Wind drift and air-sea coupling in simulations of the northern California Current System

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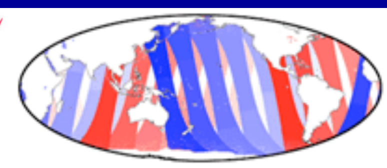


Coupled ocean-atmosphere simulations

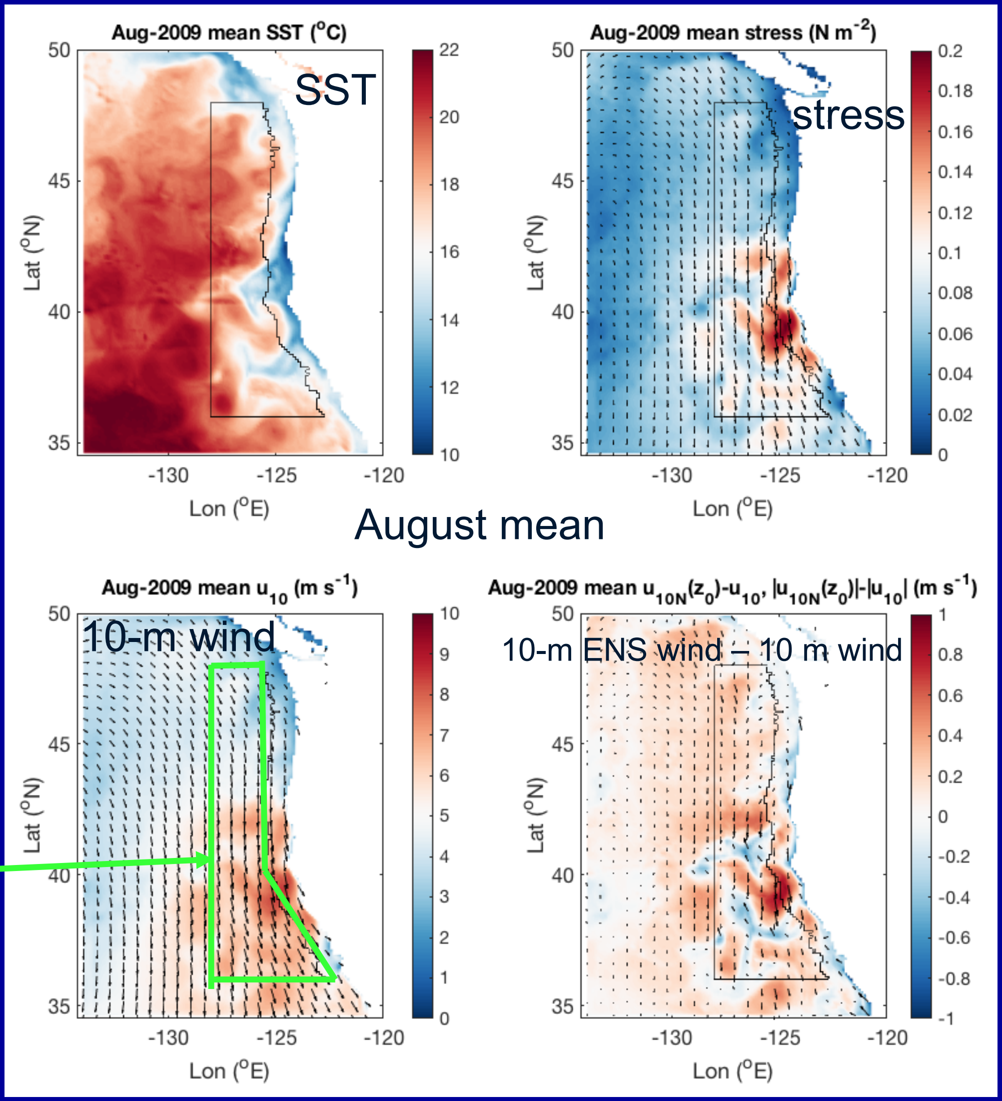
WRF atmosphere (12 km)
ROMS ocean (2 km)
COAWST coupled framework

Ocean simulation initialized from interpolated HYCOM analysis in October 2008; coupled model simulation begins 7 March 2009.

Analysis period: Jun – Sep 2009.

Five different WRF PBL schemes:
YSU, GBM, UW, MYJ, MYNN2

Coupling coefficients computed for northern CCS region
for anomalies of monthly means from seasonal (JJAS) means



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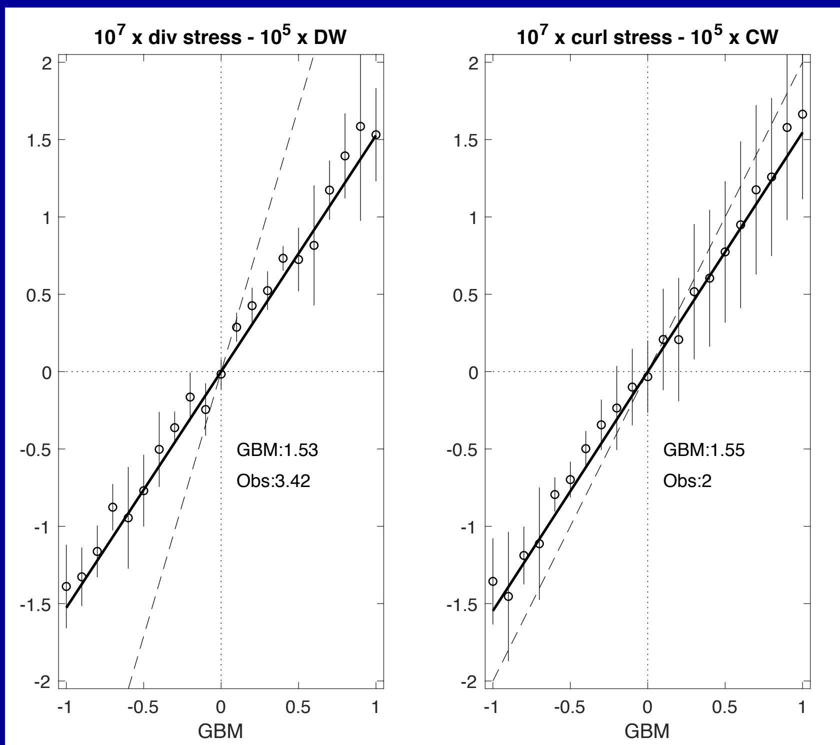
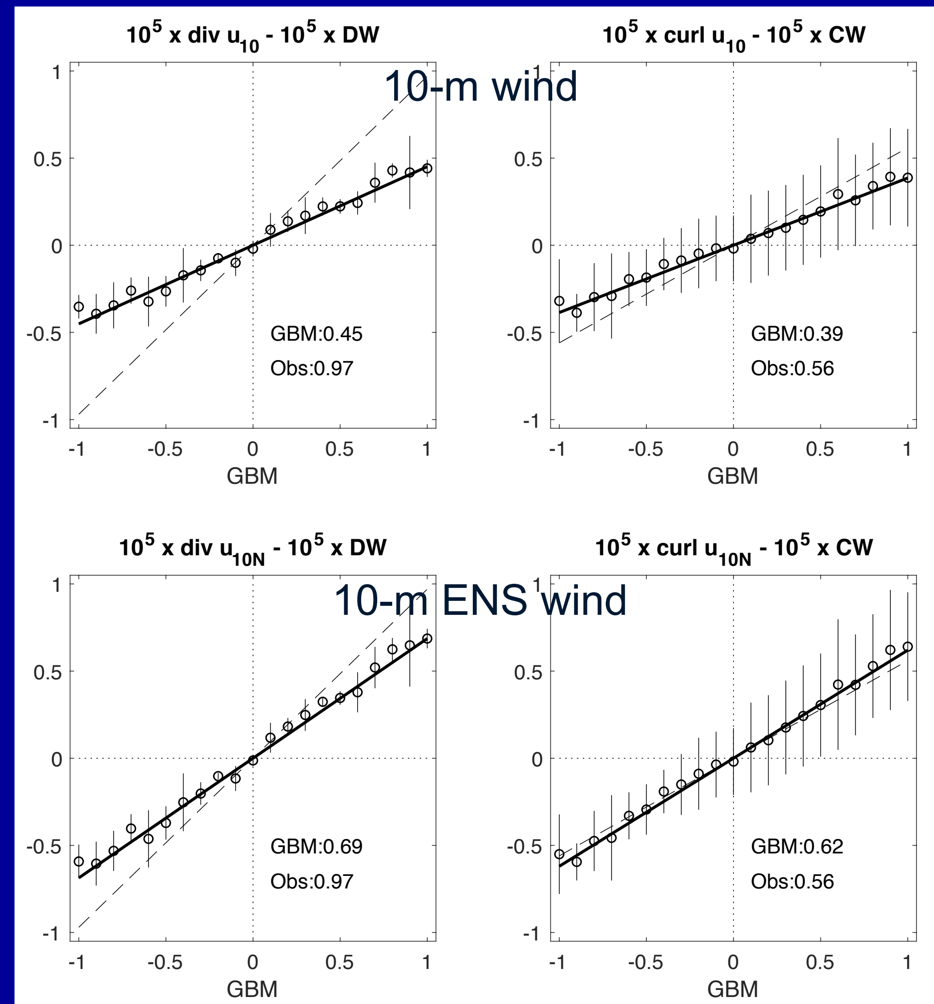
Coupling coefficients (divergence and curl)

SST-stress

div τ vs. DWSST   curl τ vs. CWSST



div u vs. DWSST   curl u vs. CWSST



Coupling coefficients (divergence and curl)

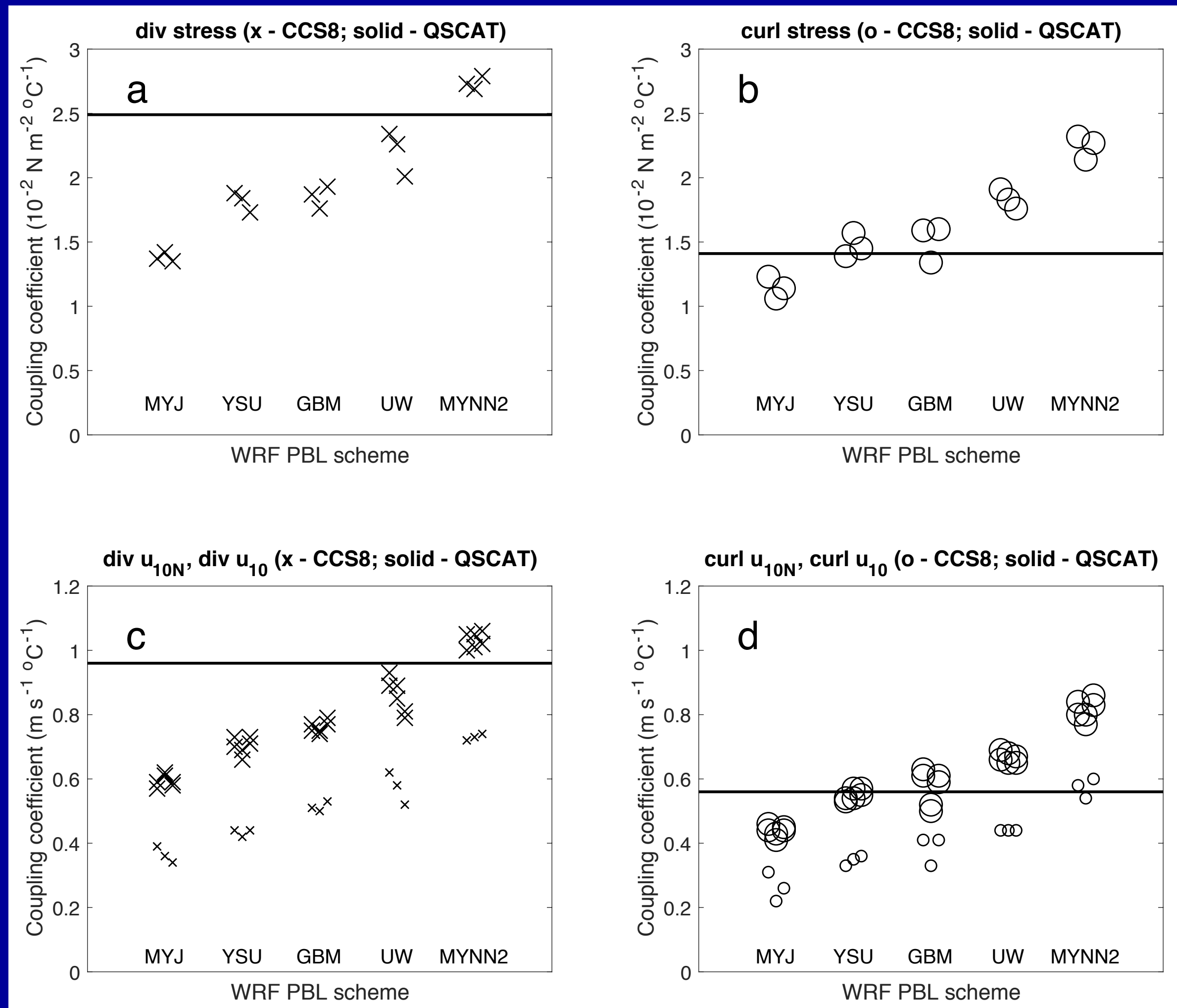
div vs. DWSST

curl vs. CWSST

stress

10-m ENS wind

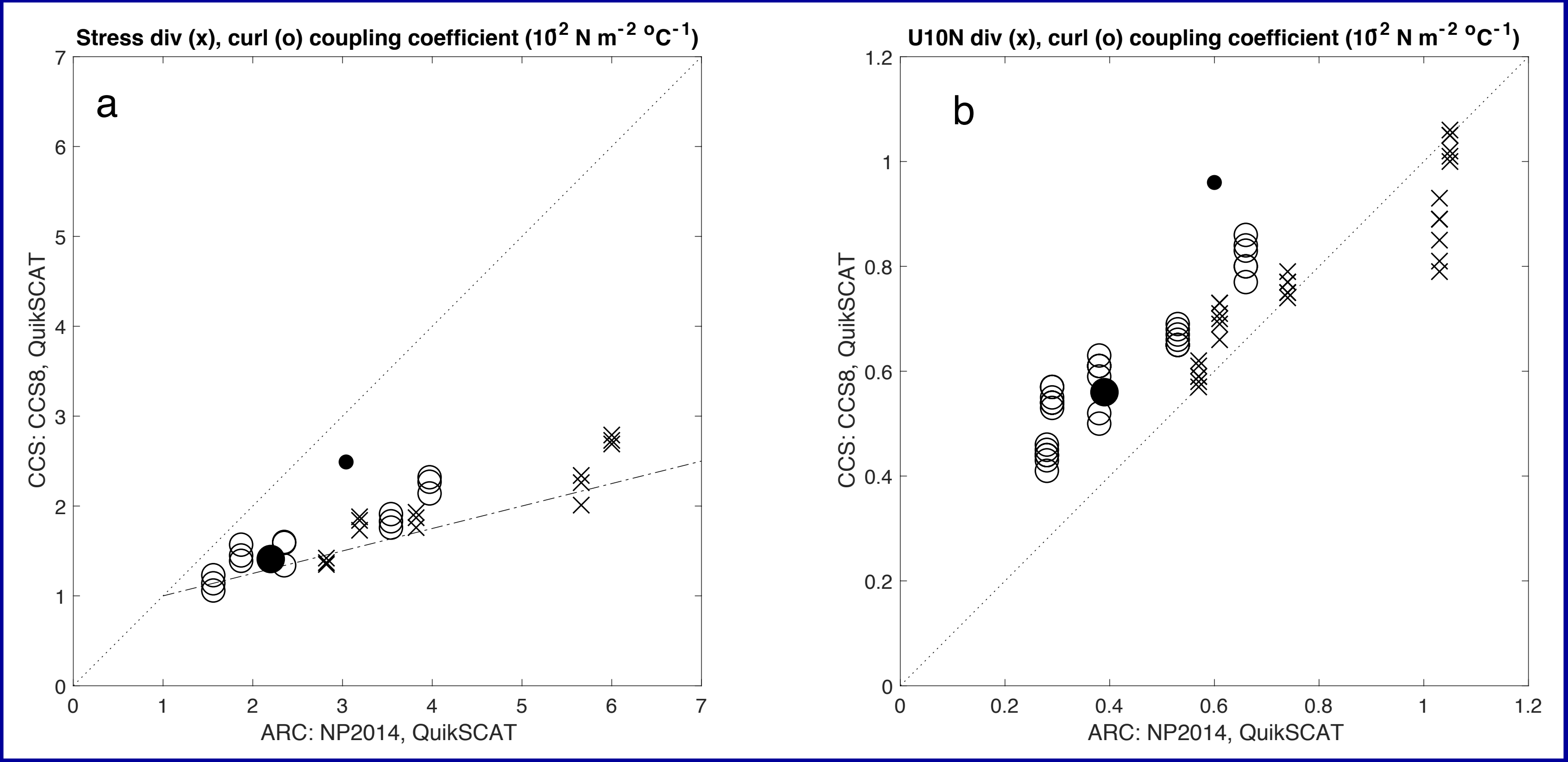
10-m wind



Coupling coefficients (divergence and curl)

stress | div vs. DWSST (x) curl vs. CWSST (o) | 10-m ENS wind

CCS



Agulhas Return Current (Perlin et al. 2014)

Stronger ARC mean winds → stronger heat flux anomaly → stronger coupling?

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Model wind coupling coefficients vs. height

Div u

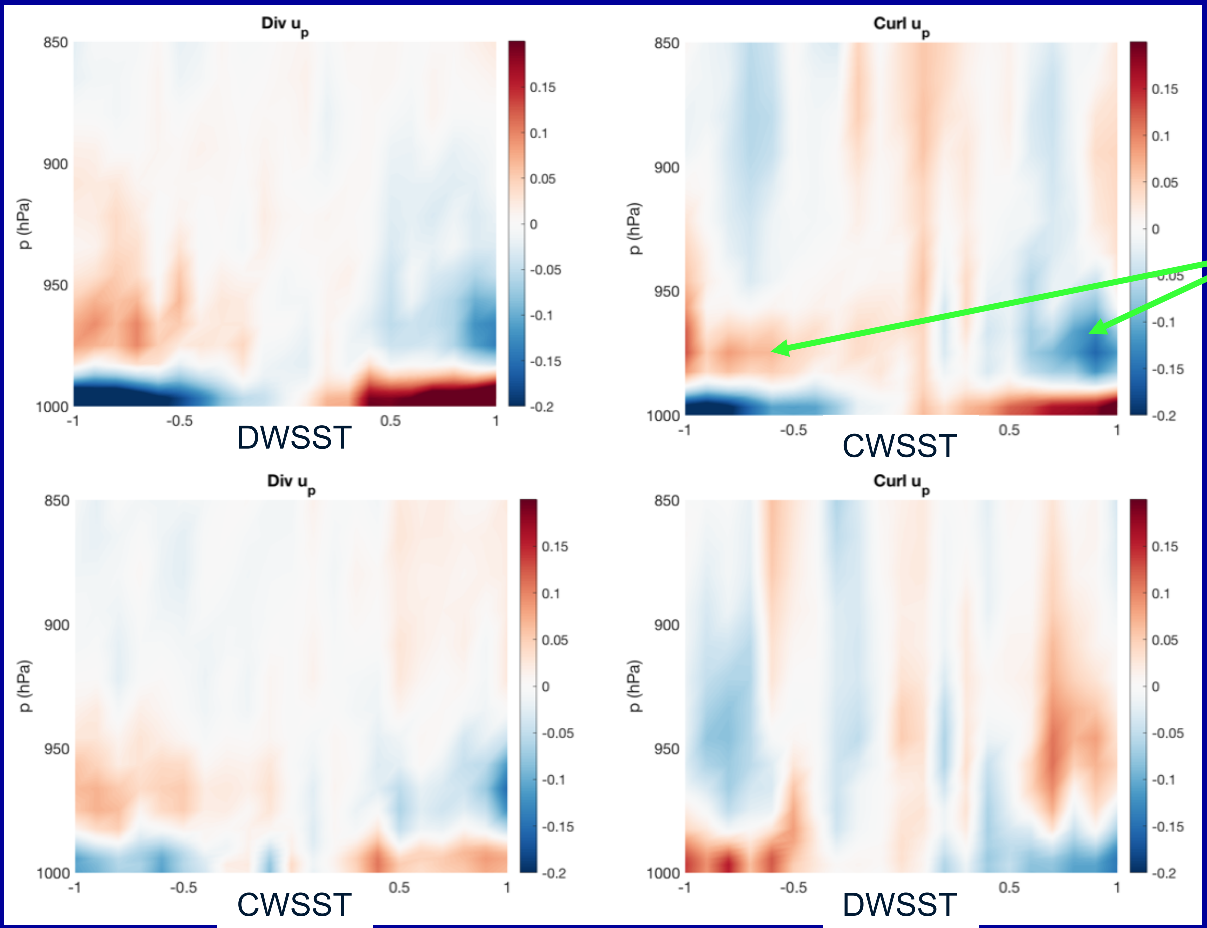
curl u (vorticity)

1500 m

pressure
(height)

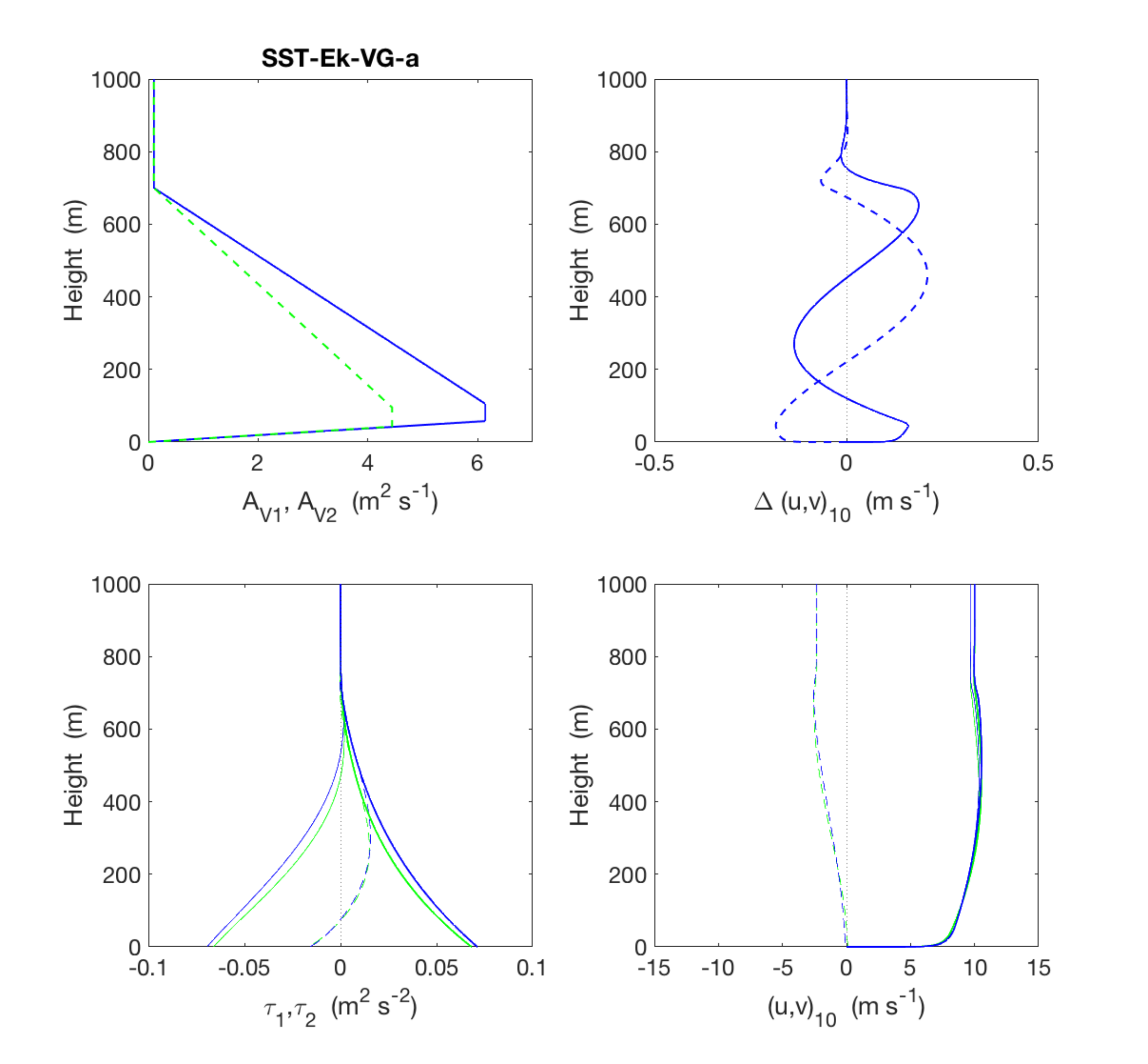
1500 m

pressure
(height)

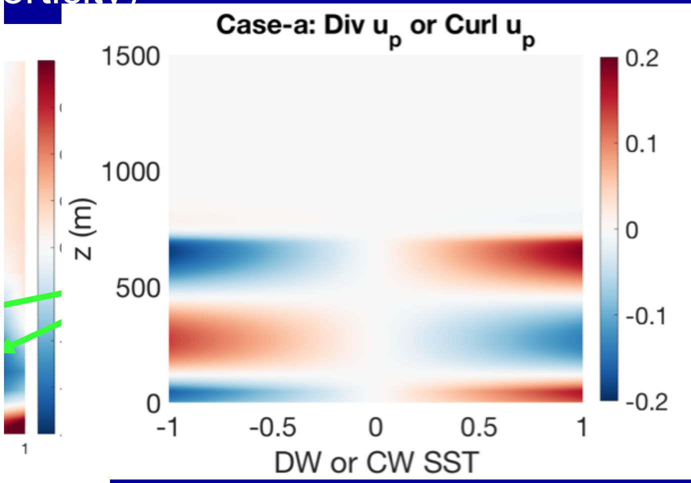


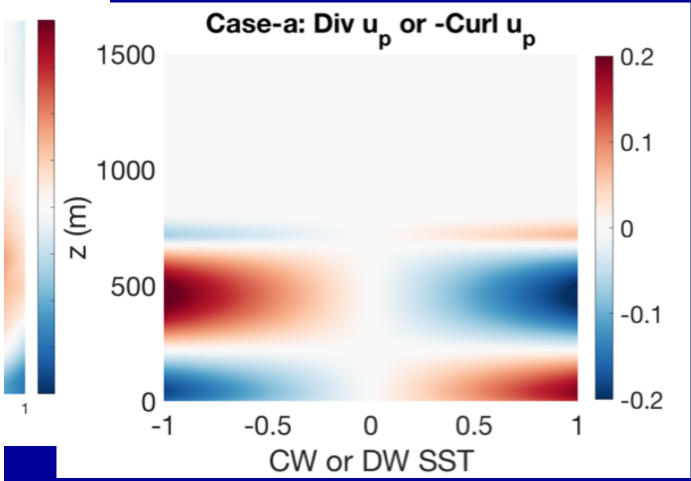
mid-level
reversal

Coupling coefficients vs. height – log-Ekman model



orticity)





Surface current coupling

The wind stress should (does; see e.g., Edson et al. 2013) depend on the difference between surface wind and surface current…

…so compute stress based on relative wind, the difference of 10-m wind and ocean surface current.

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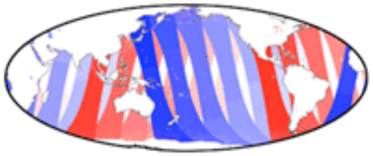
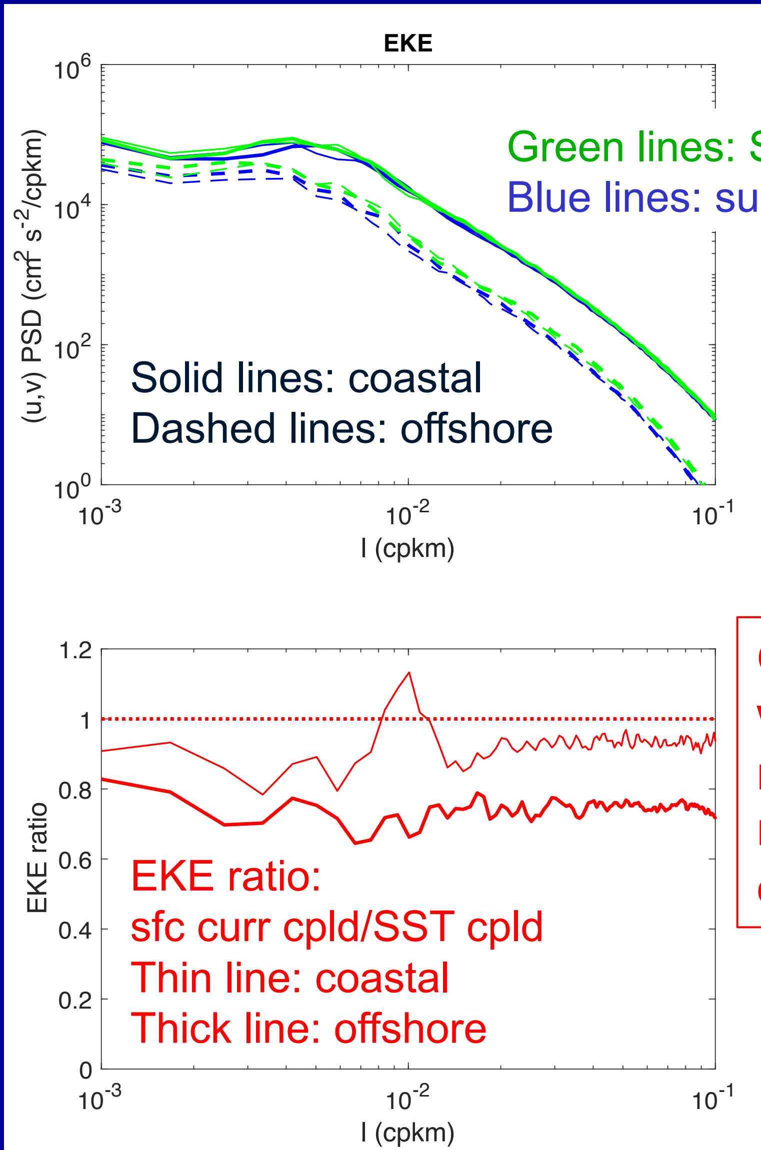


Surface current coupling – CCS model



Green lines: SST coupled
Blue lines: surface current (and SST) coupled

Offshore decay of EKE enhanced with surface current coupling, likely related to systematic damping of mesoscale eddies from relative wind effect (e.g., Gaube et al., 2015)

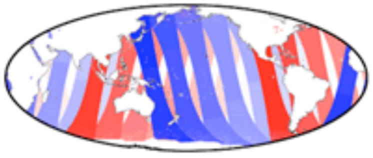
Surface current coupling

The wind stress should (does; see e.g., Edson et al. 2013) depend on the difference between surface wind and surface current…

…but, what is this surface current?

That is, what is the relevant surface current in the context of momentum coupling to the atmosphere?

The ocean surface current includes the wind drift…but the wind drift depends on the wind (or wind stress)….



Wind drift at sea surface

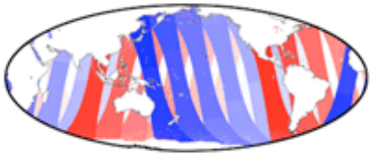
The oil-spill rule: “3% of the wind speed, 15 degrees to the right (NH) of the wind.”

- J. Weber, JPO, 1983.
- J. O’Brien, NATO ASI, 1985.
- J. Wu, JFM, 1975.

New analytical result based only on universality and symmetry arguments (Samelson, JPO, submitted):

$$\bar{\mathbf{U}}_*(0) = \frac{\alpha}{1+\alpha}(\mathbf{V}_{*G} - \mathbf{U}_{*G}) \approx \alpha\,\mathbf{V}_{*G}, \quad \alpha = \frac{u_*}{v_*} = \left(\frac{\rho_a}{\rho_o}\right)^{1/2}$$

For ρ_a = 1.25 kg m^{-3} and ρ_o = 1025 kg m^{-3}, α ≈ 0.035 (3.5%). The directional offset arises from the rotation of the 10-m wind relative to the geostrophic wind.



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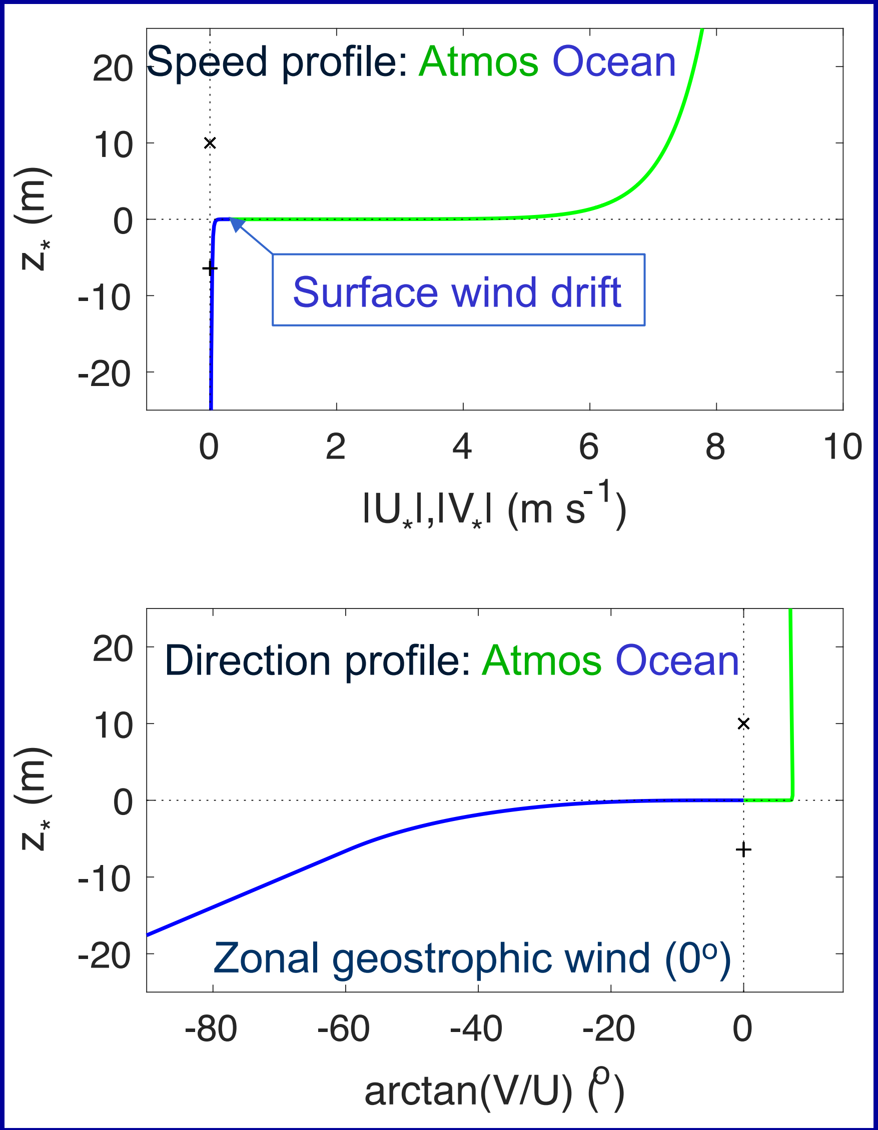
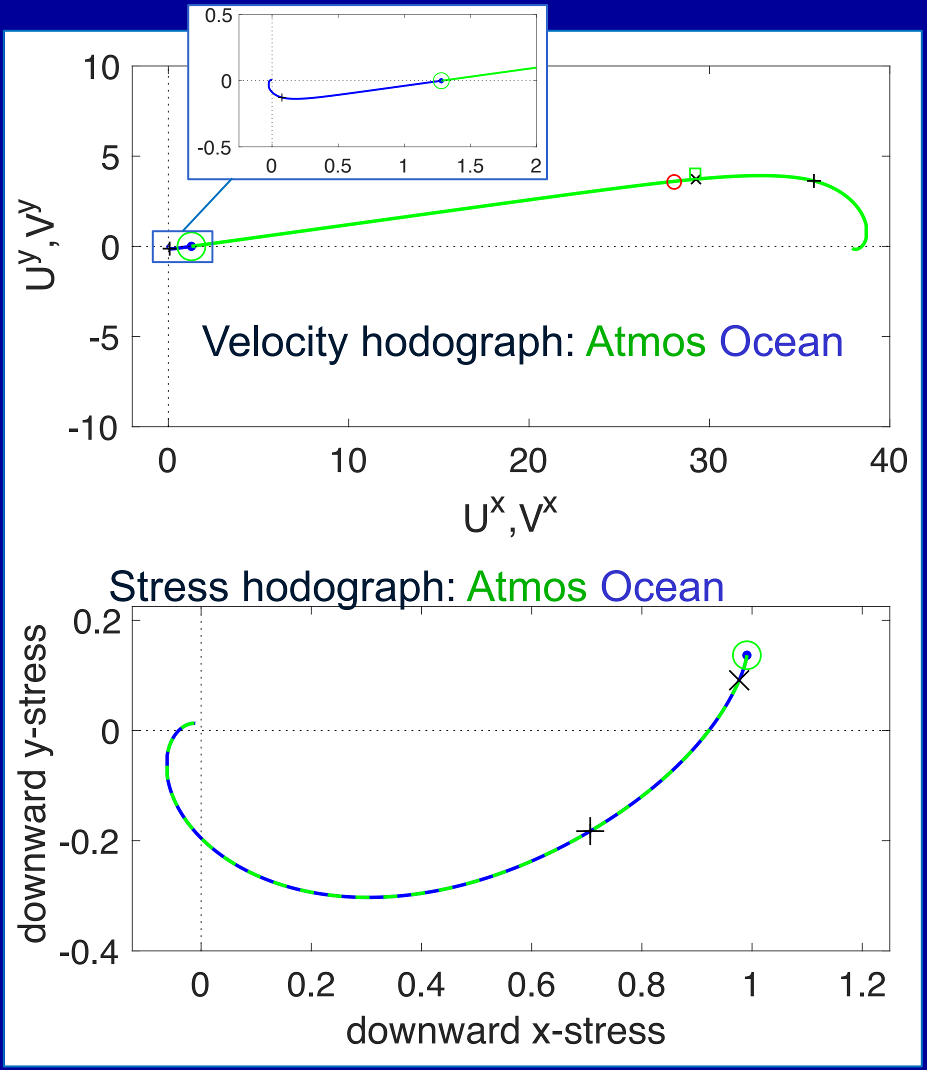
Wind drift – double log-Ekman layer





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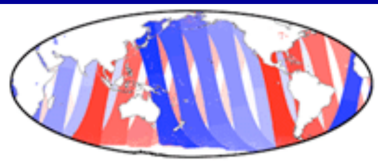
Surface current coupling

Oil-spill rule: 3% of 7 m s^{-1} = 21 cm s^{-1}
This is comparable to typical mesoscale surface geostrophic currents, so the effect (question) cannot be ignored.

Edson et al. 2013:

"When C_{DN} is computed using relative wind, the data collapse to a consistent fit that is independent of surface current speed…Although more subtle, [there is a] systematic reduction of the relative wind speeds resulting from wind-driven currents, which act to increase C_{DN}…."



Wind drift and surface current coupling

"Correct" solutions for surface-current coupling:

Practical - Use surface current equivalent to that used in empirical estimates of drag coefficient.

Theoretical - Use surface current that would exist in the absence of the wind.

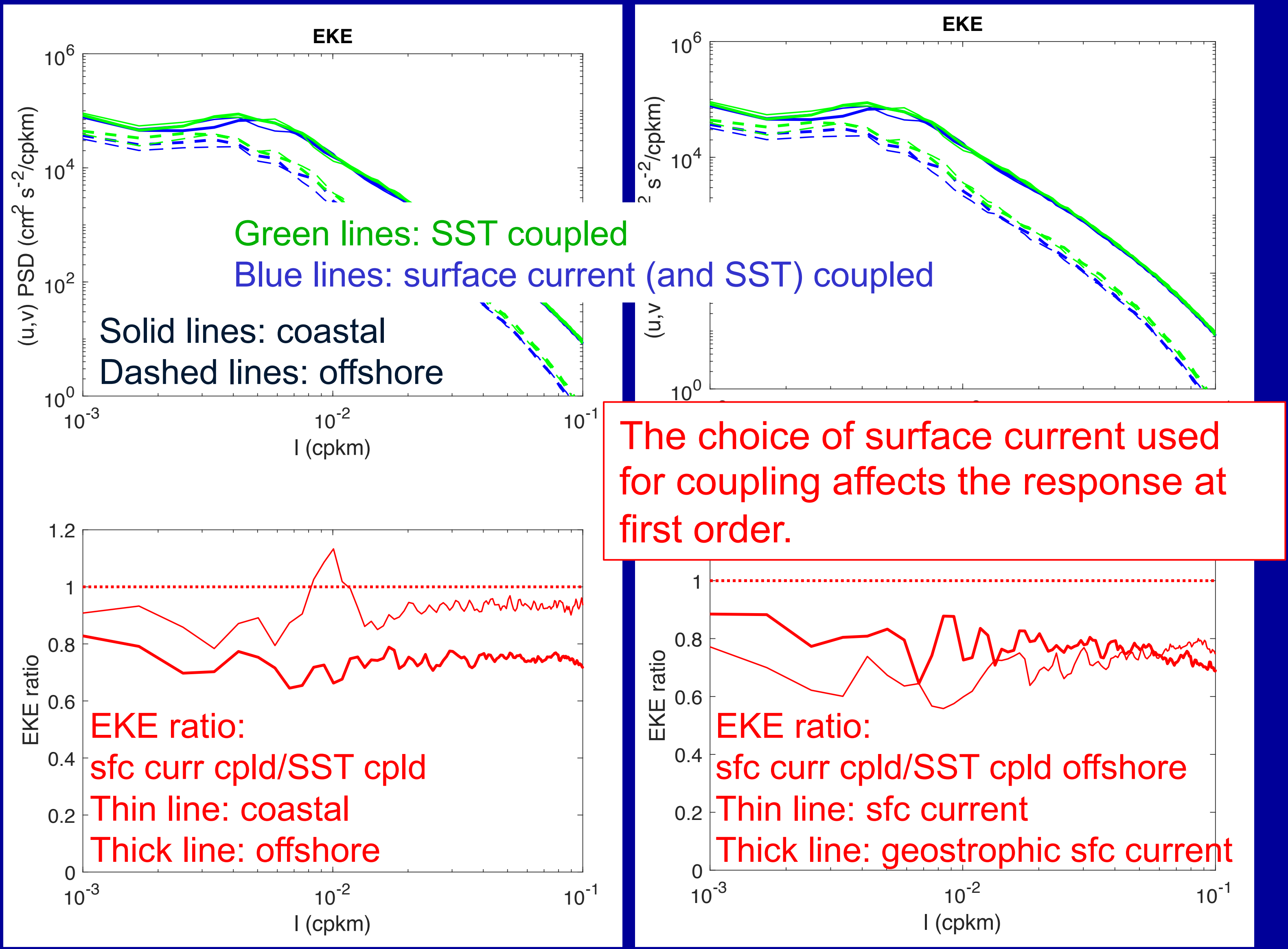
Empirical estimates use the best-available near-surface current for a given set of flux and wind observations; not systematic.

The "absent-wind" current is not easily determined, even in a model.

Two convenient choices:

- Uppermost model grid-level current
- Geostrophic surface current

Surface current coupling – CCS model



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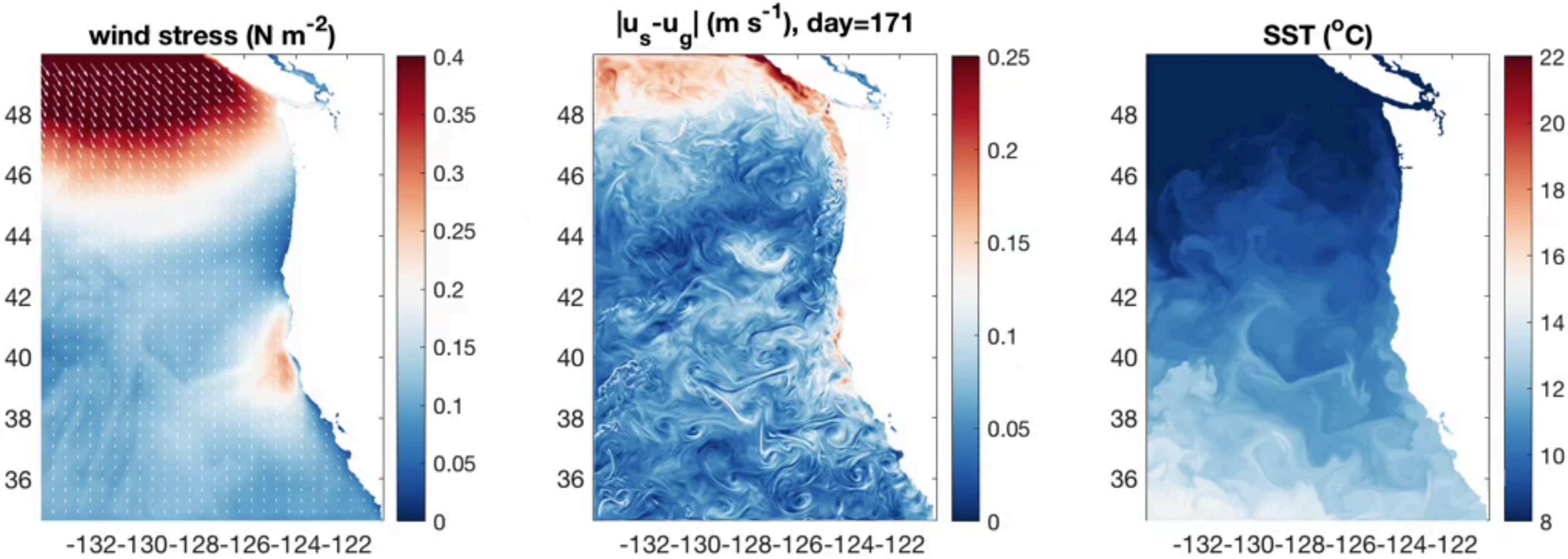
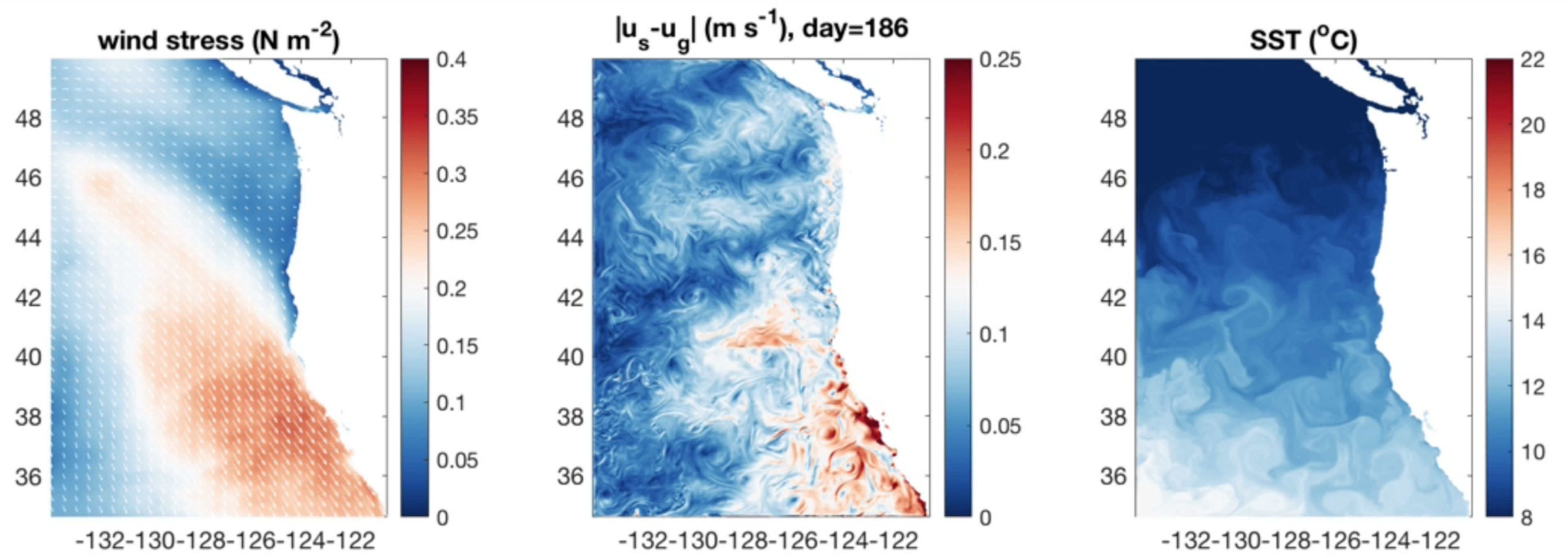
Surface current coupling – CCS model



Surface current coupling – CCS model



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Conclusions

1. SST coupling:
    - PBL schemes give range of estimates of coupling strength
    - PBL scheme dependence similar to Perlin et al. (2014) for ARC
    - 10-m wind response 30%-50% weaker than 10-m ENS wind response
    - Dependence also on spatial smoothing
    - Reversal in response at PBL mid-level; log-Ekman PBL model
    - CCS coupling weaker than ARC coupling in model;
      mean wind controls heat flux anomaly magnitudes

2. Surface current coupling:
    - What model “surface current” should be used for coupling?
    - New analytical result for surface wind drift (universality, symmetry)
    - Simulations:
      Offshore decay of EKE enhanced with surface current coupling,
      likely related to systematic damping of mesoscale eddies
      from relative wind effect (e.g., Gaube et al., 2015)
      Measurably different responses for coupling through
      uppermost grid-level and geostrophic surface currents

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