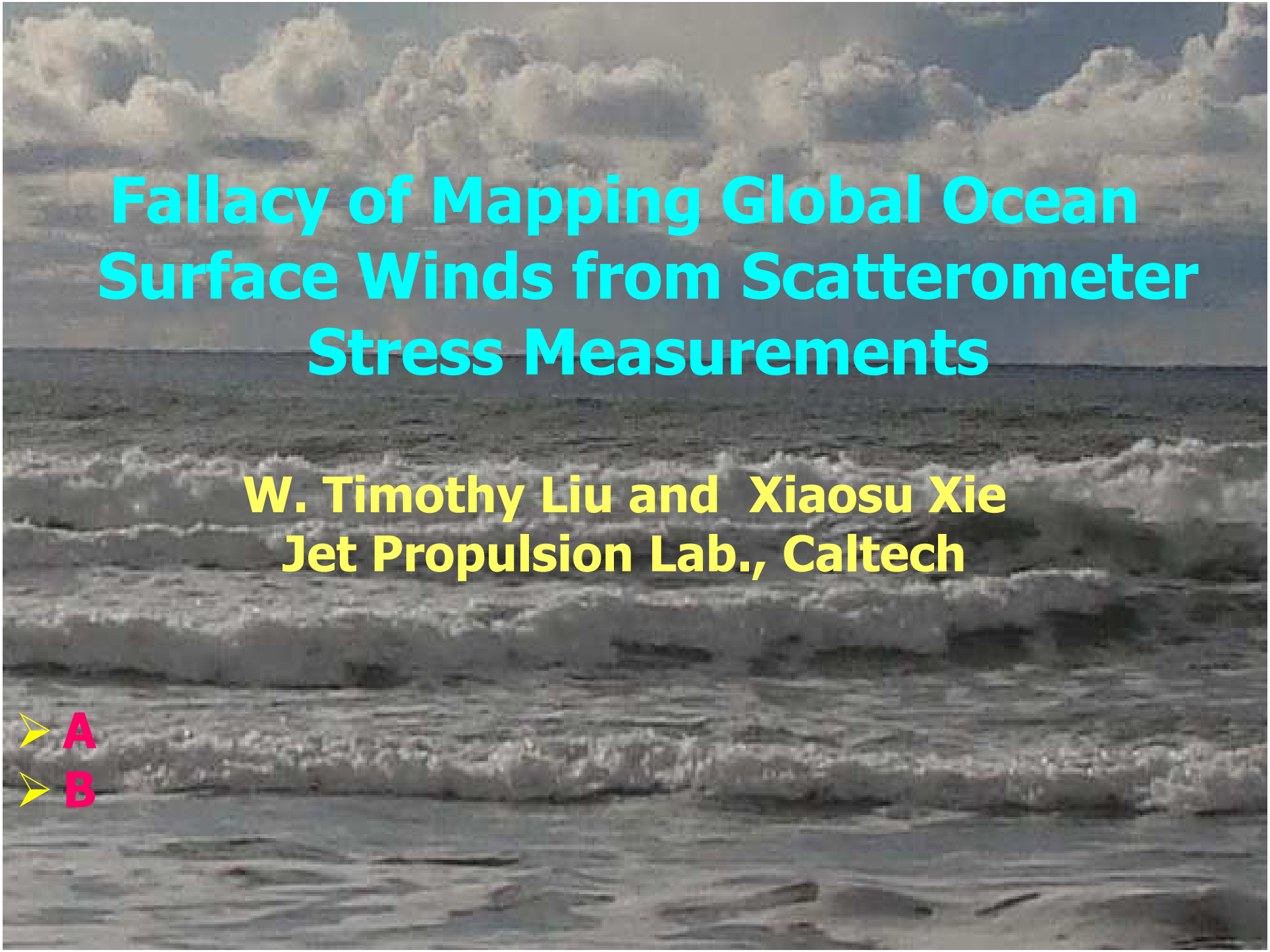
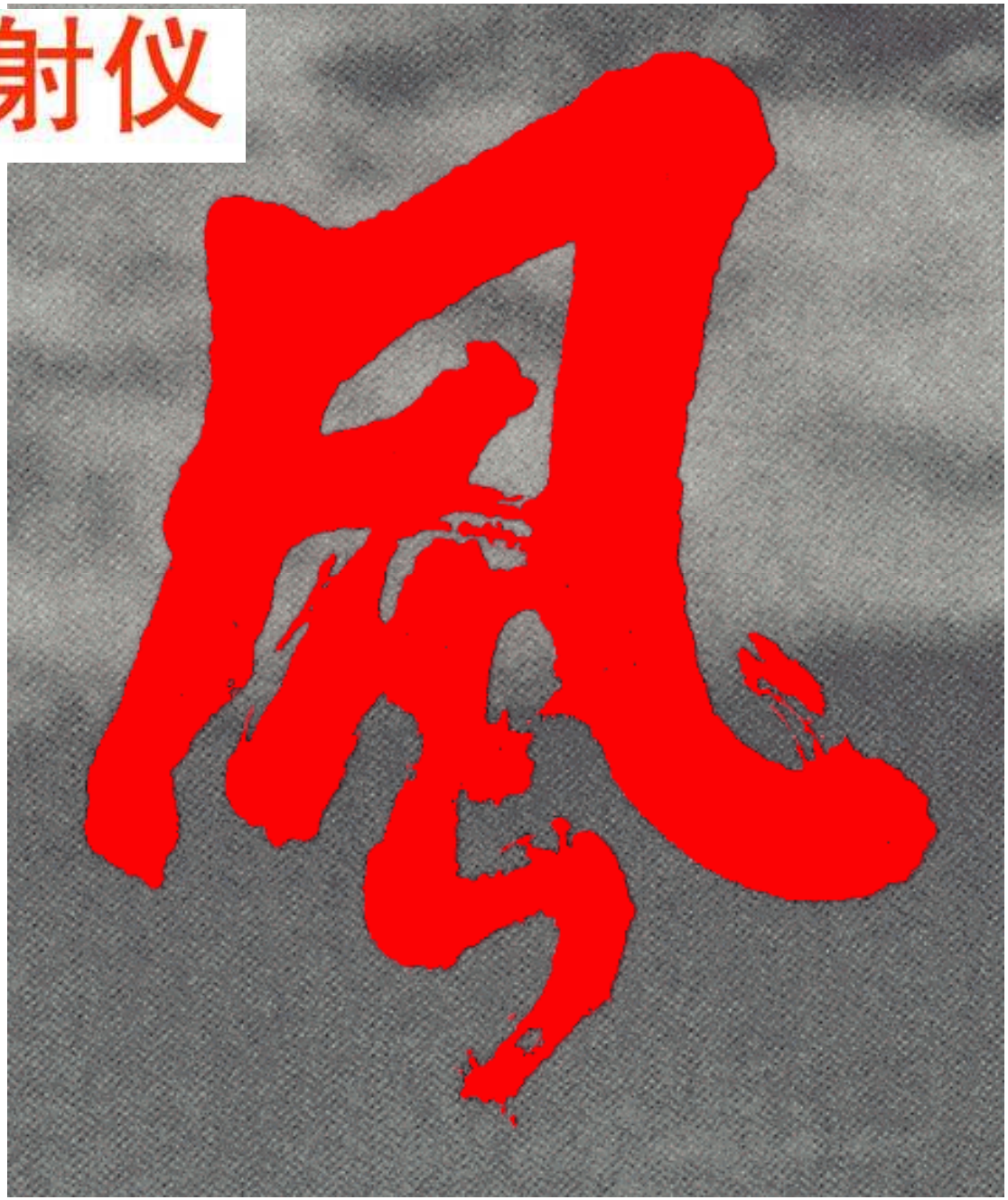


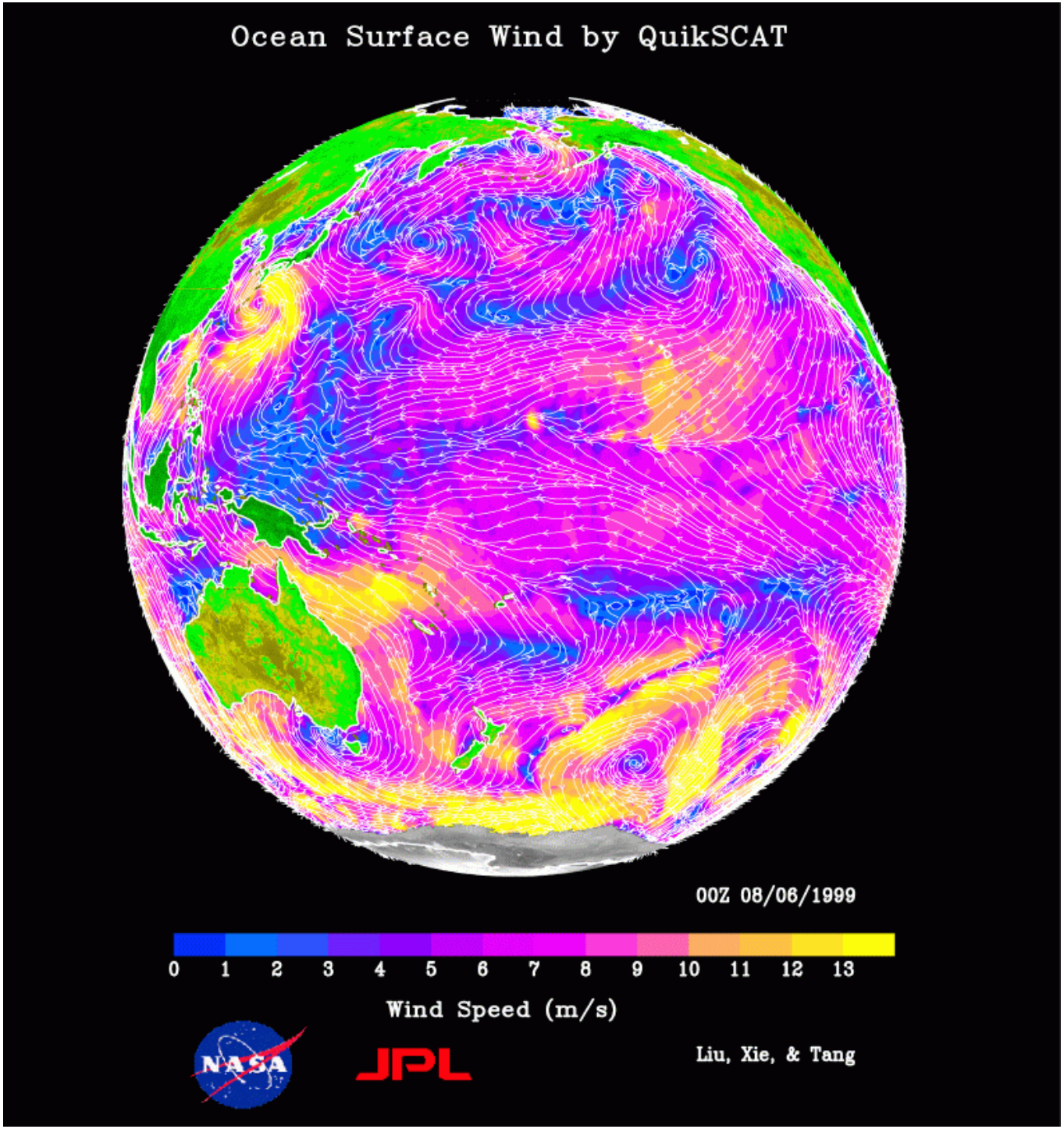
Fallacy of Mapping Global Ocean Surface Winds from Scatterometer Stress Measurements

W. Timothy Liu and Xiaosu Xie
Jet Propulsion Lab., Caltech

- A
- B

Scatterometer measures ocean surface wind/stress




Ocean Surface Wind by QuikSCAT
00Z 08/06/1999
0 1 2 3 4 5 6 7 8 9 10 11 12 13
Wind Speed (m/s)
NASA
JPL
Liu, Xie, & Tang

Definition and Basics

- Wind is air in motion. Stress is the turbulent transport of momentum. Scatterometer measures roughness which is in equilibrium with stress
- Turbulence is generated by instability caused by vertical wind shear and buoyancy.
- We do not have any large-scale stress measurements; our concept of stress distribution is largely influence by our concept of wind.
- Wind influence stress but does not uniquely define stress, and vice versa.
- Over most of the ocean, the atmosphere is neutral and the current is much smaller than wind, it is generally assumed that wind change dominates stress change.
- This may not be true over the strong current shear and temperature gradient of ocean fronts and in hurricanes.
- Measuring stress over global ocean is a unique capability of scatterometer.

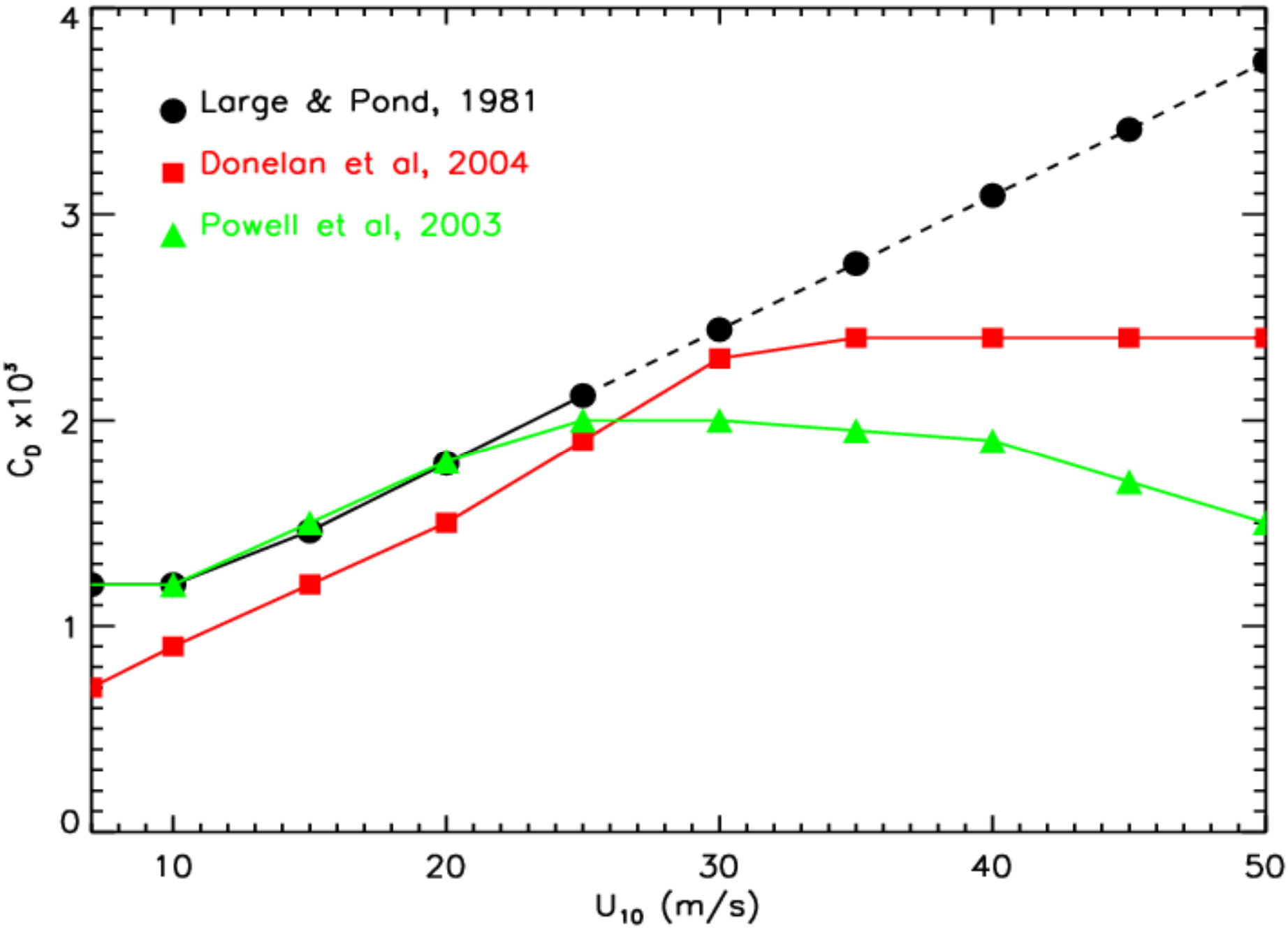
Liu, W.T.,X. Xie, and P.P. Niiler (2007) J. Climate, 30,5784-5797

Liu, W.T. and X. Xie (2008), J. Oceanogr., 64, 631-637.

Liu, W.T., W.Tang, and X.Xie (2008),Geophys. Res. Lett., 35, L13808.

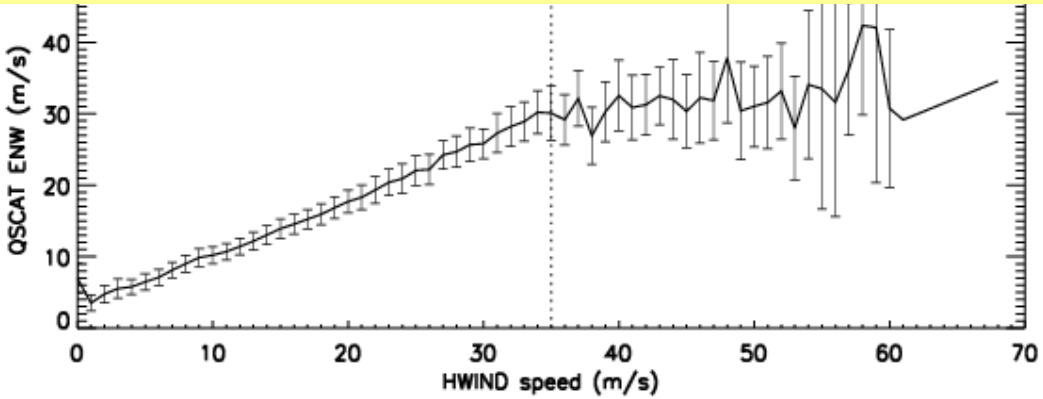
- **Now that we are all convinced that we have stress distribution over global ocean from scatterometer. How do we know whether we are getting the wind distribution?**
- **In situ measurements are not sufficient (that is the justifiction for scatterometer)**
- **NWP is not good enough either (Poor boundary parameterization before 2002 & SST before 2001. Corrupted by assumption of stress measuring wind after 2002)**

Flow Separation

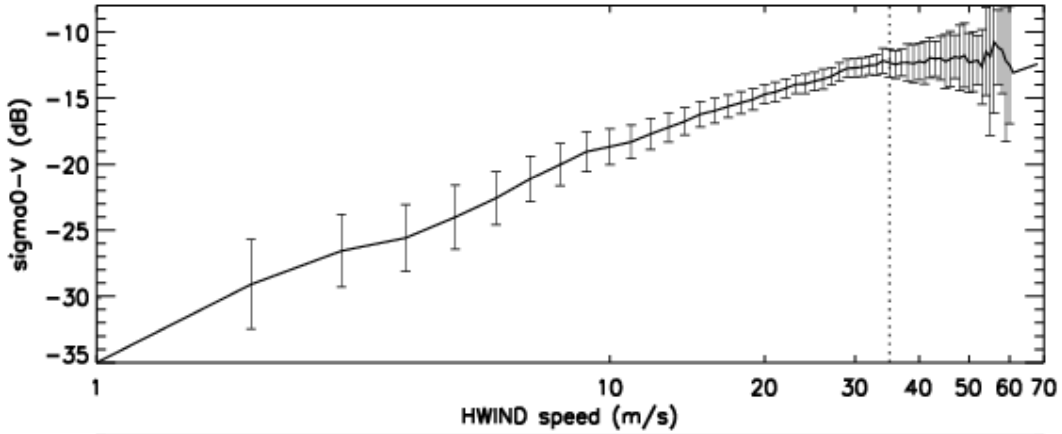

Large & Pond, 1981
Donelan et al, 2004
Powell et al, 2003
C_D x10^3
U_{10} (m/s)
0
1
2
3
4
10
20
30
40
50

QuikSCAT demonstrates flow separation in hurricanes (Similar for ASCAT)

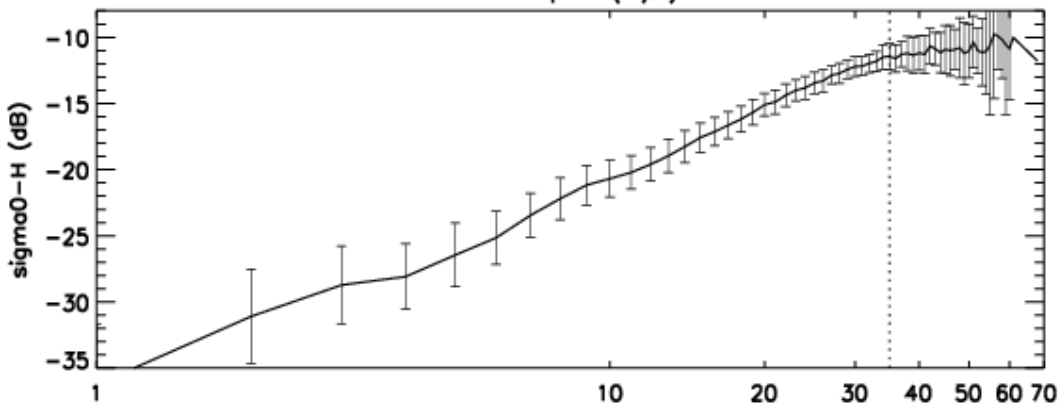
QSCAT U_{ENW}



QSCAT σ_o-V



QSCAT σ_o-H

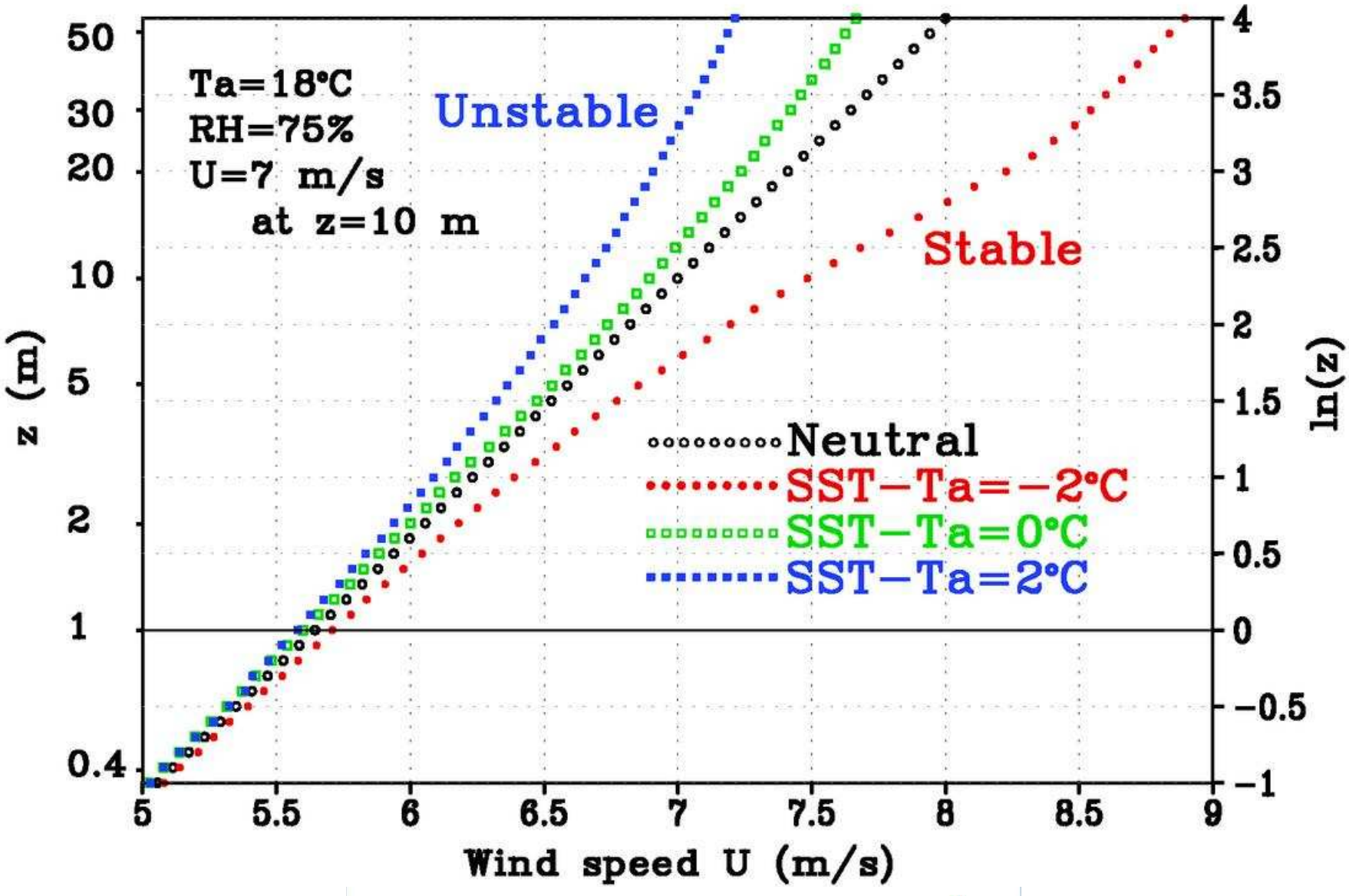


Collocated **Hwind Speed (m/s)** p=0.5

ASCAT shows similar behavior at C-band (Bentamy presented at OVWST meeting)

Hurricanes in 2005 were used. Those with more than 50% chance of coincident rain occurrence were removed.

ENW is higher than actual wind under unstable condition



$$\frac{u-u_s}{u_*}=2.5(\ln\frac{z}{z_0}-\psi_u)=\frac{1}{\sqrt{C_D}}$$

Ocean Current

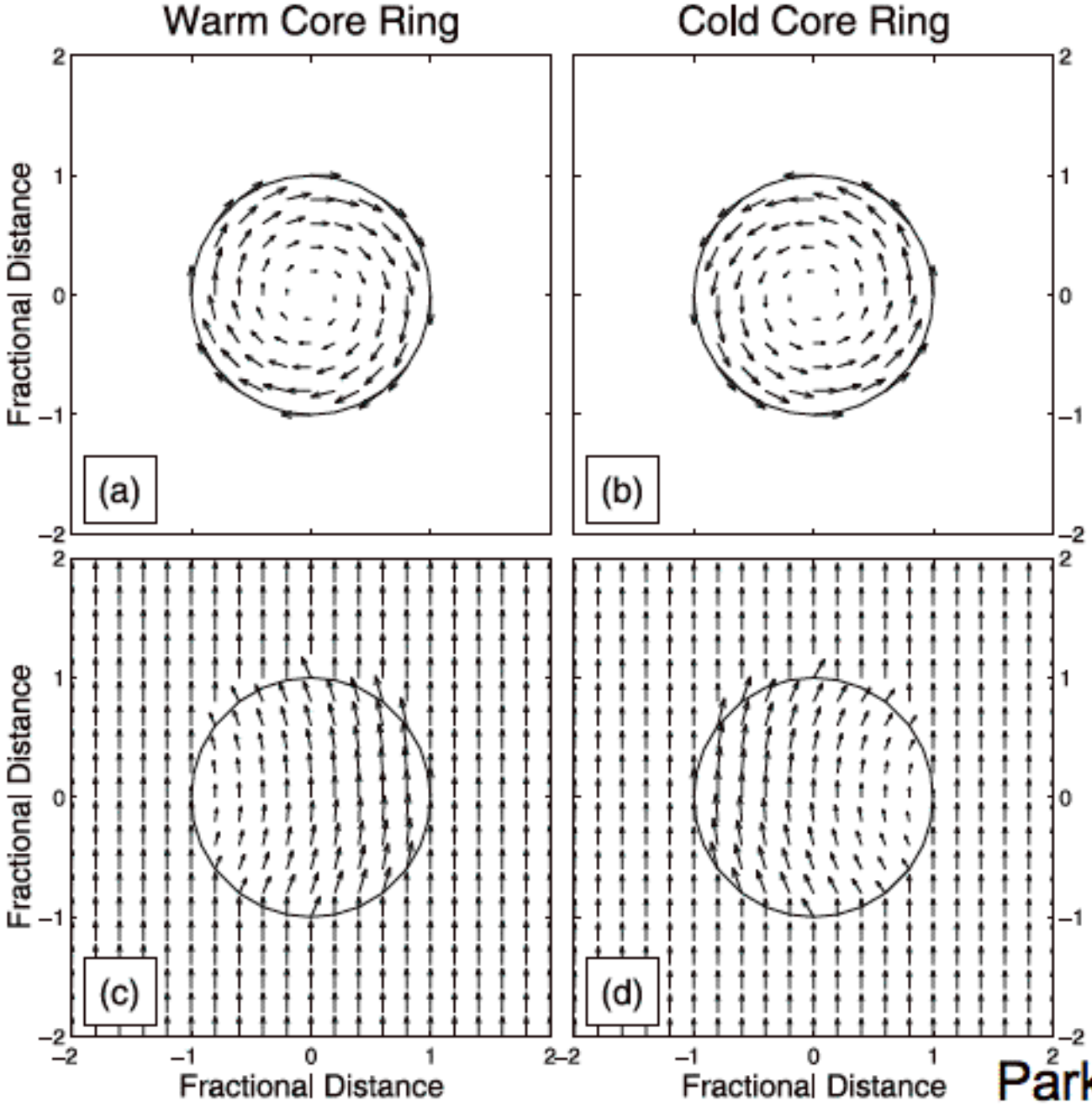
Solution

Just add current to bulk formula

Easier if directions of current & stress are the same

More difficult if we have to take directional difference into consideration

A Conceptual model for idealized ring and wind interaction

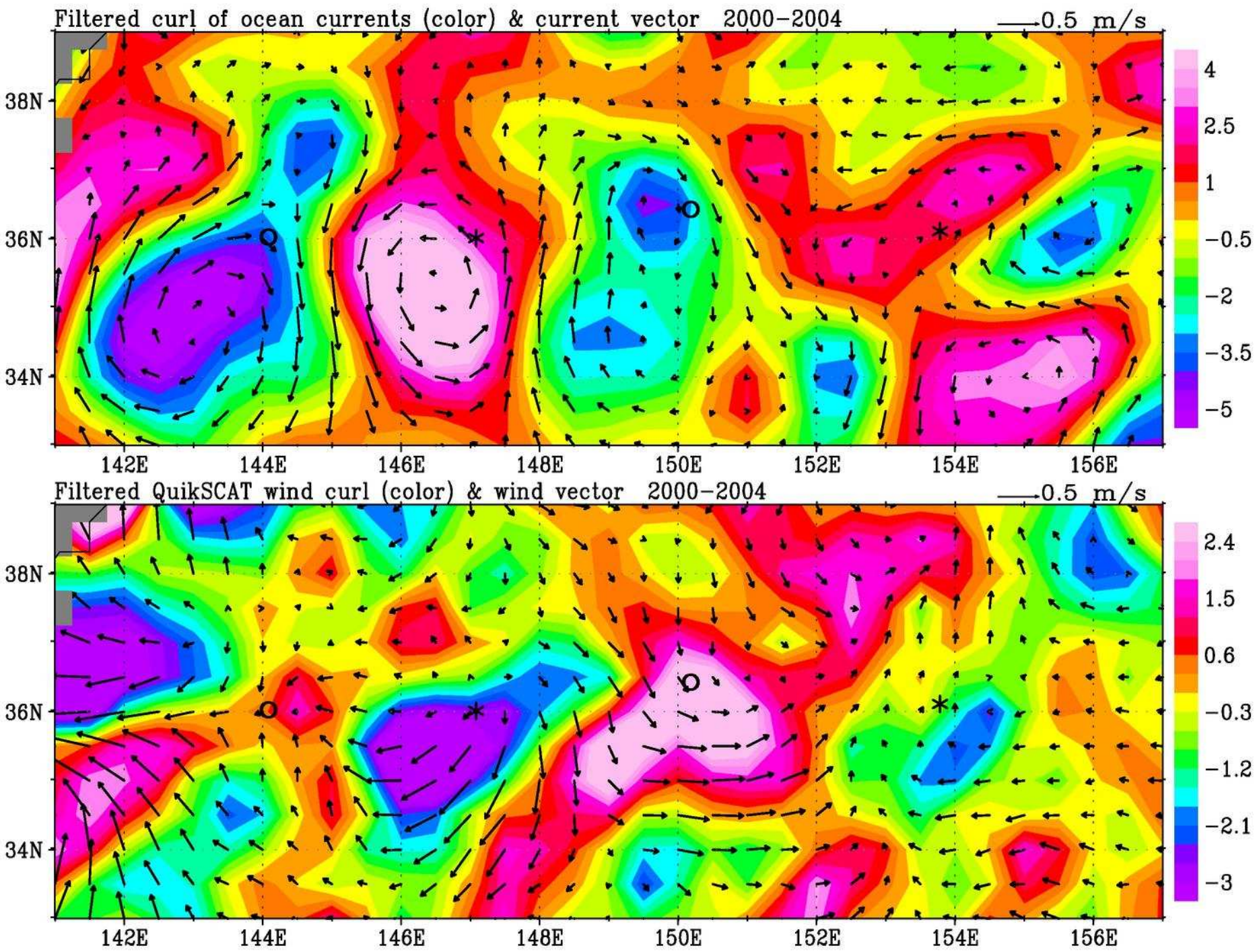


current

uniform wind

Vector difference between wind & current

Park et al, 2006


Filtered curl of ocean currents (color) & current vector 2000–2004
0.5 m/s
38N
36N
34N
142E
144E
146E
148E
150E
152E
154E
156E
4
2.5
1
−0.5
−2
−3.5
−5
Filtered QuikSCAT wind curl (color) & wind vector 2000–2004
0.5 m/s
38N
36N
34N
142E
144E
146E
148E
150E
152E
154E
156E
2.4
1.5
0.6
−0.3
−1.2
−2.1
−3

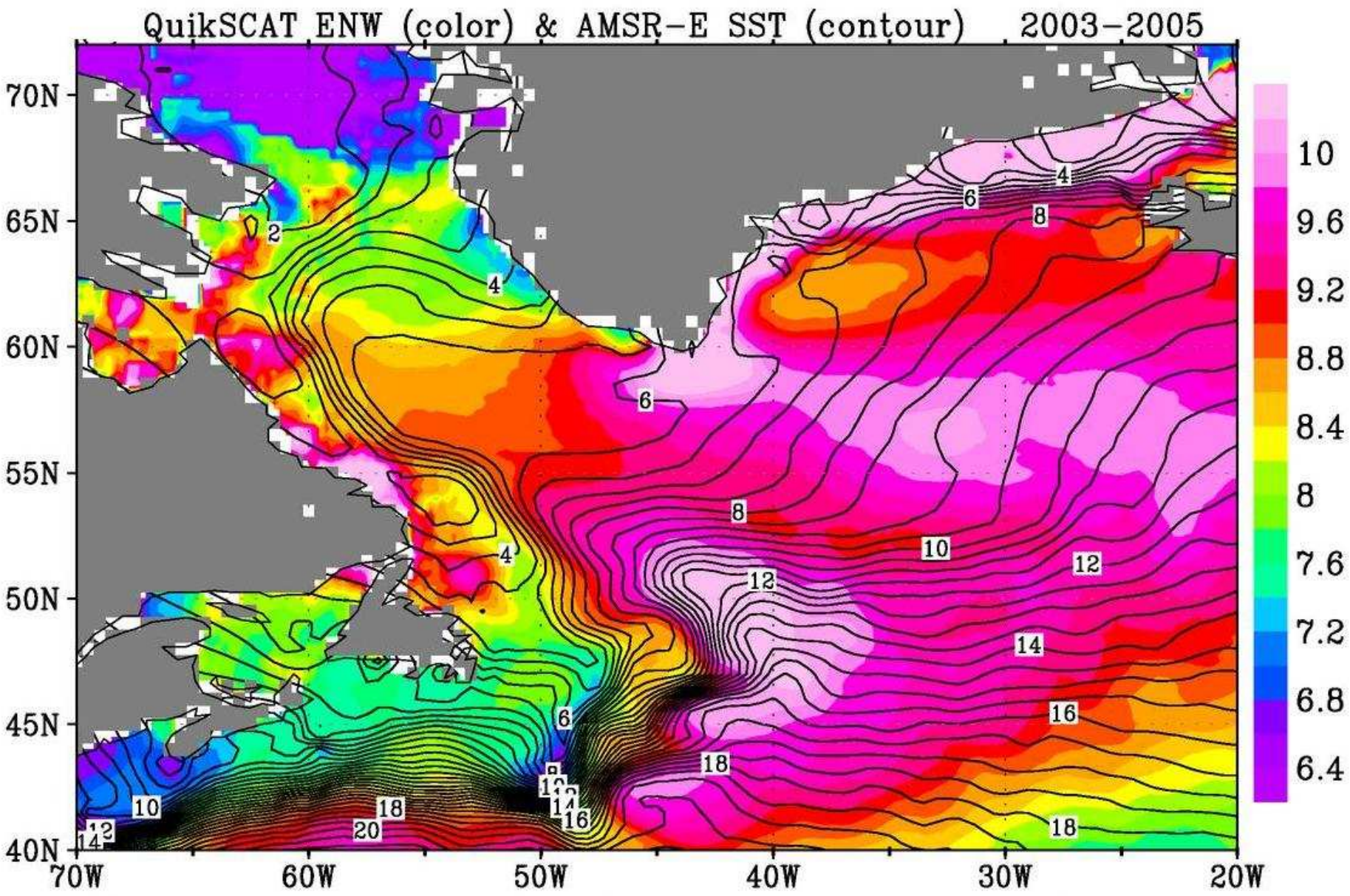
Stability

Spatial coherence between scatterometer measurements and SST is ubiquitous, under all kinds of atmospheric circulation and boundary layer conditions.

- Tropical Instability Waves [Xie et al. 1998;Cronin et al, 2003; Hashizume et a. 2002; Chelton et al. 2004]
- Kuroshio [Nonaka and Xie 2003]
- Circumpolar Current [White and Annis, 2003; O'Neill 2003]
- Indian Ocean [Vecchi et al., 2004]
- Winter outbreak in East China Sea [Xie et al.2002]
- Gulf Stream Ring [Park and Cornillon 2002]
- Typhoon wake [Lin et al., 2003]
- Numerical model simulation[Yu and Liu, 2003;Song et al. 2004]

The reason is that at small turbulent scales, factors such as Coriolis force, pressure gradient force, baroclincity, cloud entrainment, etc are not important.

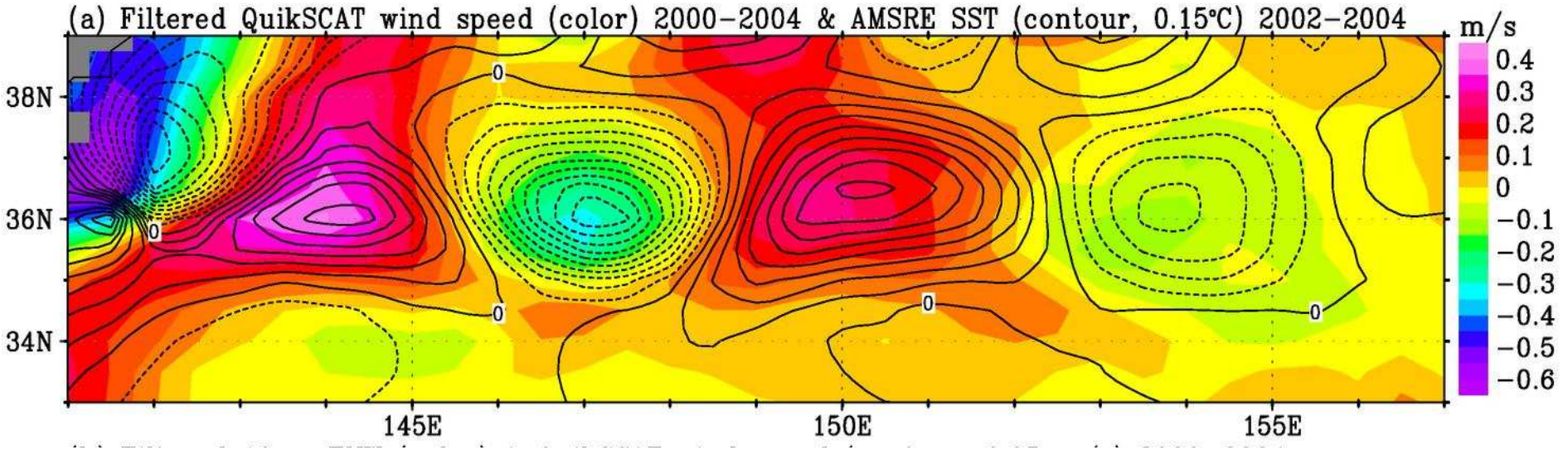
QuikSCAT ENW (color) & AMSR-E SST (contour)



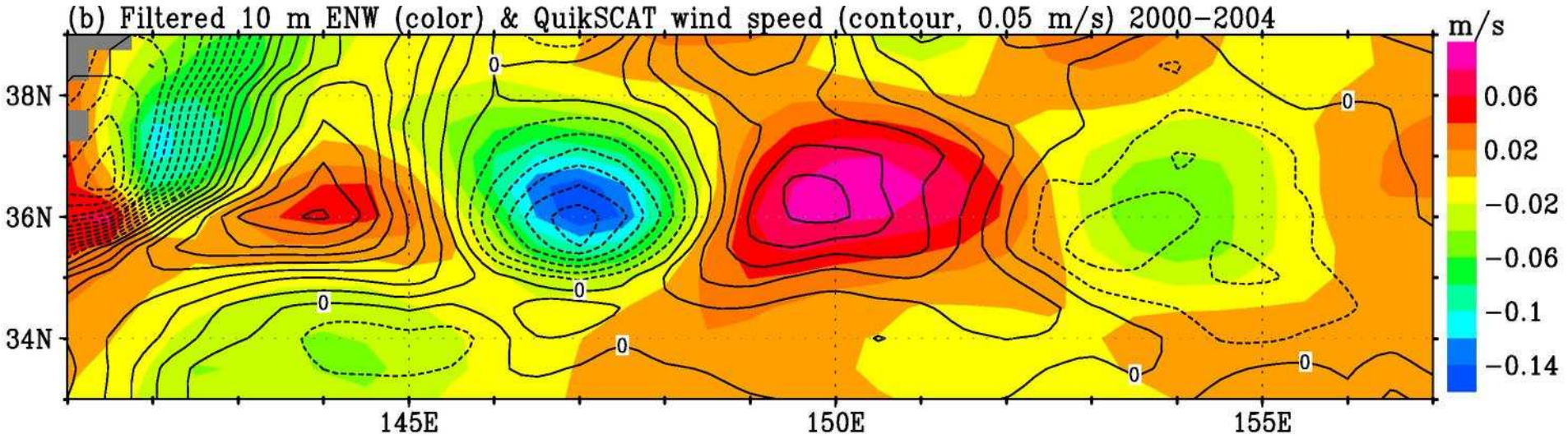
Liu et al. 2008, GRL

“For the identical ten-meter winds, the surface stress will be considerably greater when the marine atmospheric boundary layer is unstable than when it is neutral, and the capillarity will likewise be enhanced under the unstable ABL” – Ed Monahan

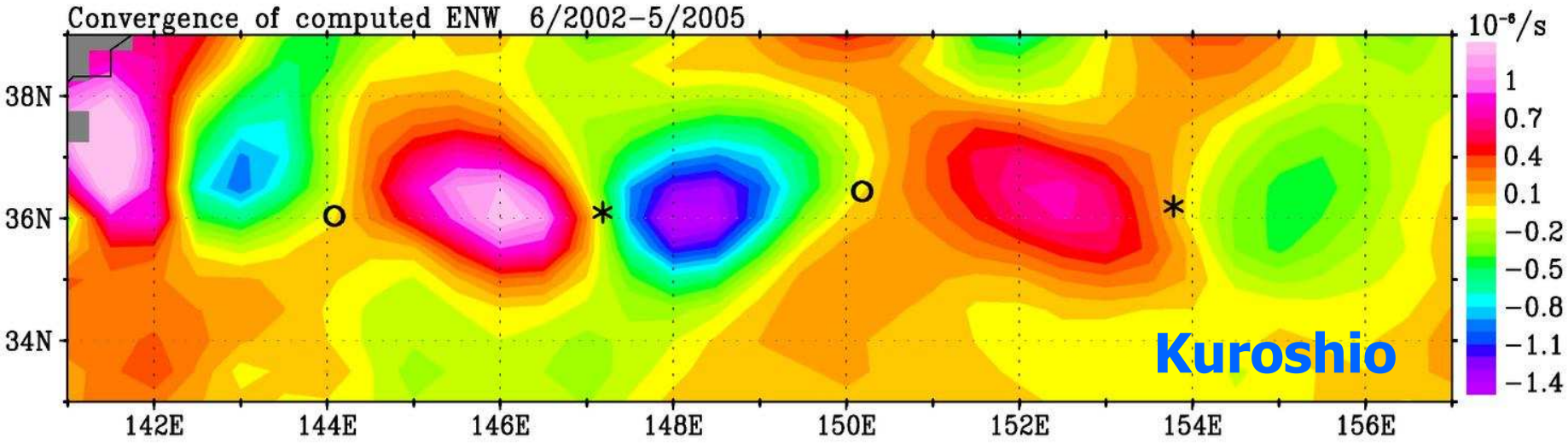
Observation from satellite



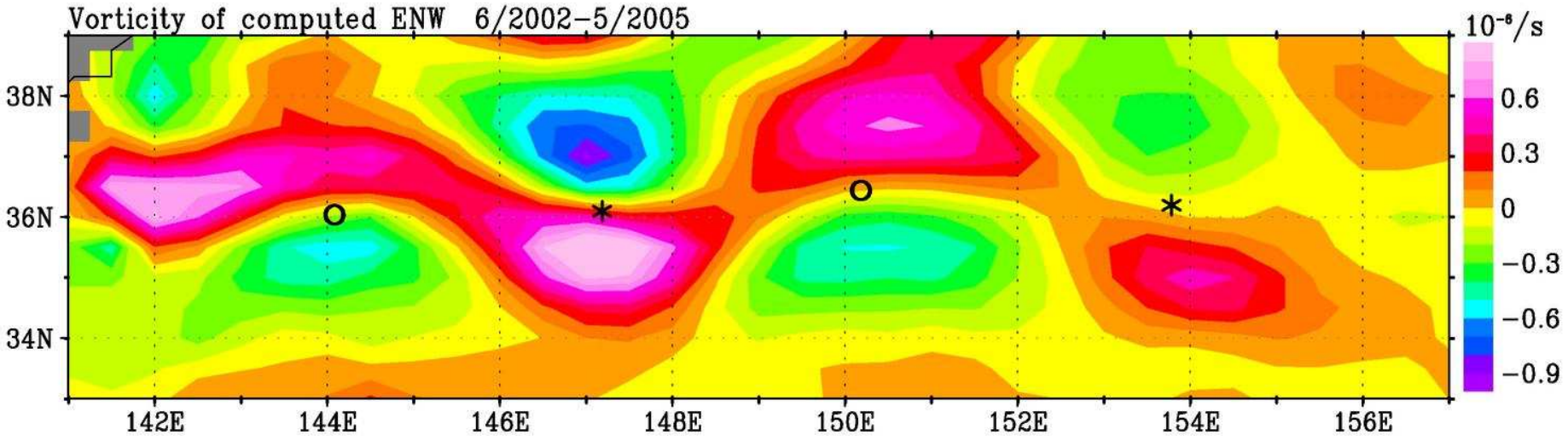
Computed from uniform wind field at 10m

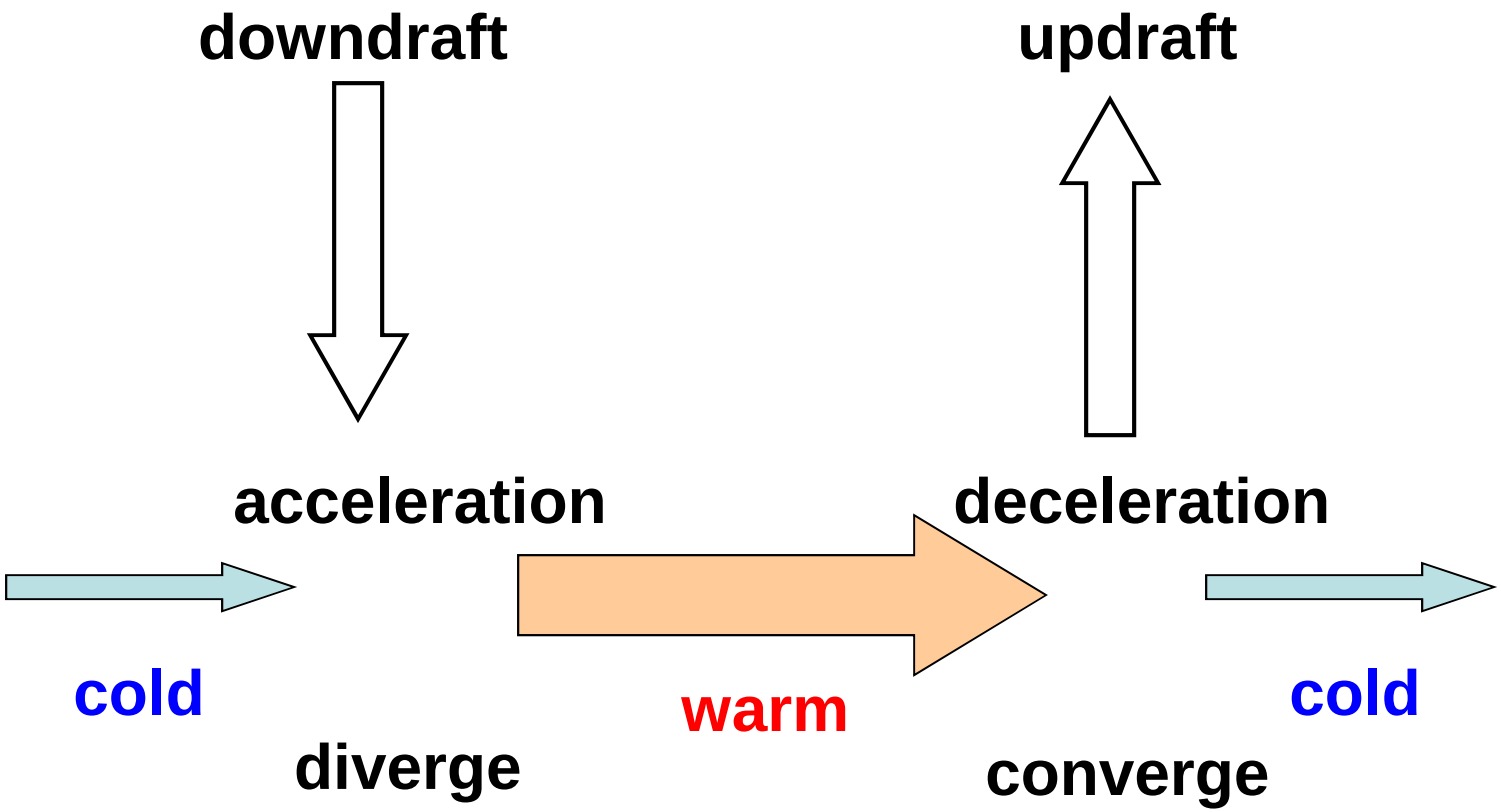


Convergence of filtered ENW computed from uniform wind



Vorticity of filtered ENW computed from uniform wind




downdraft
updraft
acceleration
deceleration
cold
warm
cold
diverge
converge

Surface stress variation of course influences the wind above.

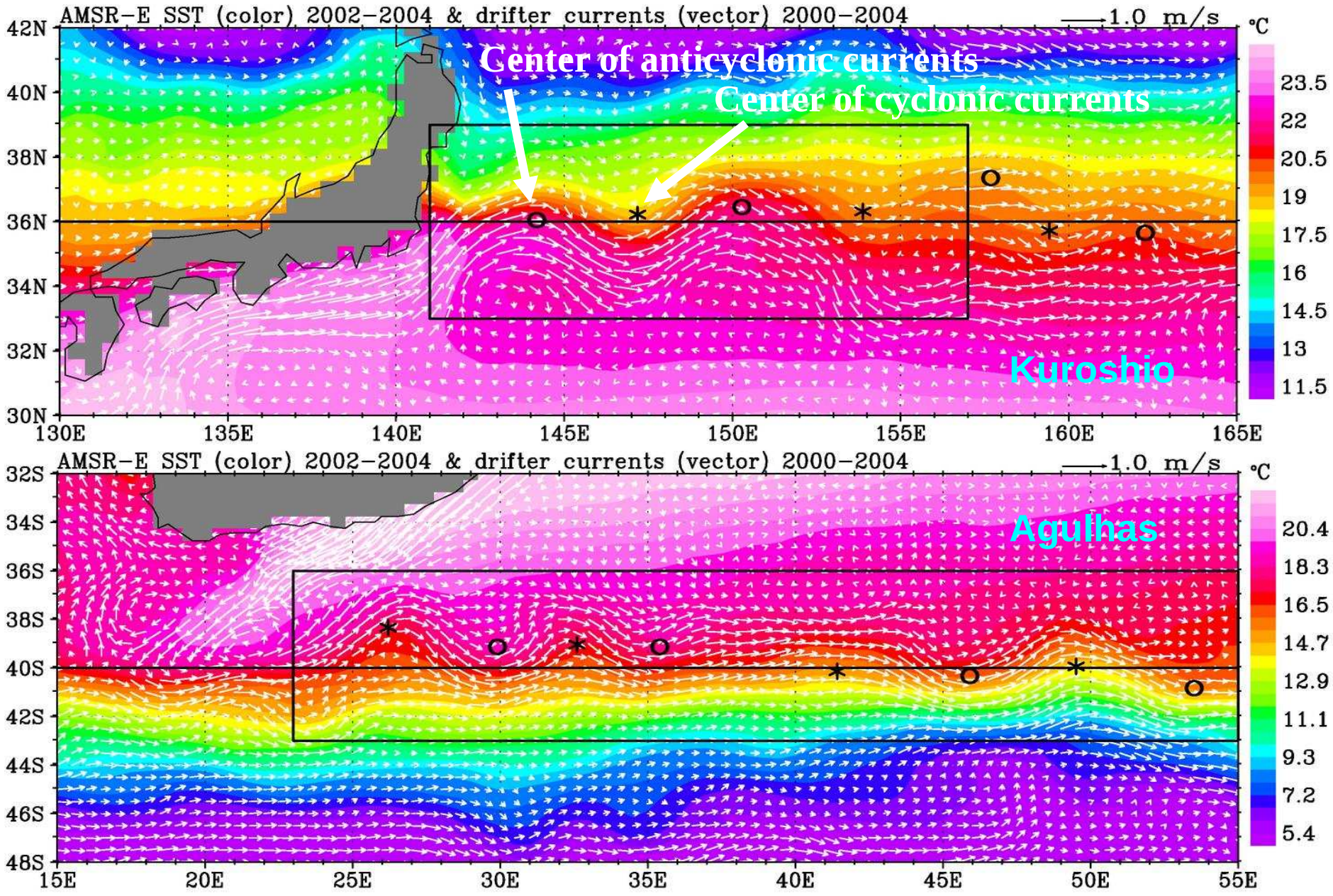
But is it contradictory to say we can use equivalent neutral wind as actual wind and then say there is strong instability driven turbulent mixing in the same breath?

How much of the wind pattern is revealed by the stress pattern in frontal regions requires a more incisive analysis.

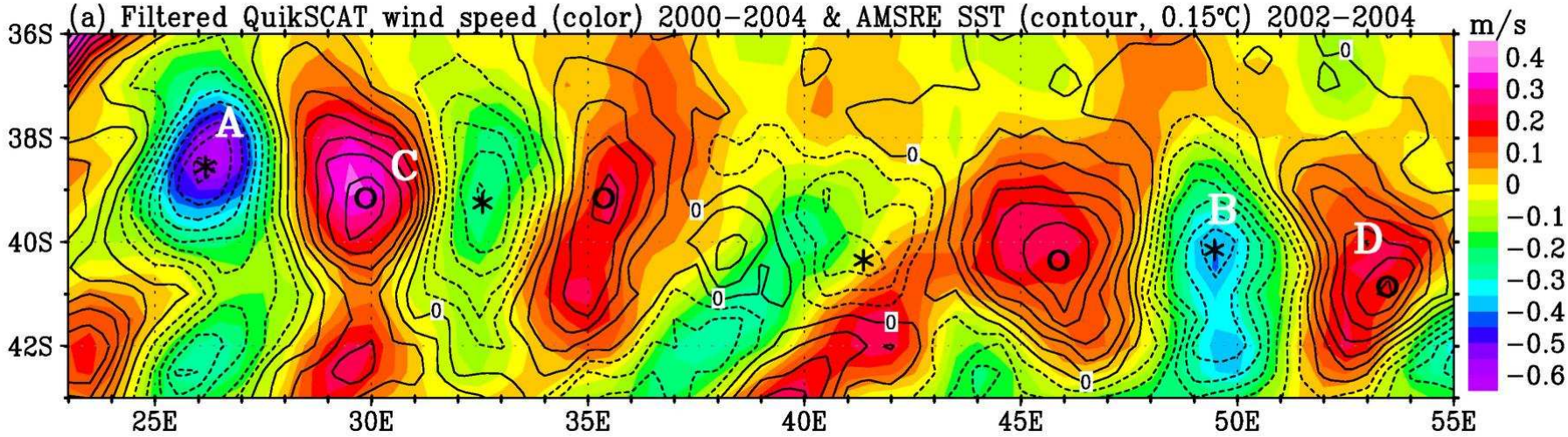
Summary

- A

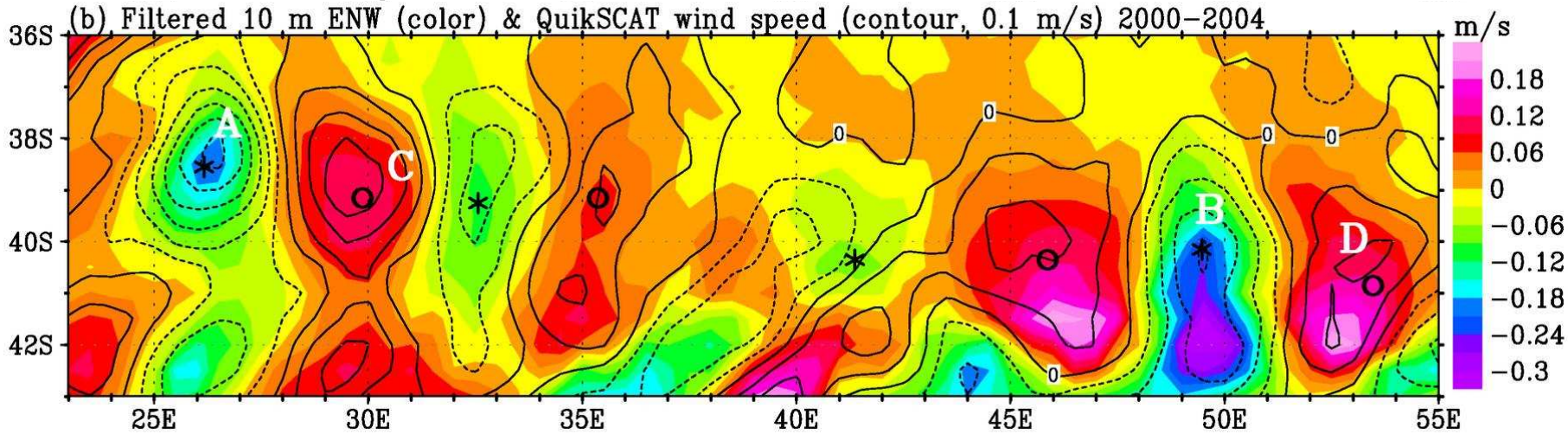
Strong Temperature Gradient & Current Shear at Ocean Front



Observation from satellite

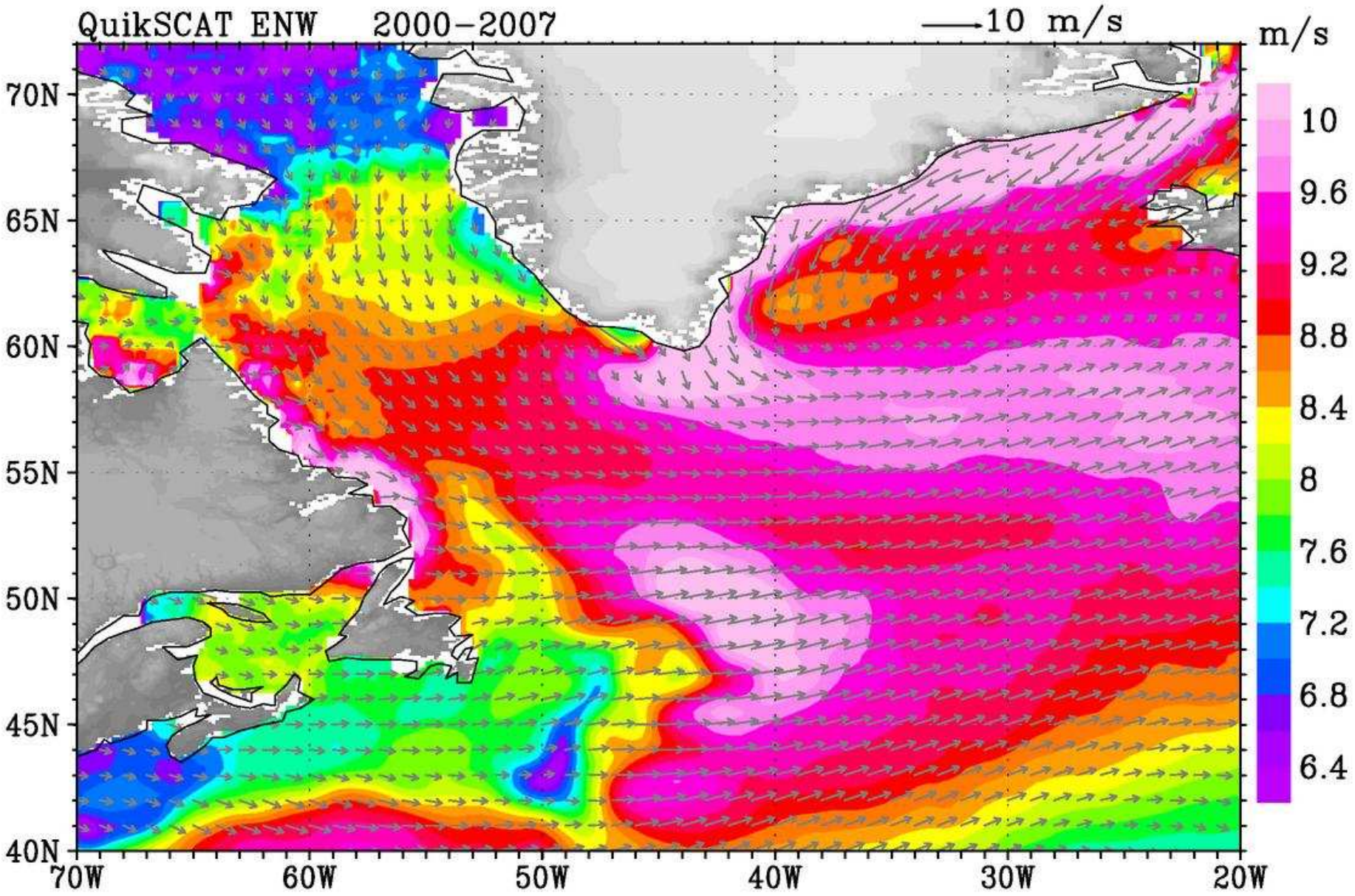


Computed from uniform wind field at 10m



Collocation of ENW magnitude with SST is inherent in the definition of ENW and turbulent mixing theory.

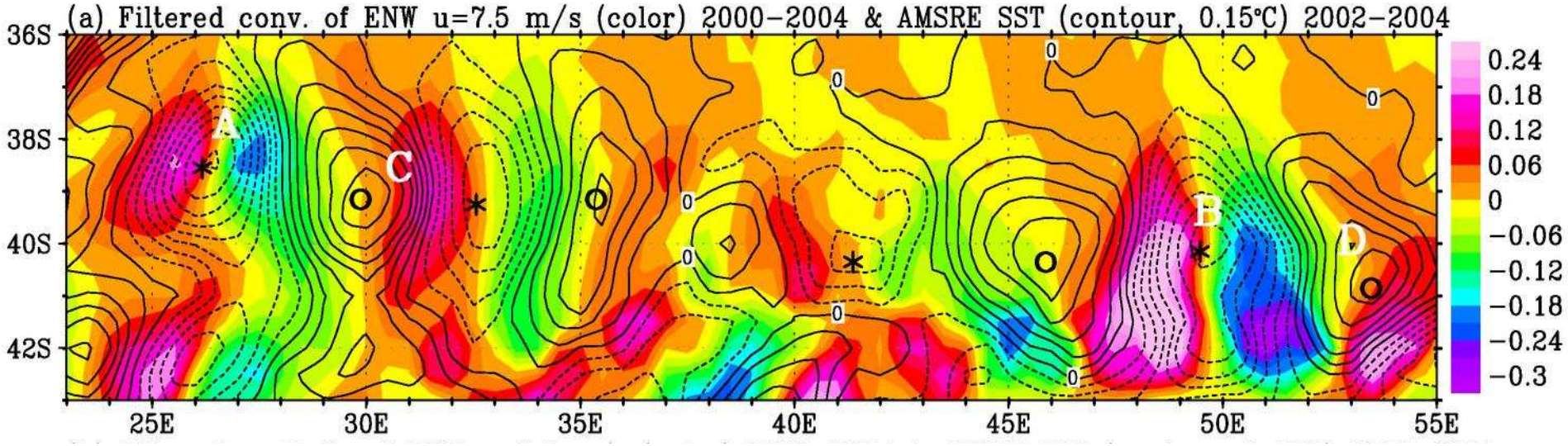
QuikSCAT ENW (magnitude & vector)



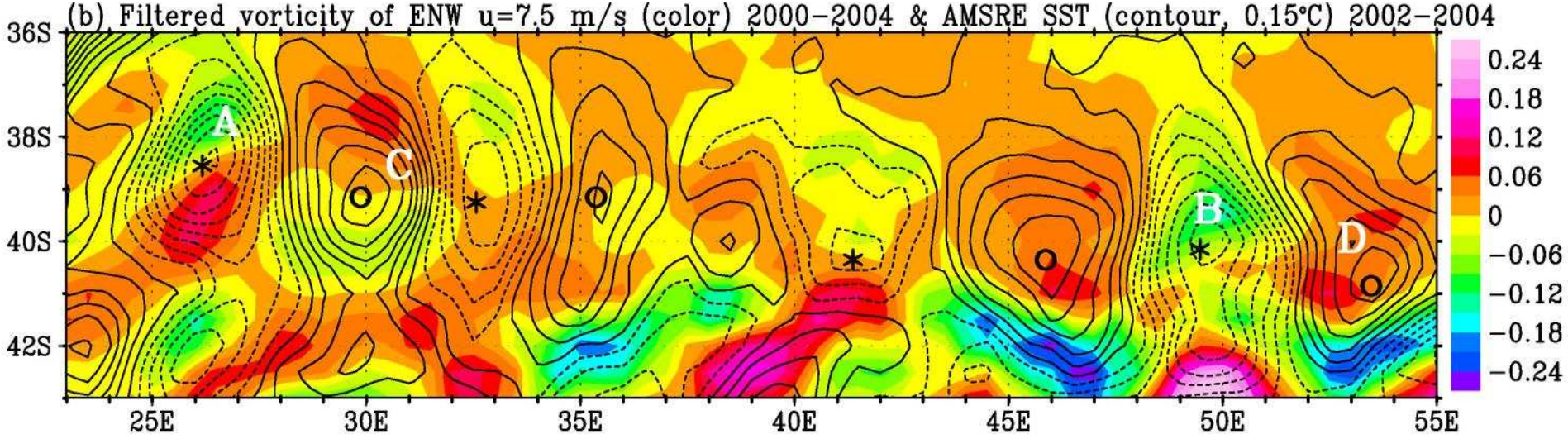
Liu et al. 2008, GRL

Computered from uniform wind at 10m

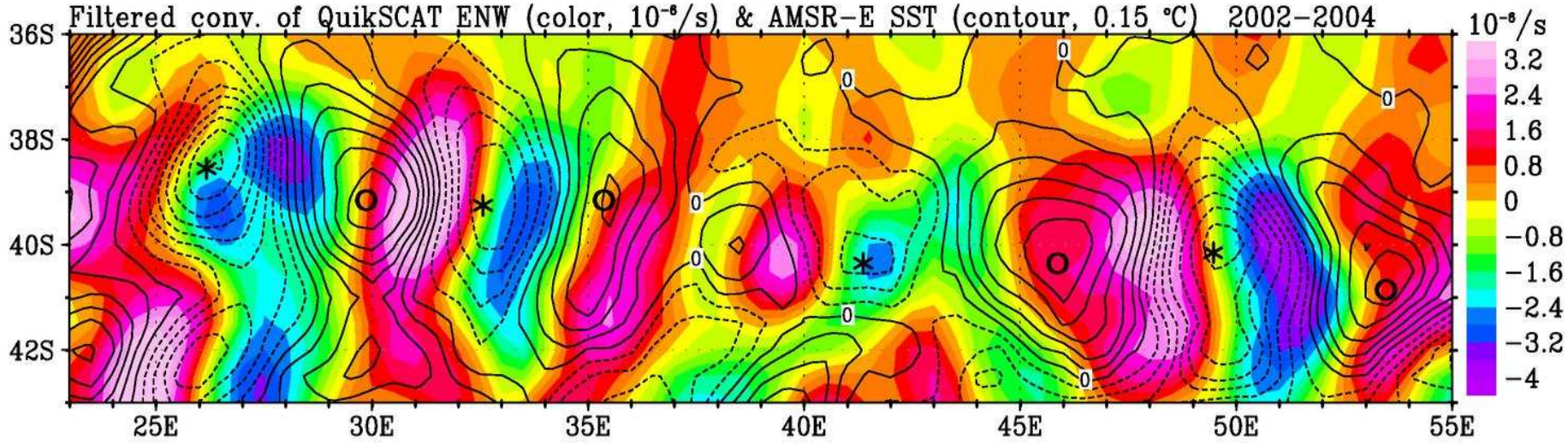
Convergence



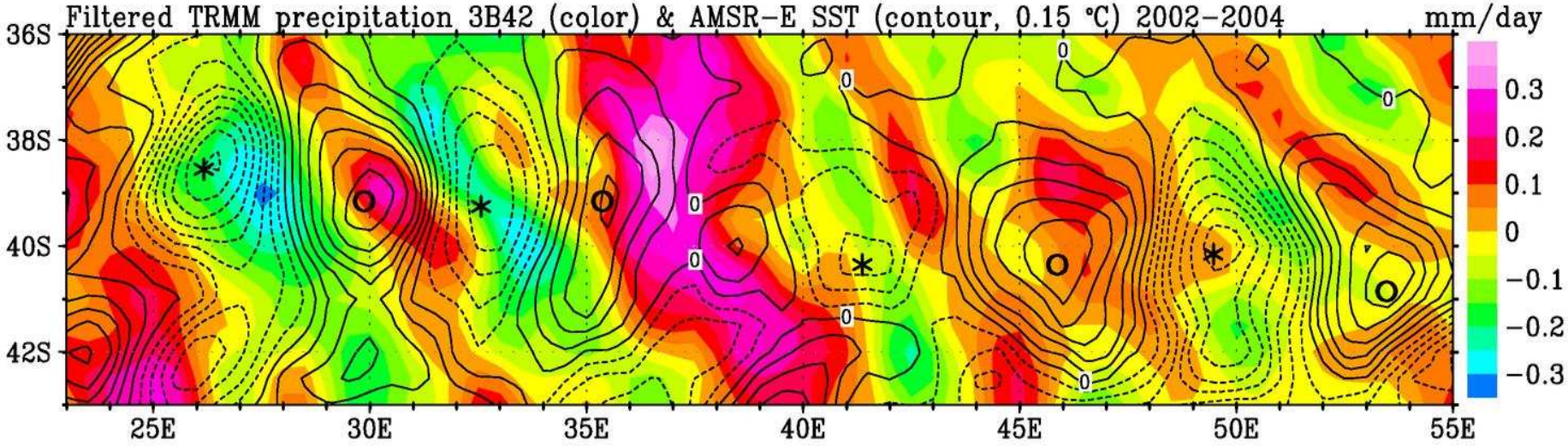
Vorticity



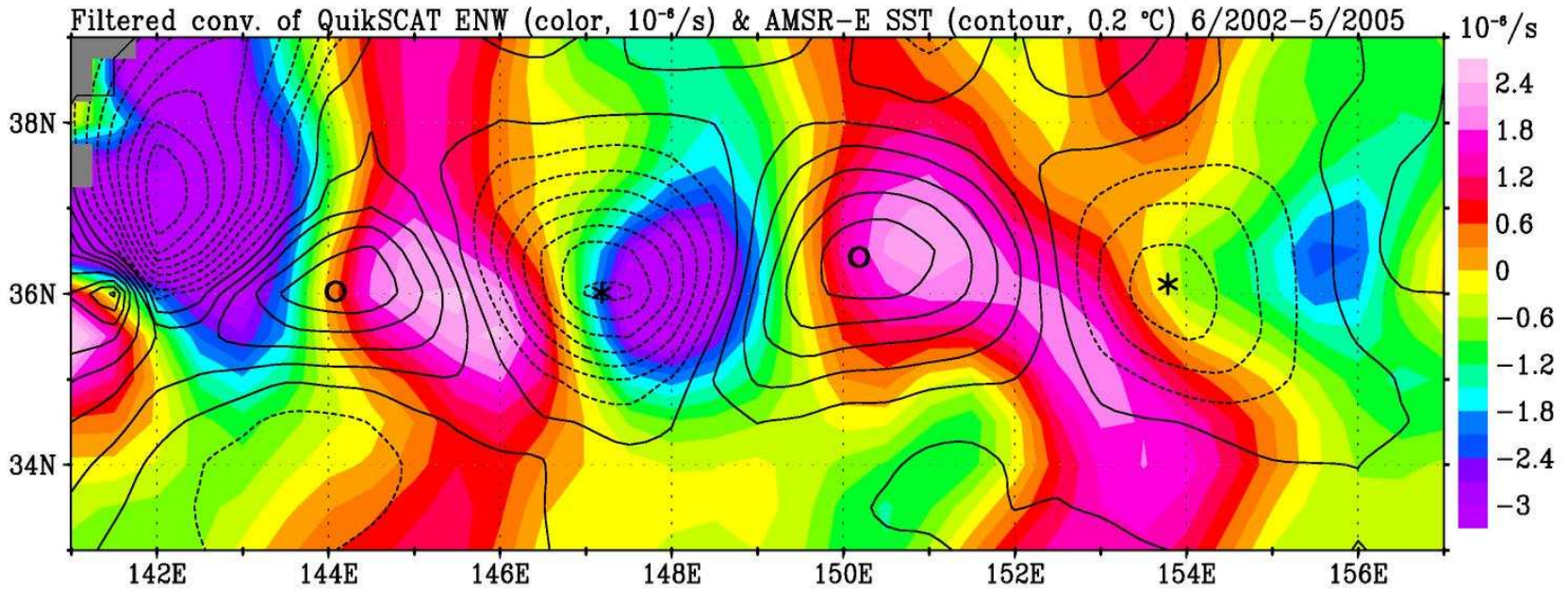
Convergence (color) & SST (contour) Agulhas



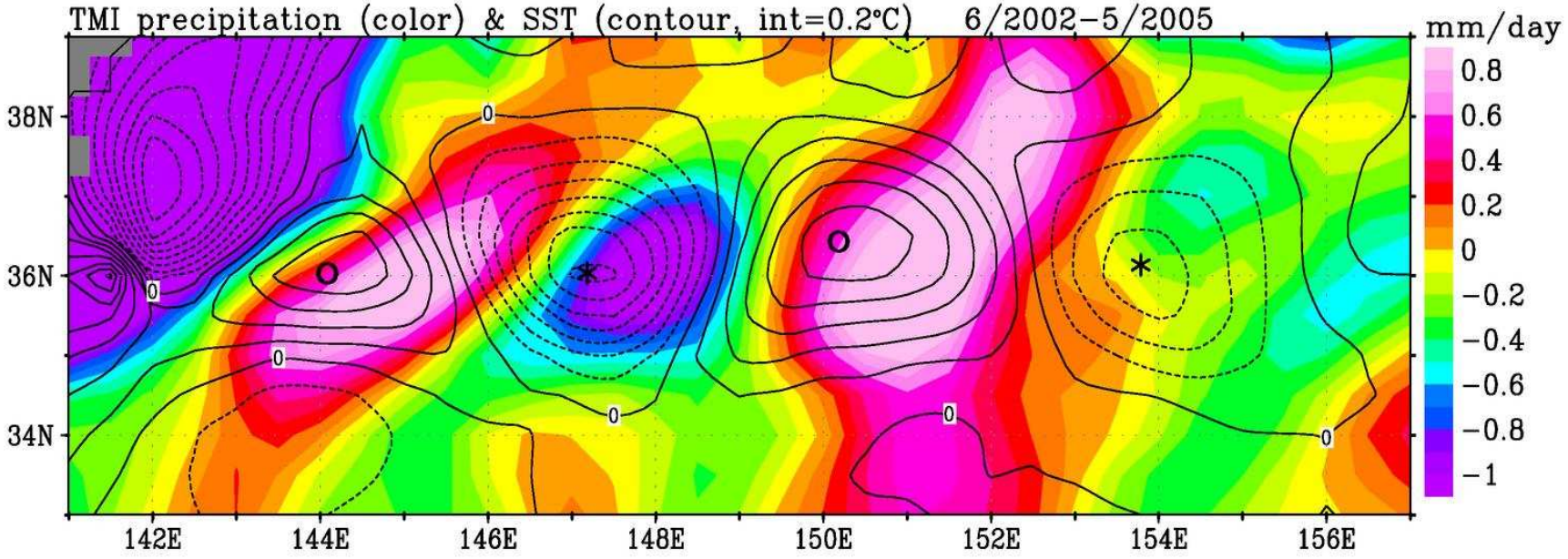
Rain (color) & SST (contour)



Convergence (color) & SST (contour) Kuroshio

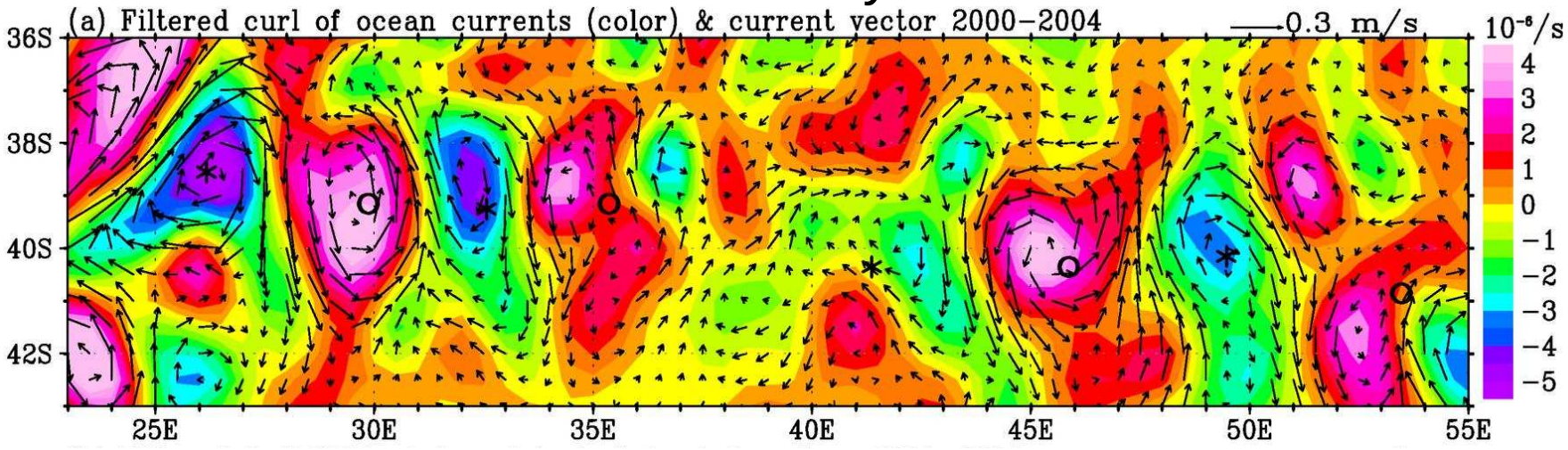


Rain (color) & SST (contour)

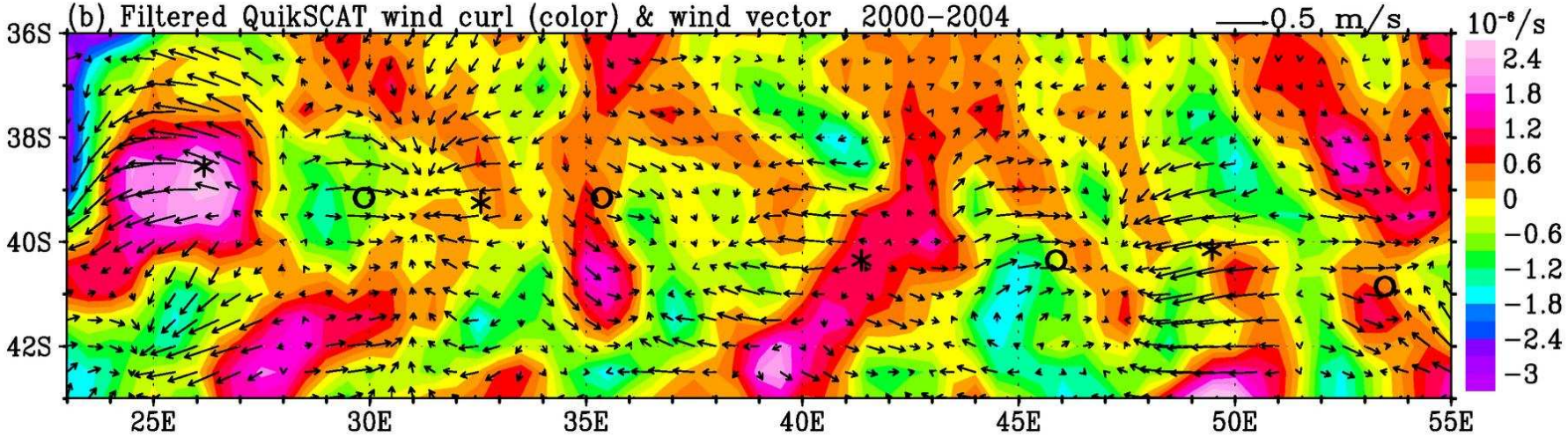


Agulhas Extension

Measurement by Drifters



Measurement by Scatterometer

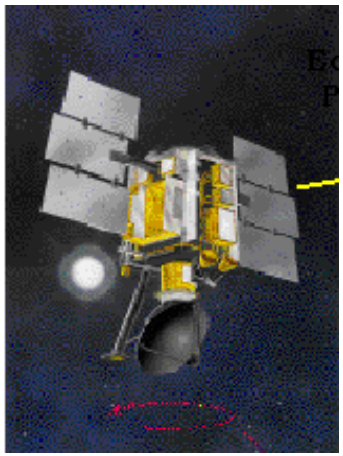


Scatterometer ENW rotates in opposite direction with surface current.

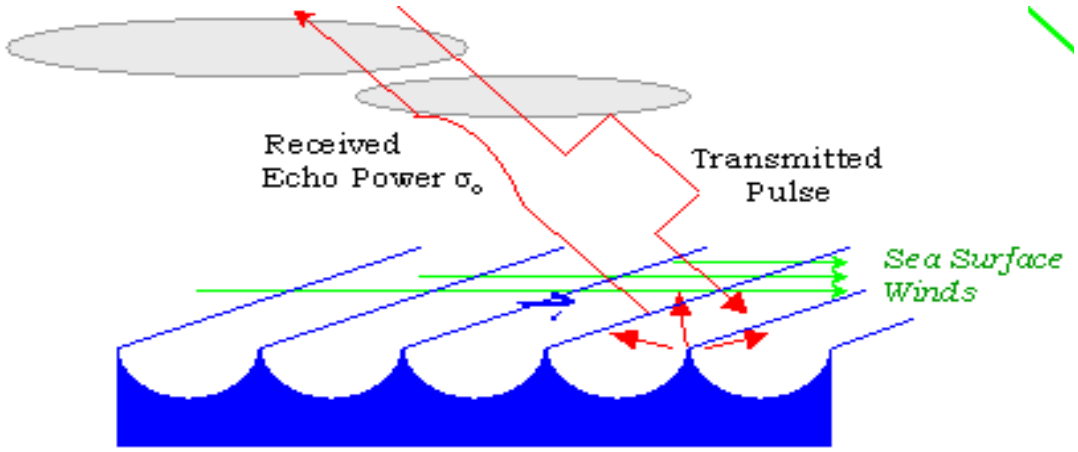
Stress spins down current rotation, although current vorticity is much stronger than ENW vorticity anomaly.

- **AIRS, TRMM, and ISCCP (3 independent sets) reveal signature of SST way above the atmospheric boundary layer at low frequencies over mid-latitude ocean fronts.**
- **Past GCM or operational NWP data, do not show the effect of ocean SST gradient beyond atmospheric boundary layer.**
- **Ocean has slow & small-scale, but atmosphere has fast and large-scale processes processes. Coupling in mid-latitudes at long time period is controversial.**
- **The observations present a challenge to modeling community in improving model dynamics and spatial versus temporal scales parameterization.**

Wind Vectors from Scatterometer



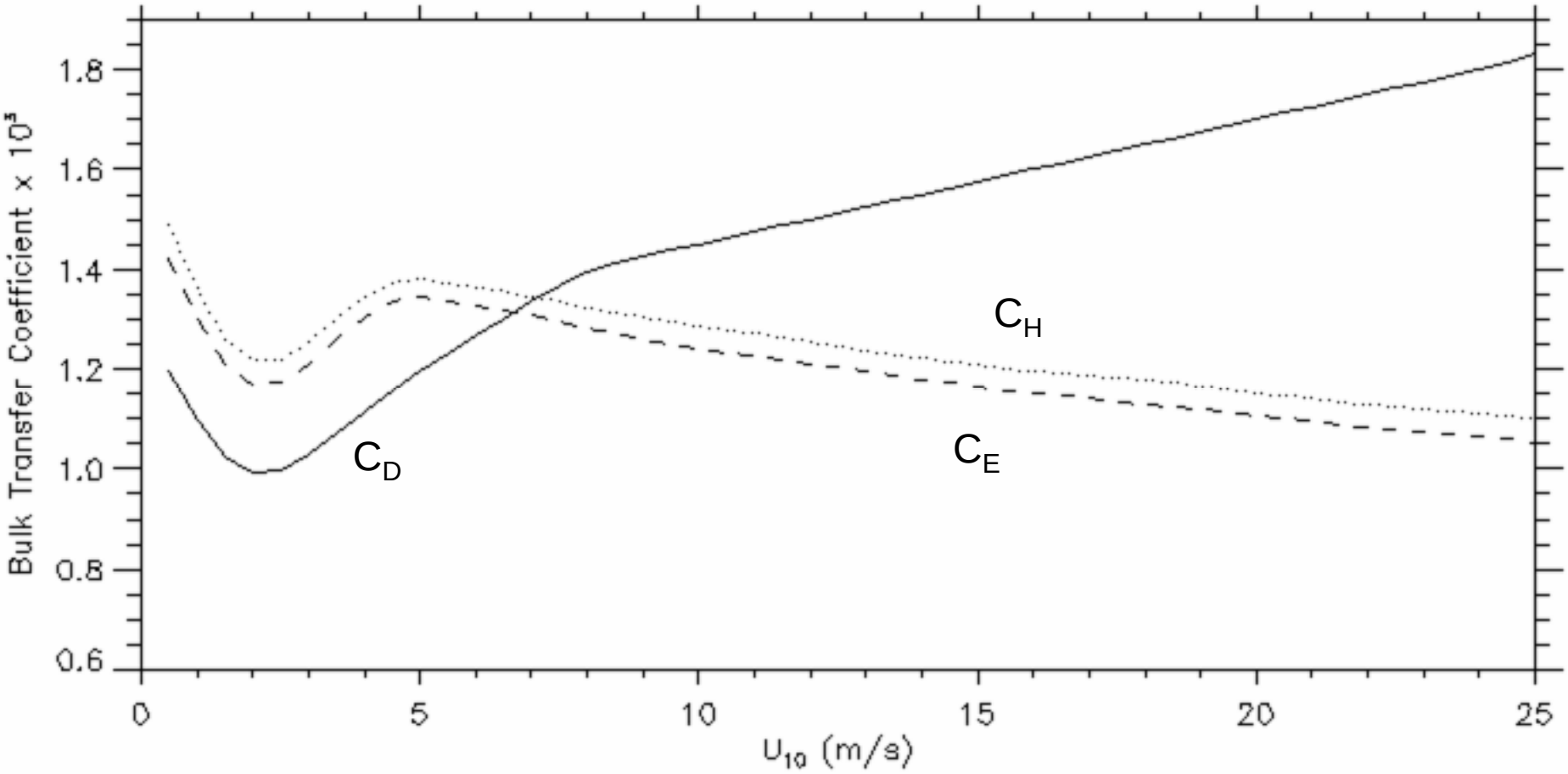
- A Scatterometer sends microwave pulses to the Earth's surface, and measures the power scattered back.
- The backscattered power depends on the surface roughness.



Surface waves in local equilibrium with wind produce Bragg scattering

- Over oceans, roughness is caused by small waves **assumed** to be in equilibrium with the wind stress.
- Measuring both stress magnitude and direction is a unique capability of a scatterometer.


Calling A Stag A Horse
指 鹿 为 马



Liu et al, 1979