Eddy-driven air-sea interaction and feedback in the western Arabian Sea

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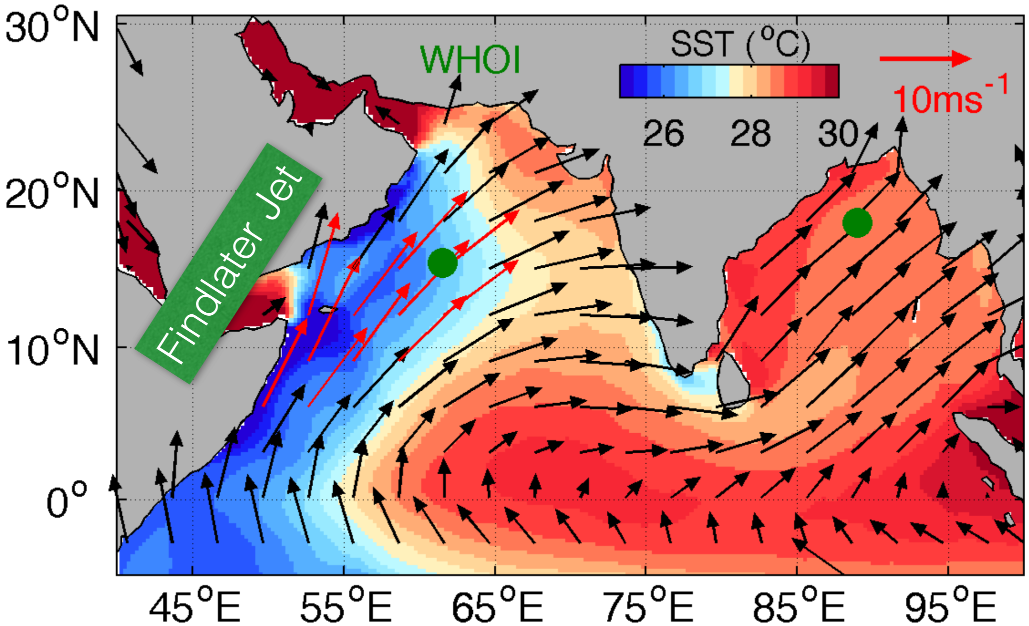
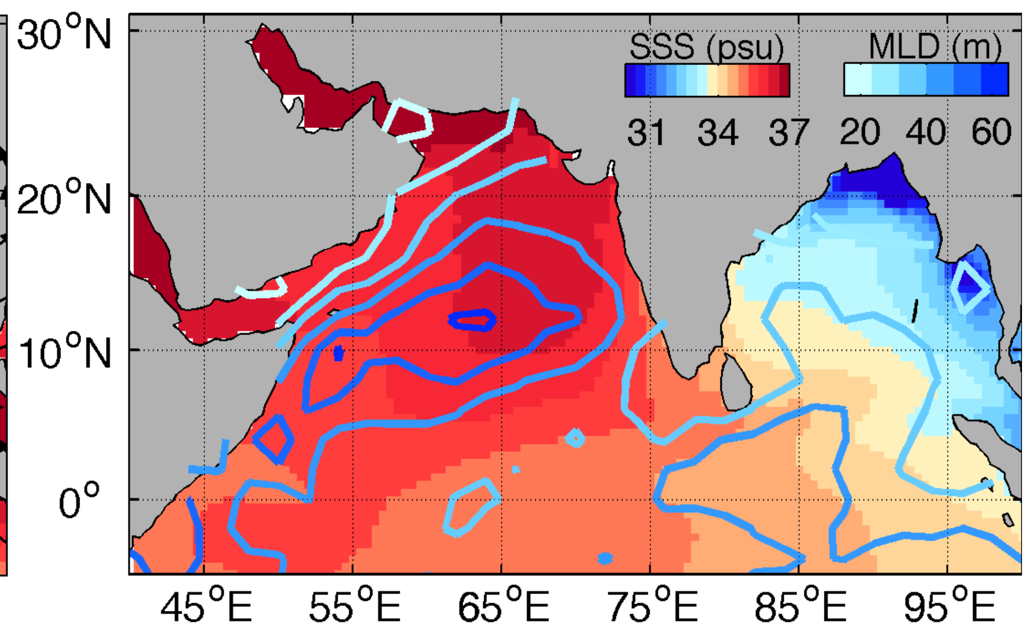
NASCar Planning Meeting
June 2-3, Reston, VA

Air-sea interaction in the Arabian Sea

Summer Climatology: SST & wind

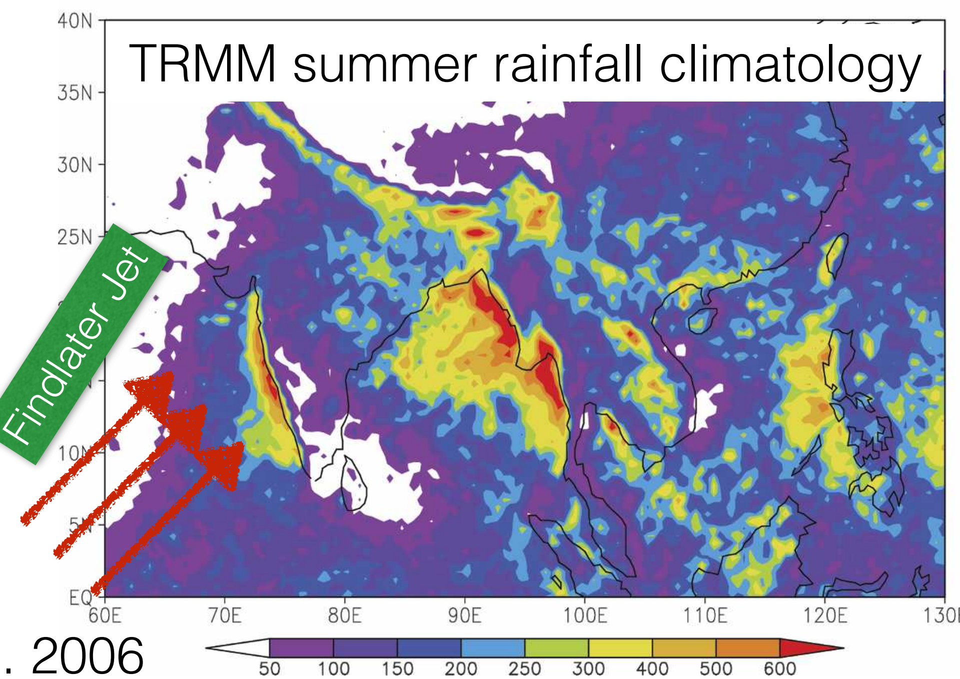


Summer Climatology: SSS & MLD



Arabian Sea

- Cold, salty, deep ML by the Findlater Jet
- Unstable boundary current, coastal upwelling, and strong eddy activity
- **Strong eddy-driven air-sea coupling**
  - affecting energetics of the current system, the low-level structure of the FJ, and the monsoon rainfall



Xie et al. 2006

Eddy-driven air-sea interactions thru wind stress

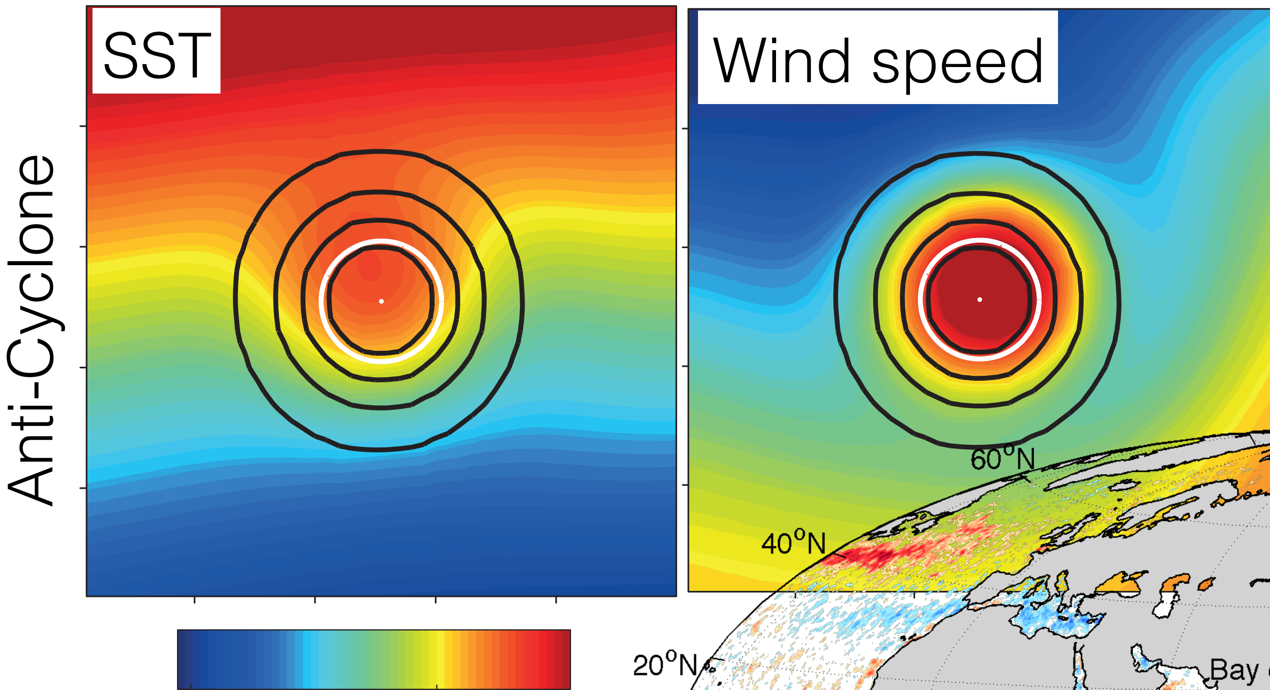
$$\tau = \rho\, C_D\, (U_a - U_o)\, |U_a - U_o|$$

surface current

10m wind

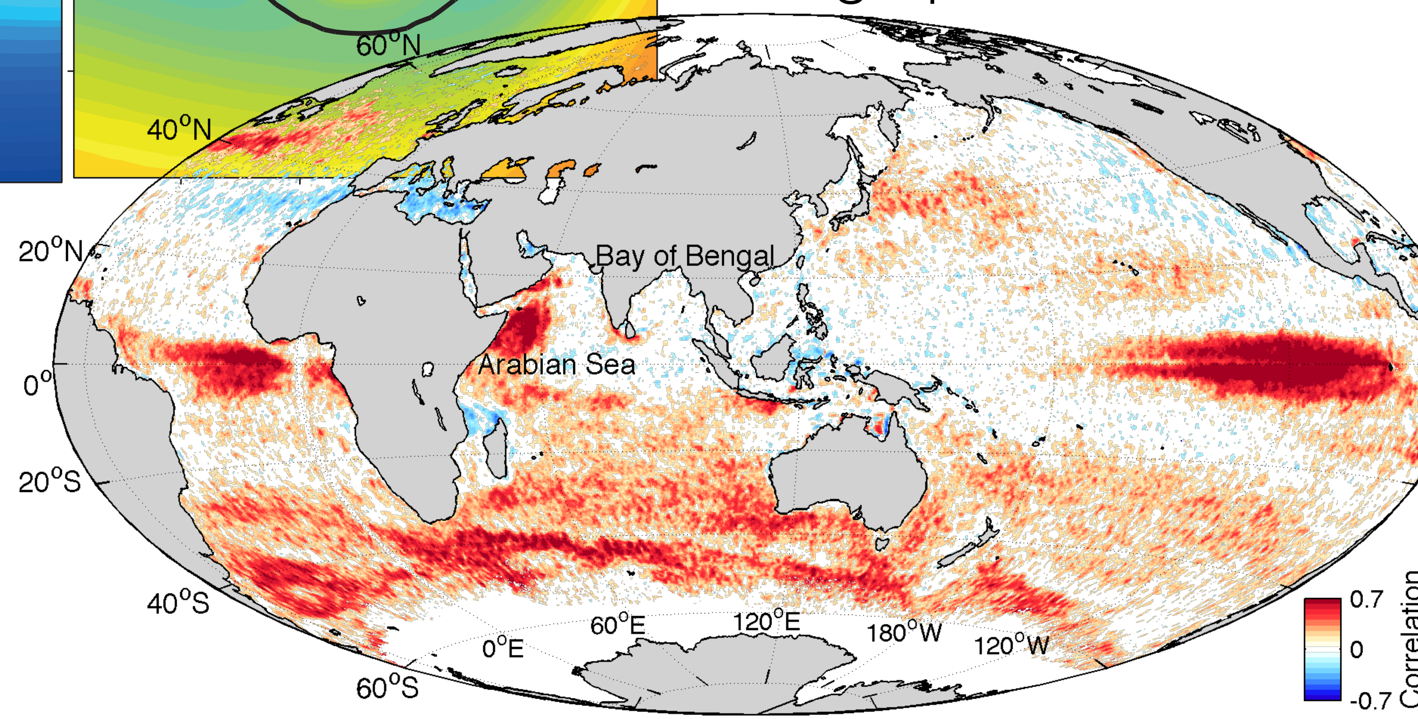
$$U_a = U_{ab} + \underline{U_{aSST}}$$

Composites in the Southern Oceans



Frenger et al. 2013

Positive correlation between JJA high-passed SST & wind



Eddy-driven Ekman pumping

$$\tau = \rho\, C_D\, (U_a - U_o)\, |U_a - U_o|$$

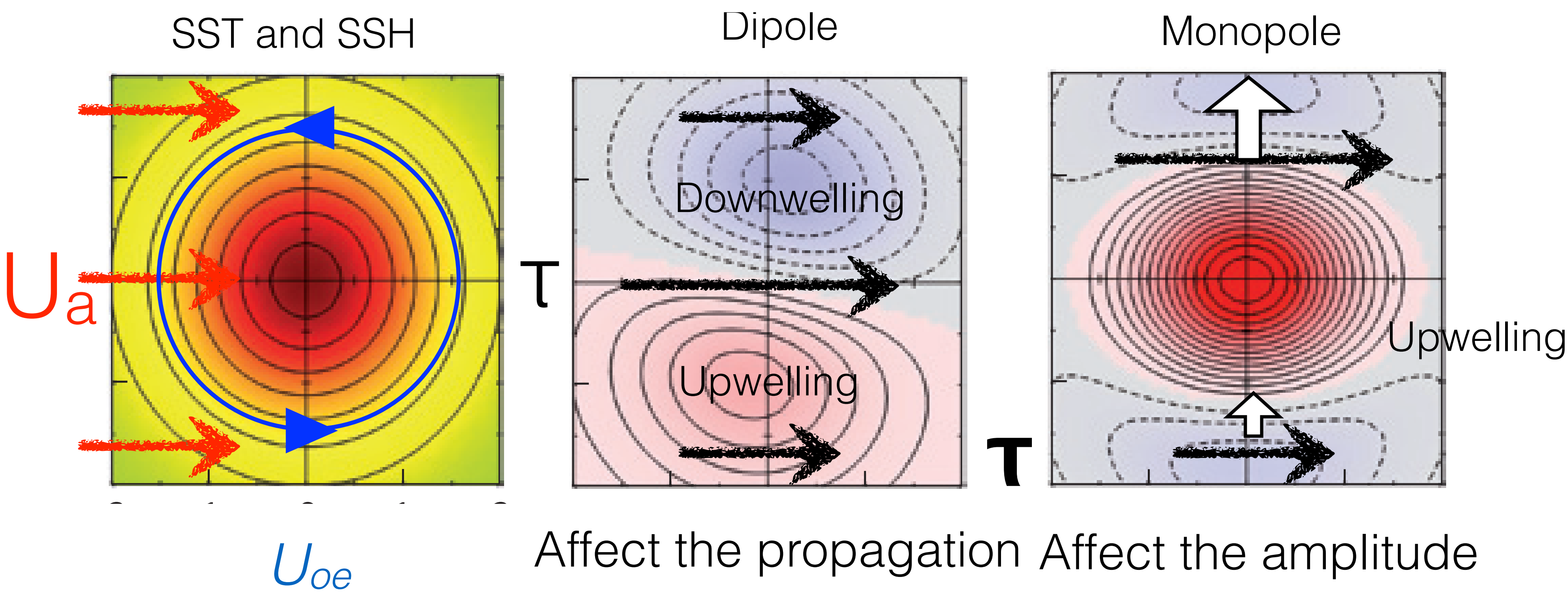
surface current

$U_o = U_{ob} + U_{oe}$

10m wind

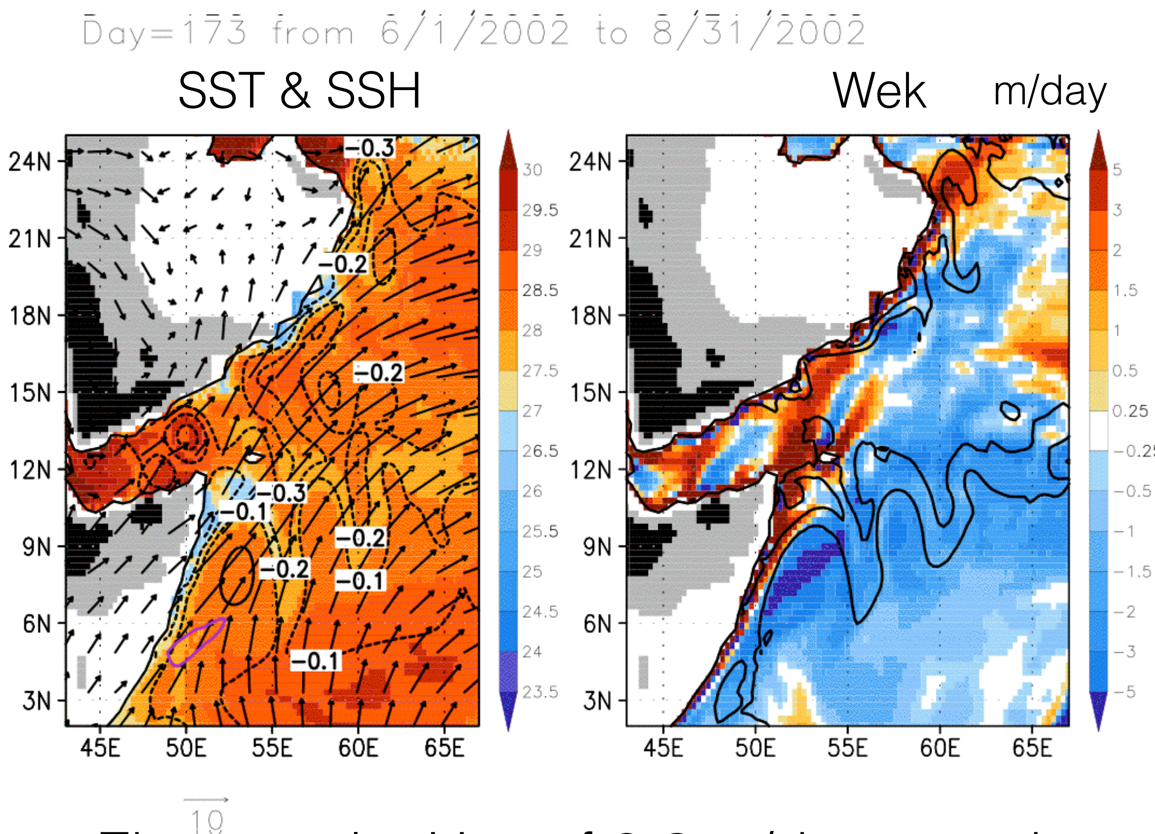
$U_a = U_{ab} + \underline{U_{aSST}}$

An anticyclonic eddy in the Southern Ocean (Chelton 2013)



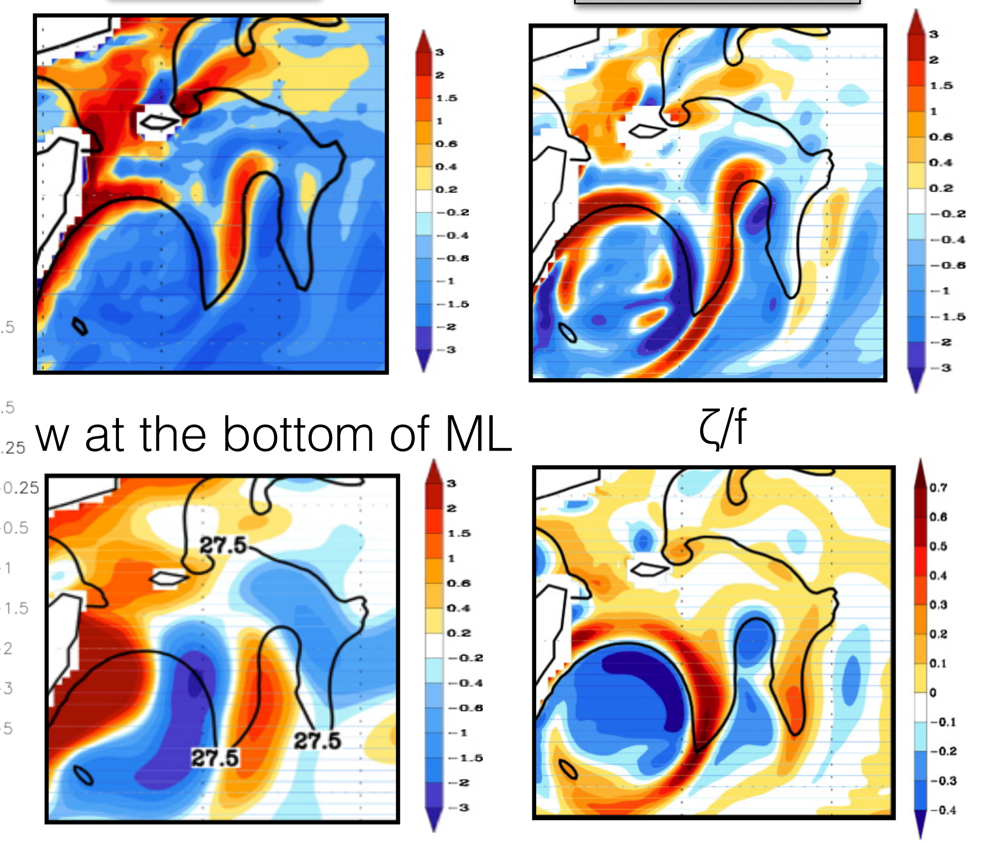
Eddy-driven Ekman pumping in the AS

25km SCOAR regional coupled model simulation for the Indian Ocean



$$W_{ek} = \frac{\nabla \times \tau}{\rho_0 f}$$

$$W_{ek} = \frac{\nabla \times \tau}{\rho_0 (f + \zeta)}$$

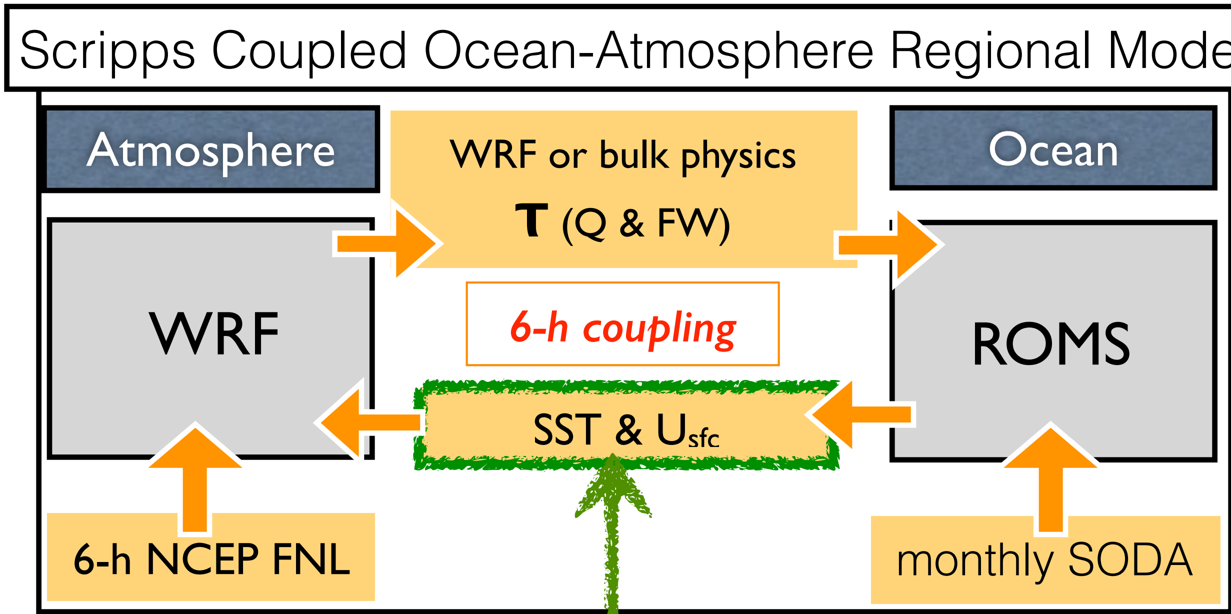


- Ekman velocities of 2-3 m/day over the cold filament, persisting >1 month
- SST and surface current both important for Ekman pumping

Seo et al. 2008: Modeling of Mesoscale Coupled Ocean-Atmosphere Interaction and its Feedback to Ocean in the Western Arabian Sea. *Ocean Modell*.

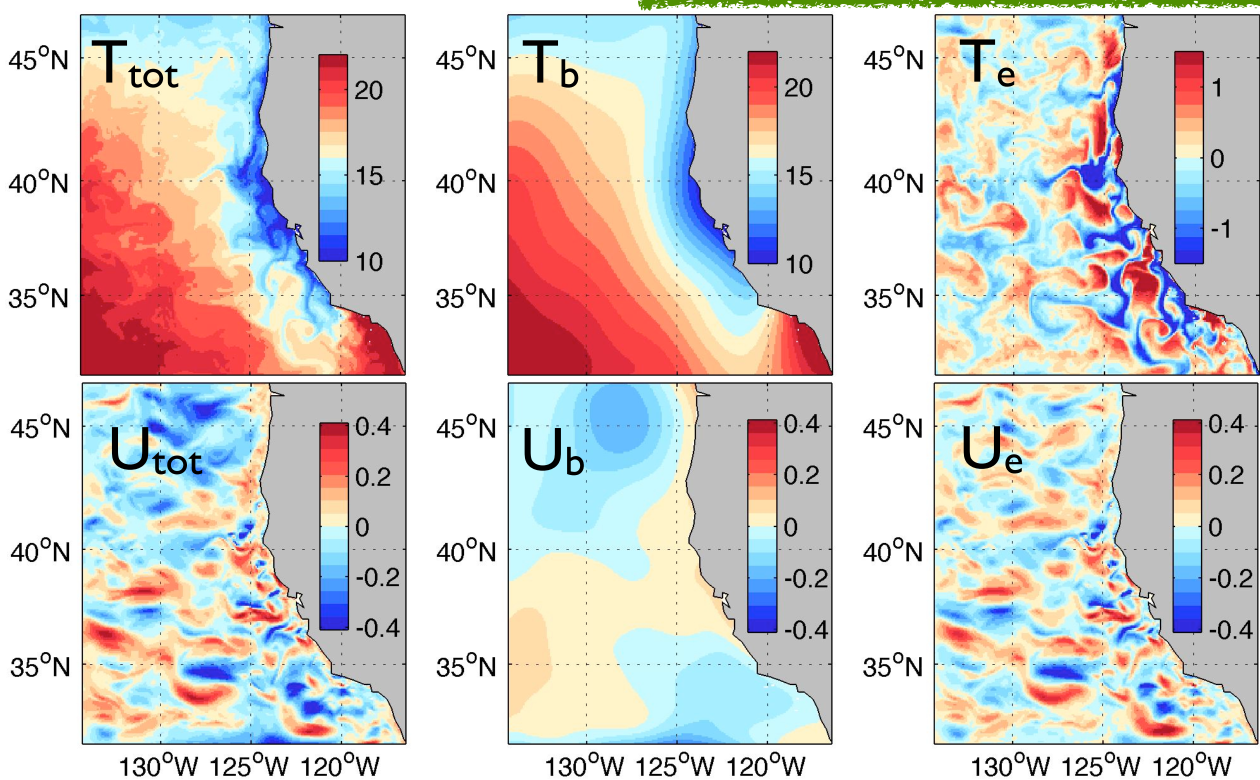
Relative effects of eddy-driven air-sea interaction via SST and surface current?

Quantifying the effect of eddy-driven air-sea coupling



- Seo et al. 2007, 2014
- 7 km O-A resolutions

Smoothing of mesoscale SST and U_o

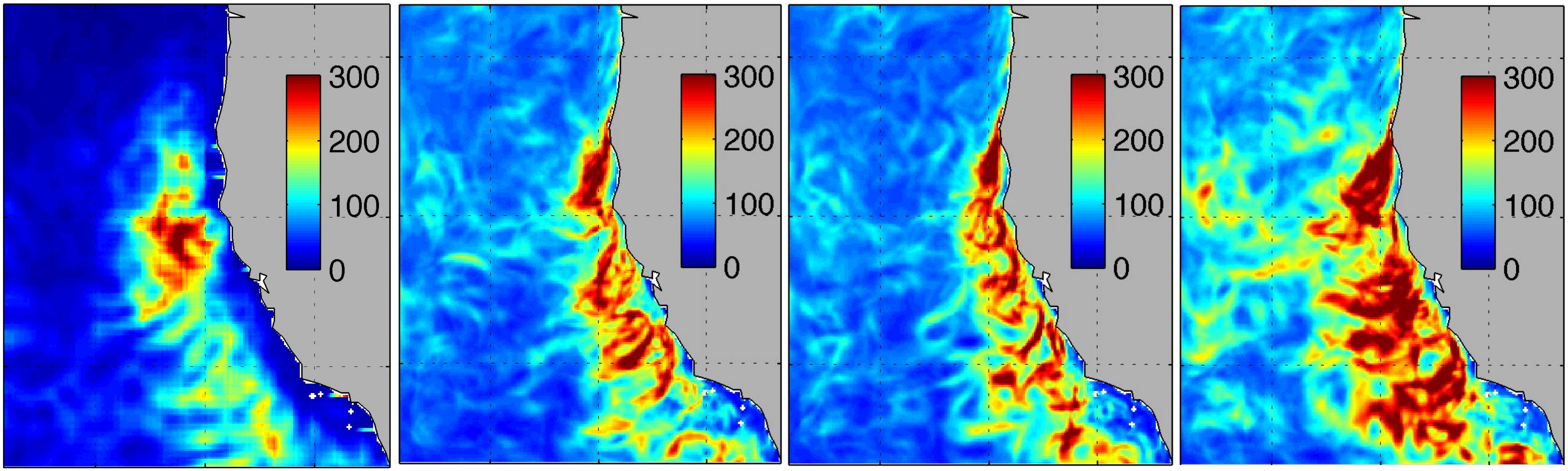


$$\tau=\rho C_D(U_a-U_o)|U_a-U_o|$$

Exp	τ formulation includes			
CTL	T_b	T_e	U_b	U_e
noT_e	T_b	(T_e, shown in grey)	U_b	U_e
noU_e	T_b	T_e	U_b	(U_e, shown in grey)

Summertime EKE in the CCS

AVISO EKE | **CTL** Includes both T_e & U_e | **noT$_e$** Without T_e effect | noU$_e$ Without U_e effect



JAS 2005-2010

- 42% reduction of EKE by U_o effect, but U_a has no strong effect
- Changes in baroclinic and barotropic energy conversion are small.
- The EKE reduction is largely explained by the enhanced eddy surface drag.

EKE budget

$$Ke_t + \vec{U}\cdot\vec{\nabla}\vec{K}e + \vec{u}'\cdot\vec{\nabla}\vec{K}e + \vec{\nabla}\cdot(\vec{u}'p') = +\rho_o(-\vec{u}'\cdot(\vec{u}'\cdot\vec{\nabla}\vec{U})) - g\rho'w' + \vec{u}'\cdot\vec{\tau}' + \varepsilon$$

Eddy-driven Ekman pumping velocity

Stern 1965
Gaube et al. 2015

$$W_{tot} = \frac{1}{\rho_o}\nabla \times \left(\frac{\boldsymbol{\tau}}{(f+\zeta)}\right)$$

$$\tilde{W}_{tot} = W_{cur} + W_{SST}$$

background wind stress

$$= \underbrace{\frac{\nabla \times \tilde{\boldsymbol{\tau}}}{\rho_o (f+\zeta)}}_{W_{LIN}} - \underbrace{\frac{1}{\rho_o (f+\zeta)^2}\left(\tilde{\tau}^y \frac{\partial \zeta}{\partial x} - \tilde{\tau}^x \frac{\partial \zeta}{\partial y}\right)}_{W_{\zeta}} + \underbrace{\frac{\beta \tilde{\tau}^x}{\rho_o (f+\zeta)^2}}_{W_{\beta}} + \underbrace{\frac{\nabla \times \boldsymbol{\tau}'_{SST}}{\rho_o (f+\zeta)}}_{W_{SST}}.$$

W_{LIN}: Curl-induced linear Ekman pumping

W_{ζ}: Vorticity gradient-induced nonlinear Ekman pumping

W_{β}: β Ekman pumping (negligible)

W_{SST}: SST induced Ekman pumping

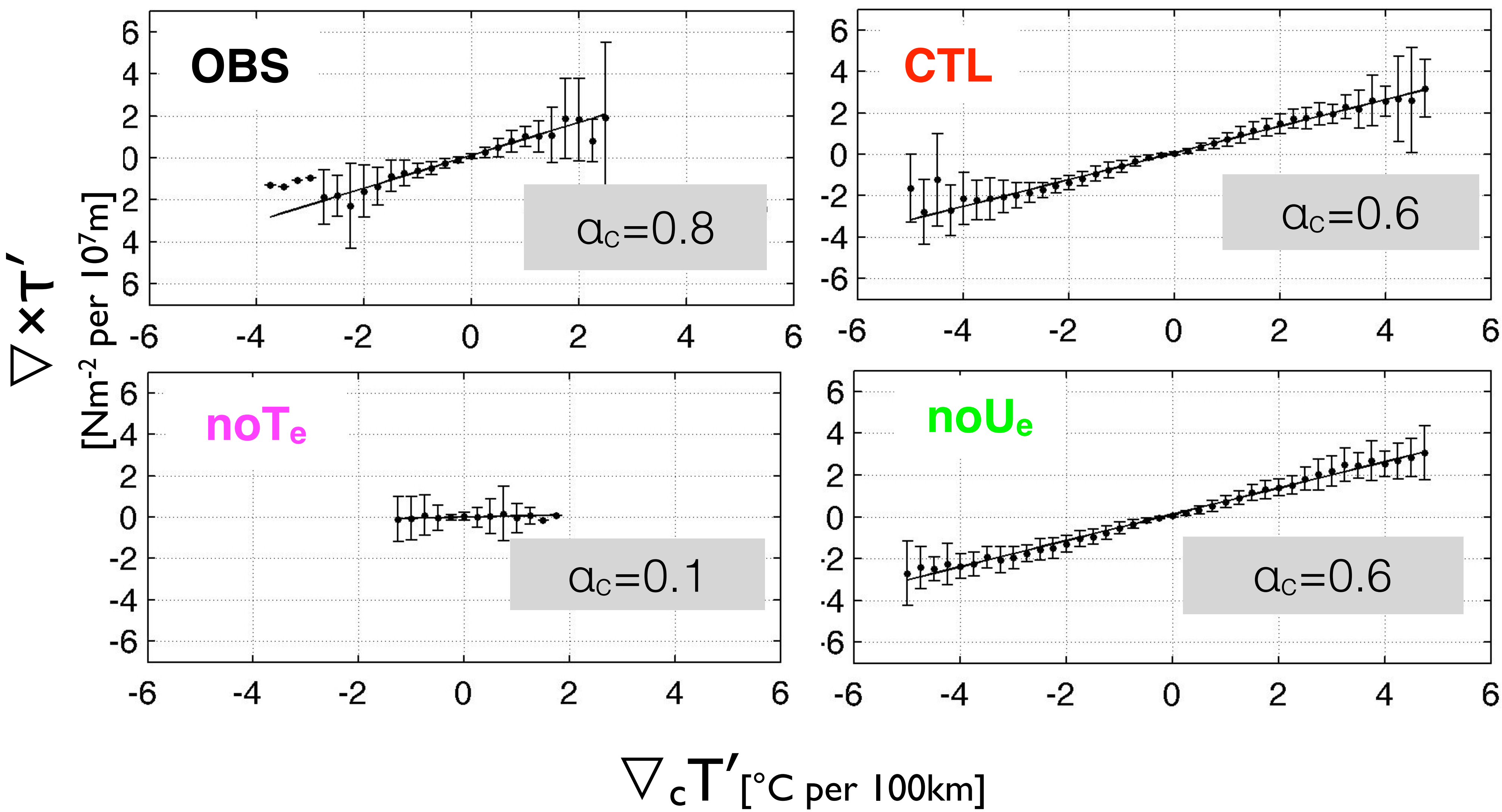
Chelton et al. 2007

$$W_{SST} = \frac{\nabla \times \boldsymbol{\tau}'_{SST}}{\rho_o (f+\zeta)} \approx \frac{\alpha_c \nabla_c SST}{\rho_o (f+\zeta)}$$

Estimating eddy SST-driven Ekman pumping velocity

Chelton et al. 2007

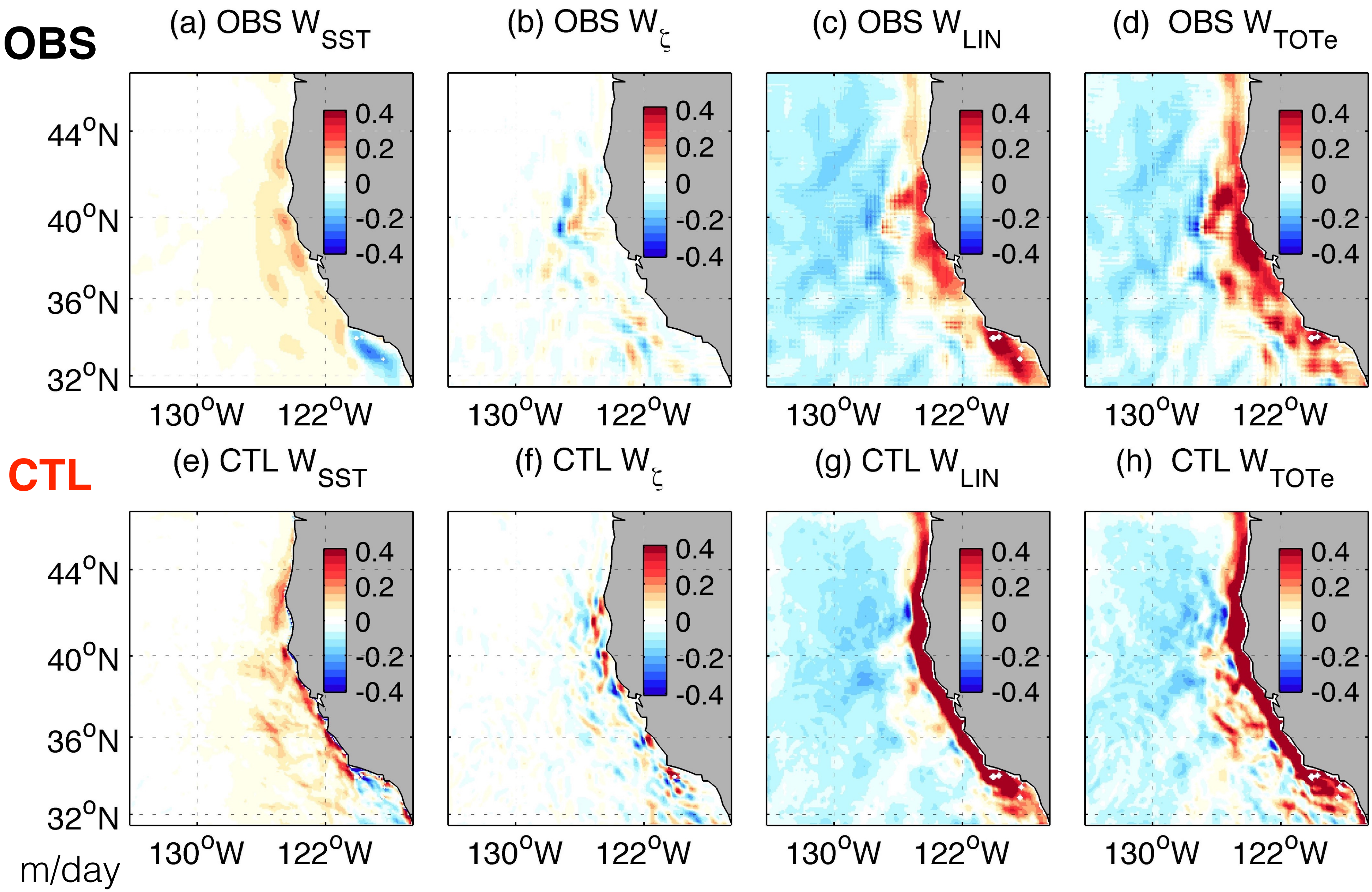
$$W_{SST} = \frac{\nabla \times \tau'_{SST}}{\rho_o(f+\zeta)} \approx \frac{\alpha_c \nabla_c SST}{\rho_o(f+\zeta)}$$



JAS 2005-2009: OBS based on QuikSCAT wind stress and TRMM SST

$$W_{TOTe} = \underbrace{\frac{\nabla \times \boldsymbol{\tau}_b}{\rho_0 (f+\zeta)}}_{W_{LIN}} + \underbrace{\frac{\nabla \times \boldsymbol{\tau}_e}{\rho_0 (f+\zeta)}}_{W_{SST}} - \underbrace{\frac{\boldsymbol{\tau}_b \times \nabla \zeta}{\rho_0 (f+\zeta)^2}}_{W_{\zeta}}$$

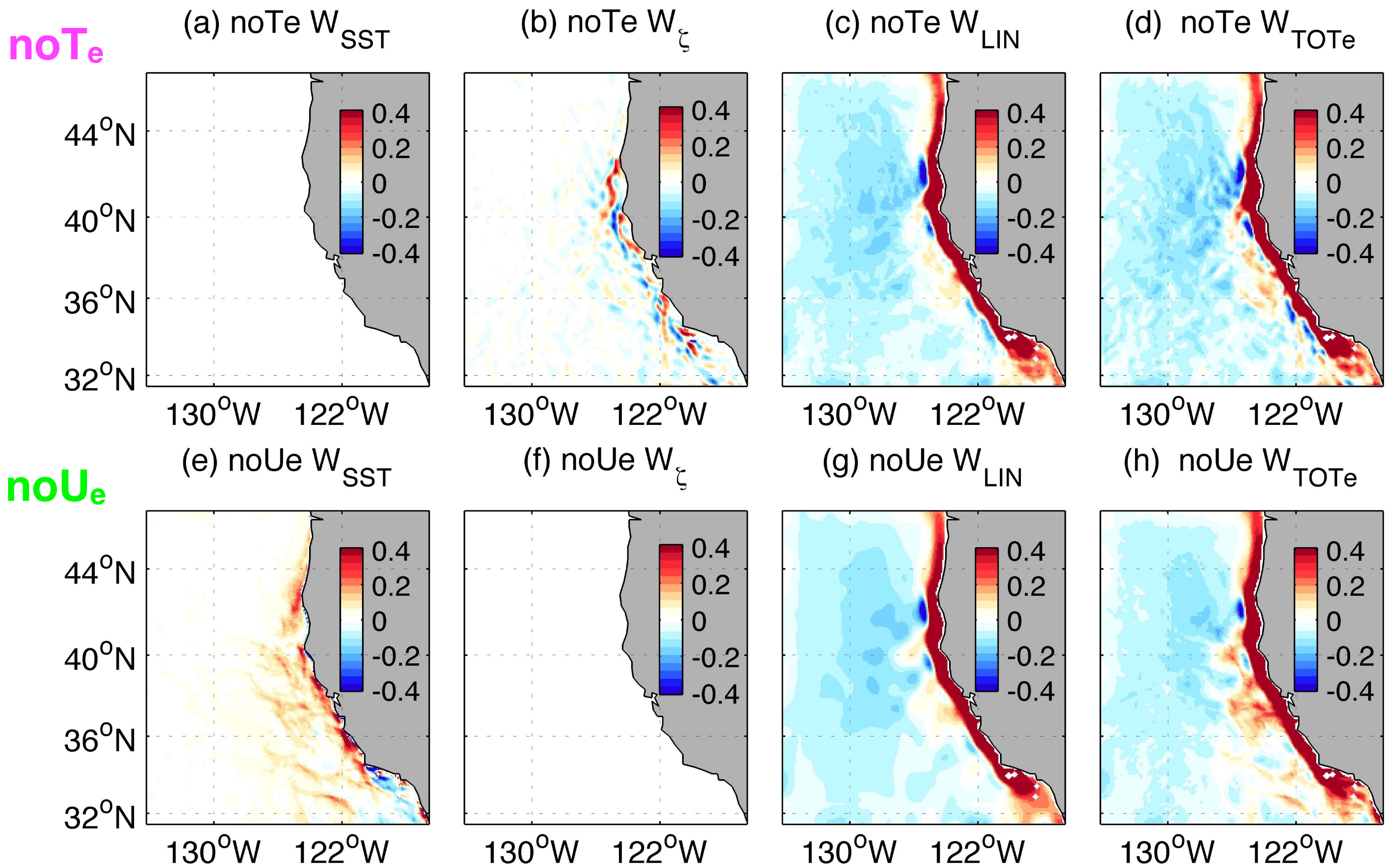
Estimated Ekman pumping velocity



JAS 2005-2009: OBS based on AVISO SSH & QuikSCAT wind stress

$$W_{TOTe} = \underbrace{\frac{\nabla \times \boldsymbol{\tau}_b}{\rho_0 (f+\zeta)}}_{W_{LIN}} + \underbrace{\frac{\nabla \times \boldsymbol{\tau}_e}{\rho_0 (f+\zeta)}}_{W_{SST}} - \underbrace{\frac{\boldsymbol{\tau}_b \times \nabla \zeta}{\rho_0 (f+\zeta)^2}}_{W_{\zeta}}$$

Estimated Ekman pumping velocity



m/day

JAS 2005-2009

Summary and Research Plan

- AS is eddy-rich. Understanding dynamics and impact of **eddy-driven air-sea interaction (both thermal and momentum)** is of my primary interest.

- From the NASCar measurements, I am interested in knowing the observed spatial-temporal structure of meso- and submeso-scale eddies and surface Ekman currents.

- From regional model simulations, I will examine
  - Local impact on the energetics and stability of the current system
  - Influence on the Findlater Jet and the downstream monsoon rainfall

Thanks

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