Mesoscale Air-Sea Interactions

Atmosphere ➜ wind & heat flux ➜ Ocean
Atmosphere ⬅ SST ⬅ Ocean

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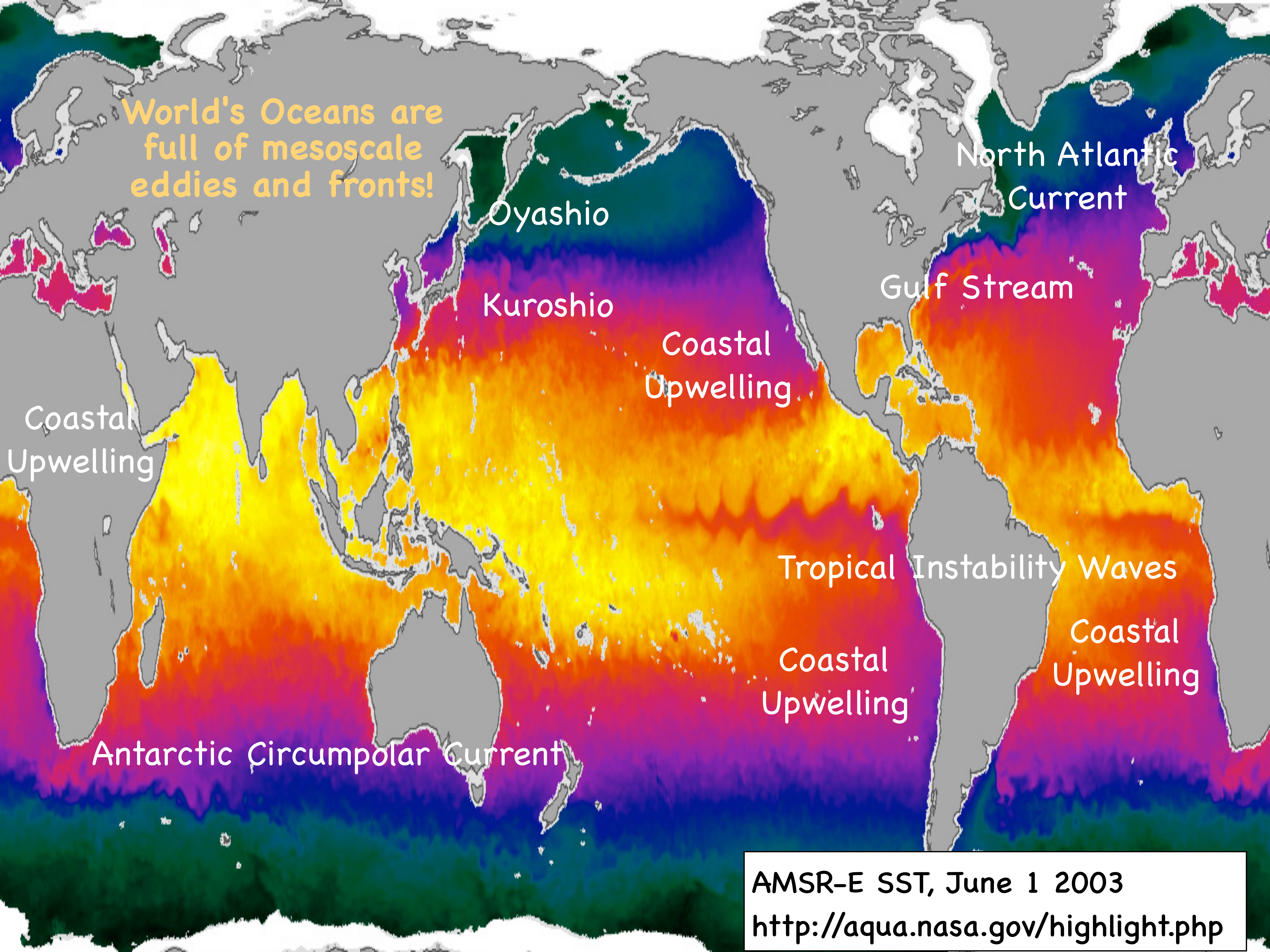

World's Oceans are full of mesoscale eddies and fronts!
Oyashio
Kuroshio
North Atlantic Current
Gulf Stream
Coastal Upwelling
Coastal Upwelling
Tropical Instability Waves
Coastal Upwelling
Coastal Upwelling
Antarctic Circumpolar Current
AMSR-E SST, June 1 2003
http://aqua.nasa.gov/highlight.php

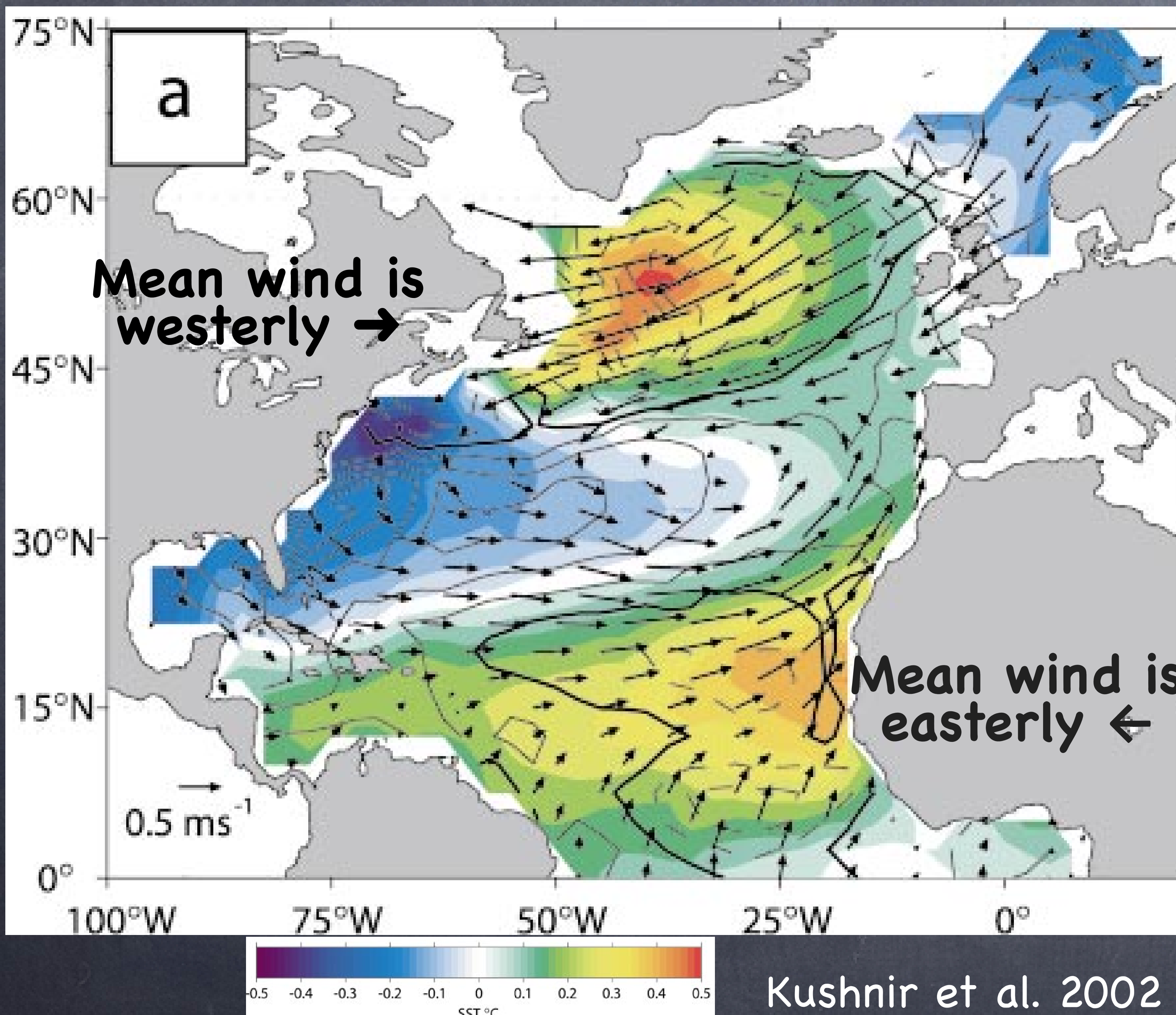
Outline

1. Air-sea interaction on mesoscale vs large-scale?
2. Mechanism for mesoscale air-sea interaction?
3. Impact on the ocean and atmosphere?
4. Summary

Air-sea interaction at basin-scale

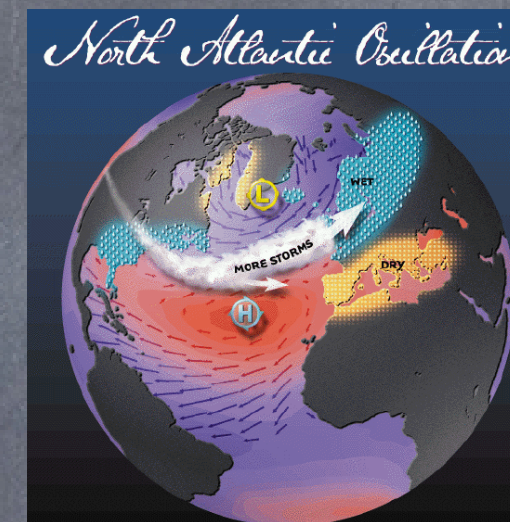
(slow and large scales)

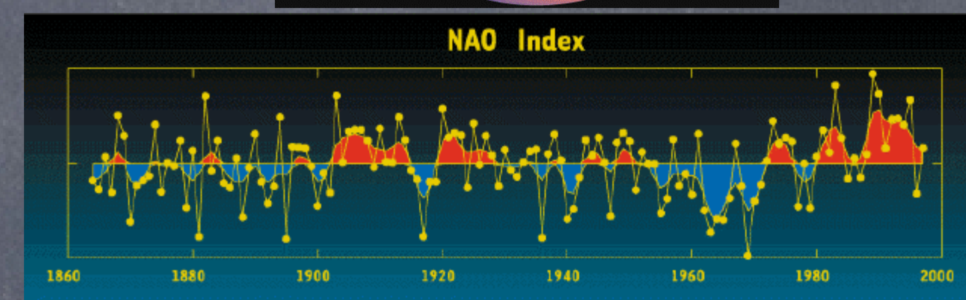
SST and wind anomaly patten related to NAO



Kushnir et al. 2002

North Atlantic Oscillation





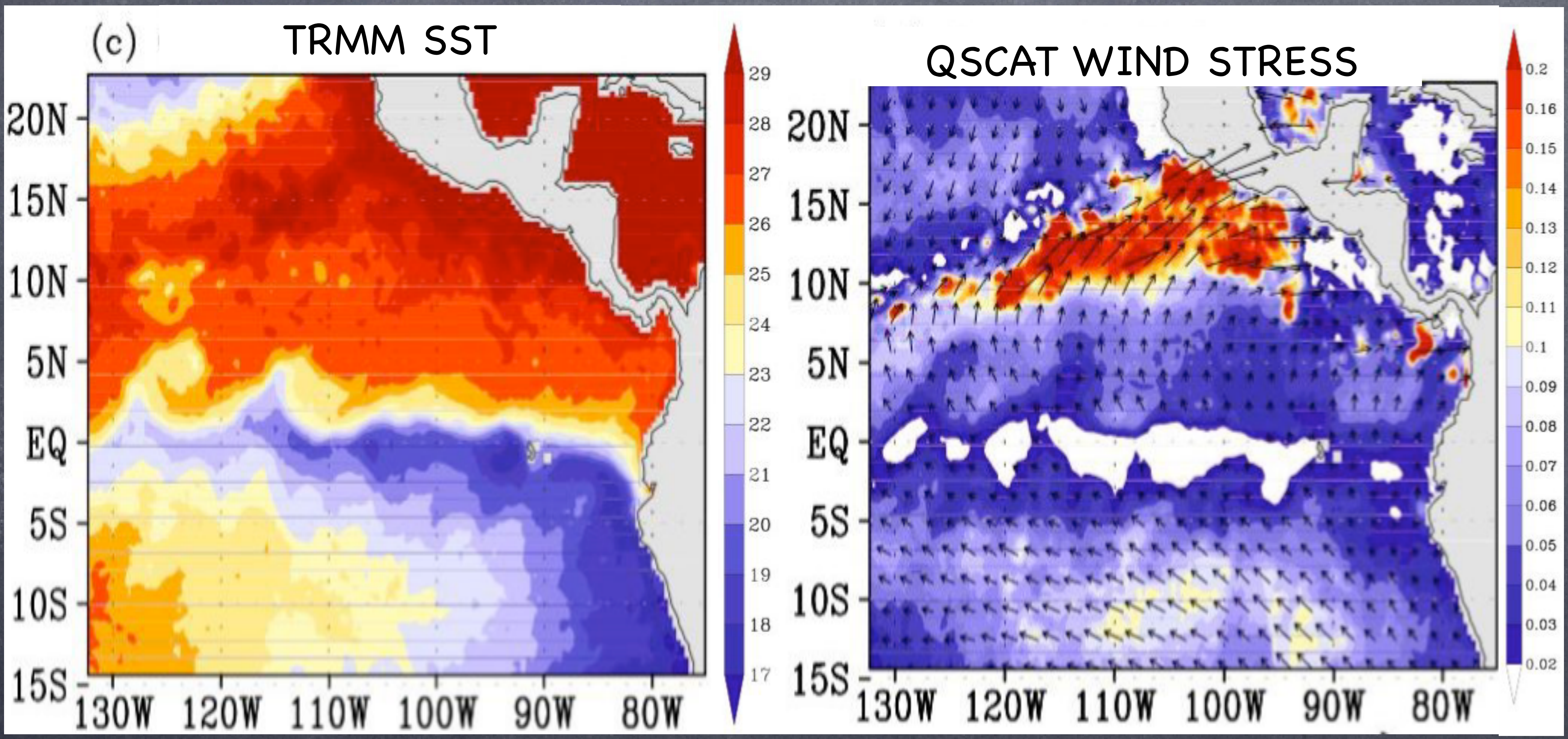
Stronger wind speed → lower SST via mixing and turbulent flux

Negative correlation:

Atmosphere drives the ocean.

Air-sea interaction at oceanic mesoscale
(fast and short scales)

TRMM SST and QuikSCAT wind stress on 3 September 1999

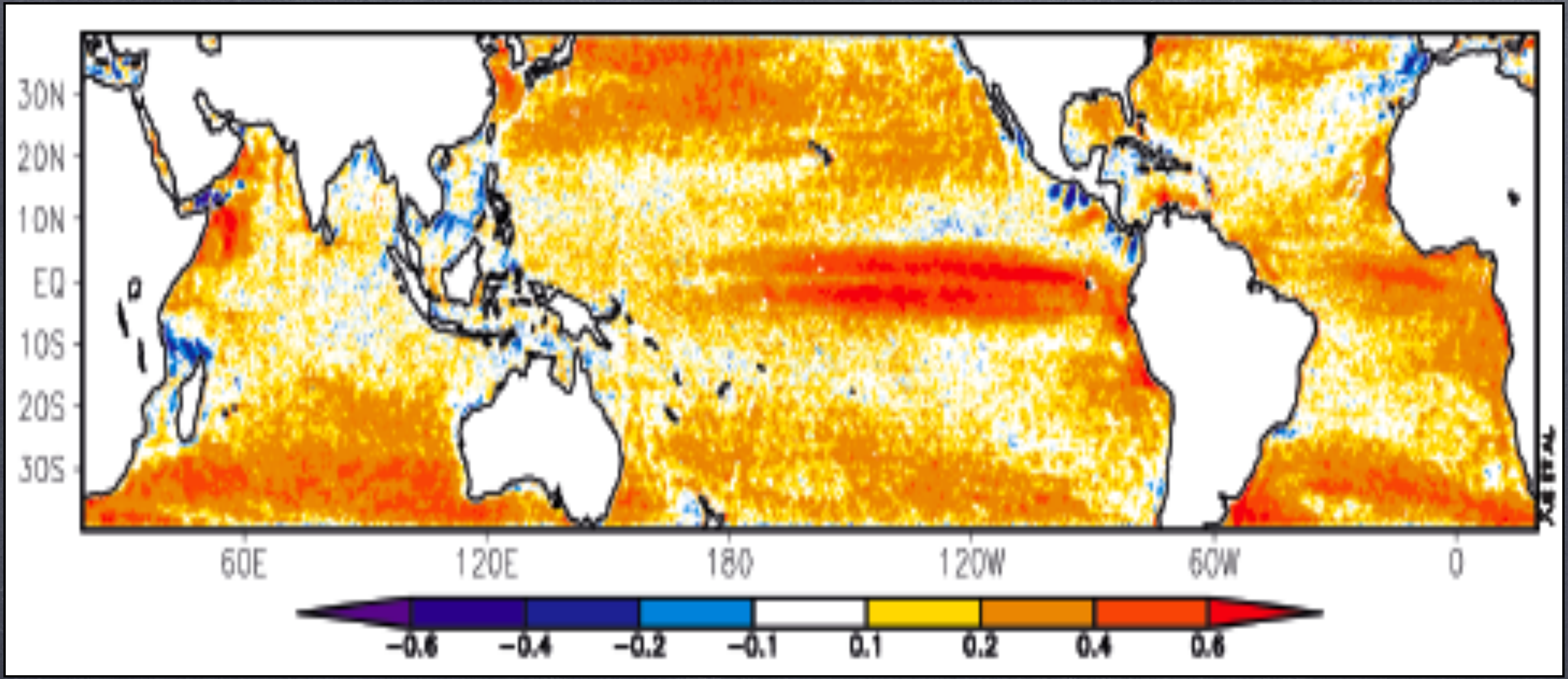


Enhanced wind speed over higher SST!

Seo et al. 2007

Air-sea interaction at oceanic mesoscales

Correlation coefficients between high-pass filtered wind speed and SST



Xie et al. 2004

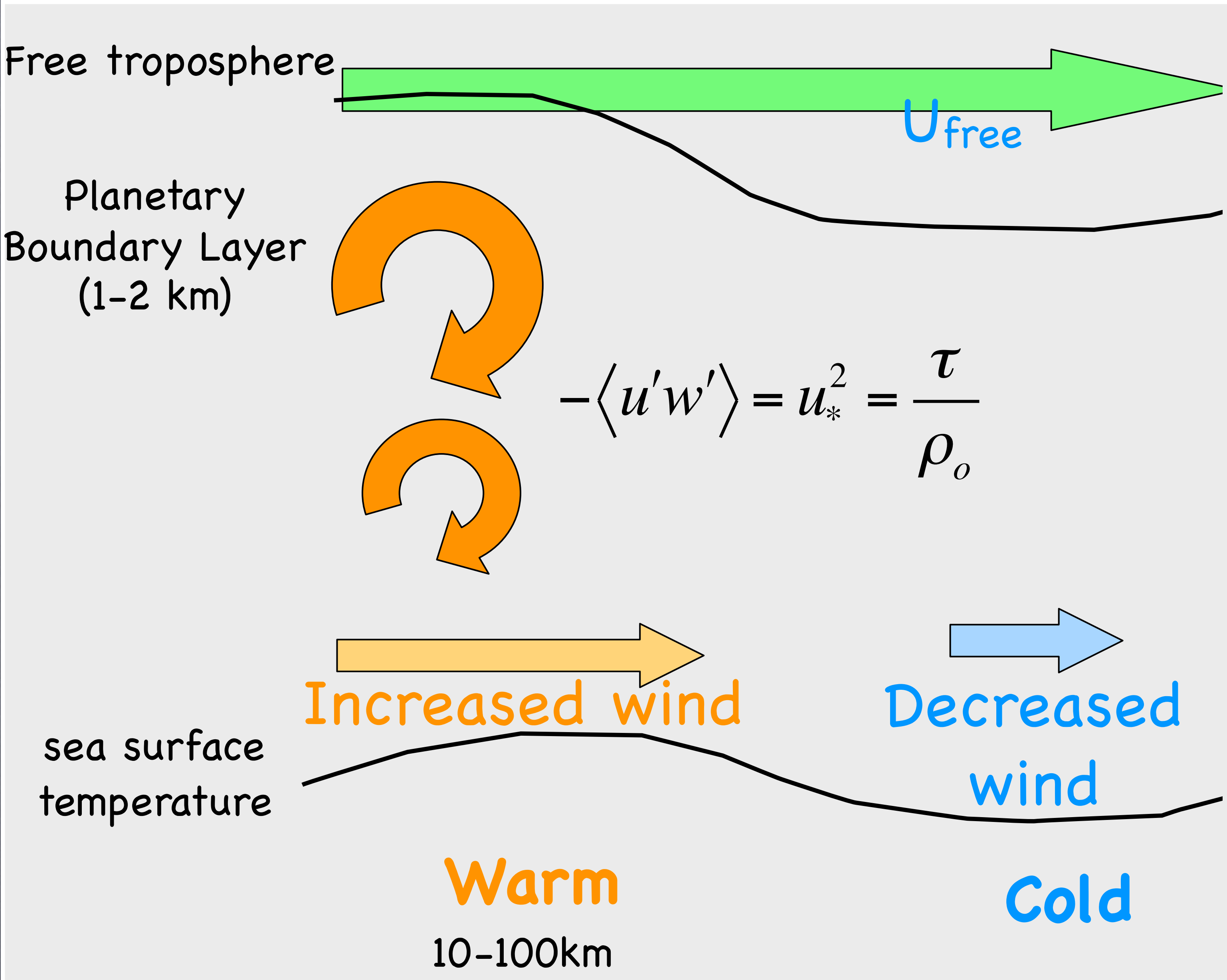
Enhanced wind speed over warm SST

Reduced wind speed over cold SST

Positive correlation: Ocean drives the atmosphere.

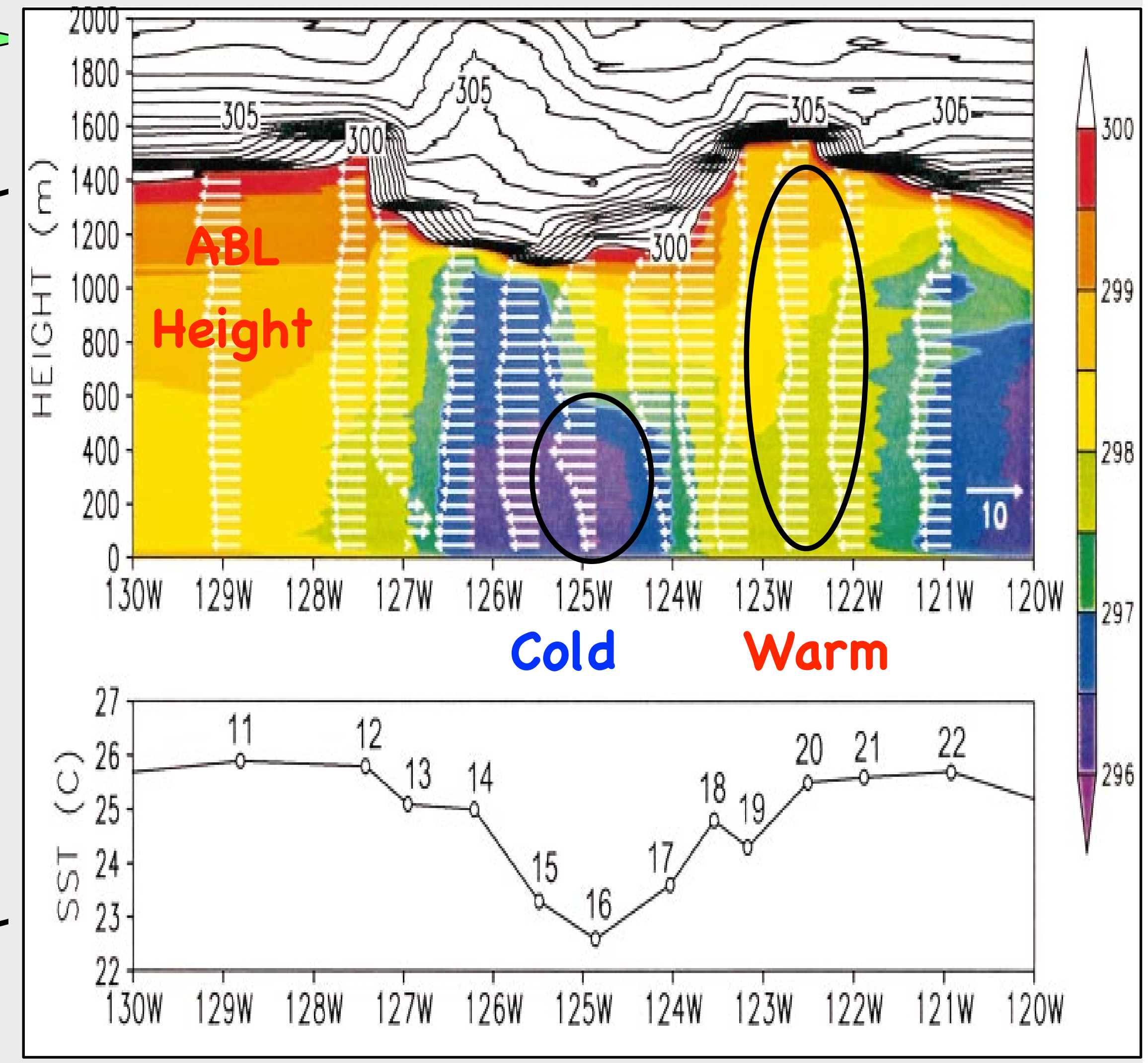
How does the mesoscale SST influence the surface wind?

Eddies alter the stability of the lower atmosphere



$$-\langle u'w' \rangle = u_*^2 = \frac{\tau}{\rho_o}$$

Radiosonde observations in the E. Pacific



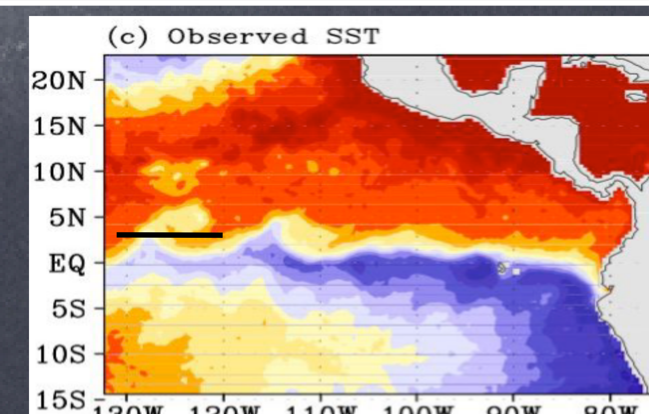
Hashizume et al. 2002

Unstable boundary layer and increased mixing

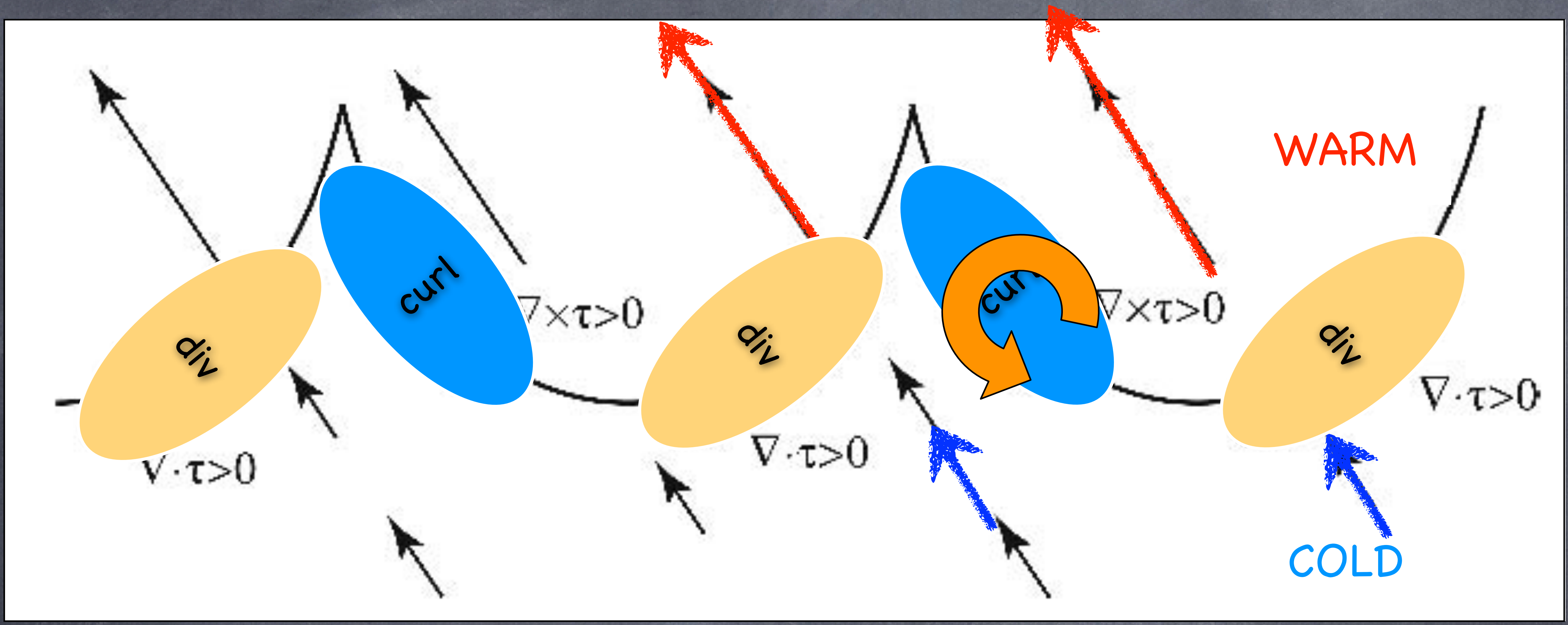
Decoupled stable boundary layer

$T' \rightarrow$ PBL stability $\rightarrow$ WS

Wallace et al. 1989



How do this coupling affect the ocean and atmosphere?



Chelton et al. 2004

- Wind curl → Ekman pumping → Ocean circulation

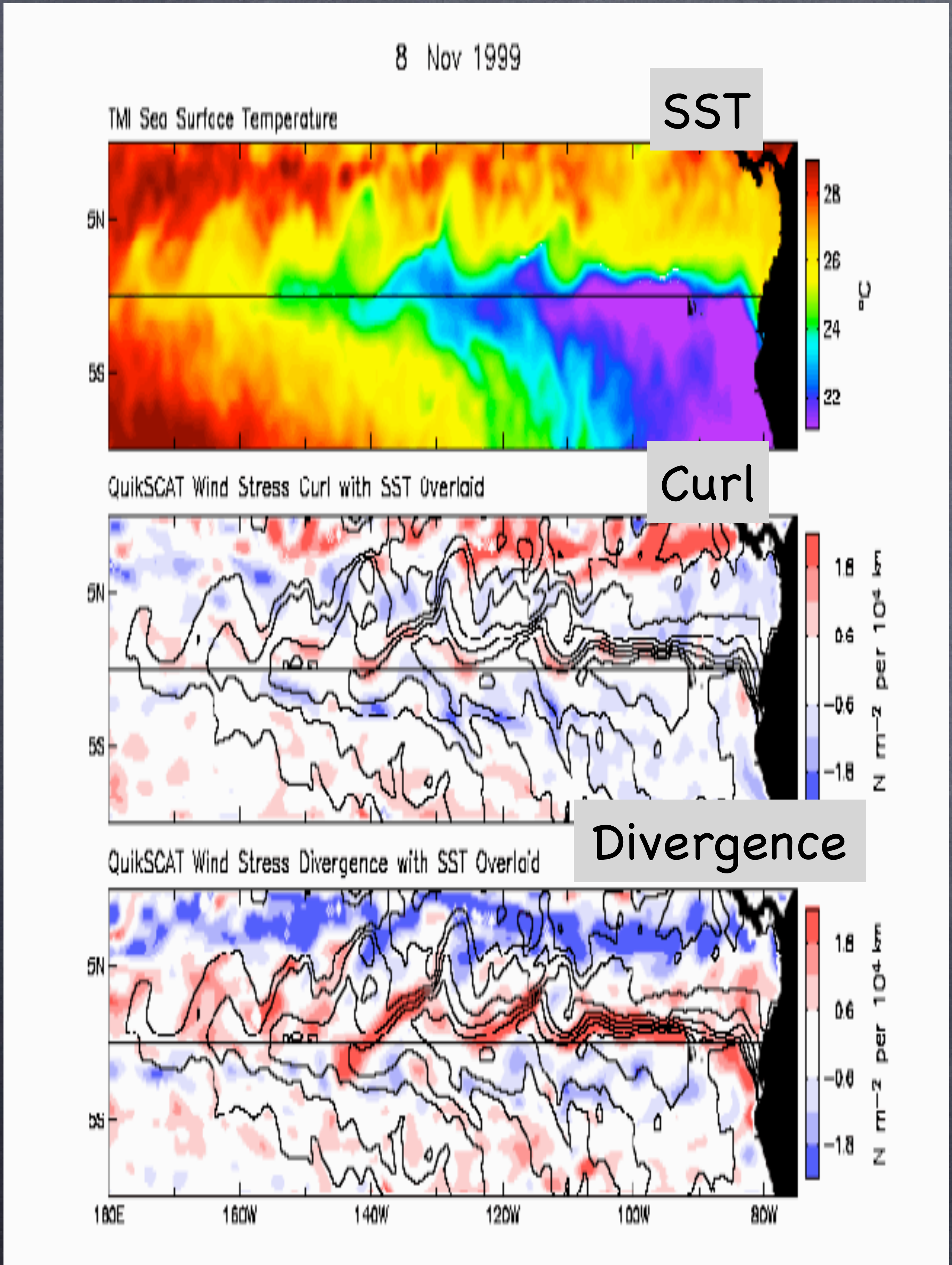
$$W'_{ek} = \nabla \times \frac{\vec{\tau}'}{\rho(f+\zeta)}$$

- Wind convergence and divergence → Atmospheric vertical motion and planetary-scale circulation

$$\nabla \cdot \vec{u} \approx -\nabla^2 SST$$

$$w \approx \frac{1}{\rho_o}\left(\frac{\varepsilon z}{\varepsilon^2 + f^2}\right)\nabla^2 SST$$

Wind stress curl and divergence from satellites



Tropical Instability Waves

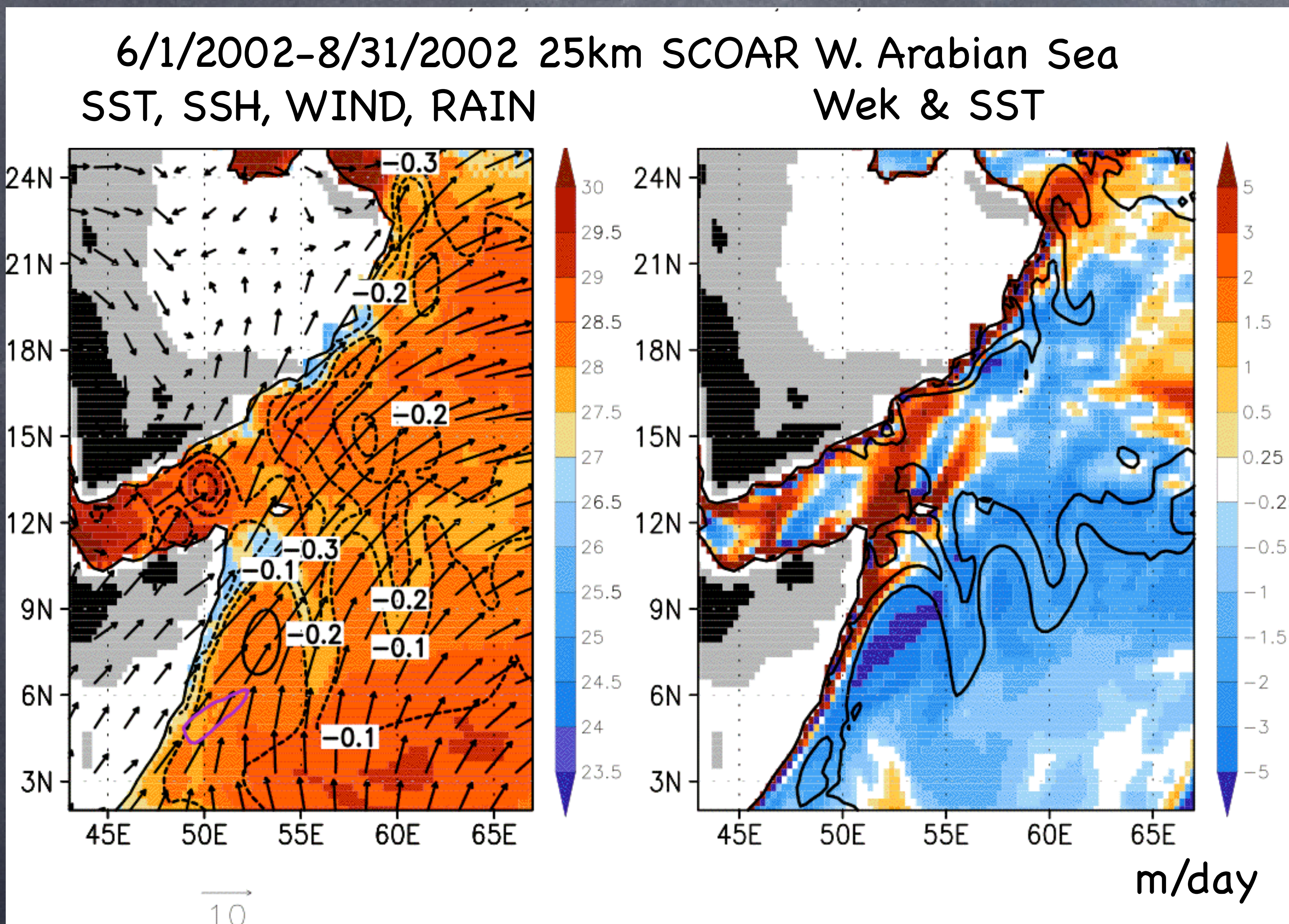
• Wind stress curl and convergence co-propagate with the front.

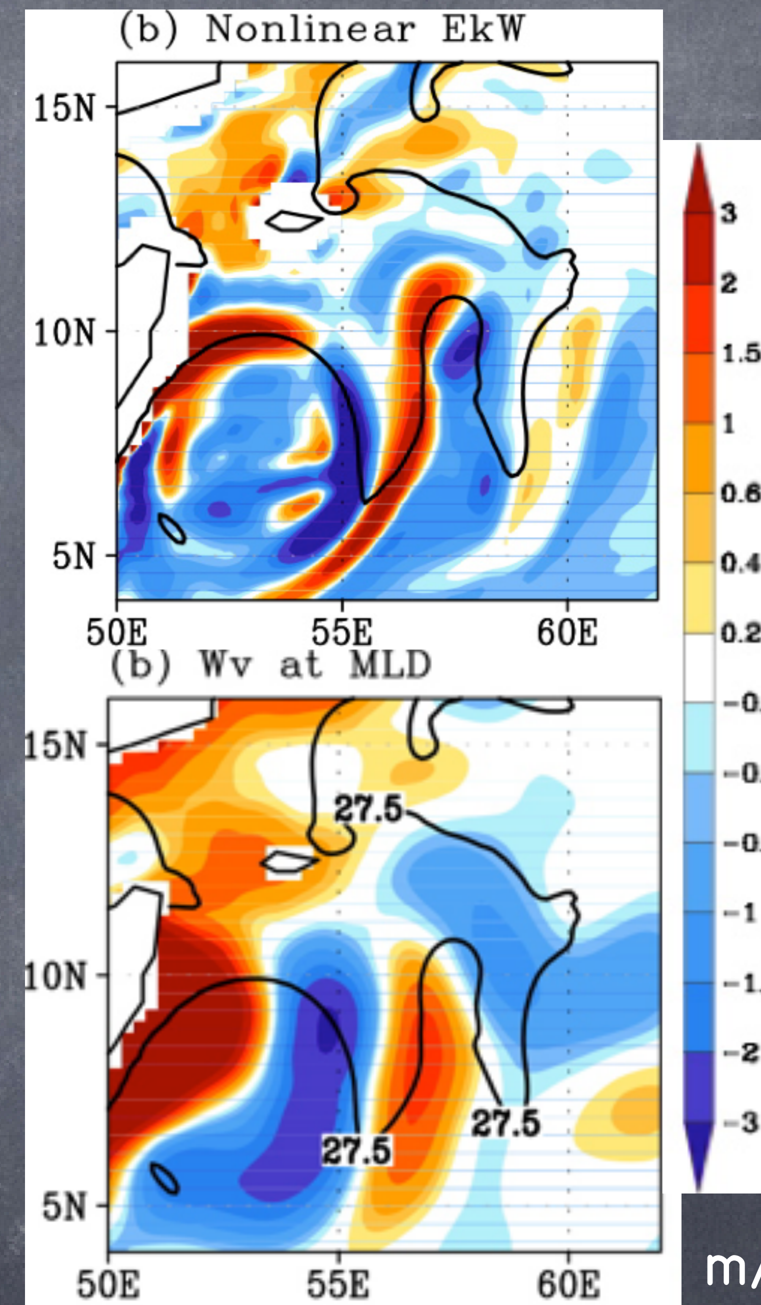
• Large-amplitude and persistence of the anomalies ➜

• Could be an important factor for dynamics of the large-scale ocean and atmosphere?

Animation from D. Chelton OSU

Impact on the ocean via Ekman pumping:
western Arabian sea upwelling case from a coupled model





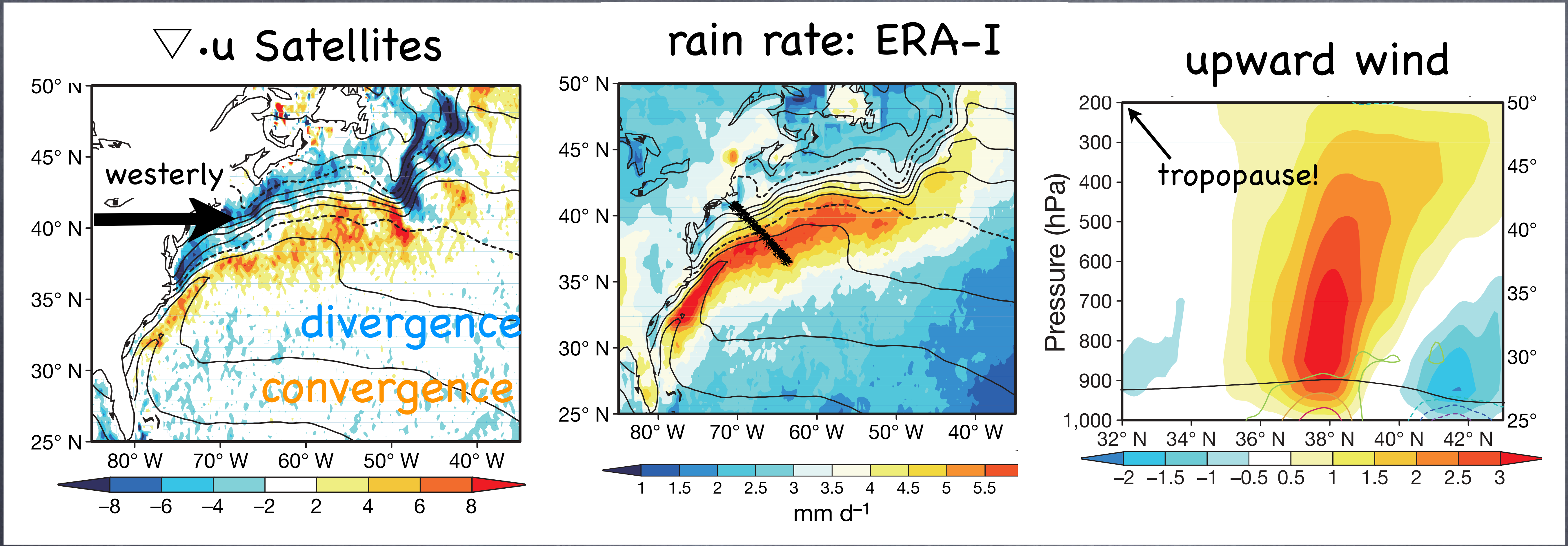
- Large Ekman pumping velocity induced by wind stress curls

$$W'_{ek} = \nabla \times \frac{\vec{\tau}'}{\rho(f+\zeta)}$$

- |Wek/W|~O(1)
- A significant factor for evolution of eddies.

Seo et al. 2008

Impact on the atmosphere via vertical motion: Gulf Stream case from the observations



Minobe et al. 2008

- Wind convergence (divergence) over warmer (colder) flank of the GS.
- Intense precipitation where wind converges.
- Vertical motion reaching all the way up to the tropopause!
- This will excite the planetary-scale Rossby waves and influence the atmospheric general circulation.

Summary

- SST variations associated with mesoscale eddies and fronts cause coherent perturbations in the atmosphere.
  - a ubiquitous feature observed throughout the World Oceans,
  - potentially important for mesoscale ocean dynamics and atmospheric circulation,
  - net effect on large-scale climate dynamics remains uncertain but is an active area of research.
- In situ data, satellite observations and and high-resolution climate models are all important tools to examine the dynamics of coupling and the effect on large-scale flows.

Thanks!

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