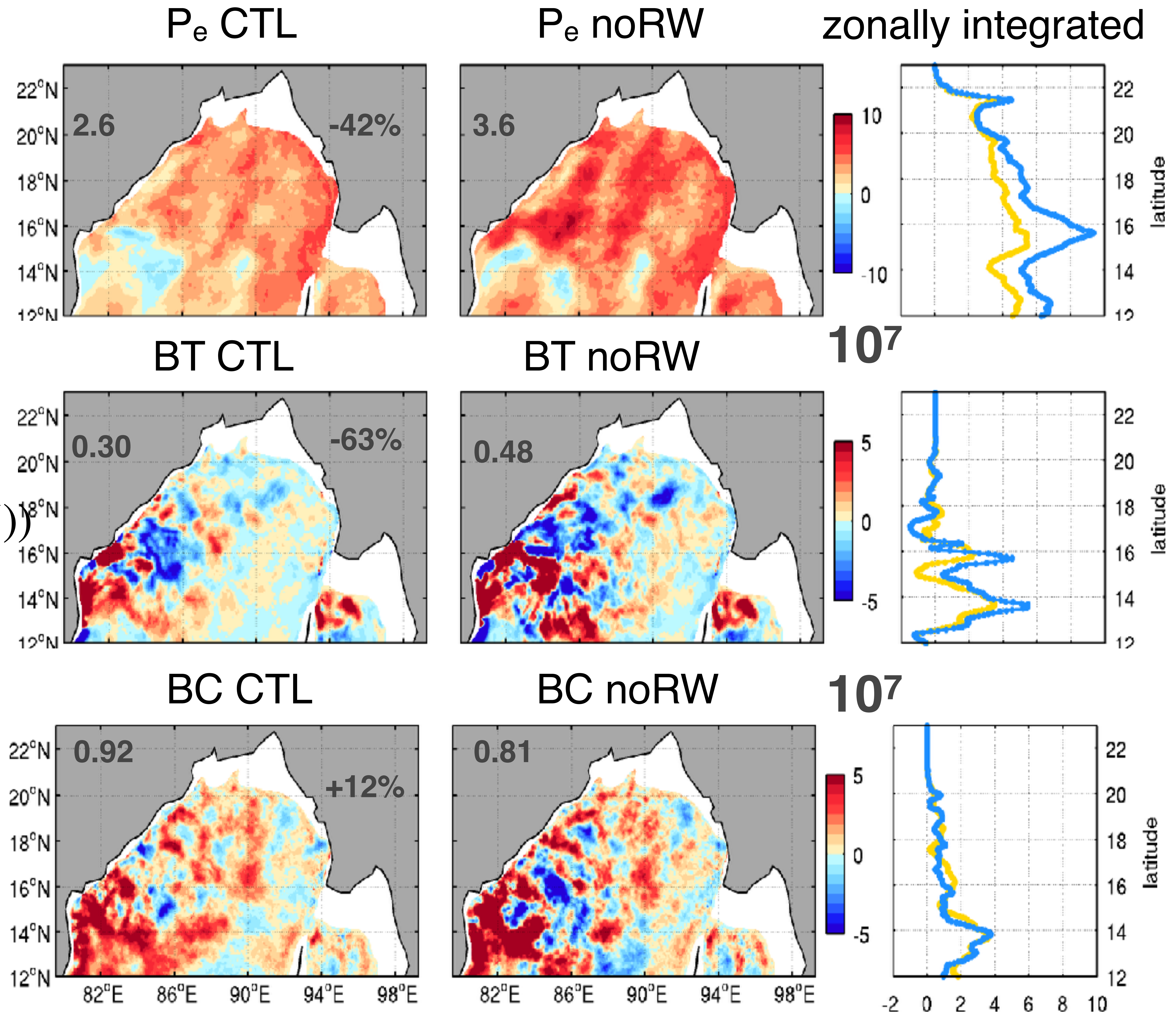
Area-averaged MKE is reduced by >100% & EKE by 94%!

Reduced eddy wind work is the primary factor

$$P_e = +\frac{1}{\rho_o}\langle \vec{u}'_{sfc} \cdot \vec{\tau}' \rangle$$

$$BT = +(-\vec{u}' \cdot (\vec{u}' \cdot \vec{\nabla}\vec{U}))$$

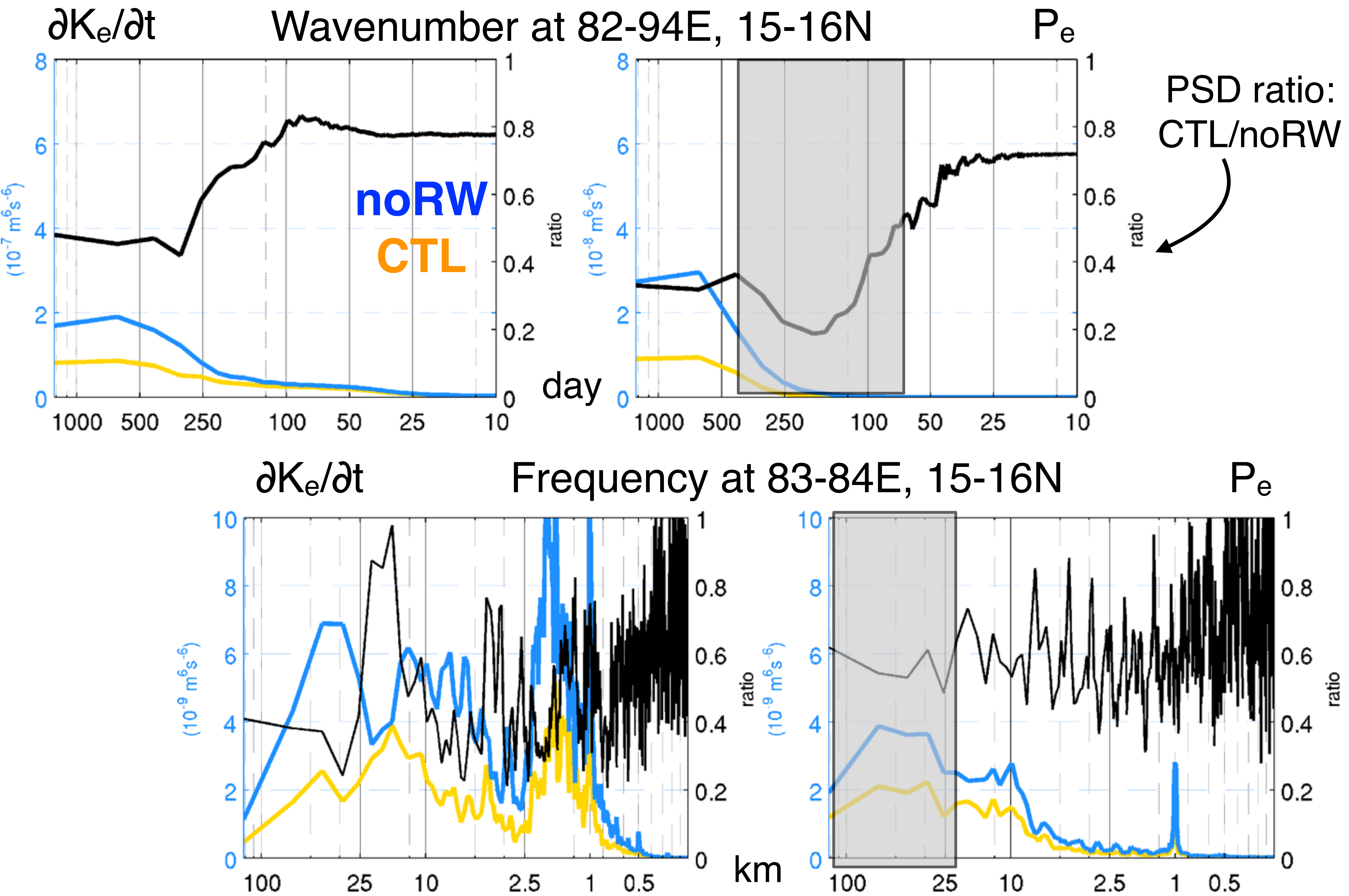
$$BC = -\frac{g}{\rho_0}\langle \rho' w' \rangle$$



Energy source and depth-integrated conversion terms

Integrated for the top 300m

Largest reduction in mesoscale and intraseasonal bands



The largest reduction of P_e and EKE tendency occurs mesoscale (50-300km) and intraseasonal (25-100 days) bands

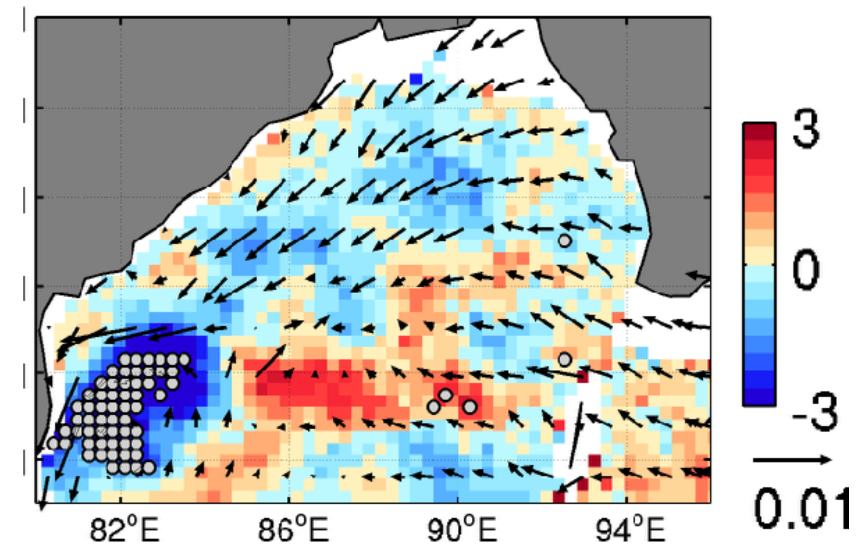
Reduced mixed layer depth

MLD is reduced where wind and current is in the aligned, especially along the EICC path. Two possible reasons:

1) Reduced TKE available for mixing in the Ekman layer → $\frac{1}{\rho_o}\left\langle \vec{u}_{ageo} \cdot \vec{\tau} \right\rangle$

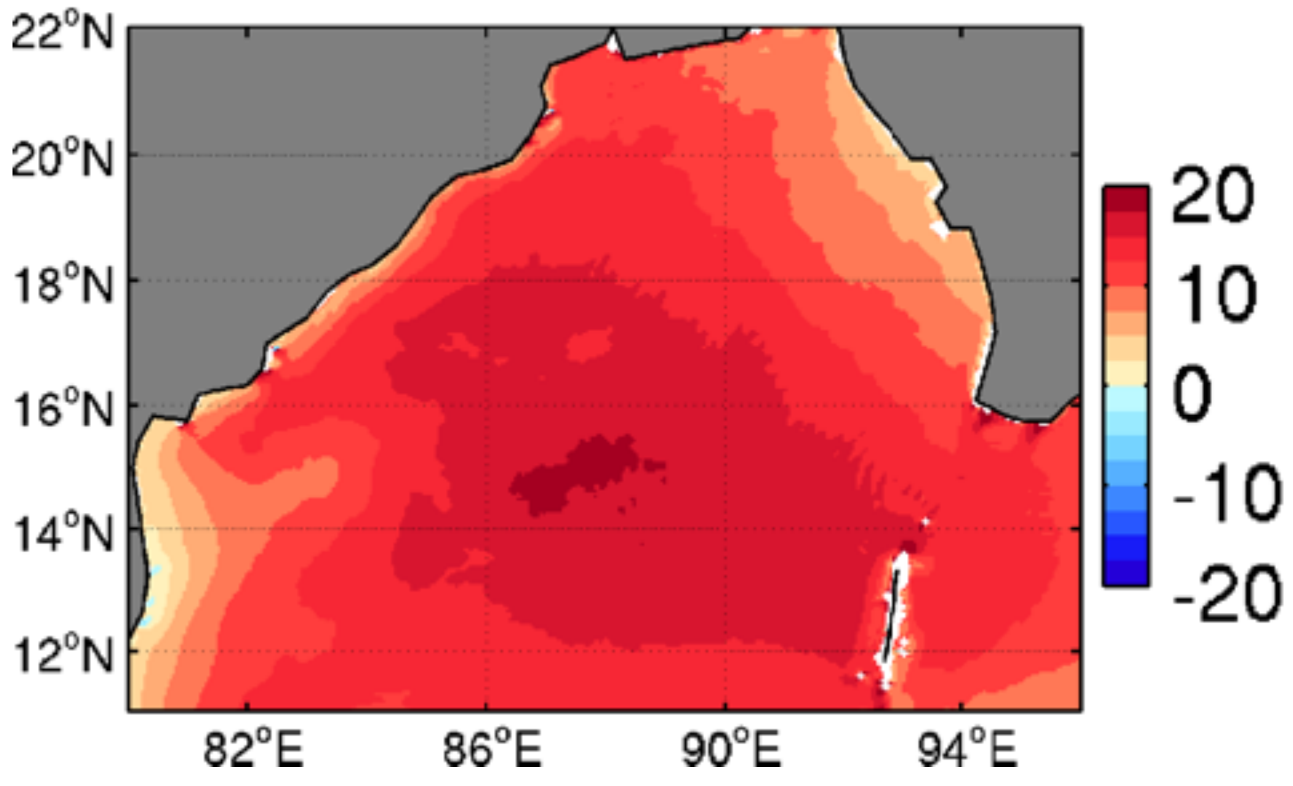
2) Modulation of Ekman pumping velocity by surface vorticity → $W_e = \frac{1}{\rho_o} \nabla \times \frac{\tau}{(f+\zeta)}$

Mixed layer energetics

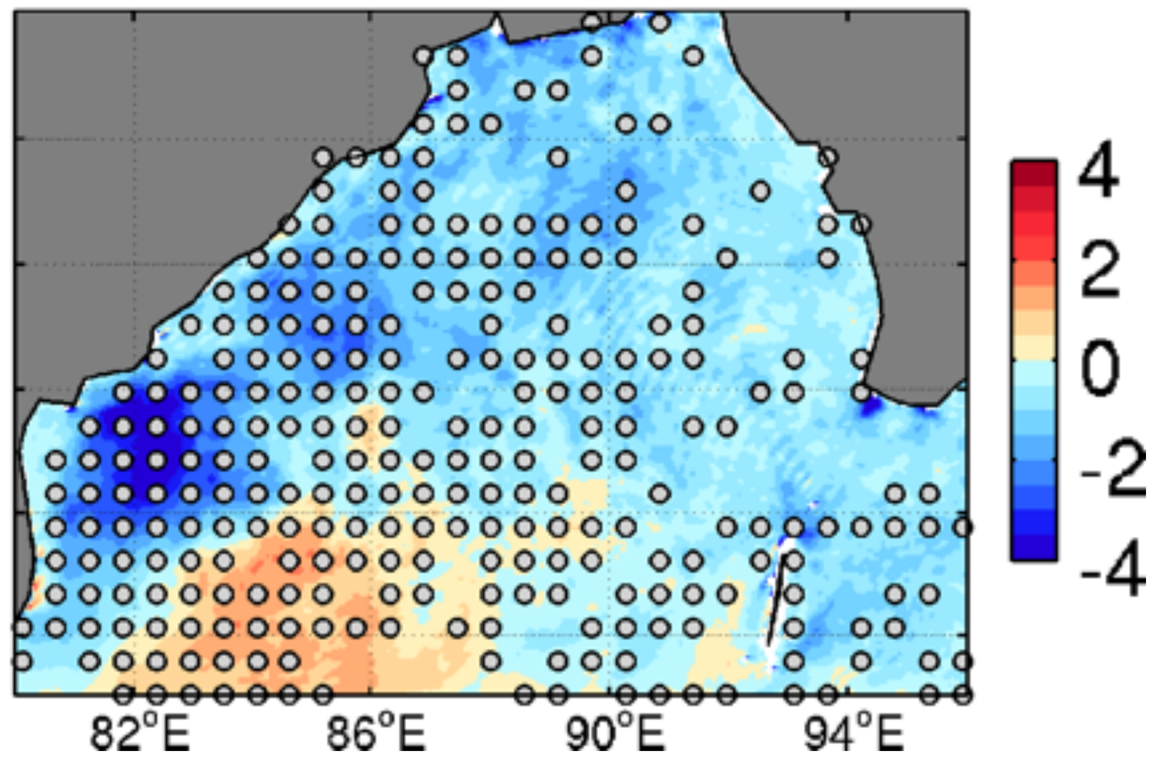


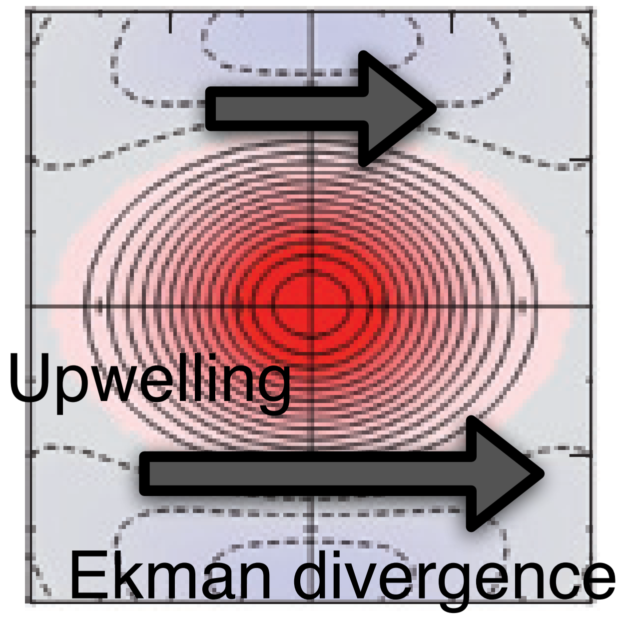
$$P_{ageo} = \frac{1}{\rho_o}\left\langle \vec{u}_{ageo} \cdot \vec{\tau} \right\rangle$$

CTL



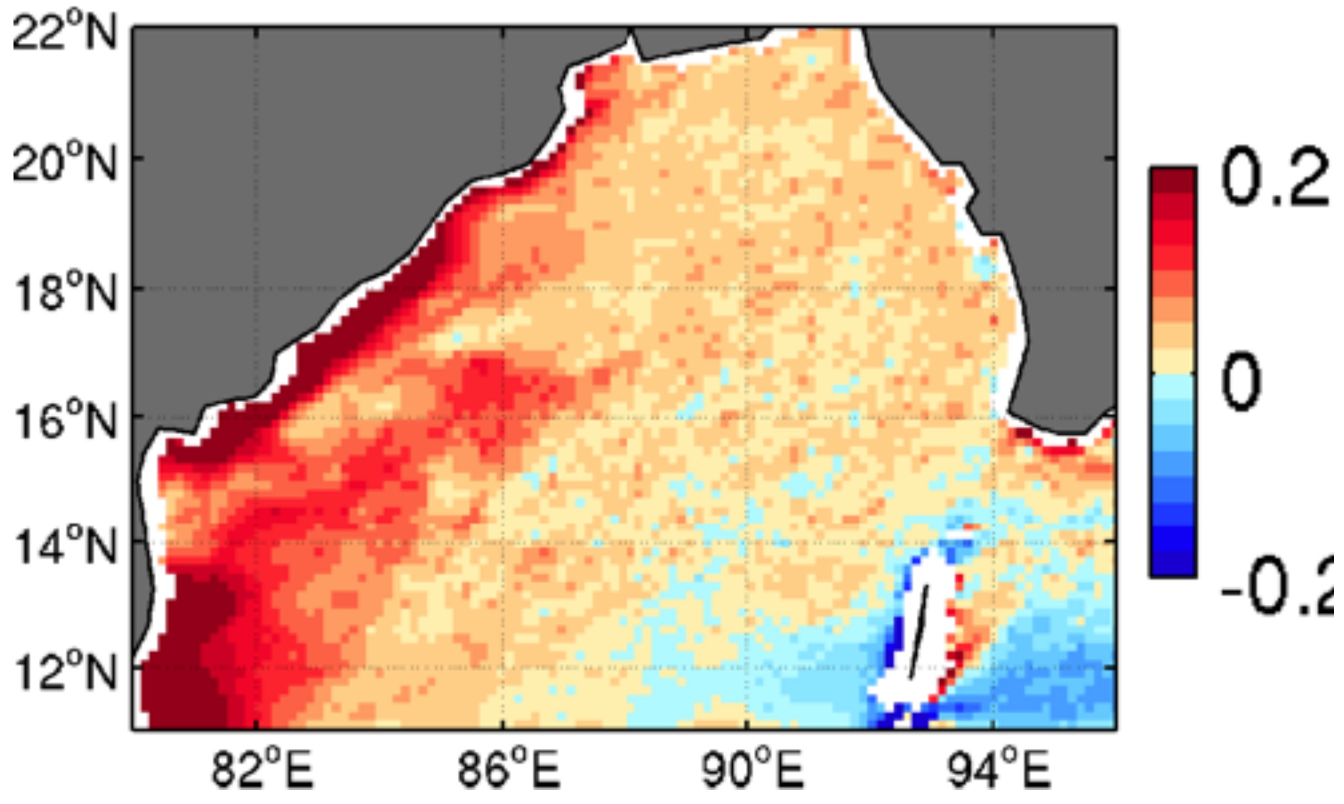
CTL-noRW





$$W_e = \frac{1}{\rho_o} \nabla \times \frac{\tau}{(f + \zeta)}$$

CTL



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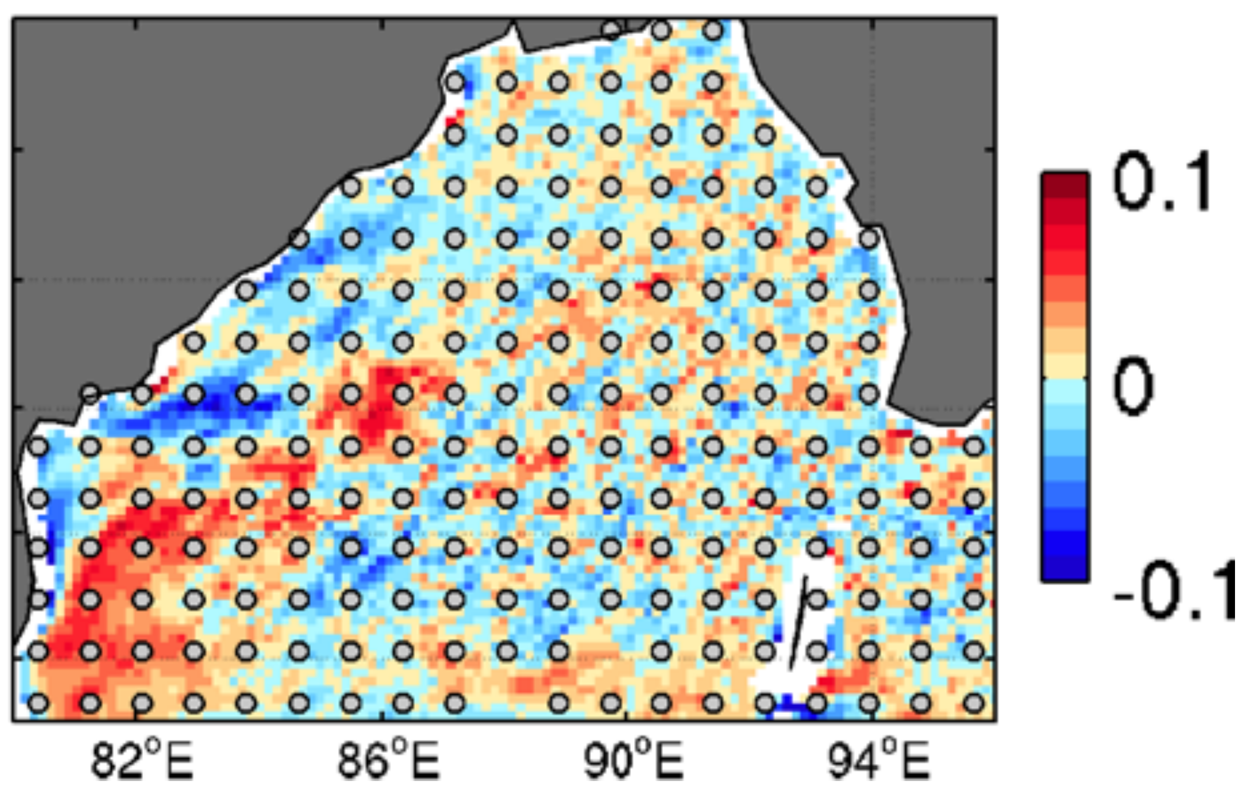
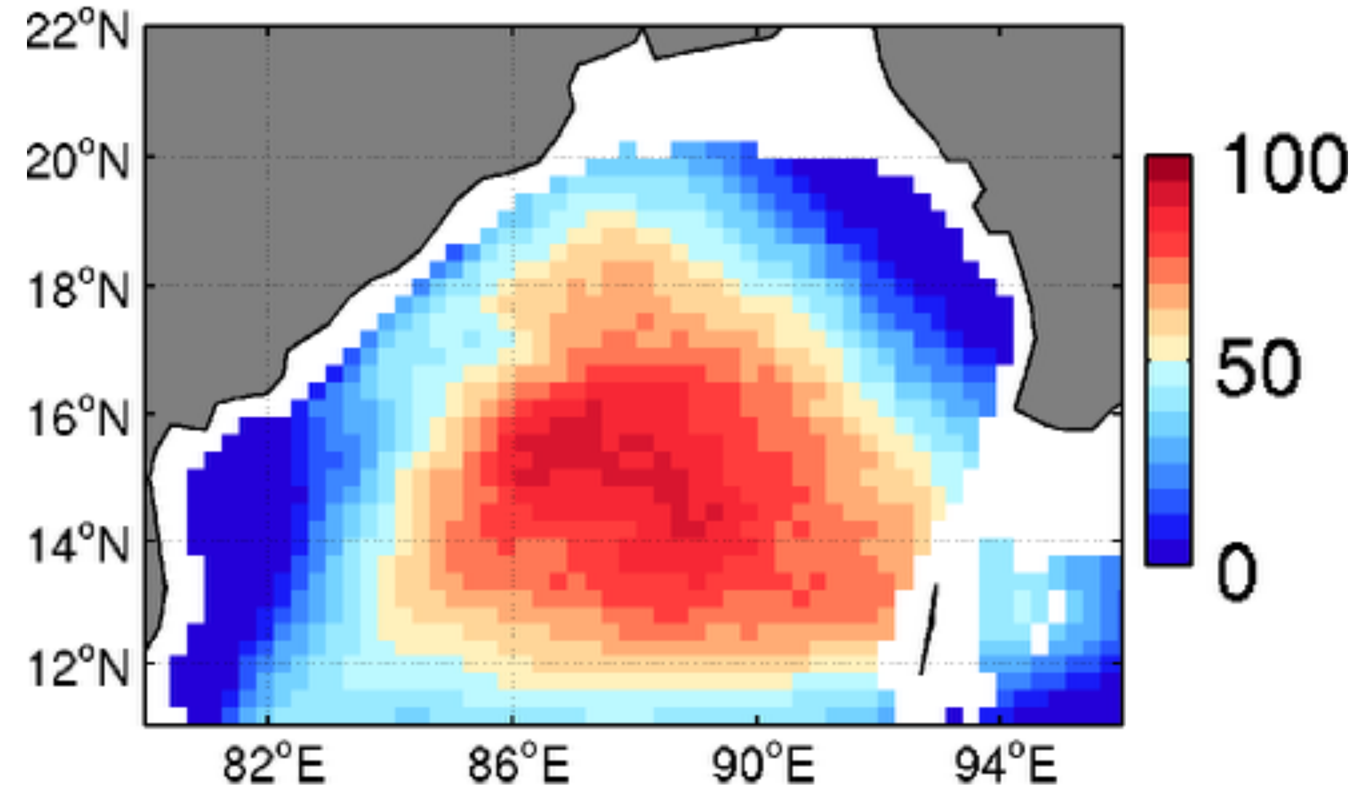


$$ATKE = (\eta_G - \eta_D)\rho_w v_*^3 - \rho_w \varepsilon_m h,$$

CTL



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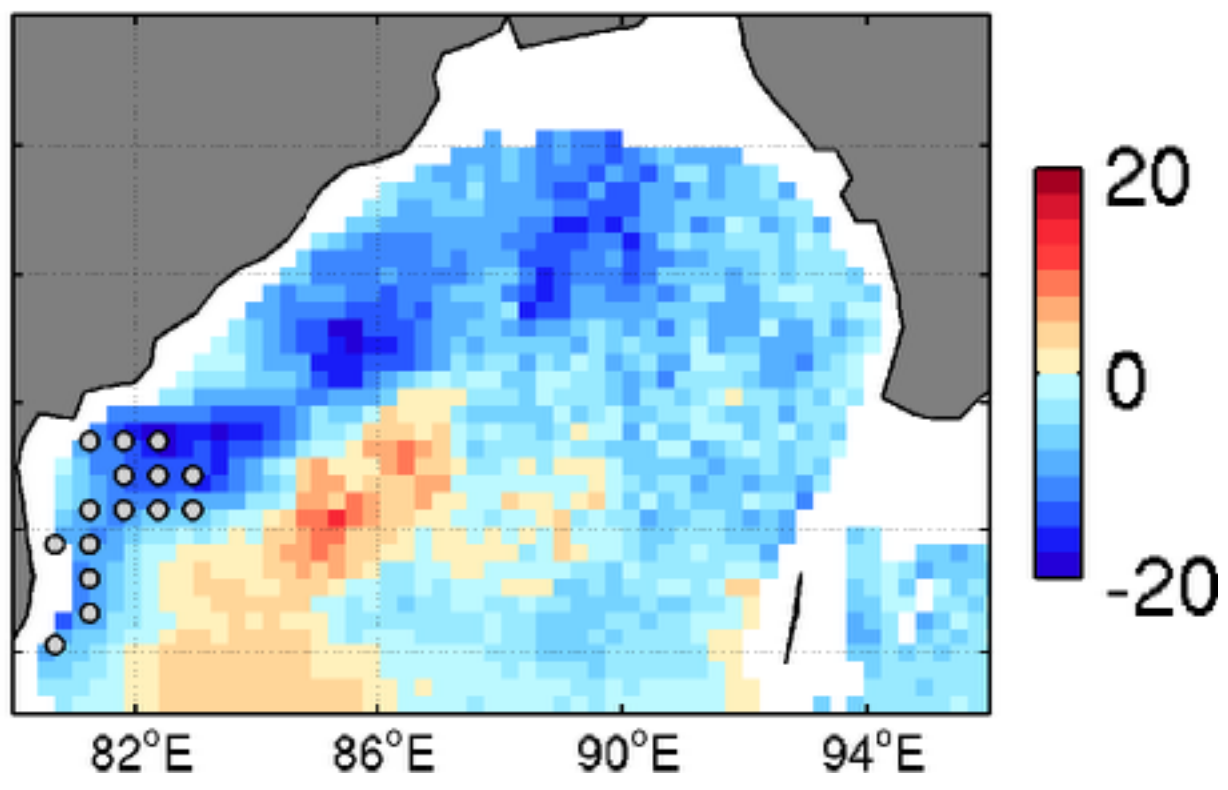
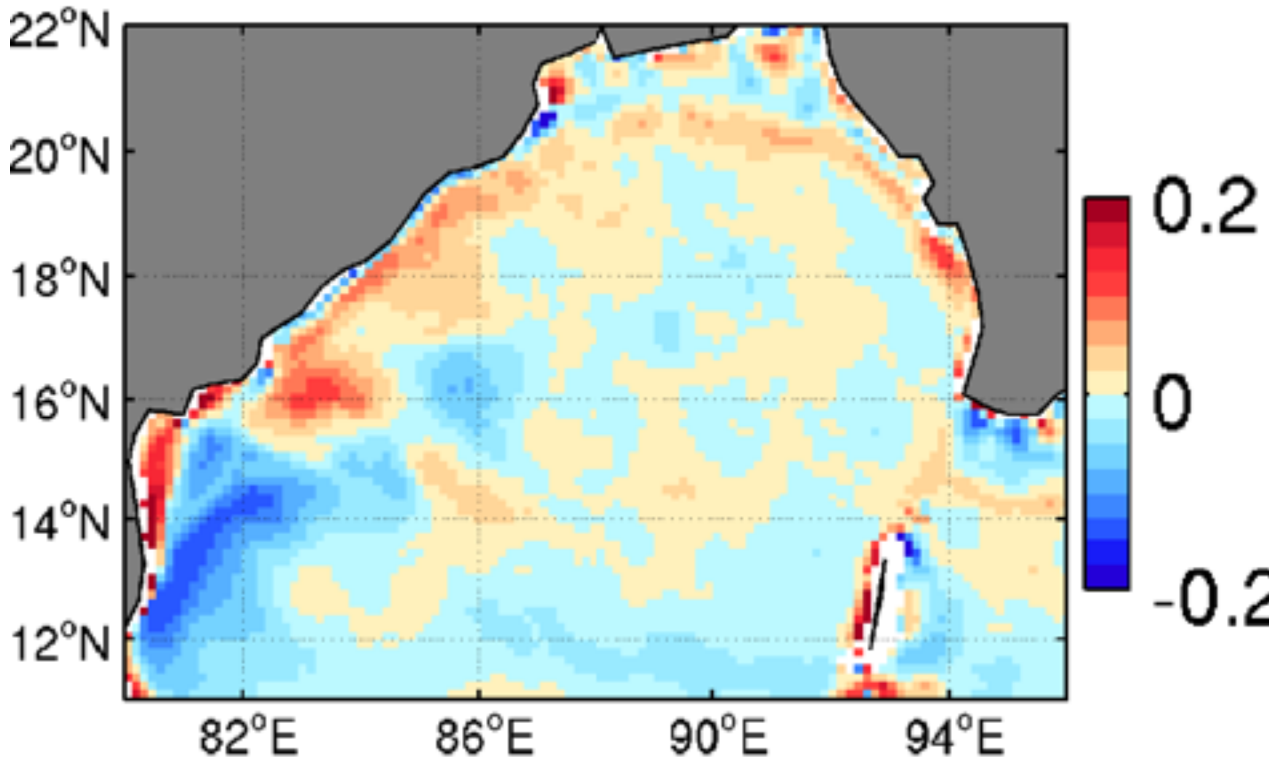


$$\zeta = \nabla \times \vec{u}_{sfc}$$

CTL



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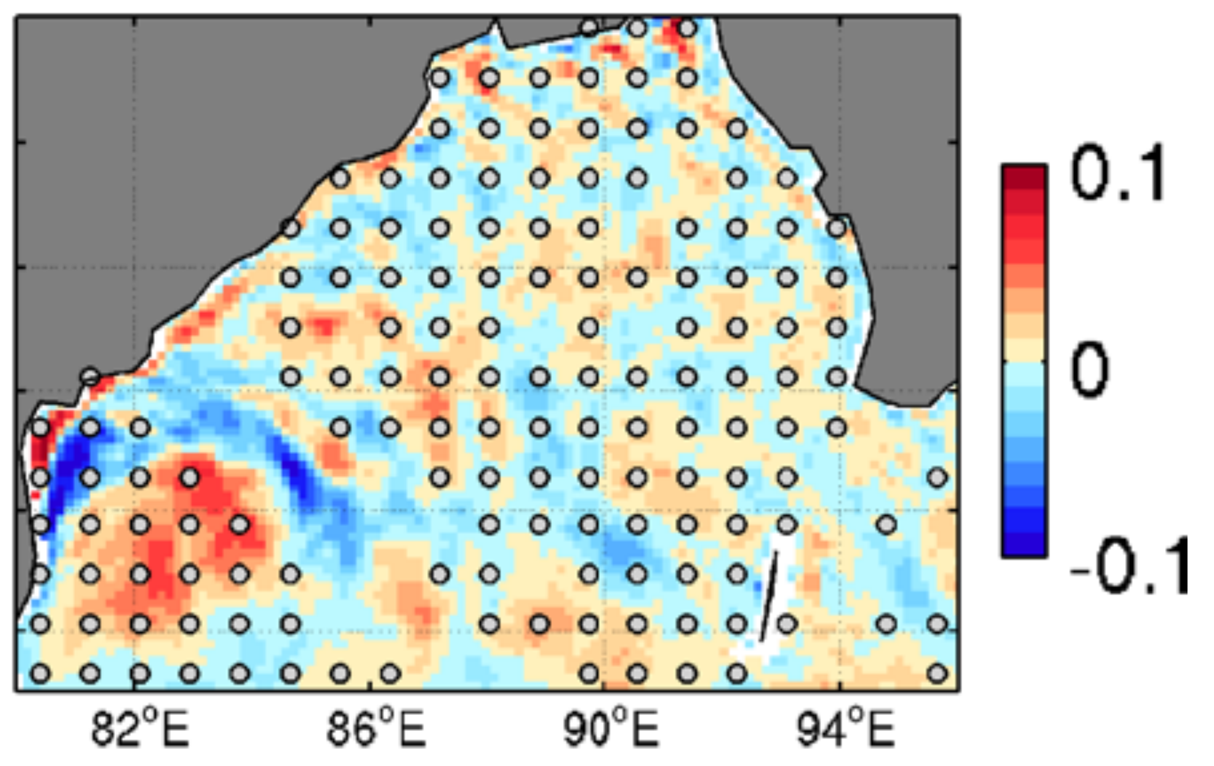
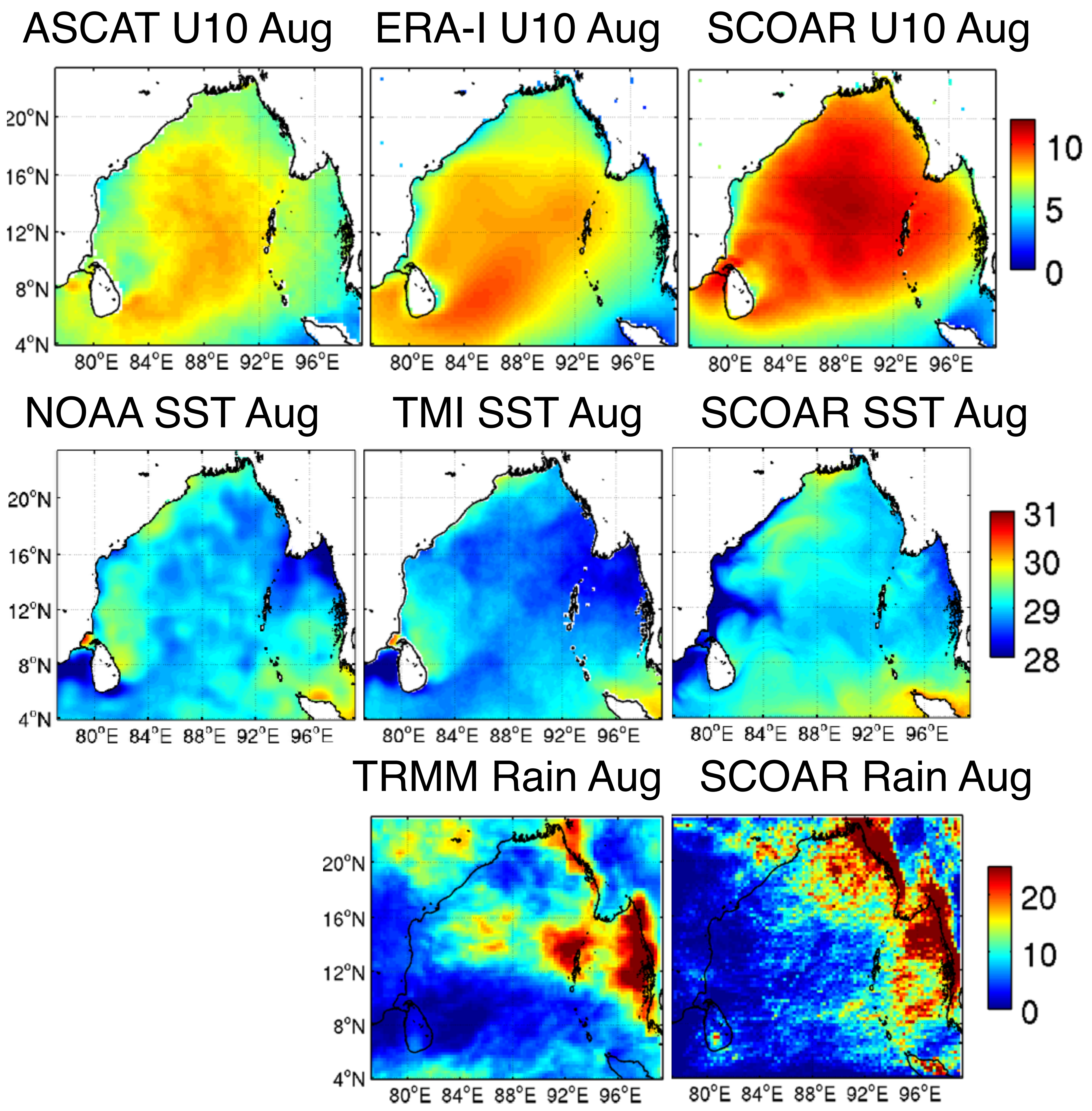




Ongoing analysis and issues

Implication to SST ISV and MISO rainfall.

Issues: Biases of high wind and spurious coastal upwelling undermine the sensitivity of the MISO to BoB

Summary

Modulation of wind work by surface current has two effects

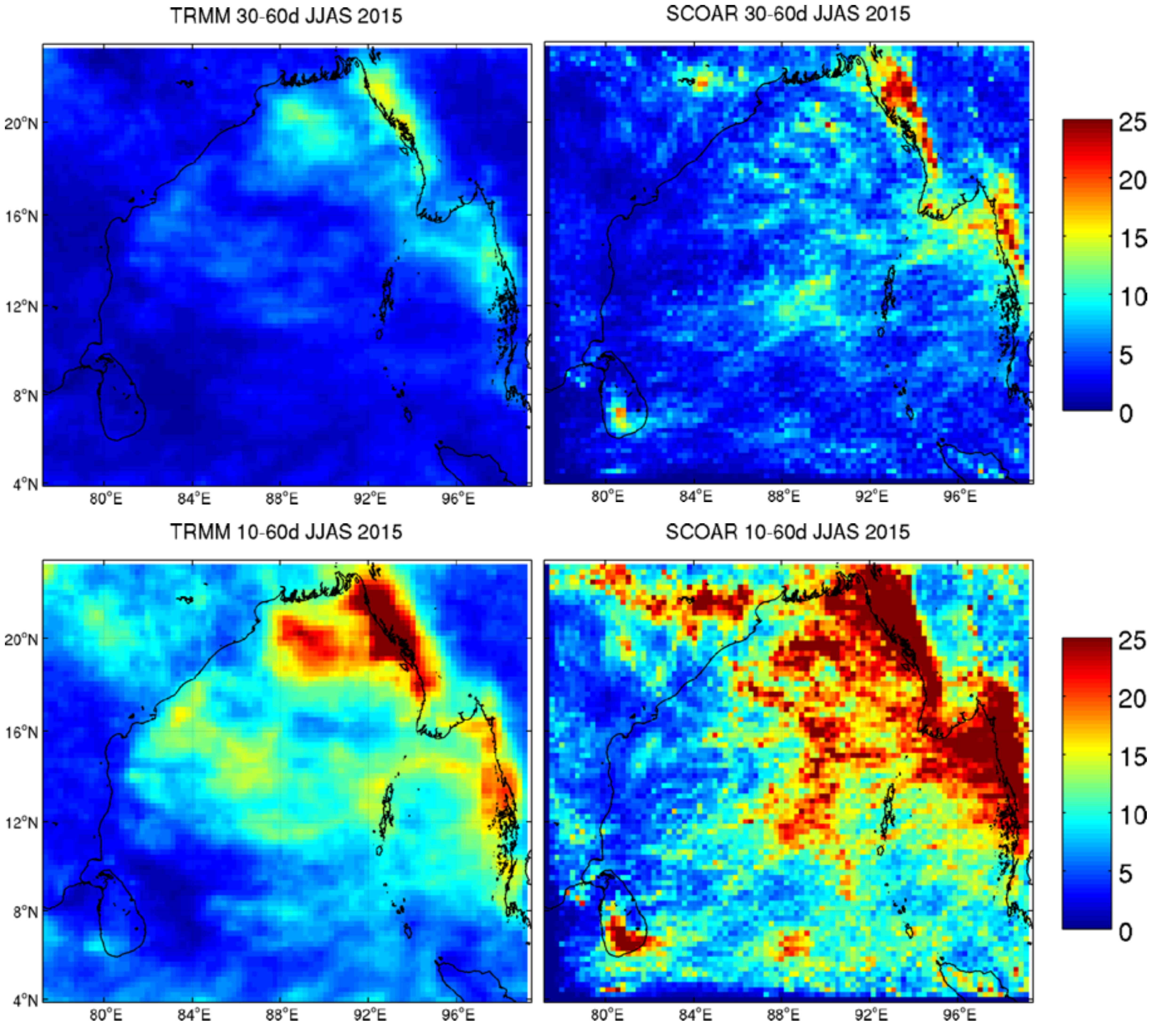
1) Reduced eddy wind work, leading to less energetic geostrophic circulation (EICC) and mesoscale activity (EKE).

2) Reduced ageostrophic wind work (ATKE) and surface vorticity reduces vertical shear and increases upward upwelling velocity.

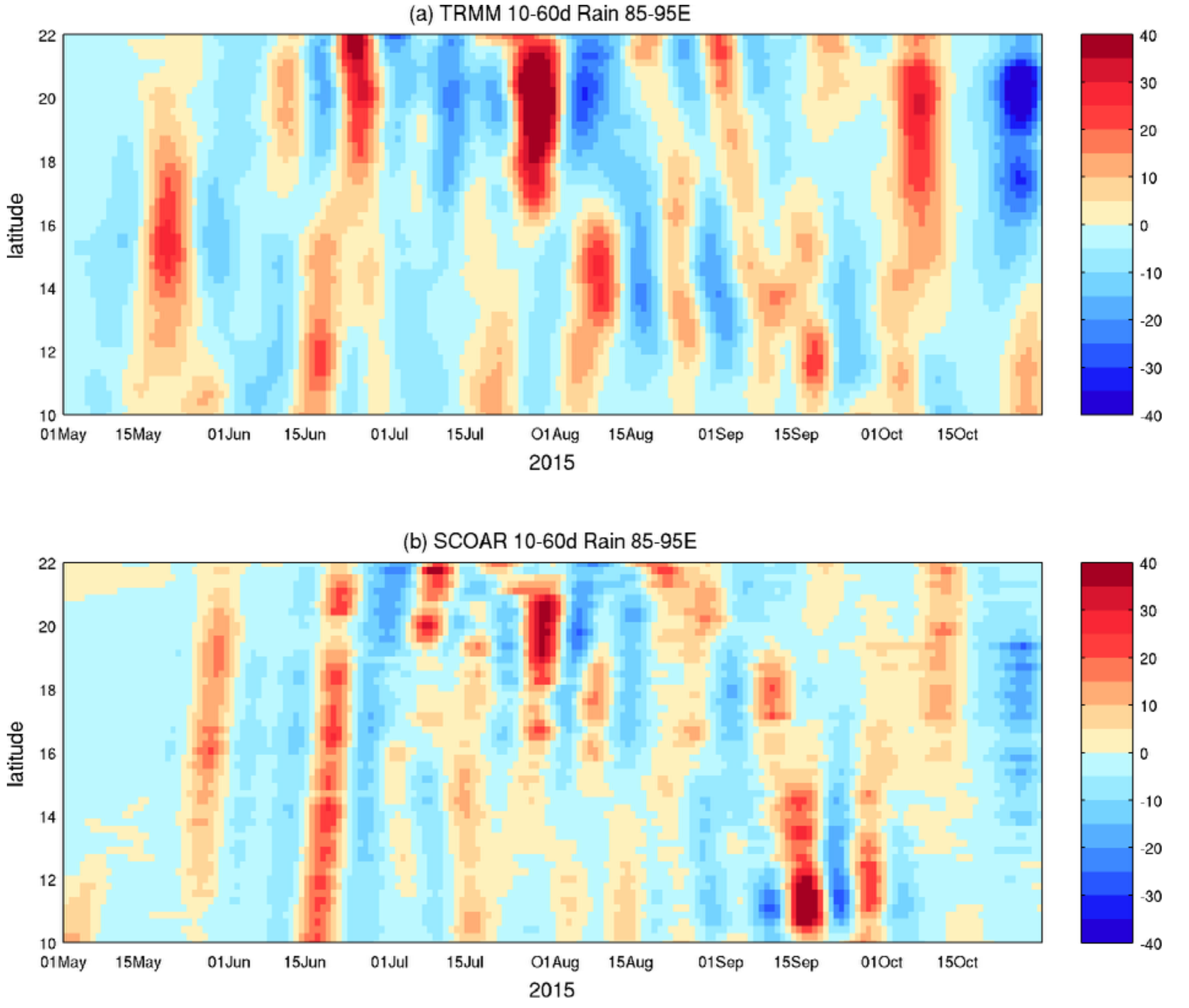
extra

Simulated MISO rainfall

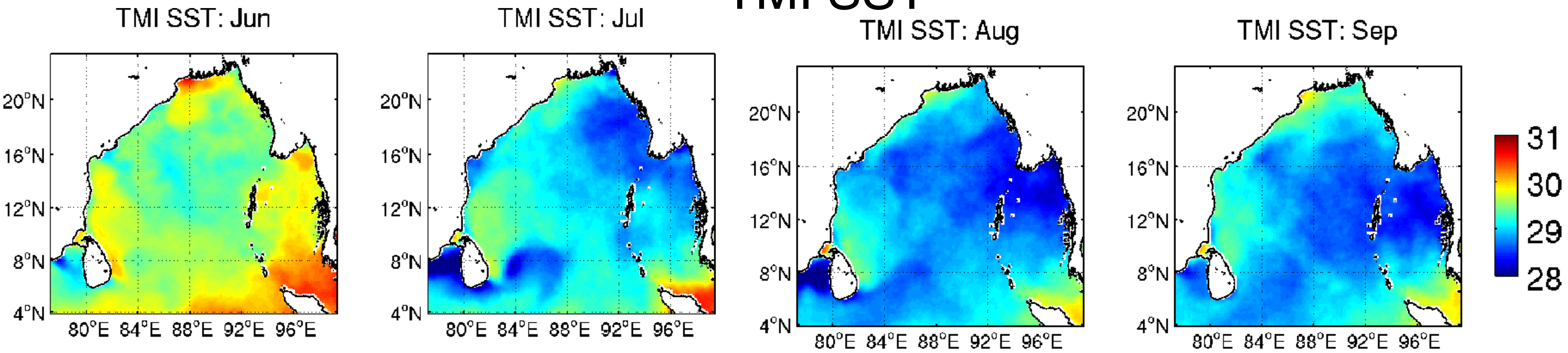
JJAS mean



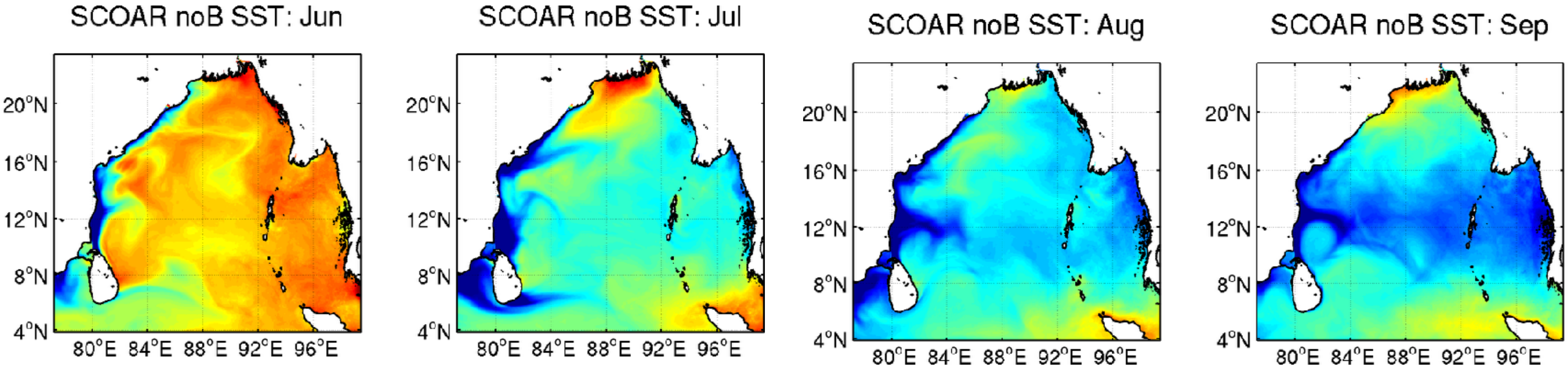
10-60 day 85-95E

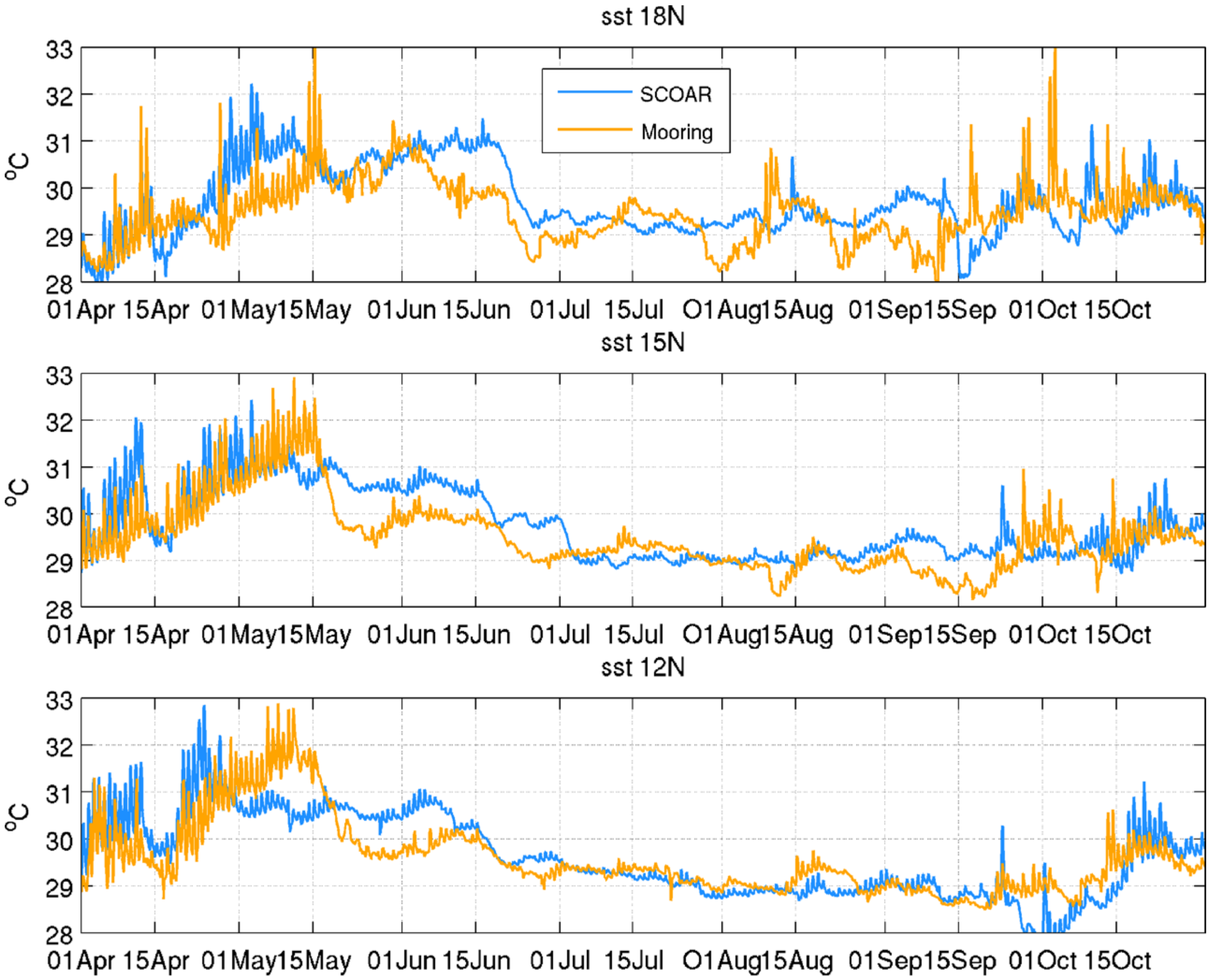


TMI SST



SCOAR model




sst 18N
SCOAR
Mooring
°C
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01Apr 15Apr 01May15May 01Jun 15Jun 01Jul 15Jul 01Aug15Aug 01Sep15Sep 01Oct 15Oct
sst 15N
°C
01Apr 15Apr 01May15May 01Jun 15Jun 01Jul 15Jul 01Aug15Aug 01Sep15Sep 01Oct 15Oct
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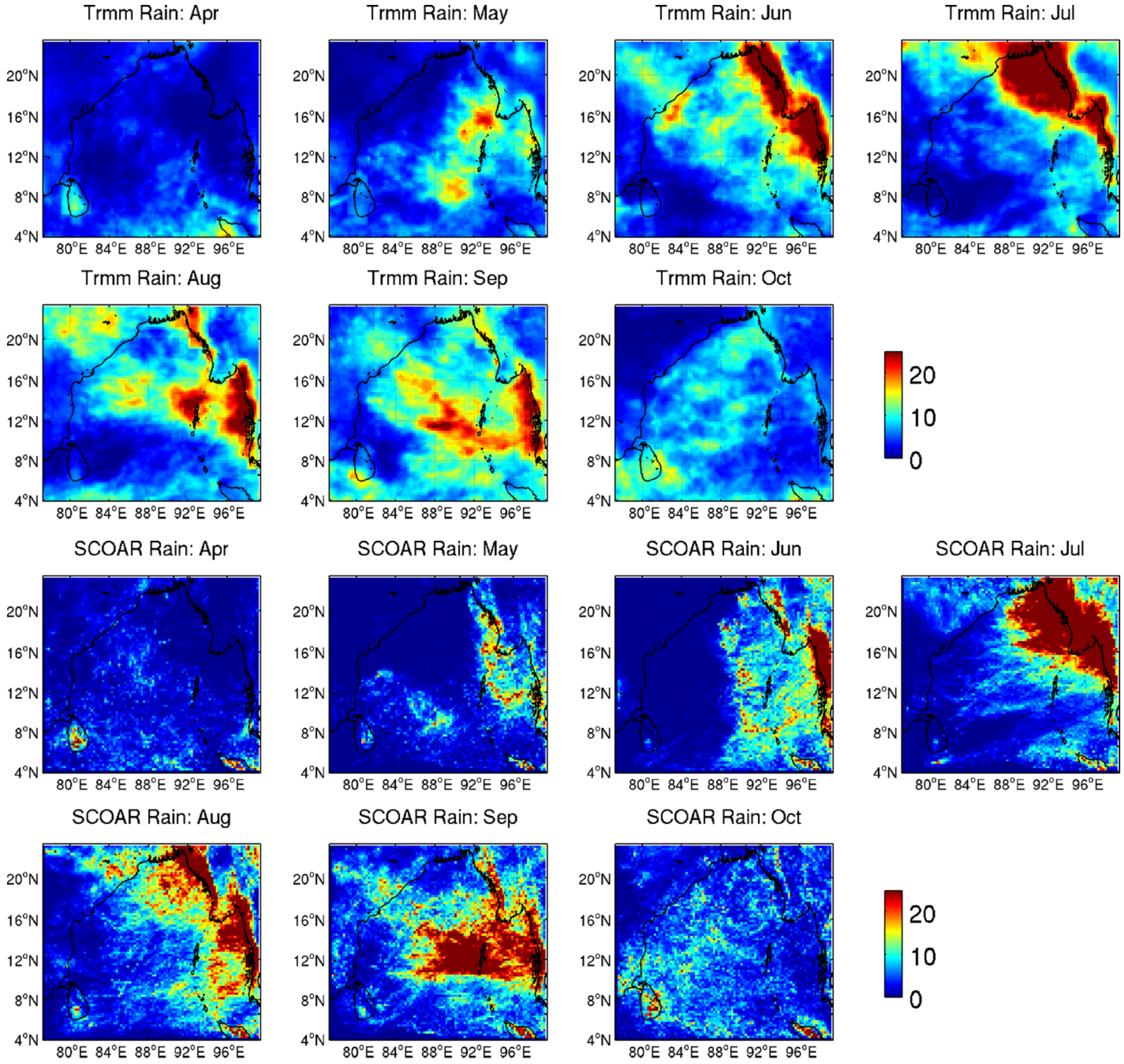
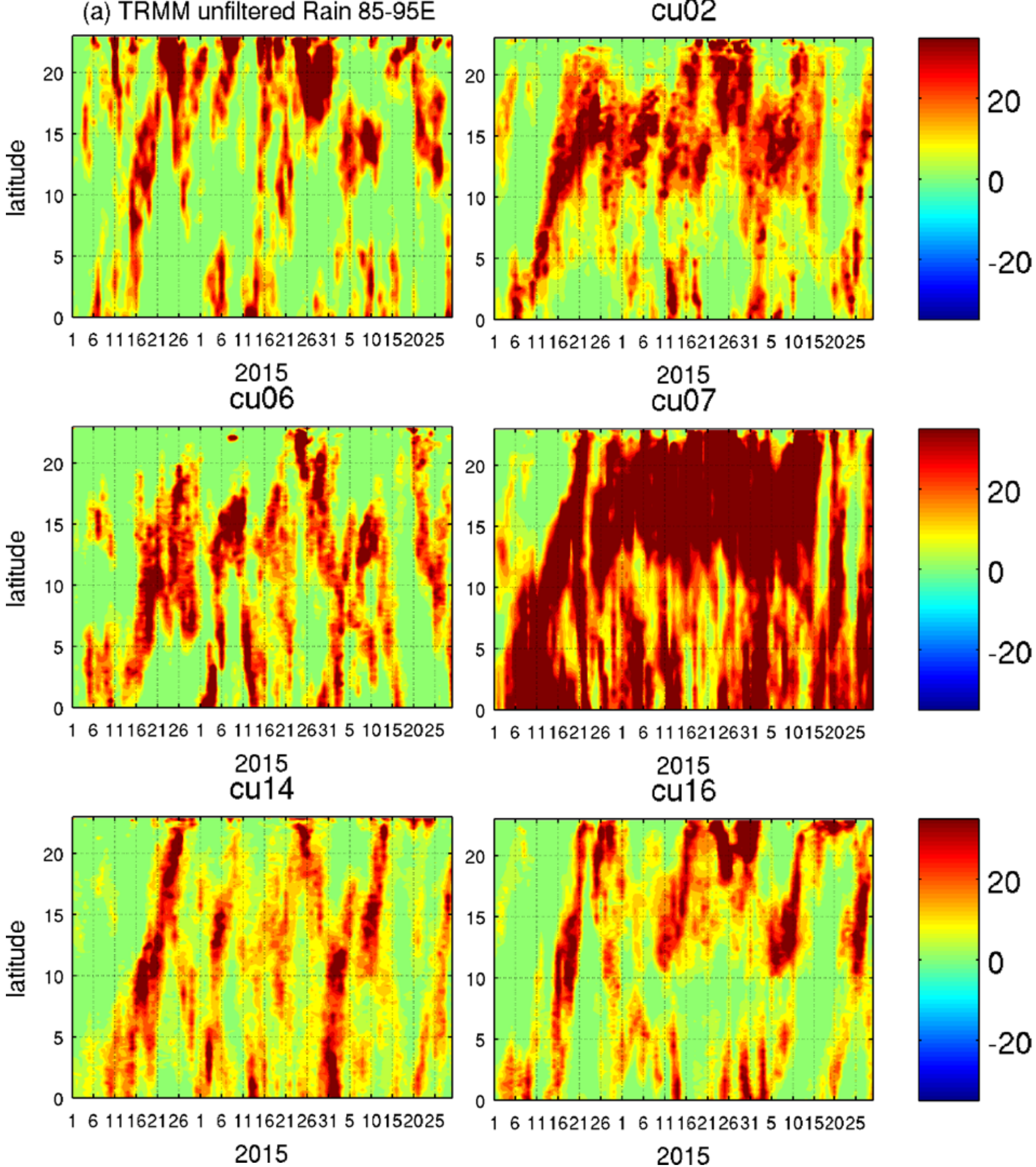
01Apr 15Apr 01May15May 01Jun 15Jun 01Jul 15Jul 01Aug15Aug 01Sep15Sep 01Oct 15Oct

Monthly evolution of rainfall 2015

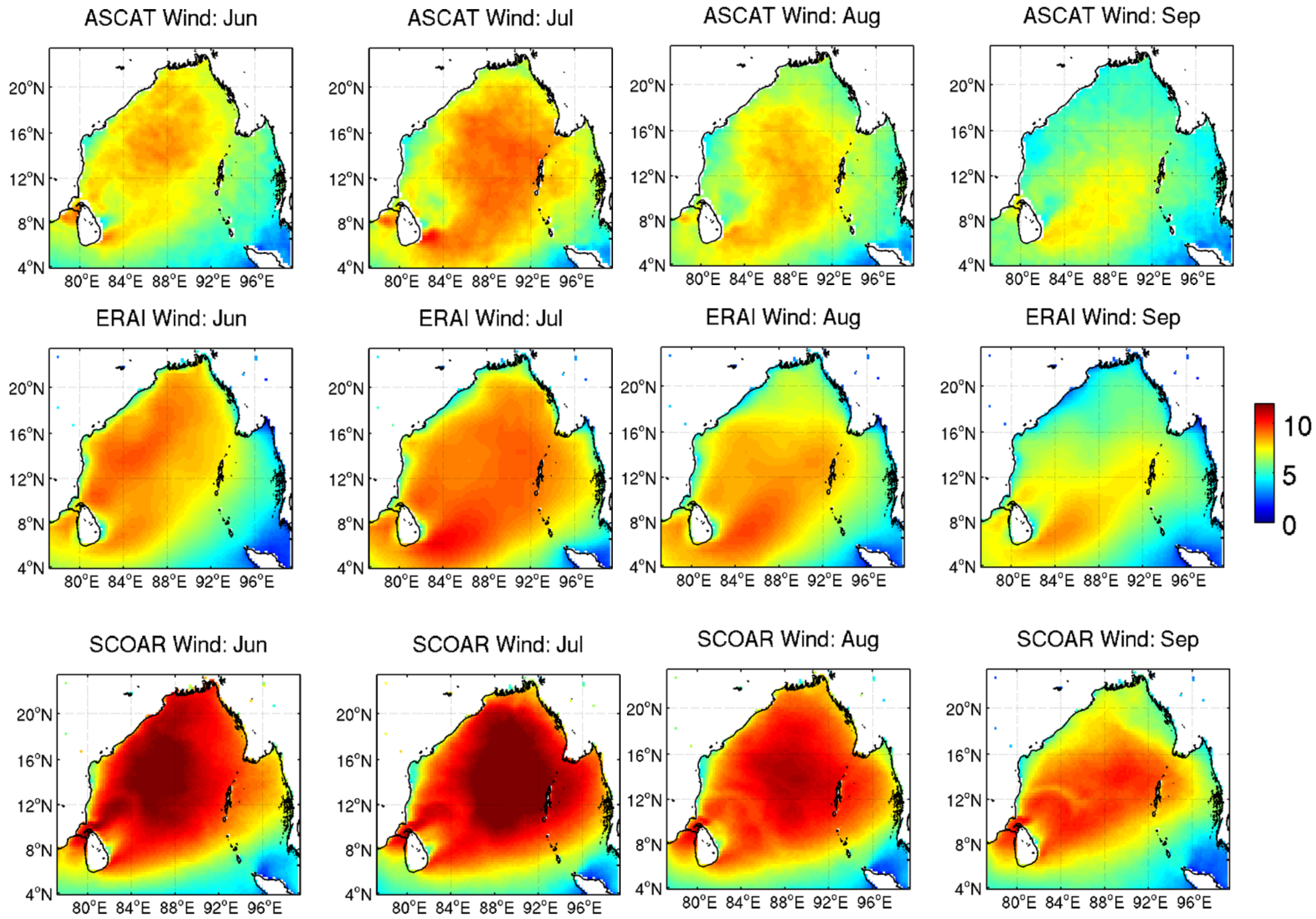


MISO rainfall sensitivity to convection schemes

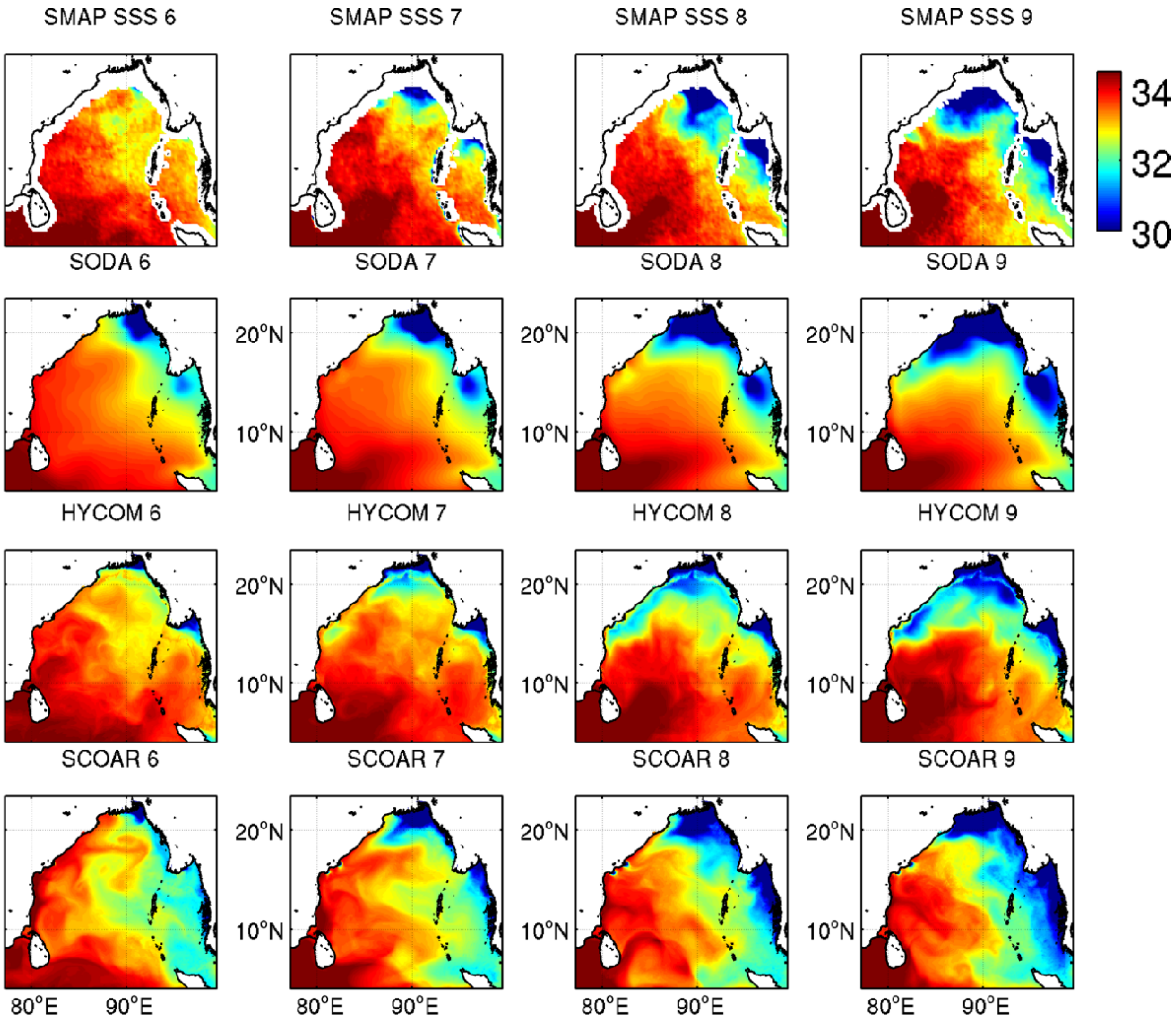


SST sensitivity to chosen water type

10-m wind speed



JJAS mean wind speed


SMAP SSS 6
SMAP SSS 7
SMAP SSS 8
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10°N
HYCOM 6
HYCOM 7
HYCOM 8
HYCOM 9
SCOAR 6
SCOAR 7
SCOAR 8
SCOAR 9
80°E
90°E