Effect of Eddy-Wind Interaction on Ekman pumping and Eddy Kinetic Energy in the California Current System: A Regional Coupled Modeling Study

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Surface wind stress

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

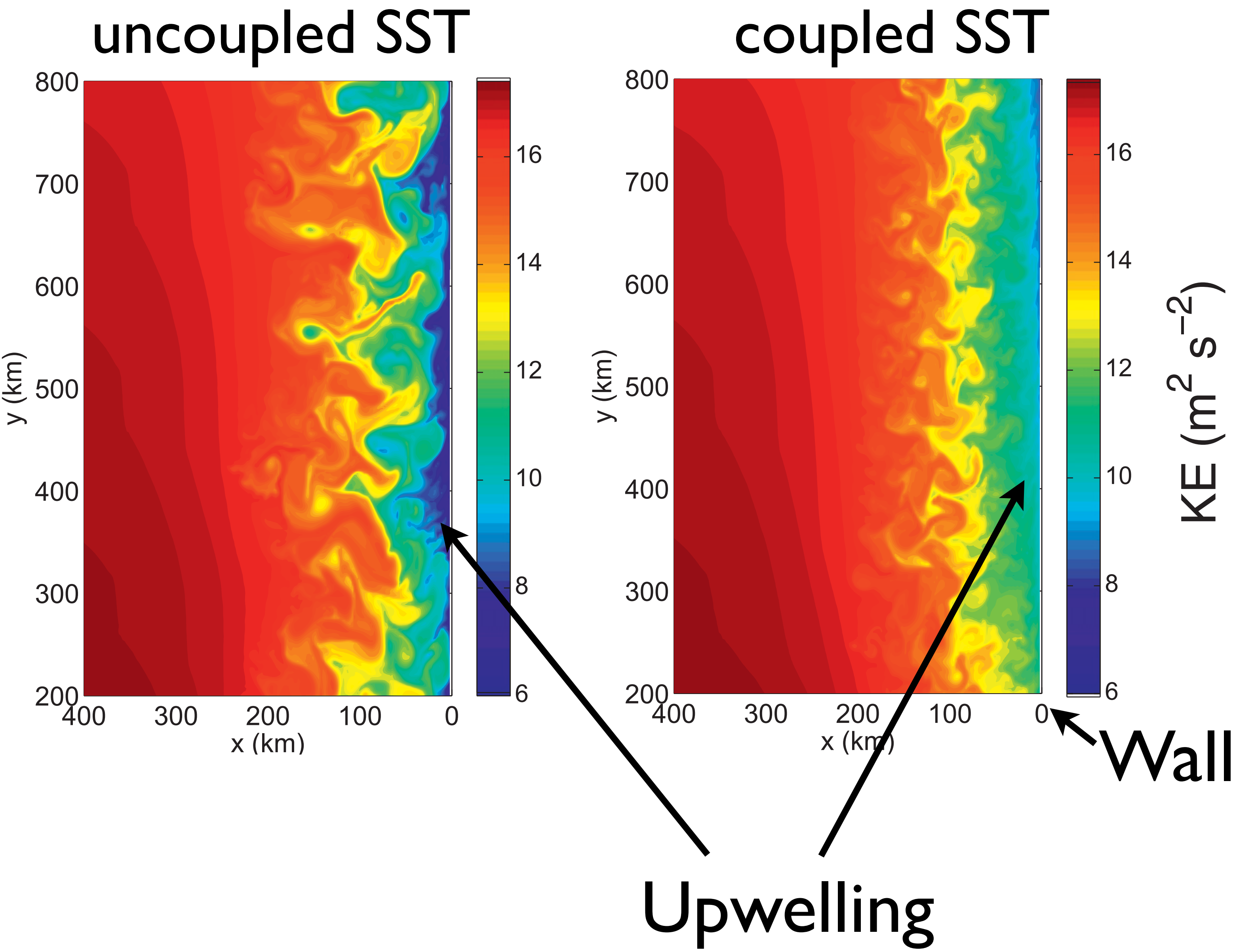
ocean surface current
$U_o = U_{ob} + U_{oe}$

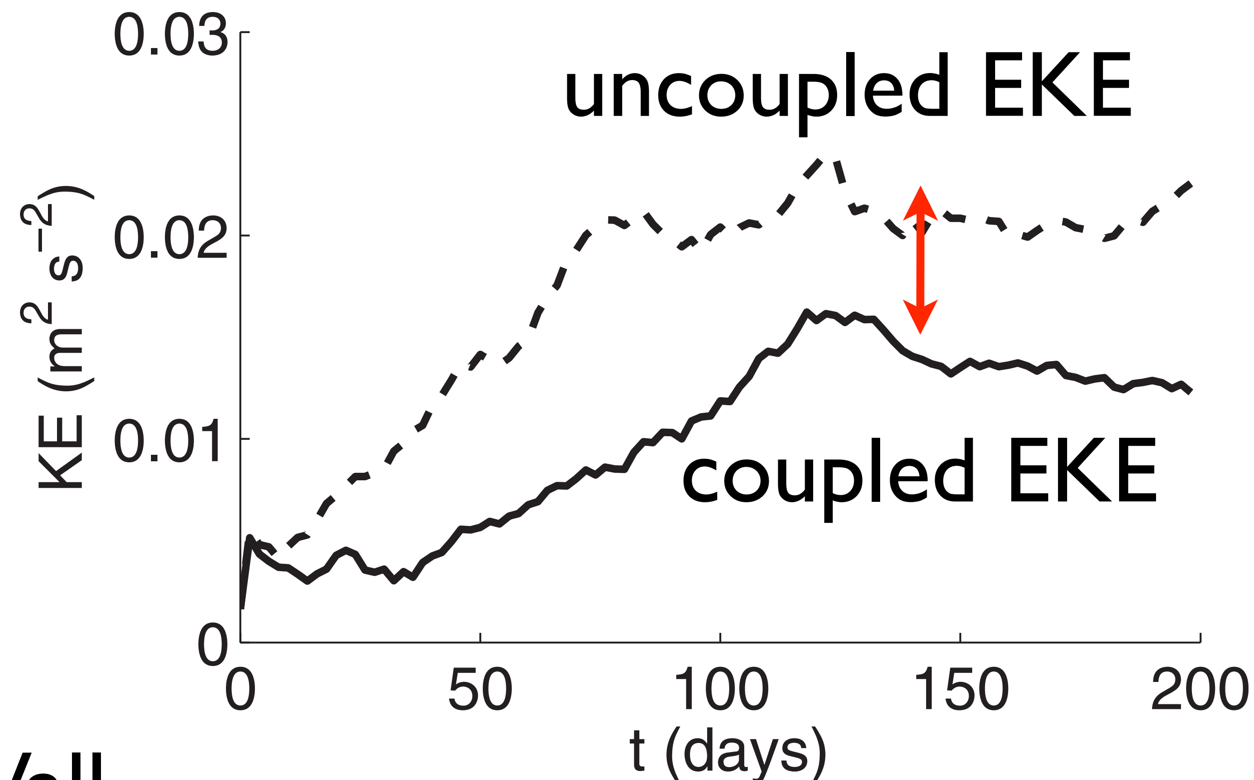
10m wind speed
$U_a = U_{ab} + U_{aSST}$
(Chelton et al. 2001)

resulting wind stress
$\tau \approx \tau_b + \tau_{SST} + \tau_{ob} + \tau_{oe}$

Effects of τ_{SST} and τ_{CUR} on the ocean?

SST-τ coupling effect: *Jin et al. (2009)*
an idealized ocean model with empirical coupling of SST and τ

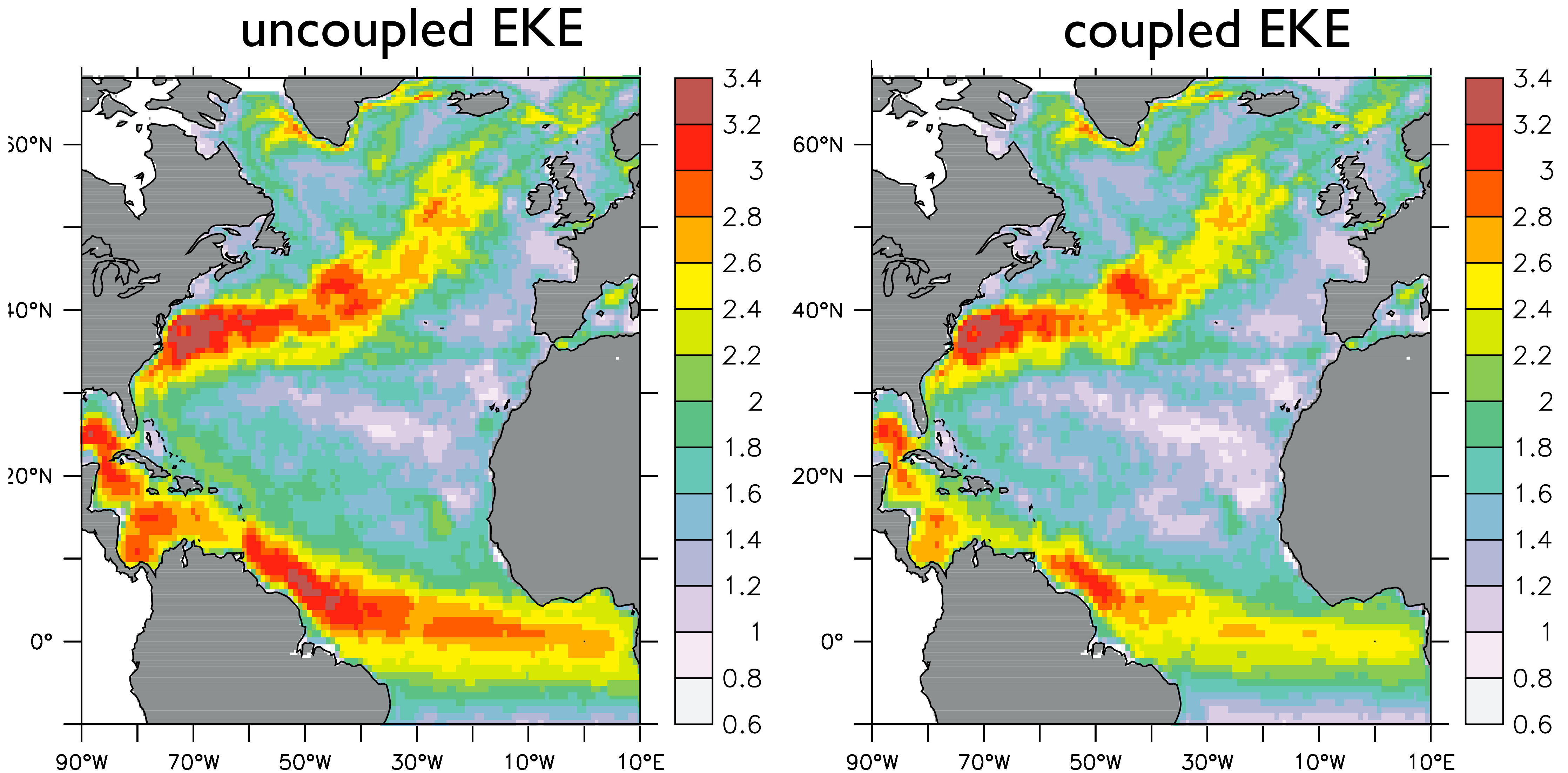




25% reduction of EKE
with SST-τ coupling

- Reduces alongshore wind stress, baroclinic instability and Ekman transport

U_o-τ coupling effect: *Eden and Dietze (2009)*
an OGCM with inclusion of u_{sfc} in τ

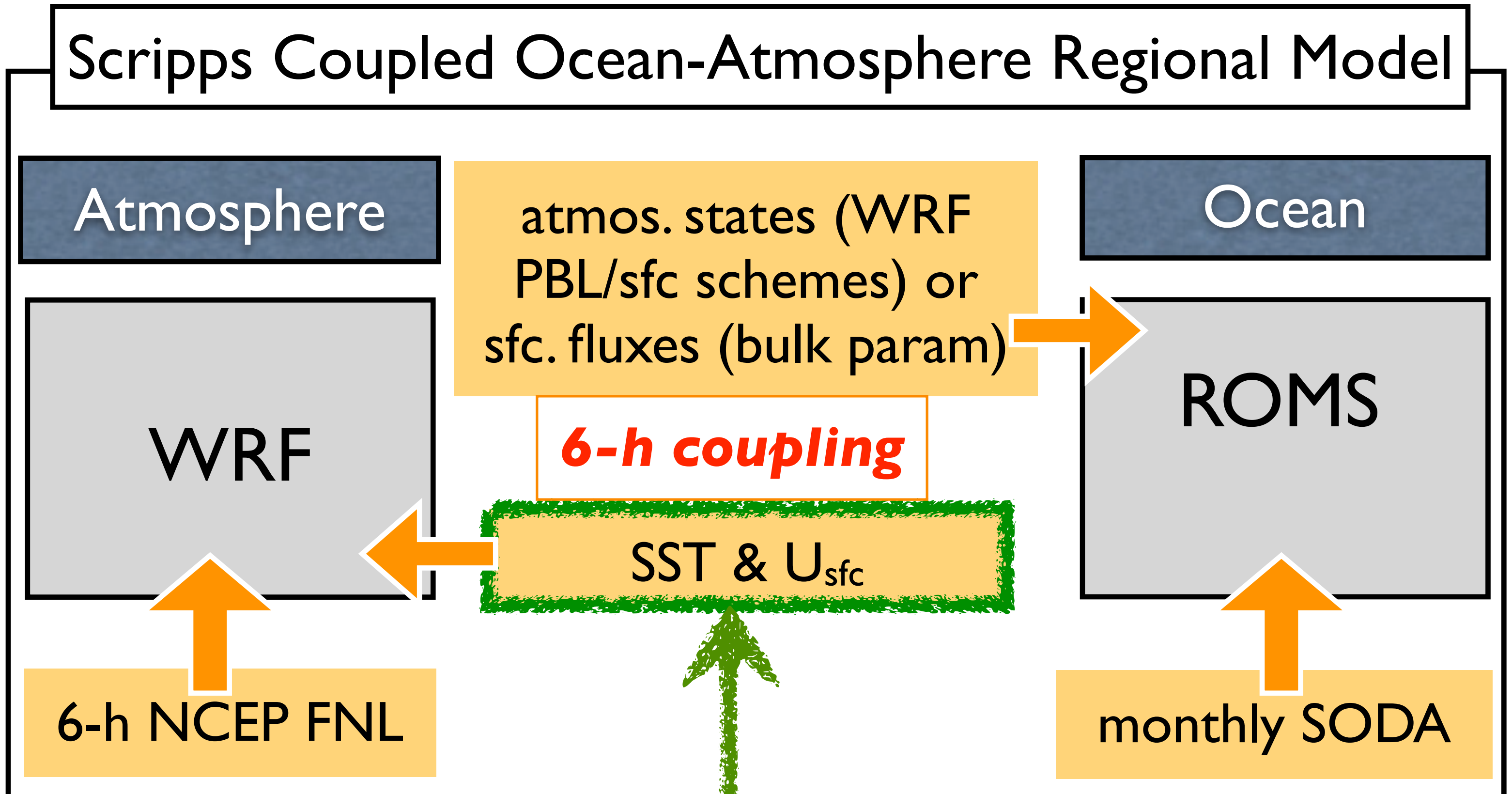


- 10% reduction in EKE in the mid-latitude and ~50% in the tropics
- Primarily due to increased eddy drag ($\tau'\cdot u'$, direct effect)
- Change in baroclinic and barotropic instability (indirect effect) of secondary importance

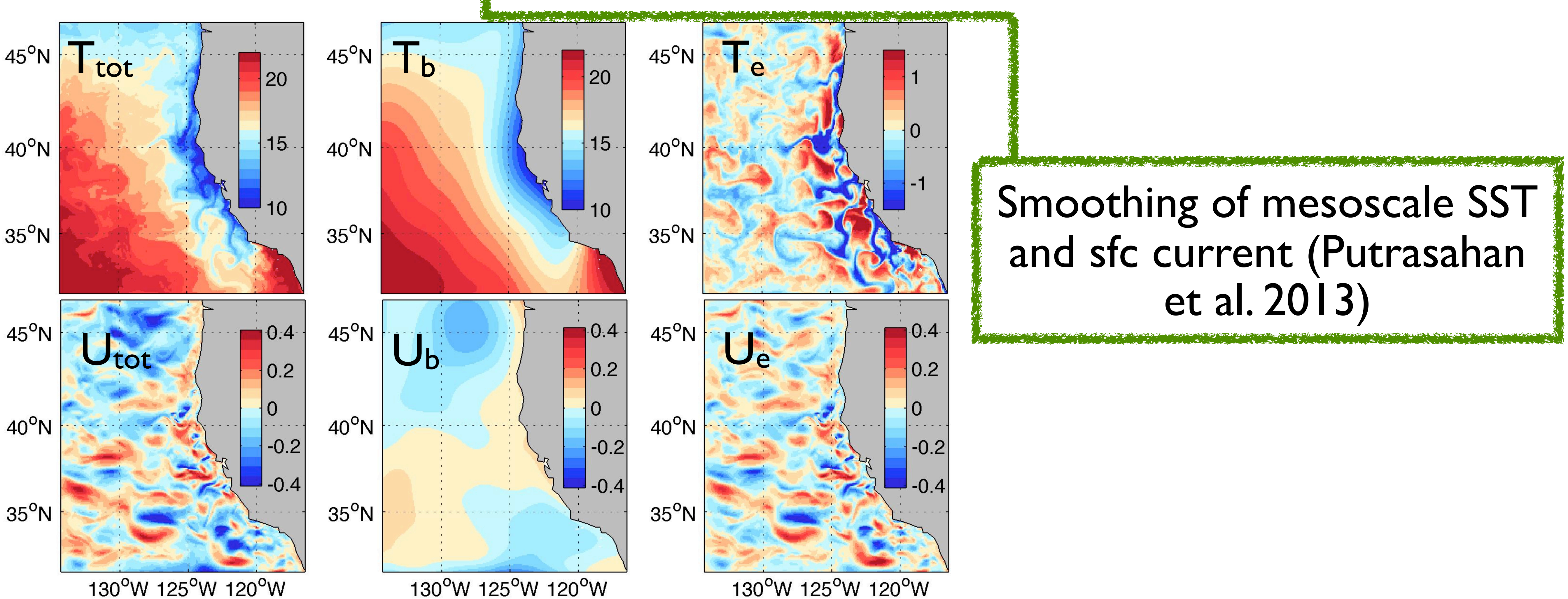
Result from previous studies and goal of this study

- Previous studies considered either SST or u_{sfc} in τ formulation in ocean-only models and saw weakened eddy variability.
- This study examines the relative importance of SST and u_{sfc} (u_{ob} vs u_{oe}) in a fully coupled model, where wind speed adjusts to SST.

Regional coupled model



- Seo et al. 2014 (WRF-ROMS)
- An input-output based coupler; portable, flexible, expandable
- 7 km O-A resolutions & matching mask
- 6-yr integration (2005-2010)



Experiments

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

$T_{tot} = T_b + T_e$

$U_{tot} = U_b + U_e$ 5° loess filtering (≈ 3° boxcar smoothing)

Experiments	τ formulation includes			
CTL	T_b	T_e	U_b	U_e
noT_e	T_b	T_e	U_b	U_e
noU_e	T_b	T_e	U_b	U_e
no$T_e U_e$	T_b	T_e	U_b	U_e
noU_{tot}	T_b	T_e	U_b	U_e

Experiments

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

$T_{tot} = T_b + T_e$

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Experiments	τ formulation includes			
CTL	T_b	T_e	U_b	U_e
noT_e	T_b	T_e	U_b	U_e
noU_e	T_b	T_e	U_b	U_e
noT_eU_e	T_b	T_e	U_b	U_e
noU_{tot}	T_b	T_e	U_b	U_e

effect of mesoscale surface temperature (T_e)

Experiments

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

$T_{tot} = T_b + T_e$

$U_{tot} = U_b + U_e$ 5° loess filtering (≈ 3° boxcar smoothing)

Experiments	τ formulation includes			
CTL	T_b	T_e	U_b	U_e
noT_e	T_b	T_e	U_b	U_e
noU_e	T_b	T_e	U_b	U_e
noT_eU_e	T_b	T_e	U_b	U_e
noU_{tot}	T_b	T_e	U_b	U_e

effect of mesoscale surface current (U_e)

Experiments

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

$T_{tot} = T_b + T_e$

$U_{tot} = U_b + U_e$ 5° loess filtering (≈ 3° boxcar smoothing)

Experiments	τ formulation includes			
CTL	T_b	T_e	U_b	U_e
noT_e	T_b	T_e	U_b	U_e
noU_e	T_b	T_e	U_b	U_e
noT_eU_e	T_b	T_e	U_b	U_e
noU_{tot}	T_b	T_e	U_b	U_e

effect of mesoscale surface temperature (T_e) and current (U_e)

Experiments

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

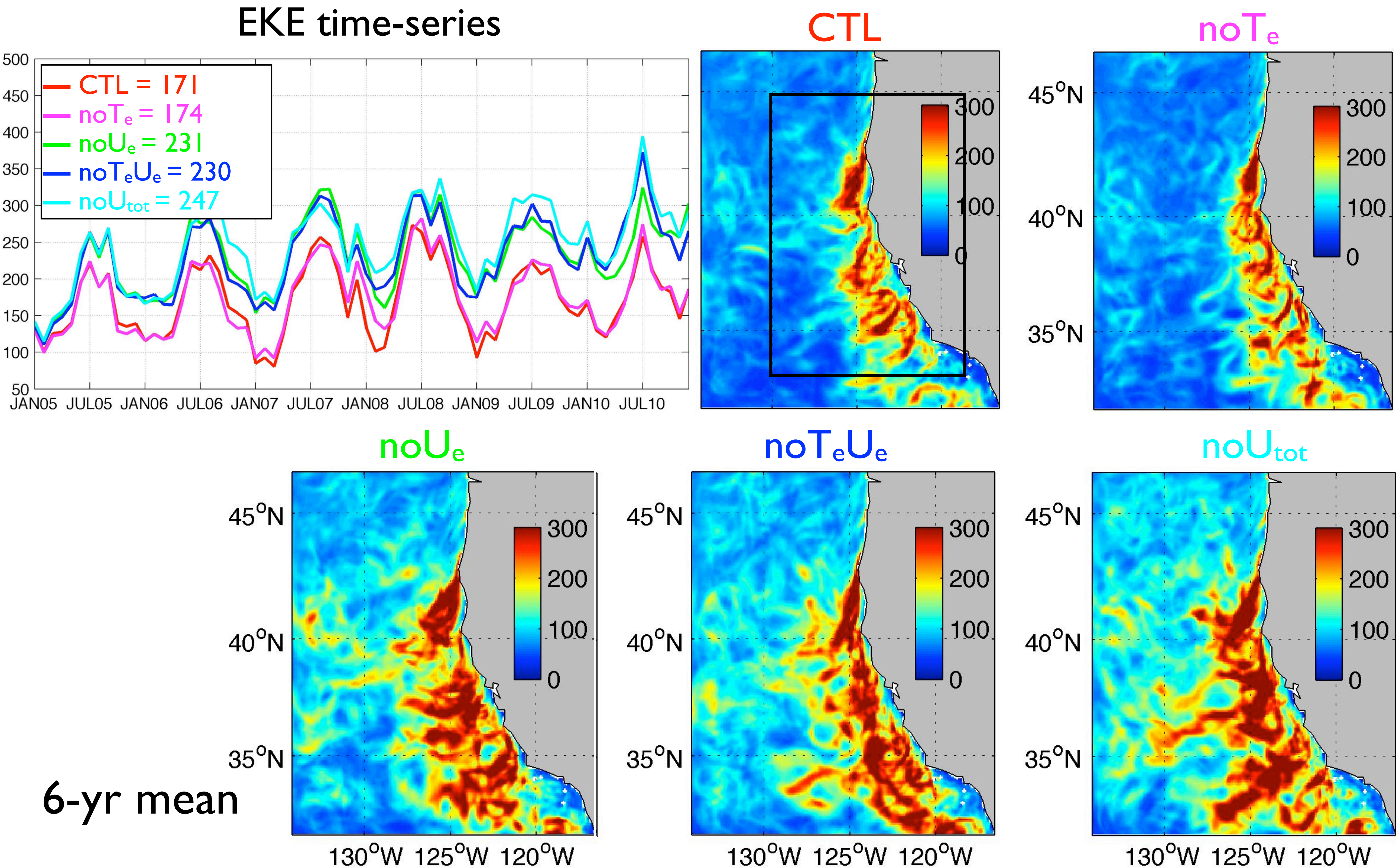
$T_{tot} = T_b + T_e$

$U_{tot} = U_b + U_e$ 5° loess filtering (≈ 3° boxcar smoothing)

Experiments	τ formulation includes			
CTL	T_b	T_e	U_b	U_e
noT_e	T_b	T_e (grayed)	U_b	U_e
noU_e	T_b	T_e	U_b	U_e (grayed)
no$T_e U_e$	T_b	T_e (grayed)	U_b	U_e (grayed)
noU_{tot}	T_b	T_e	U_b (grayed)	U_e (grayed)

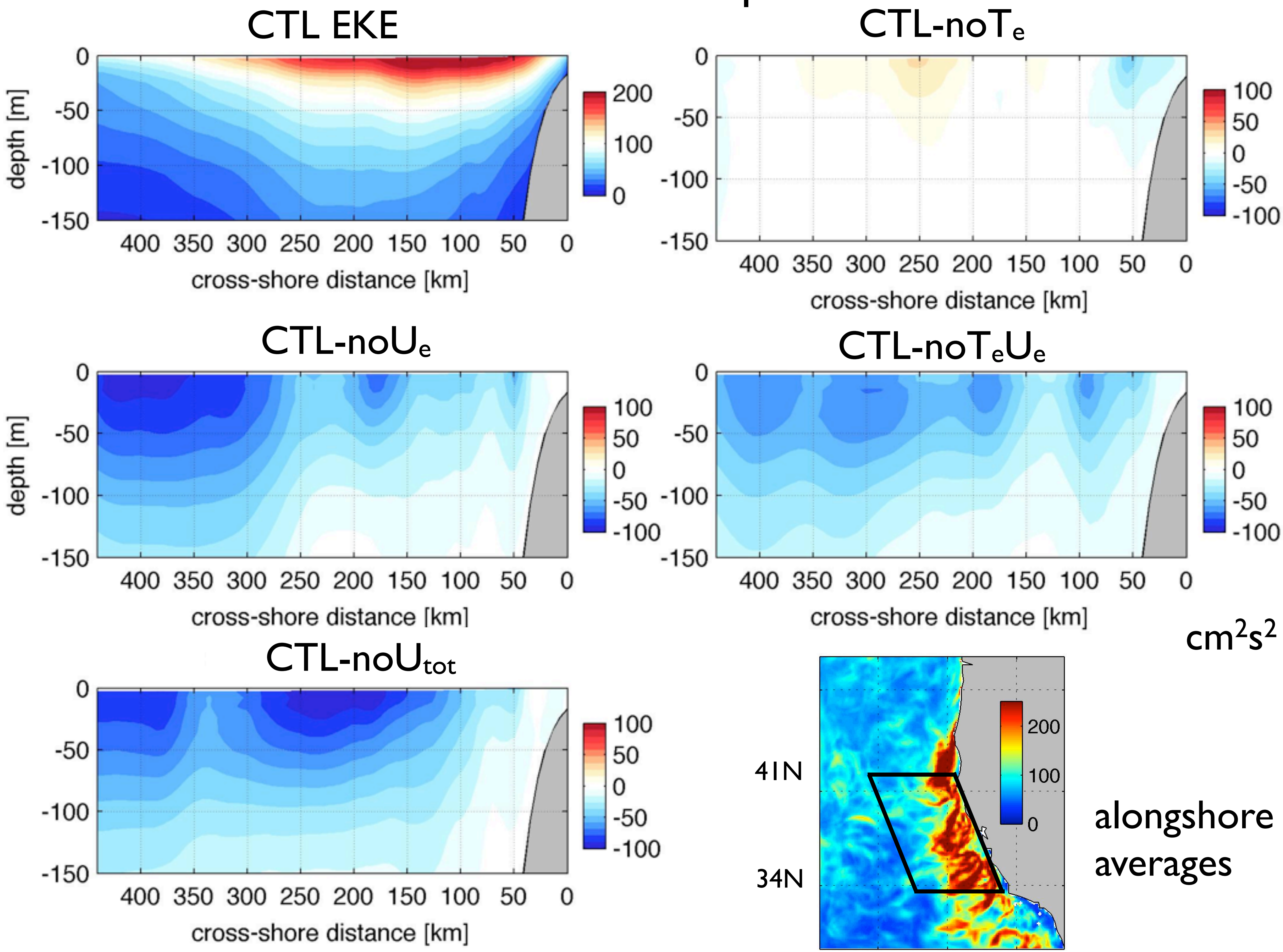
effect of total surface current ($U_{tot}=U_e+U_e$)

Summer surface eddy kinetic energy



• T$_e$ no impact • <u>25% weaker</u> EKE with U$_e$ • <u>30% weaker</u> EKE with U$_b$+U$_e$

Cross-shore vs depth EKE



Eddy kinetic energy budget

$$Ke_t + \vec{U}\cdot\vec{\nabla}\vec{K}e + \vec{u}'\cdot\vec{\nabla}\vec{K}e + \vec{\nabla}\cdot(\vec{u}'p') =$$

$$\underbrace{-g\rho'w'}_{\text{baroclinic conversion (BC)}} + \underbrace{\rho_o(-\vec{u}'\cdot(\vec{u}'\cdot\vec{\nabla}\vec{U}))}_{\text{barotropic conversion (BT)}} + \underbrace{\vec{u}'\cdot\vec{\tau}'}_{\text{wind work (P) (or eddy drag)}} + \varepsilon$$

baroclinic conversion (BC)

barotropic conversion (BT)

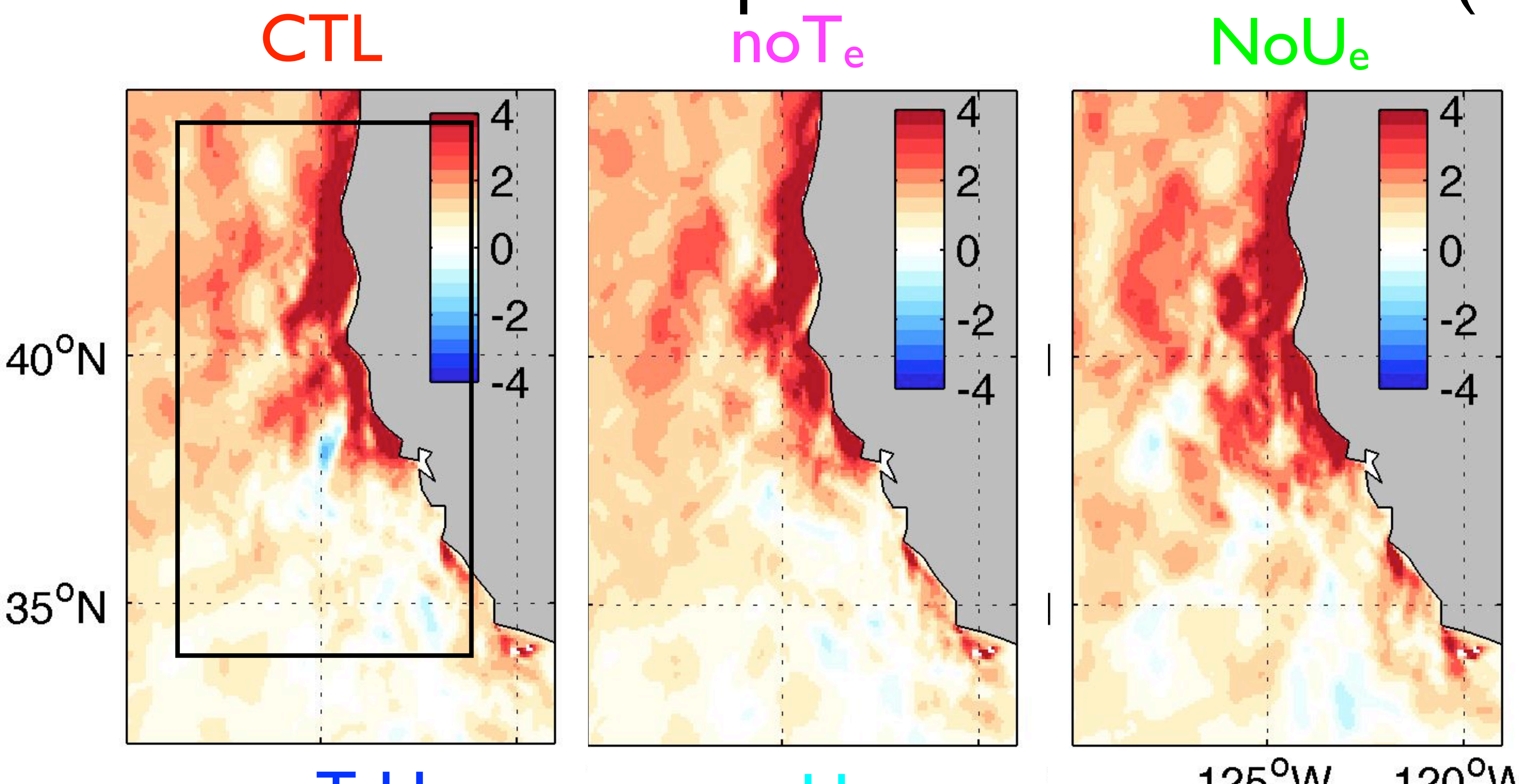
wind work (P) (or eddy drag)

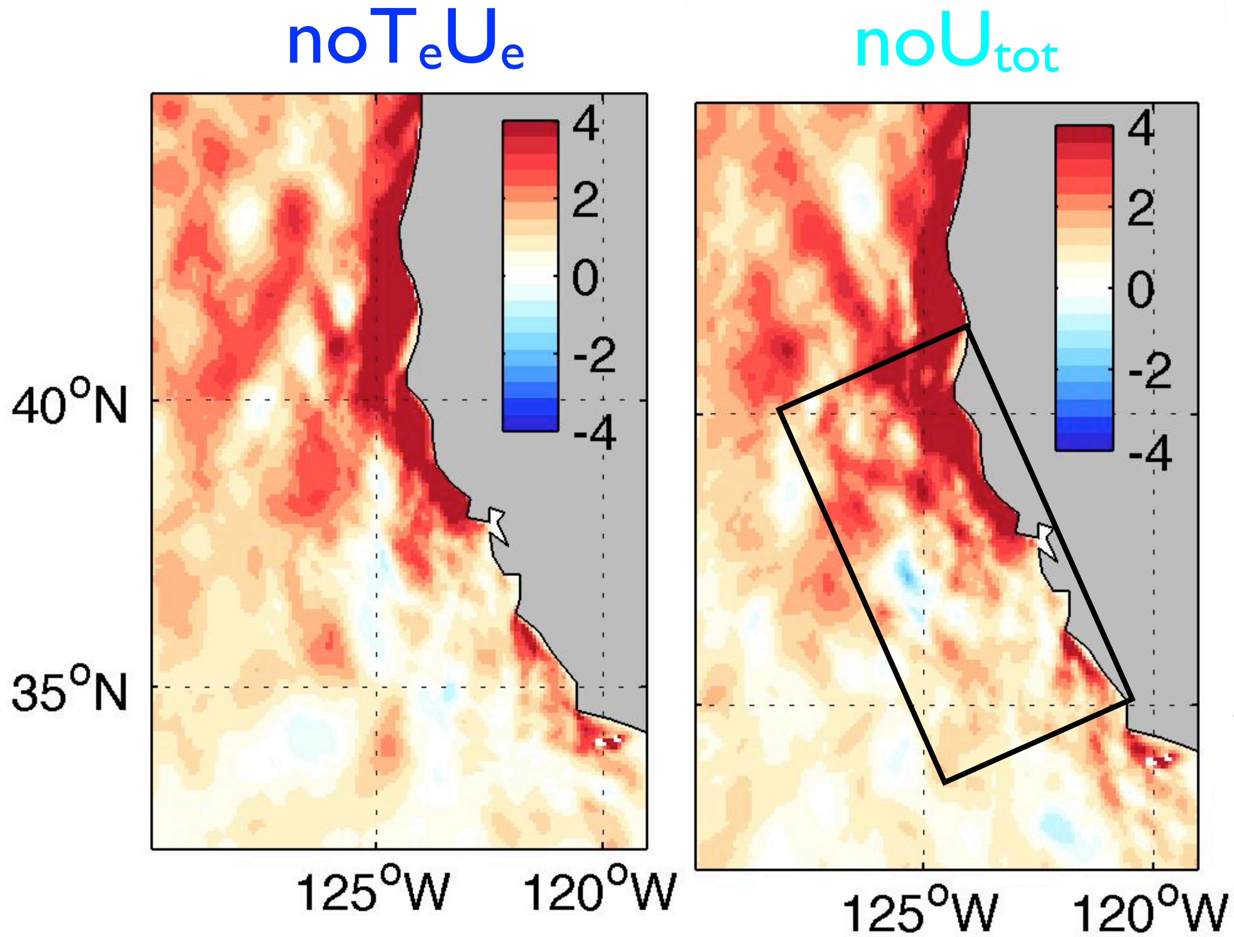
↑ Significant difference in only P

Upper 100 m average

H~fL/N, where $f=10^{-4}$, $L=10^4$m, $N=10^{-2}$ → $H=10^2$m

Comparison of wind work ($P = \tau' \cdot u'$)





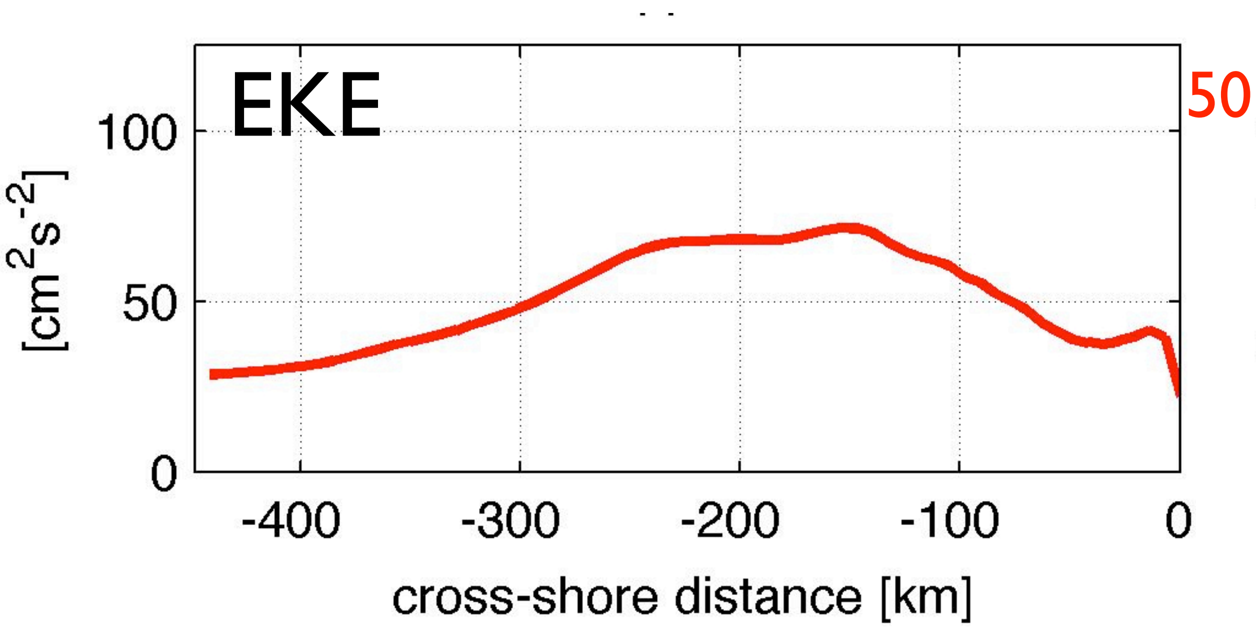
Exp	$\tau' \cdot u'$
CTL	1.33
noT$_e$	1.38
noUe	1.61
noT$_e$U$_e$	1.62
noU$_{tot}$	1.73

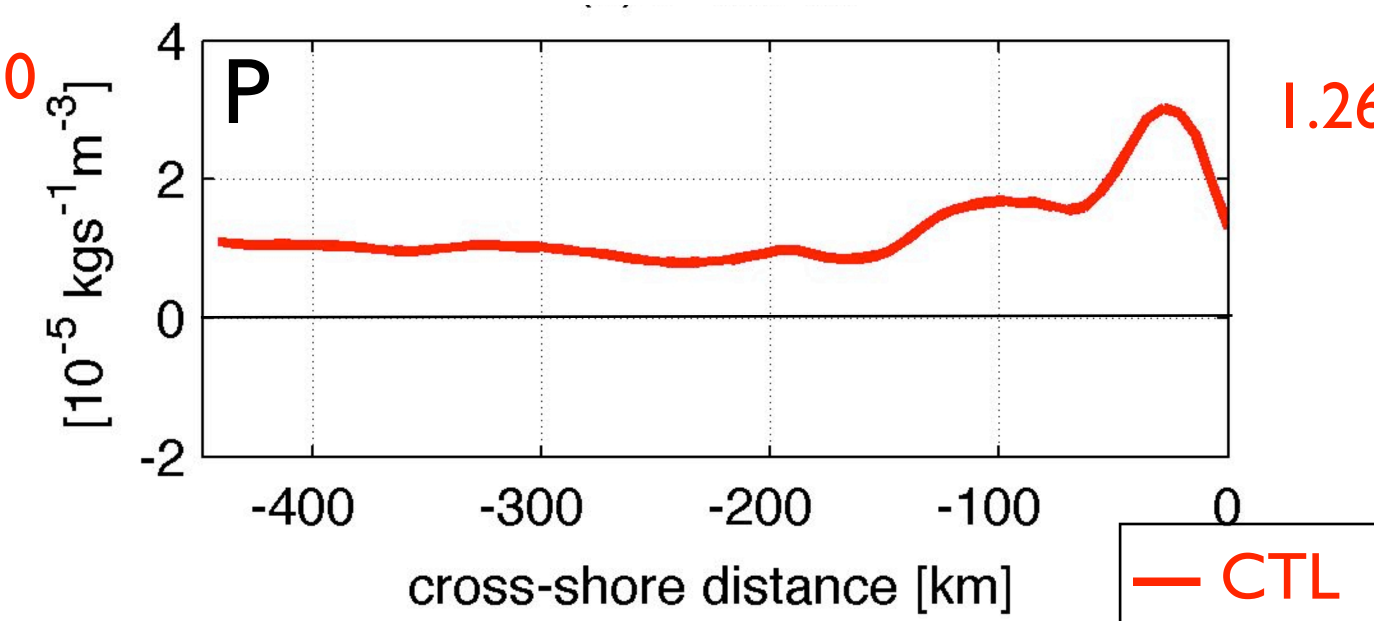
[10^{-5} kgs^{-1}m^{-3}]

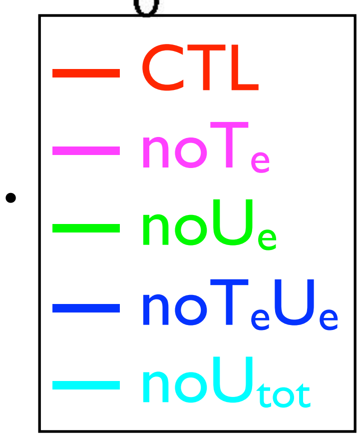
- No significant change associated with T$_e$
- 17% weaker P with U$_e$
- 23% weaker P with U$_b$+U$_e$

alongshore averages

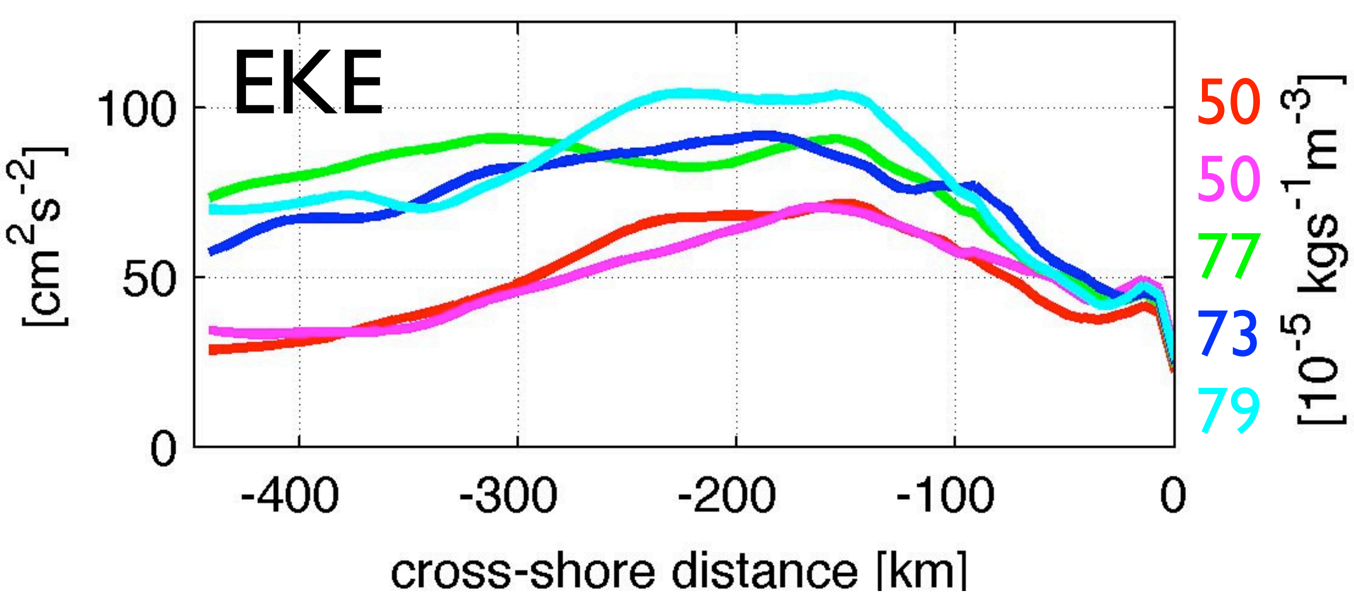
Cross-shore distribution of EKE and P

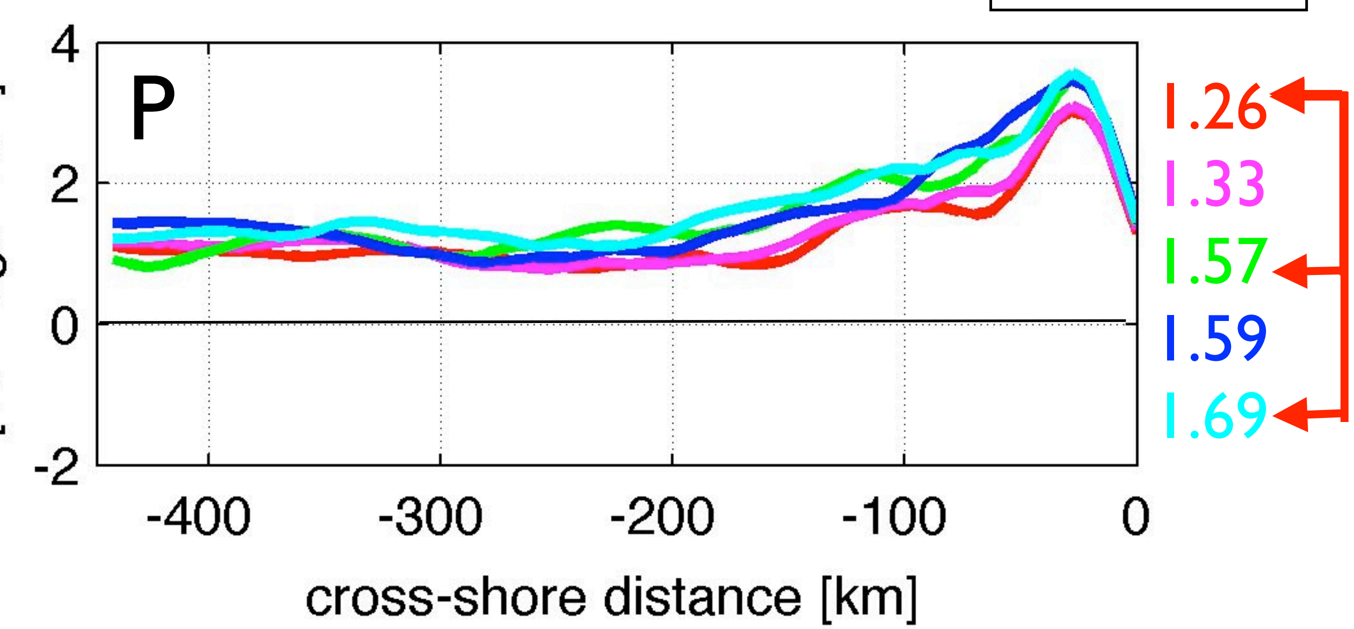






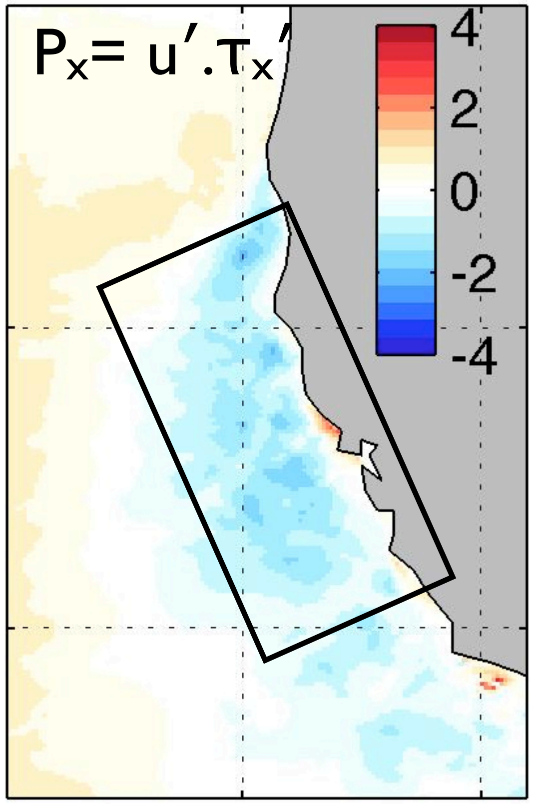
- Positive P ($u'.\tau'$) with the maximum near the coast (20-30 km).
  - v' is a linear response to τ_y', increasing EKE.

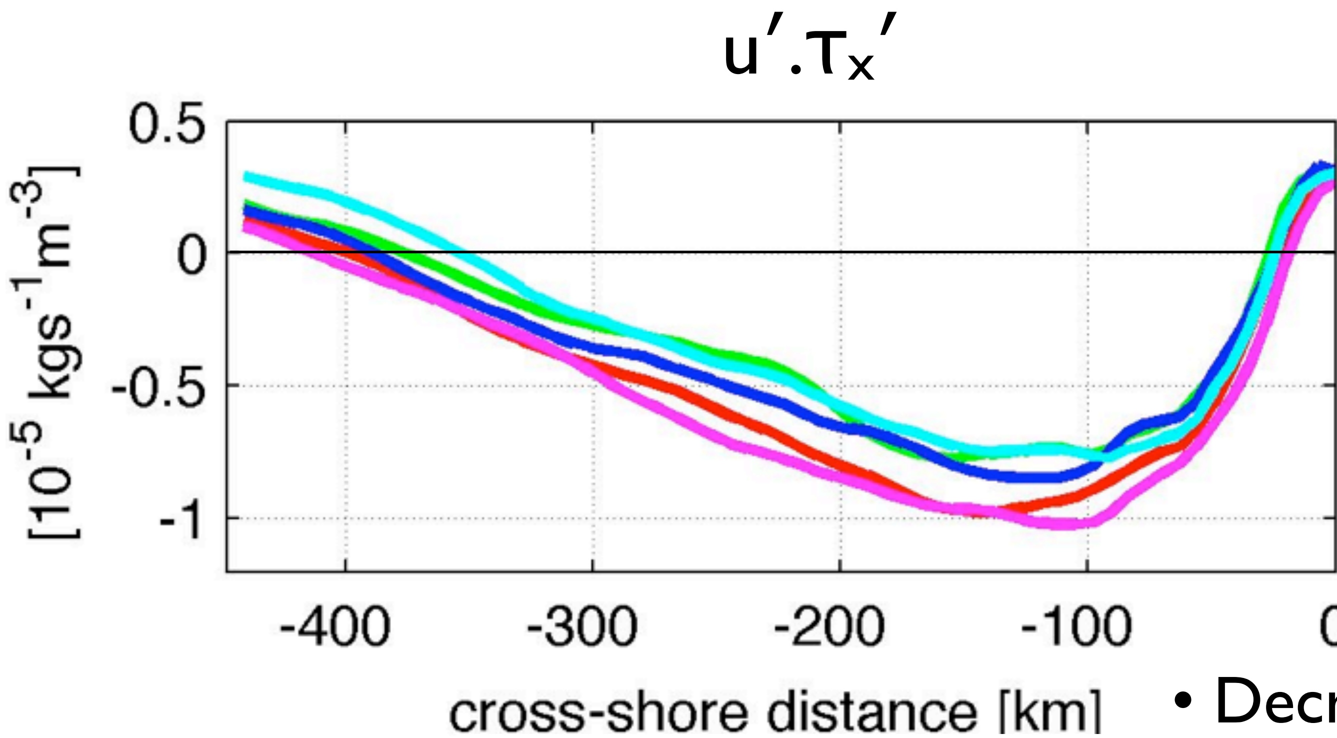




- P decreases by 20-25% 100-300 km offshore with U_e+U_b

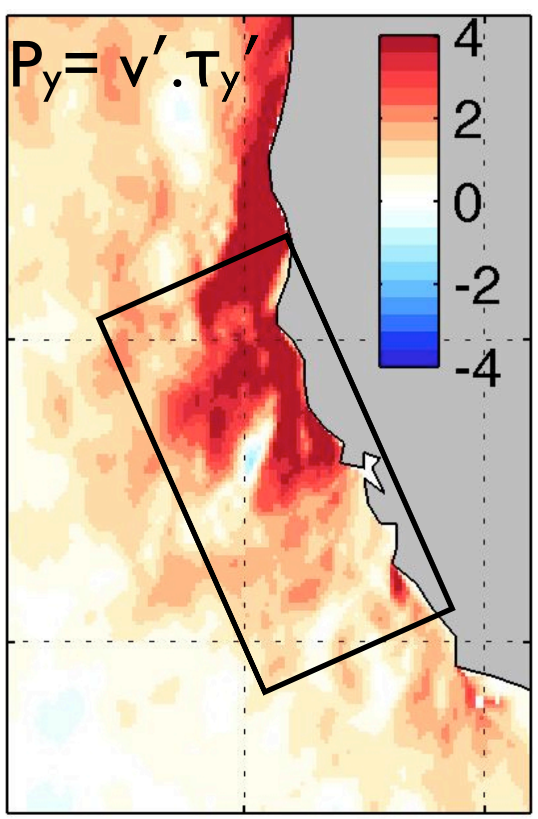
Zonal and meridional components of wind work

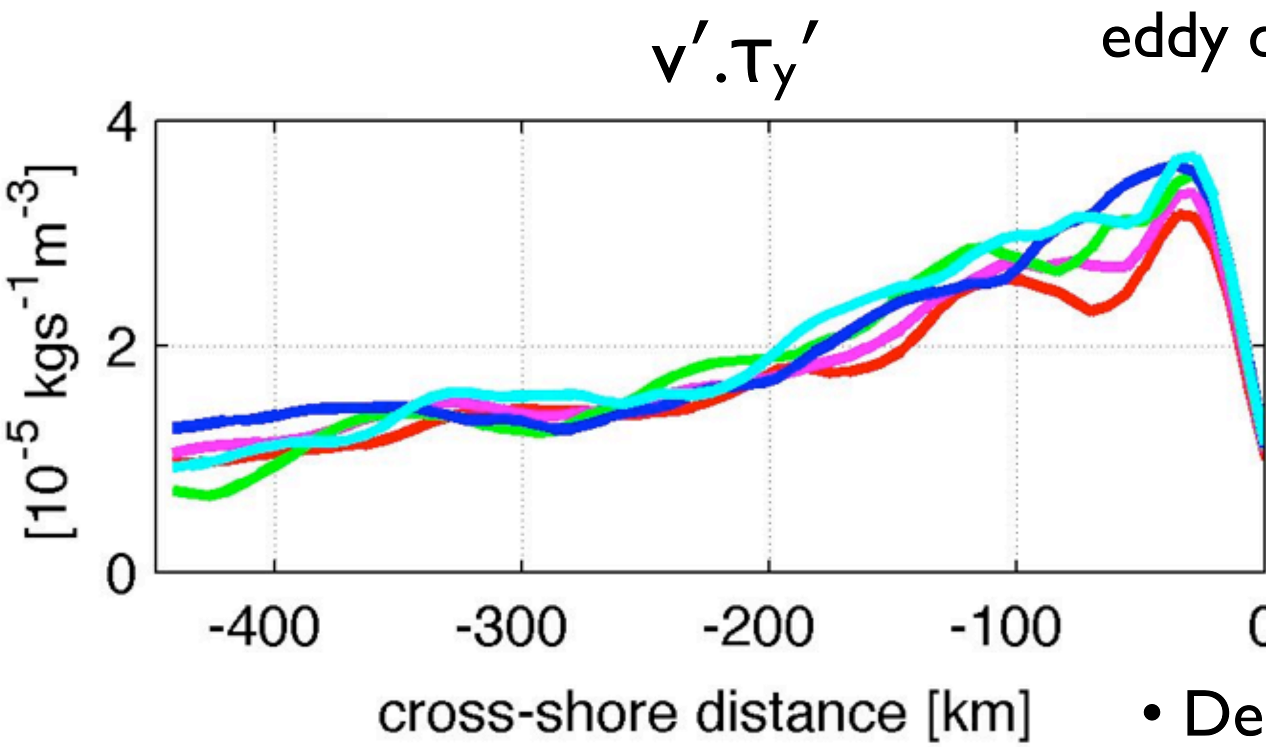




CTL=−0.47
noT$_e$=−0.53
noU$_e$=−0.33
noT$_e$U$_e$=−0.38
noU$_{tot}$=−0.31

- Decrease in P (or increase in eddy drag) by u′.τ$_x$′ is -0.14



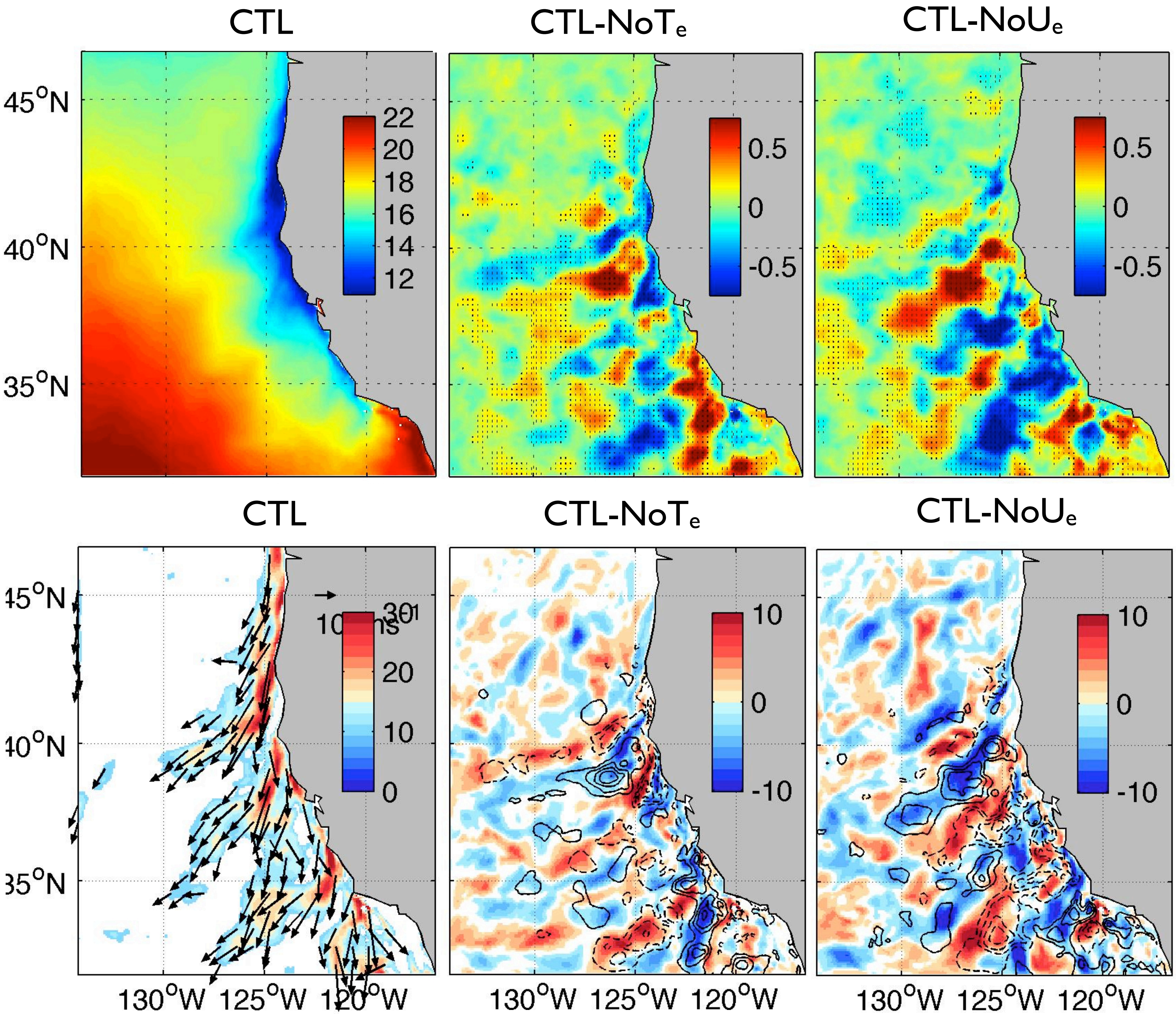


CTL=1.74
noT$_e$=1.86
noU$_e$=1.90
noT$_e$U$_e$=1.97
noU$_{tot}$=2.0

- Decrease in P by v′.τ$_y$′is -0.16

Both directions contribute equally to the decreased P and EKE.

Change SST and surface current



Change in offshore (onshore) temperature advection by mean current mainly responsible for the cold (warm) SST

Summary

- Examined the *relative* importance of τ_{SST} vs $\tau_{current}$ in the EKE in the CCS using a fully coupled SCOAR model.

- Surface EKE is weakened by ~25% due to mesoscale current.
  - ~5% further weakening by background current.
  - SST has no impact.

- EKE budget analysis: wind work ($P = \tau' \cdot u'$) is weakened with the mesoscale current (17%) and background current (23%)
  - SST has no impact.
  - Comparable contribution from zonal (eddy drag) and meridional (wind work) direction.

- Change in SST pattern is related to change in mean and eddy horizontal temperature advection.

Thanks!