On the Interpretation of Scatterometer Winds near Sea Surface Temperature Fronts

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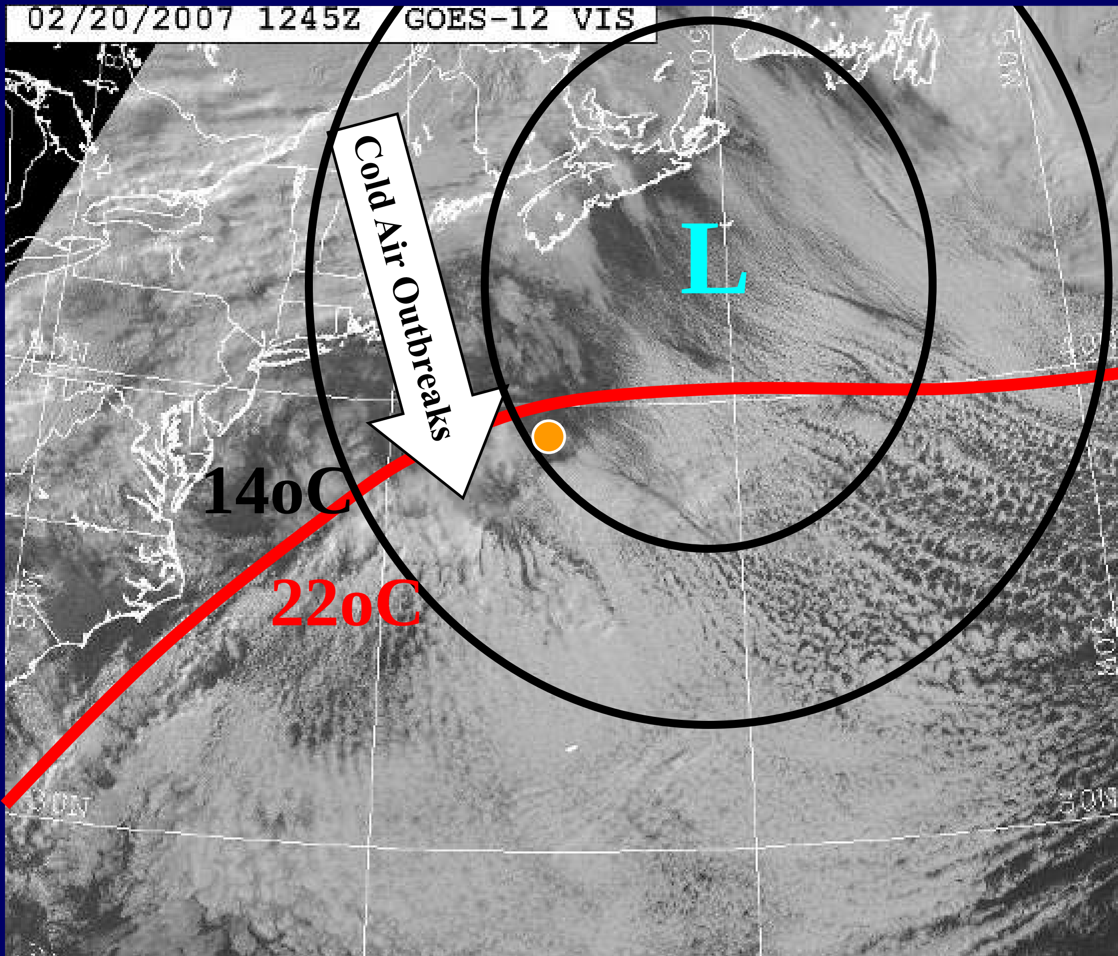
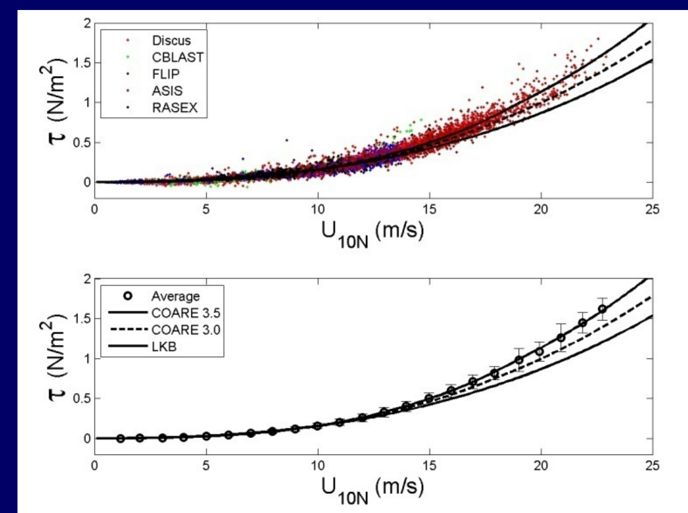
IOVWST Meeting

Utrecht, NL

June 14, 2012

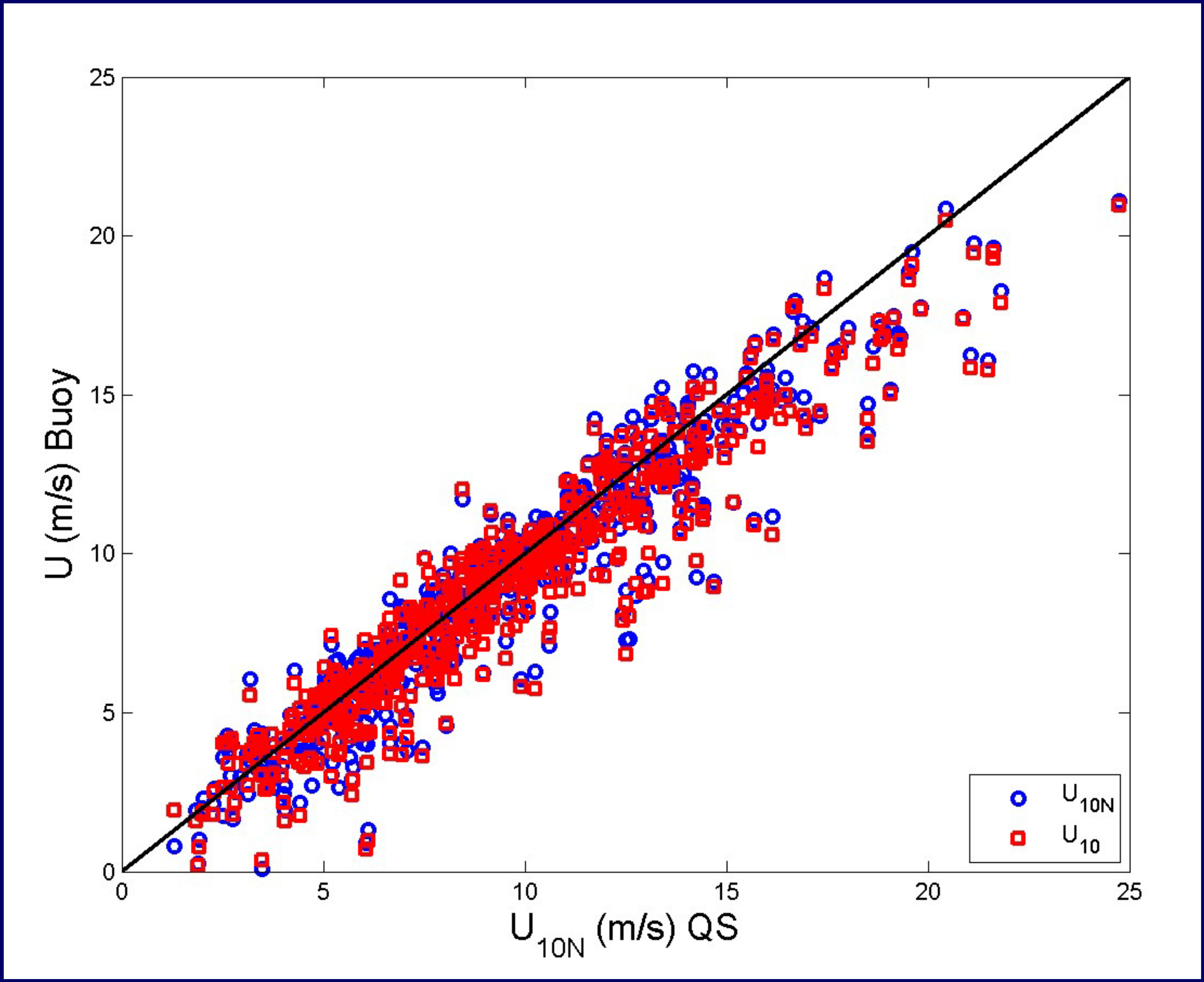
The Gulf Stream



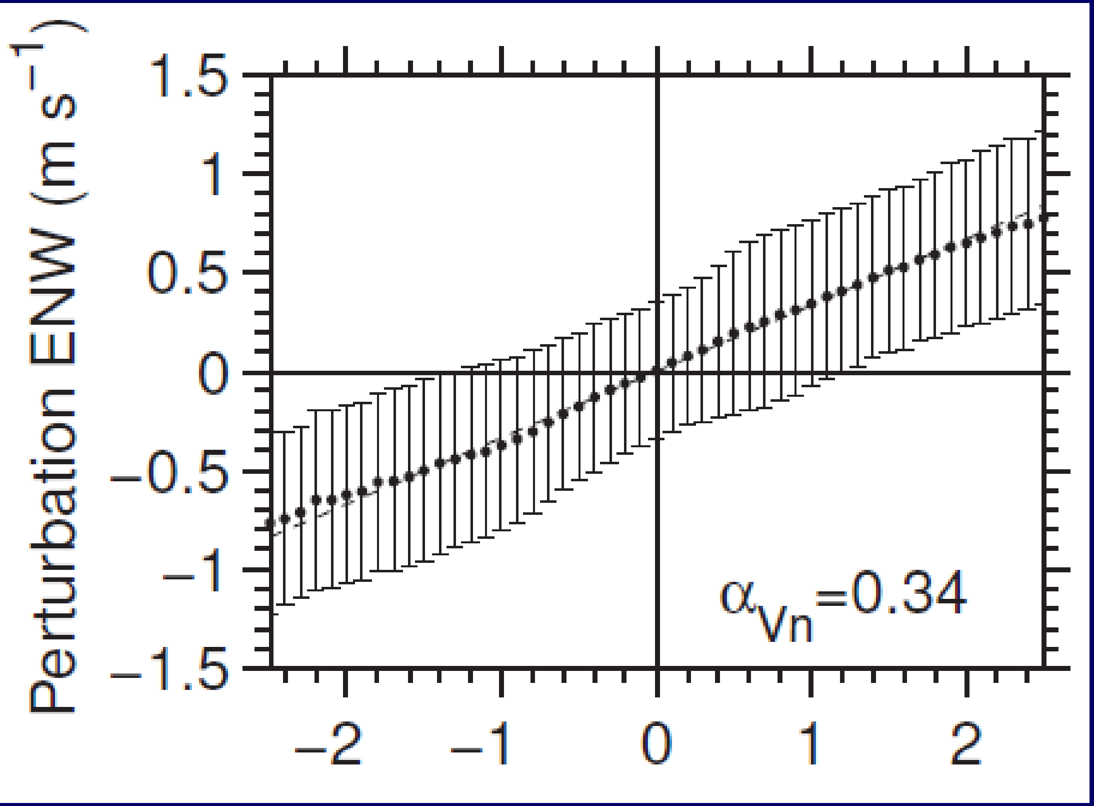


- Cold air outbreaks drive extremely active convection over the region.
- The net winter heat loss in this region is 400 W/m^2.
- Hourly combined latent and sensible heat fluxes reached 1400 W/m^2.

QuikSCAT vs. Buoy Wind Speeds

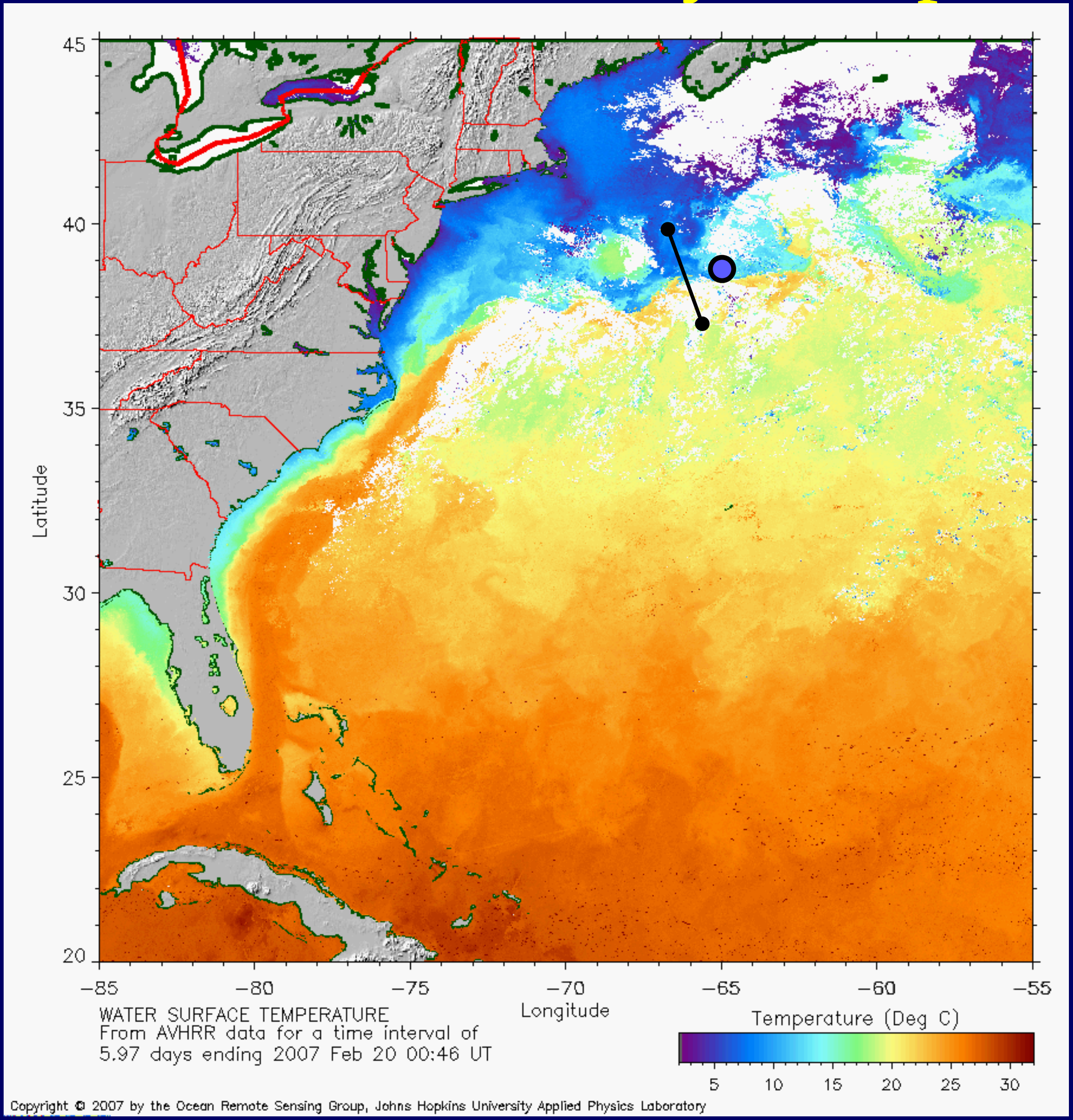


Coupling Coefficients



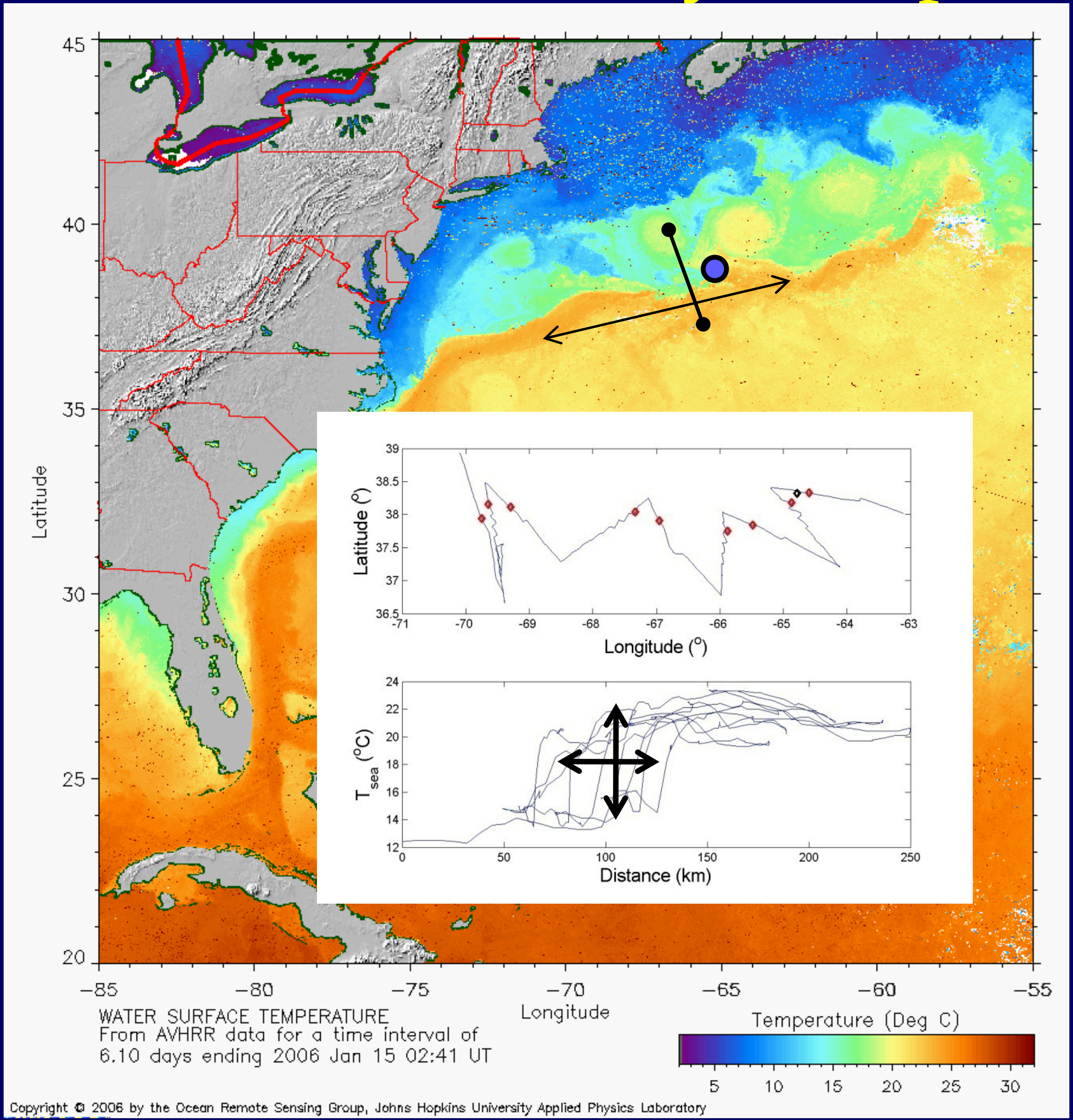
O’Neill et al. (2011)

SST Field – 7 Day Composite



Courtesy of JHU/APL Ocean Remote Sensing http://fermi.jhuapl.edu/avhrr/

SST Field – 7 Day Composite



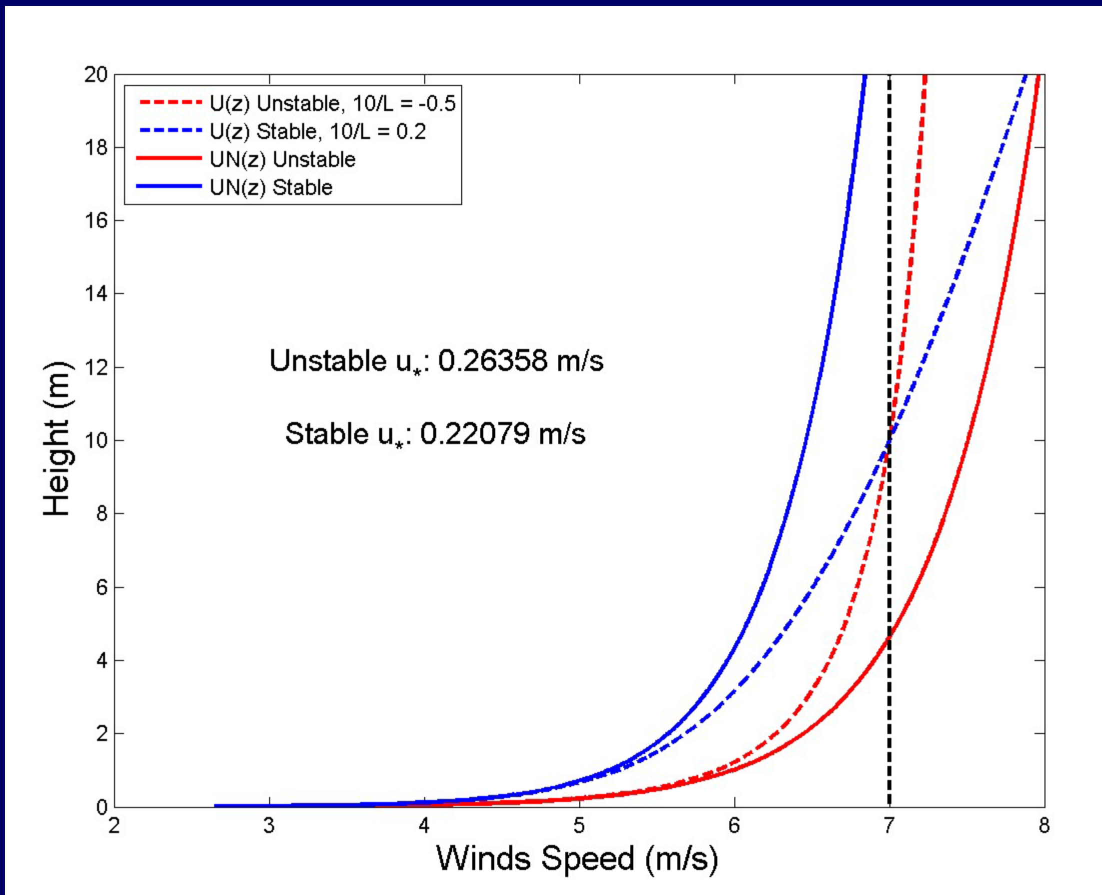
Courtesy of JHU/APL Ocean Remote Sensing http://fermi.jhuapl.edu/avhrr/

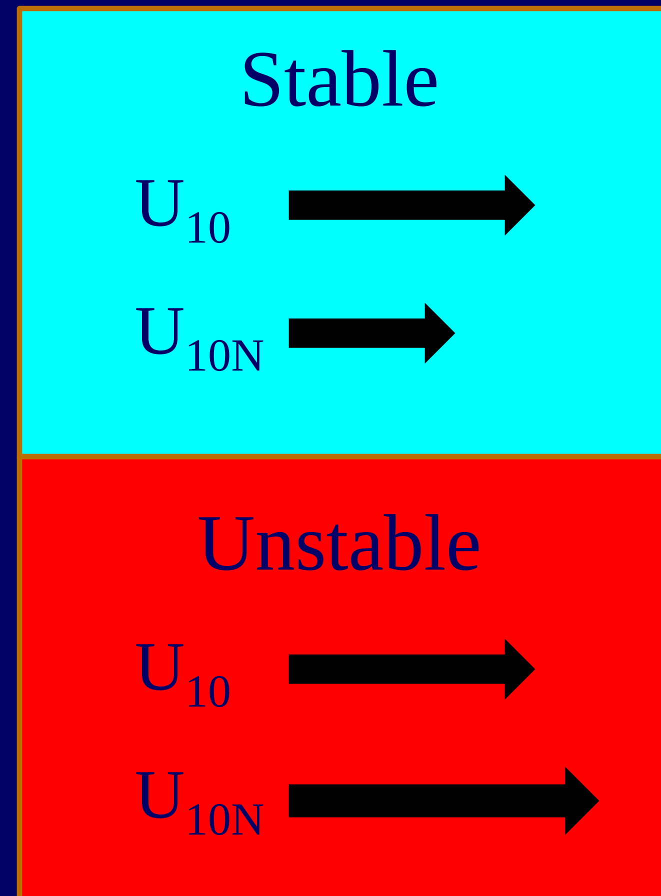
Stability Effects Near SST Fronts

- Surface Layer (Stability) Adjustment (Bottom Up)
  - QuikSCAT measures surface roughness/stress
  - Surface stress is proportional to neutral winds, U_N
    - $U_N < U$ in unstable conditions
    - $U_N > U$ in stable conditions
- Baroclinic adjustment to horizontal temperature gradients that drive a secondary (thermally direct) circulation .
- Enhanced surface winds due to boundary layer mixing (Top Down).
- All of these effects are likely acting to drive variability in surface winds.
- Can we quantify any of these processes?

QuikSCAT vs. Buoy Wind Speeds

“Surface Layer Adjustment”





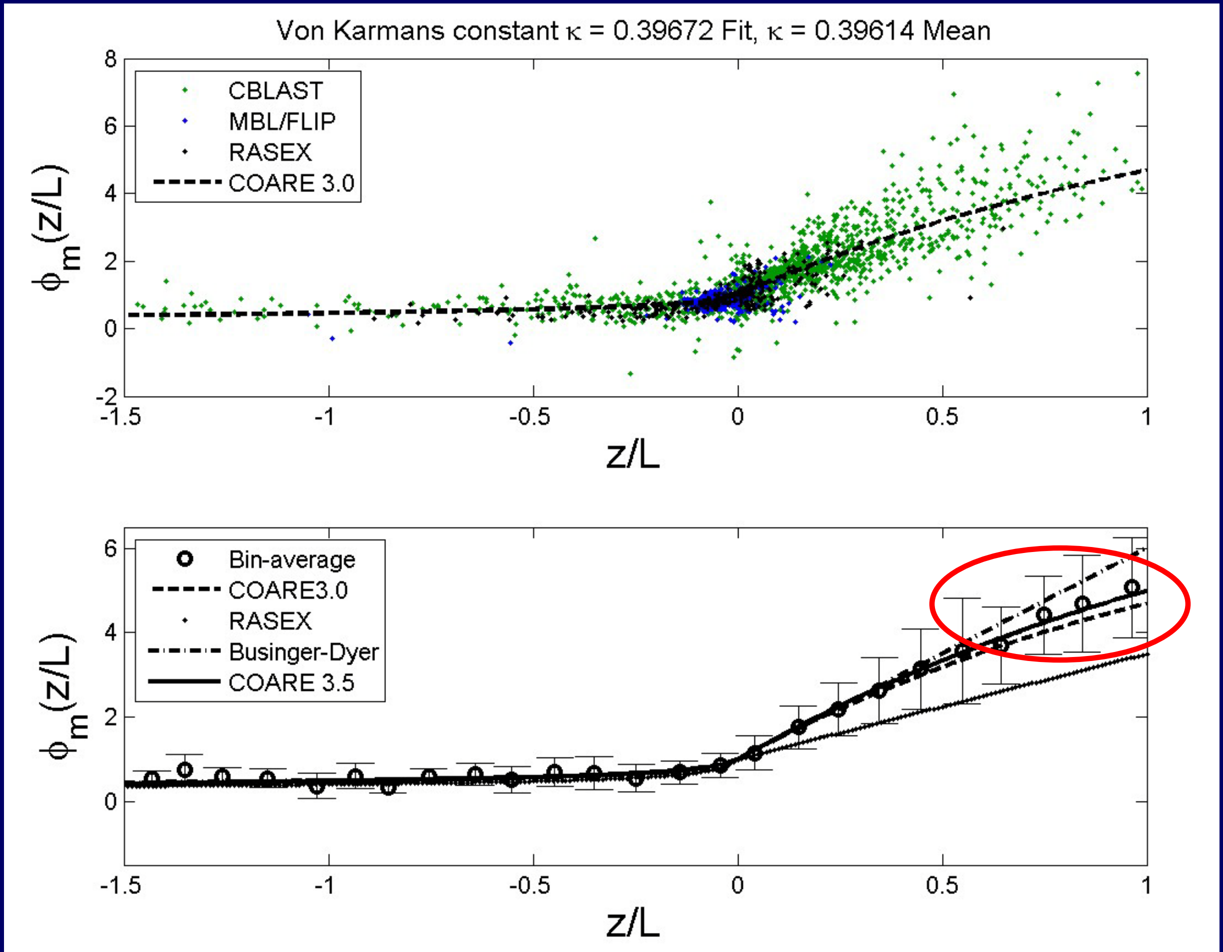
$U_N(z) = u_*/\kappa[\ln(z/z_o)]$ $\quad$ $U(z) = U_N(z) - u_*/\kappa\, \psi_m(z/L)]$

QuikSCAT vs. Buoy Wind Speeds

"Surface Layer Adjustment"

Dimensionless Shear over the Ocean

$$\phi_m\left(\frac{z}{L}\right) = \frac{\kappa z}{u_*}\frac{\partial U}{\partial z}$$

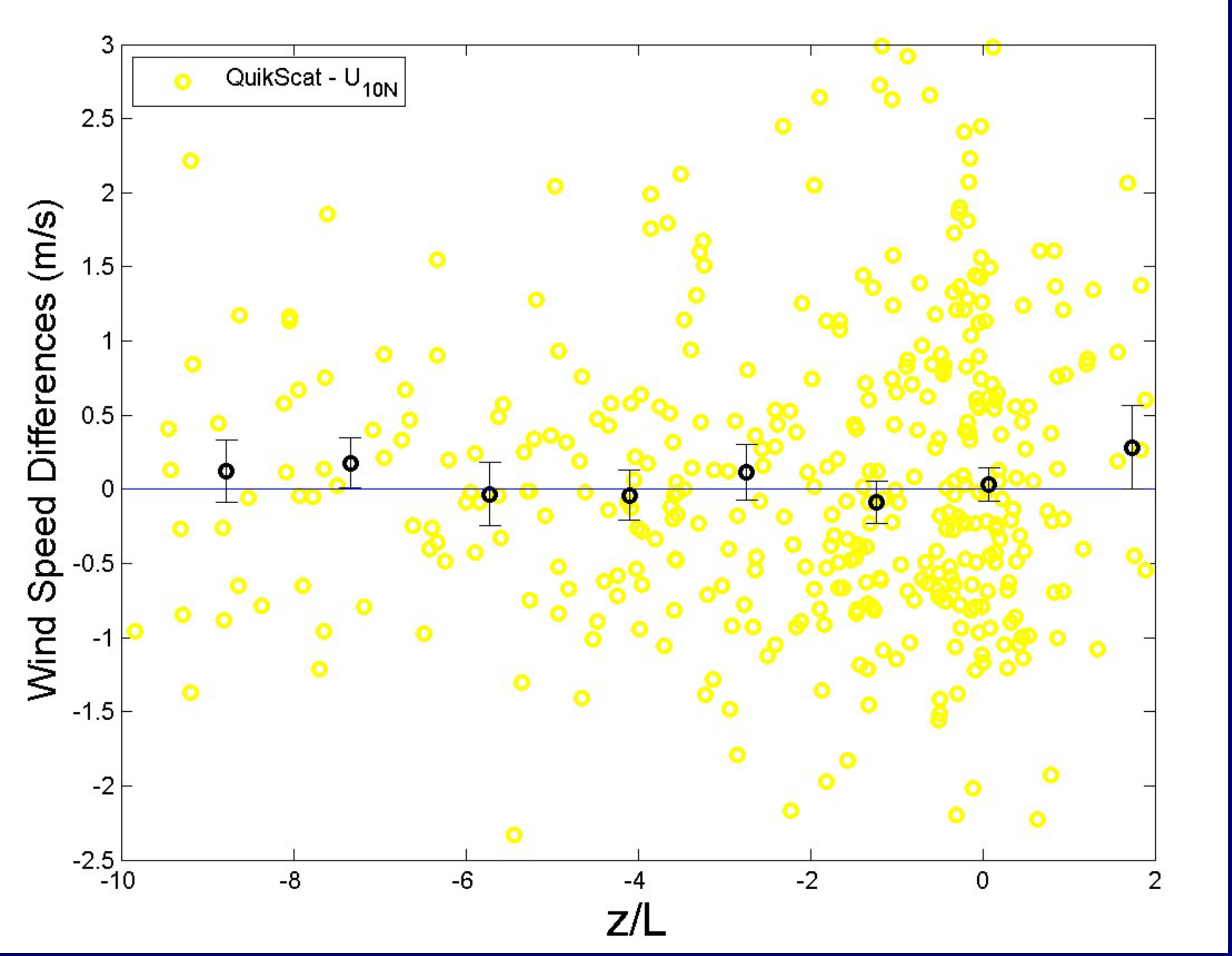


Marine surface layer is very Kansas-like in the mean.

$$U_N(z) = u_*/\kappa[\ln(z/z_o)] \qquad U(z) = U_N(z) - u_*/\kappa\ \psi_m(z/L)]$$

QuikSCAT vs. Buoy Wind Speeds

"Surface Layer Adjustment"

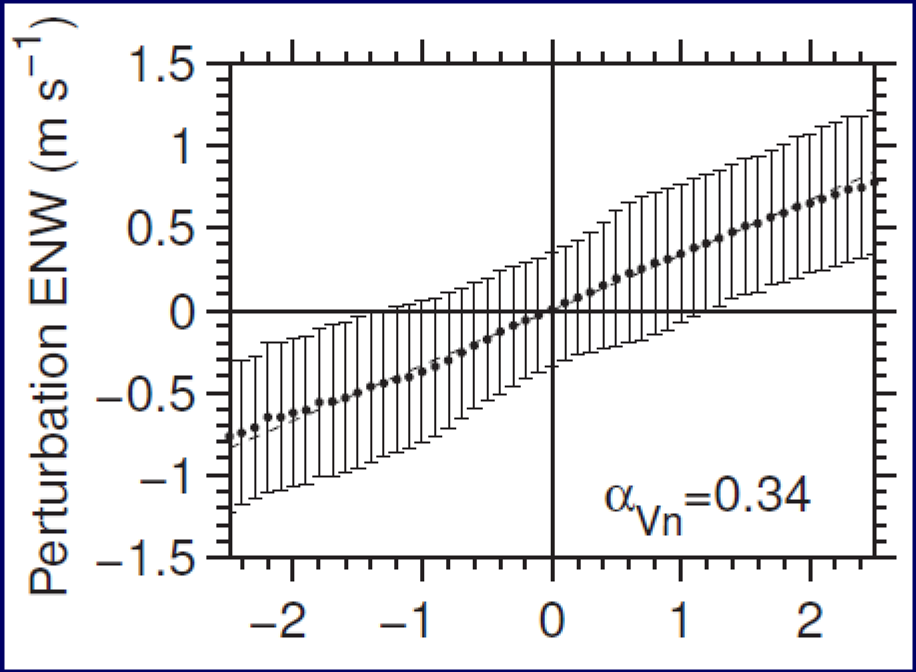


$U_N(z) = u_*/\kappa[\ln(z/z_o)]$ $U(z) = U_N(z) - u_*/\kappa\ \psi_m(z/L)]$

Surface Layer Adjustment

- Surface Layer Adjustment (Bottom Up)
  - QuikSCAT approximates the Neutral Wind, U_N.
  - These obey Monin-Obukhov similarity theory – at least in the mean.

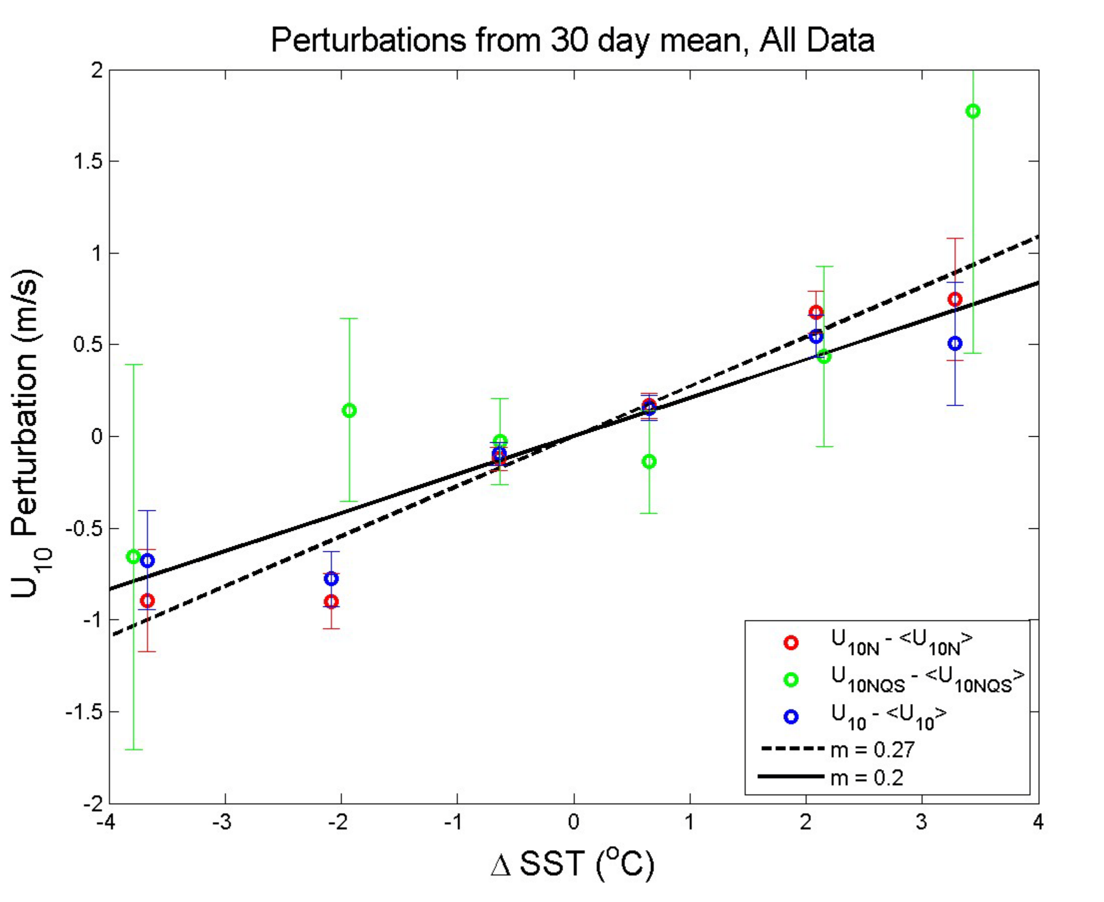
- Can surface layer adjustment explain this result?

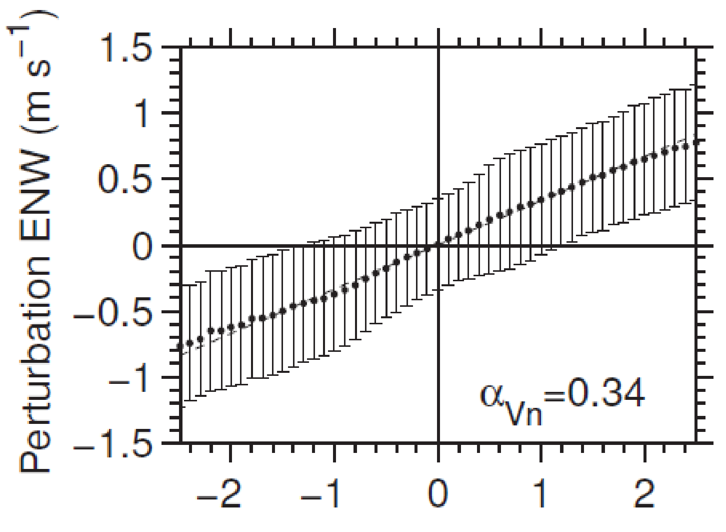


O'Neill et al. (2011)

QuikSCAT vs. Buoy Wind Speeds

"Boundary Layer Adjustment"





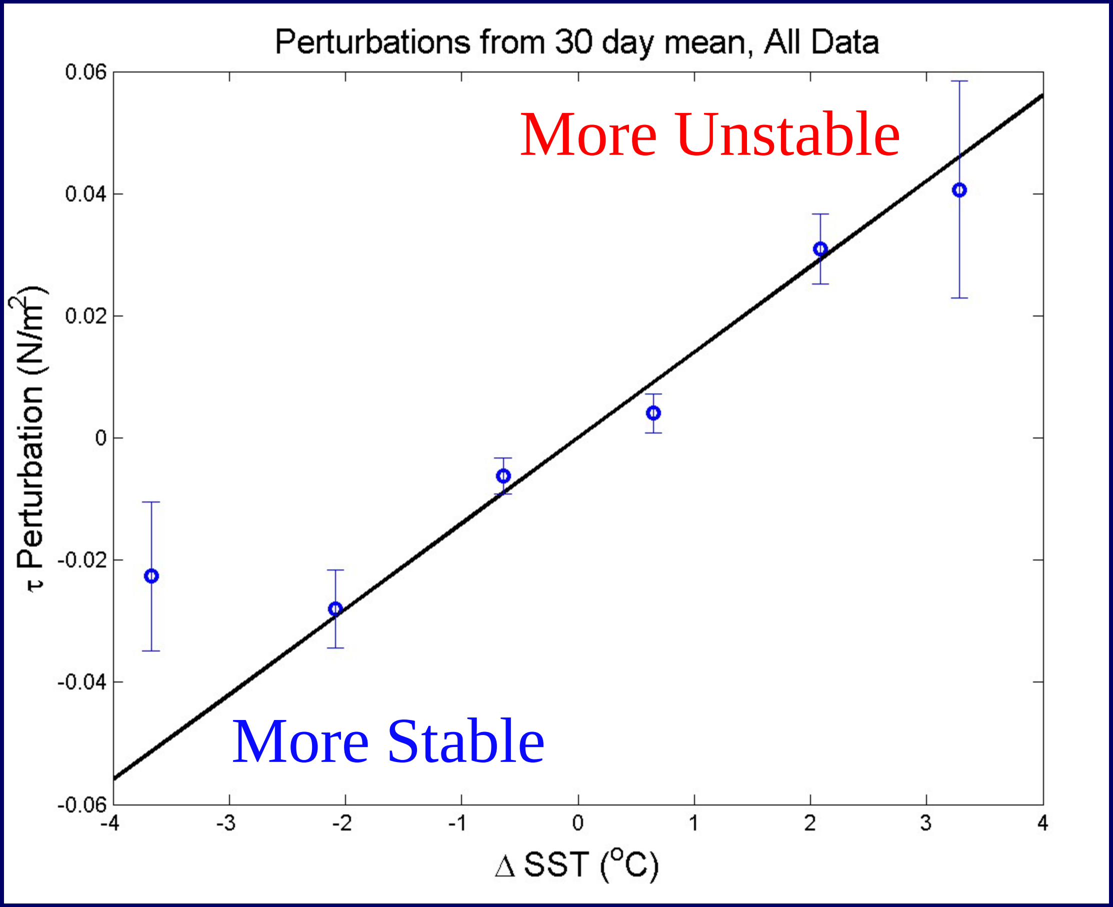
O'Neill et al. (2012)

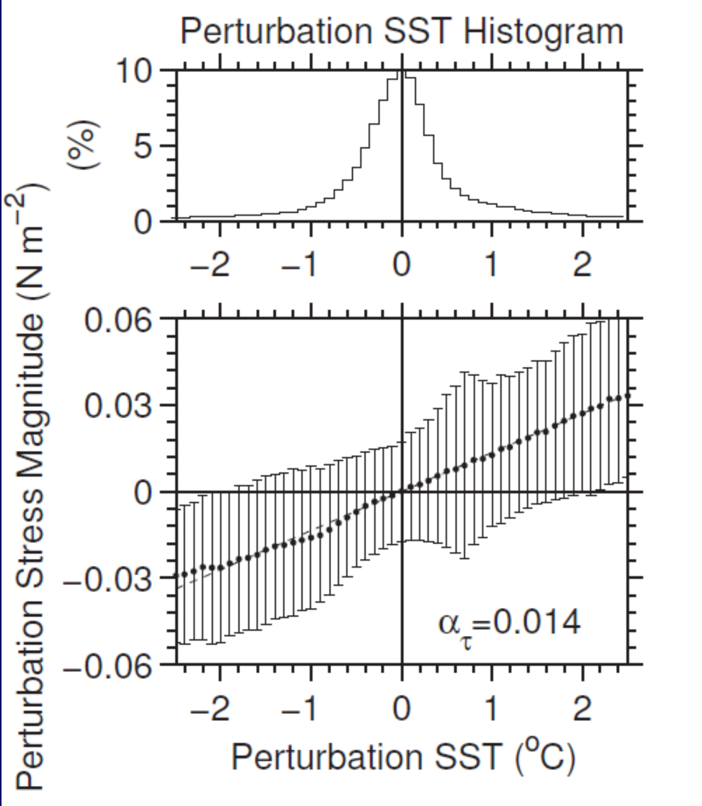
Can surface layer adjustment explain this result?

Some but not all.

QuikSCAT vs. Buoy Wind Speeds

“Boundary Layer Adjustment”

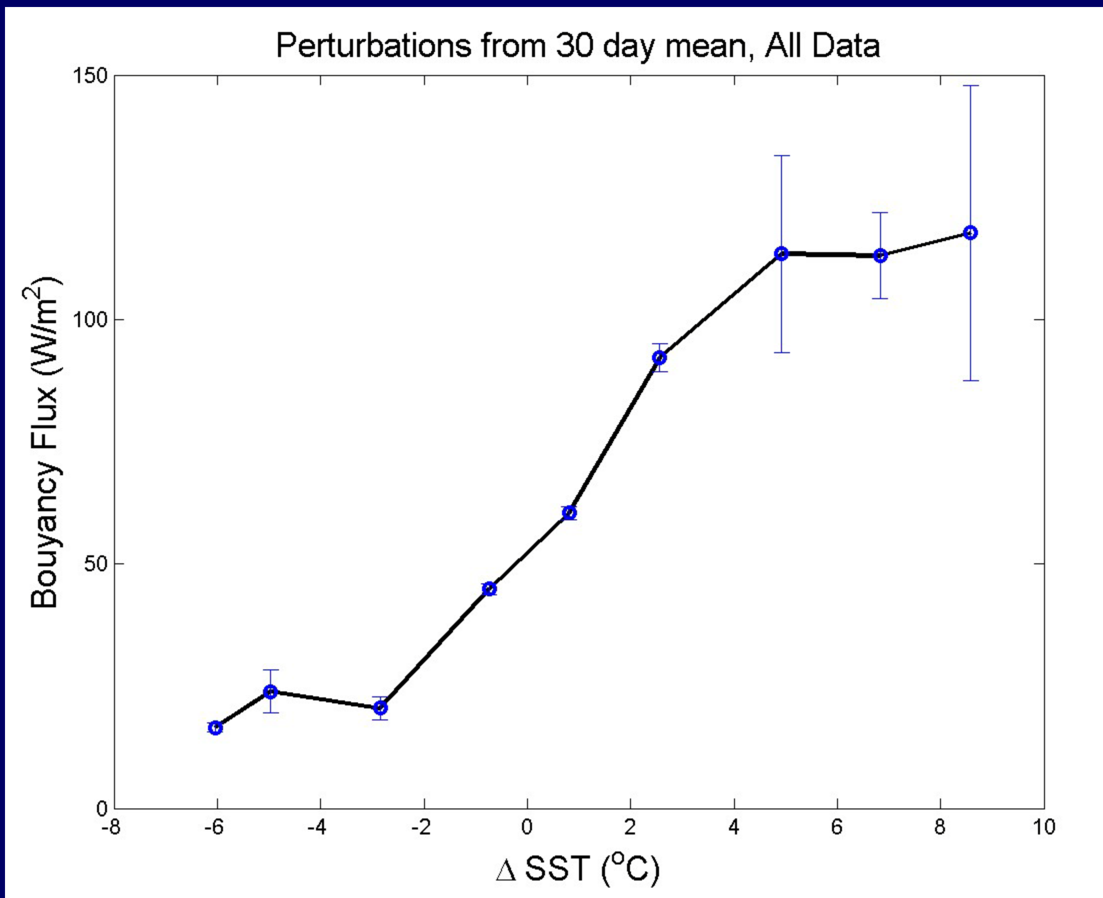




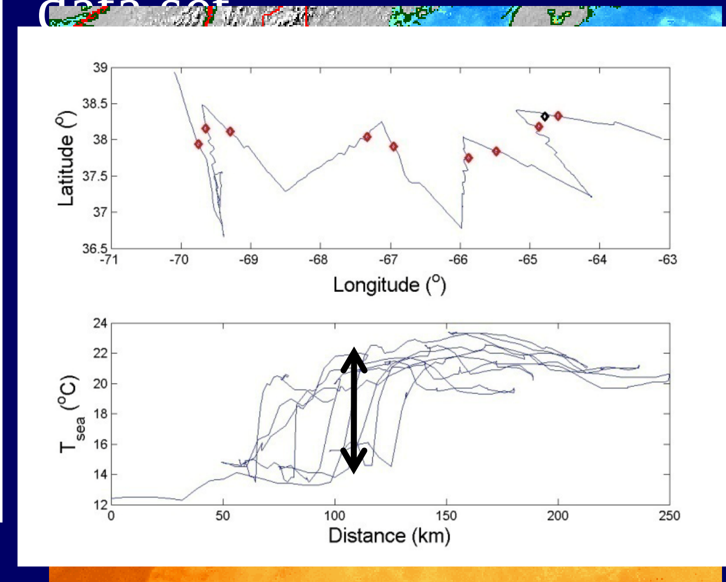
O’Neill et al. (2012)

QuikSCAT vs. Buoy Wind Speeds

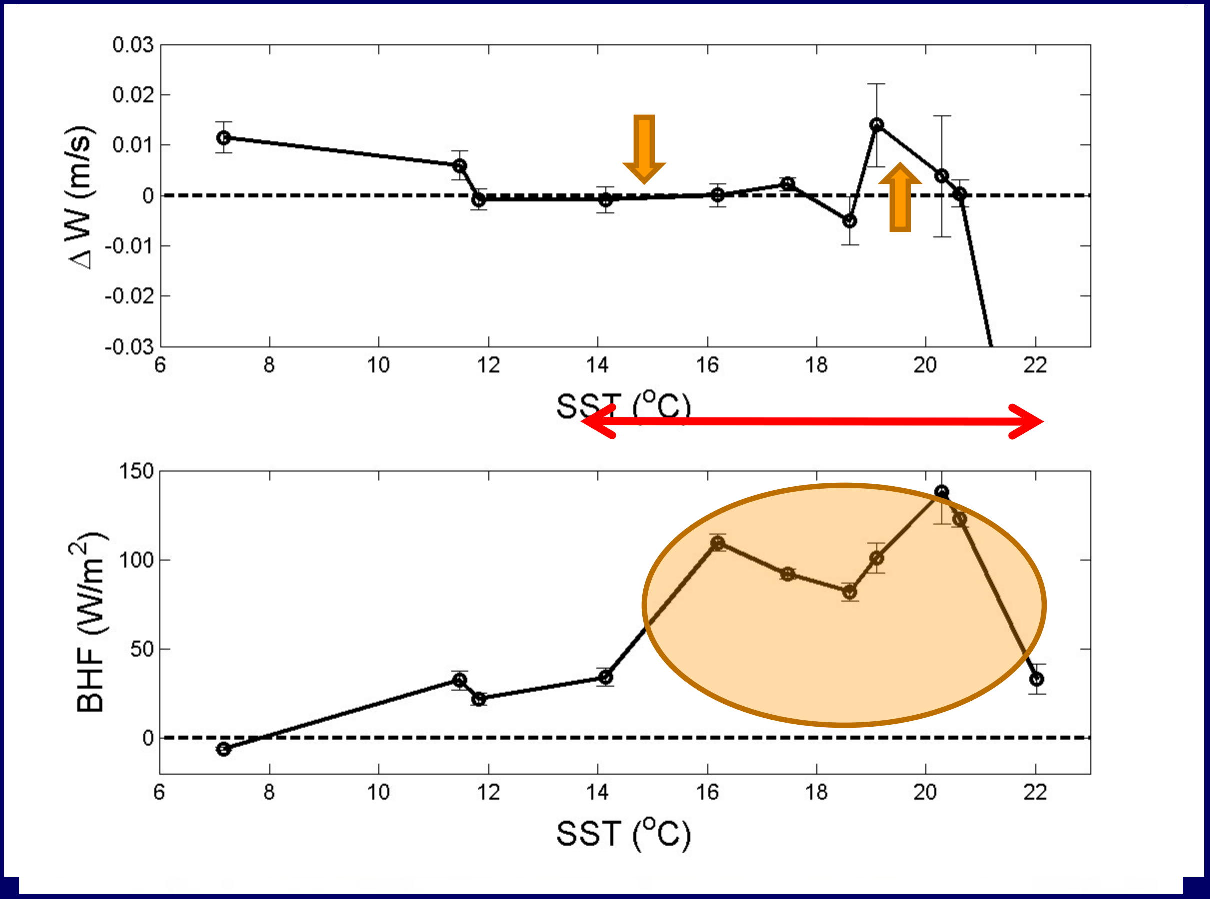
“Boundary Layer Adjustment”



The warm water is clearly associated with the largest fluxes. Note that even the cooler water is, on average, unstable in this data set.



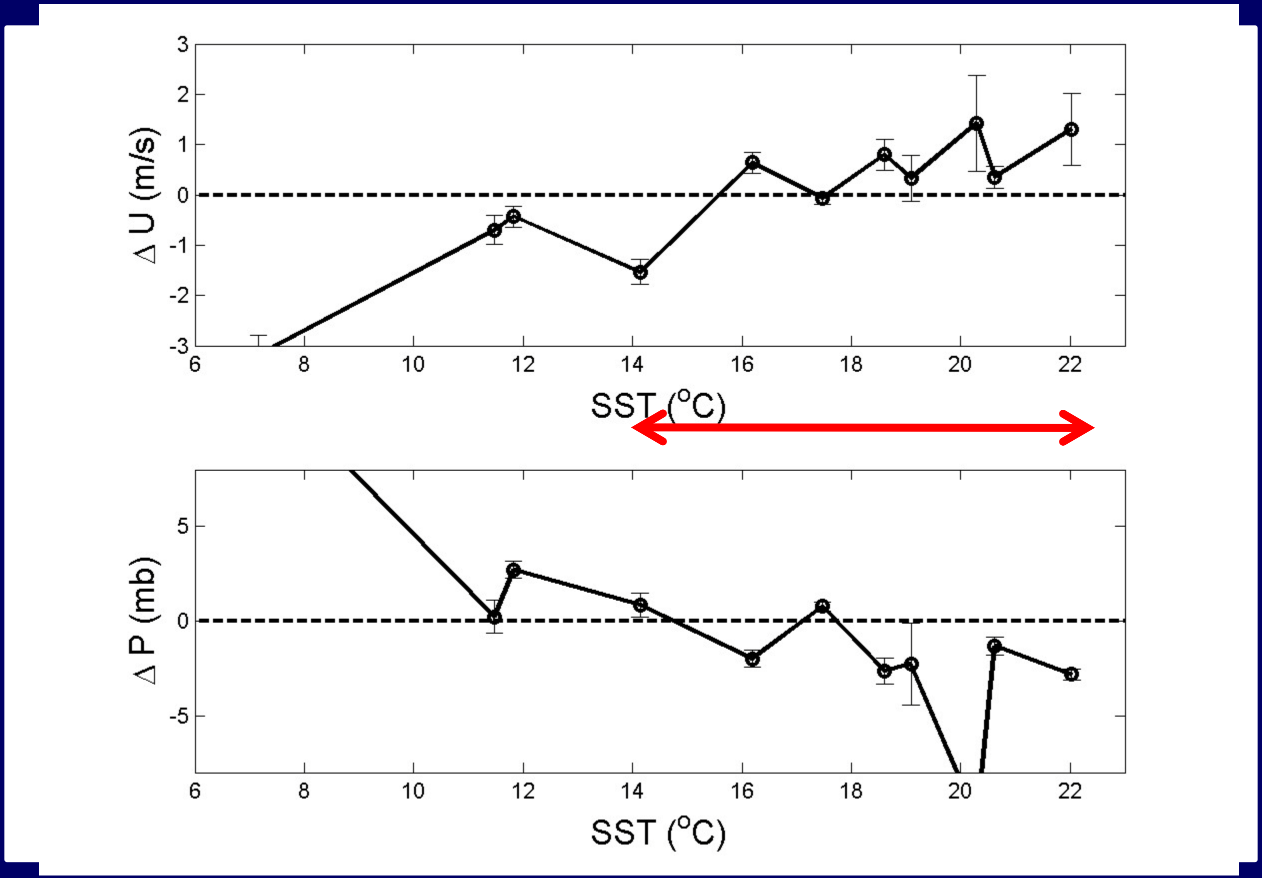
Thermally Driven Mesoscale Circulation



Wei and Stage, 1989: Dynamical Analysis of marine atmospheric boundary layer structure near the Gulf Stream oceanic front, Q. J. R. Meteorol. Soc, 115 29-44.

Investigated the response of the atmosphere to a SST front that ranged from 6-19°C over 350 km using a geostrophic wind blowing from cool to warm at 10 m/s. A thermally direct circulation develops due to the frontally induced PGF and mixing.

Thermally Driven Mesoscale Circulation



Warner et al., 1990: Marine Atmospheric Boundary Layer Circulation Forced by Gulf Stream Sea Surface Temperature Gradients, Mon. Wea. Rev., 118, 309-323.

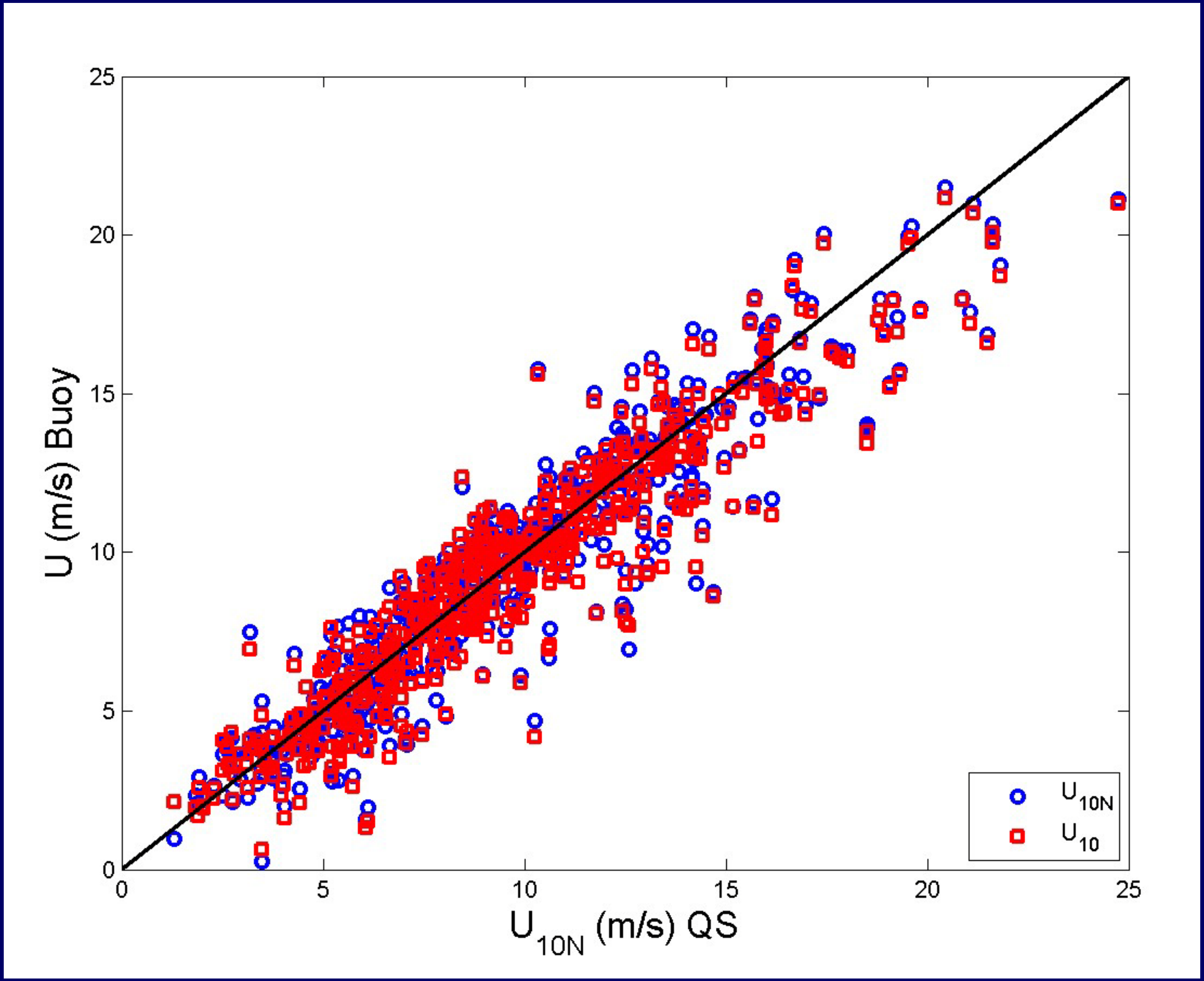
Initialized with a barotropic atmosphere with no synoptic pressure gradient based on a profile from GALE. Resulting flow is purely a response too the SST gradient. Results were very sensitive to strength of SST front.

Summary

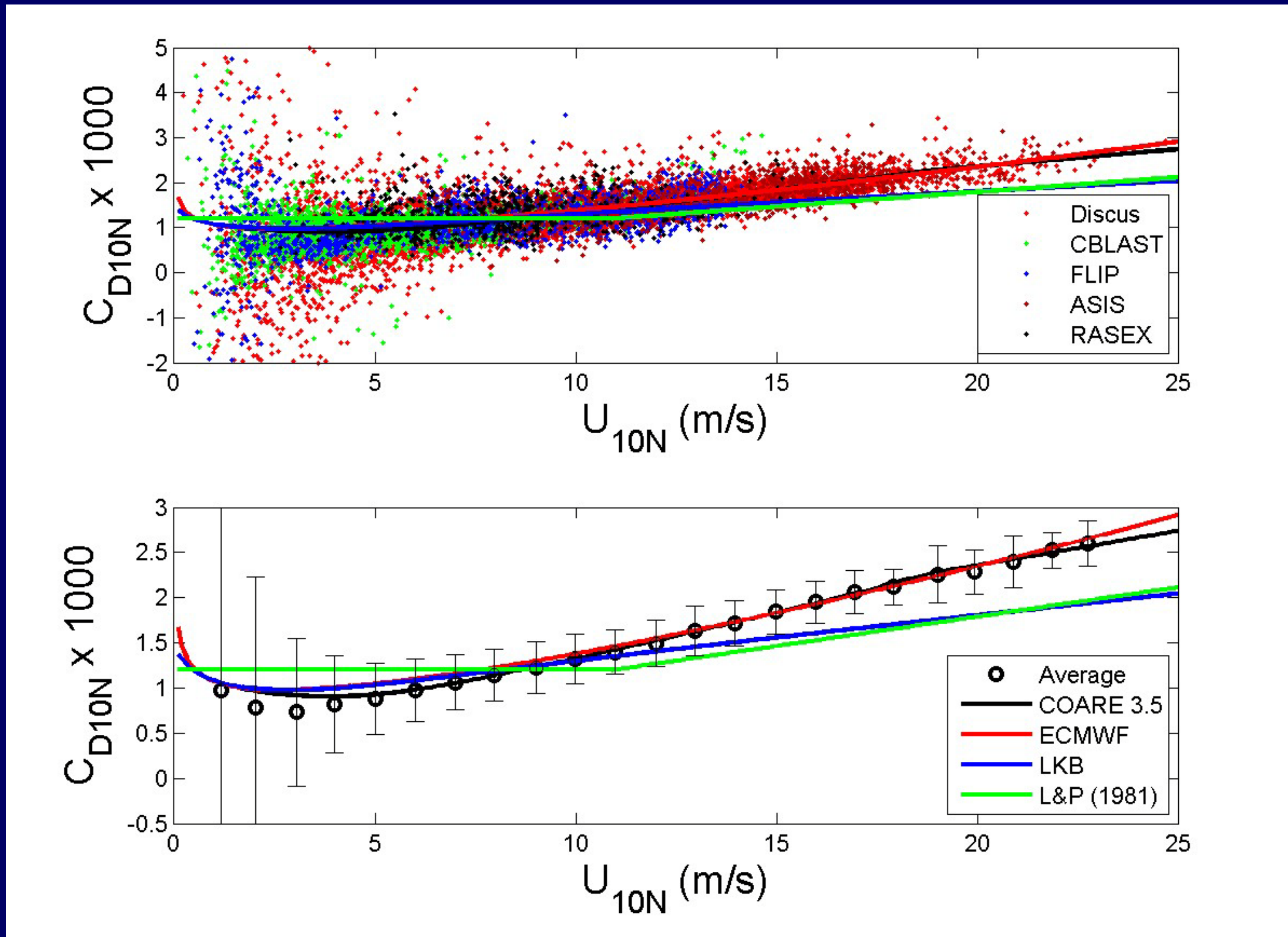
- Some of the variability in the QuikSCAT winds is due to stability induced changes in stress (and thereby the ENW) rather than changes in the actual wind speeds.
  - This ENW obeys MO-Similarity in the mean.
  - This effect enhances the gradient in neutral winds across the front, which needs to be removed through stability correction.
  - However, significant variability in the QuikSCAT winds is not explained by this effect
- The one-buoy approximation of the coupling coefficients is in reasonably good agreement with previous studies.
  - This includes the measured wind and directly measured stress.
  - The buoyancy flux is largest in the region of the largest SST perturbations, which makes intuitive sense.
- The data is in qualitative agreement with modeling studies that have shown a secondary atmospheric mesoscale circulations driven by the SST front.
  - However, our approach is sensitive to the length of the averaging periods and difficult to map onto physical space .
  - We probably pushed the 1-buoy approach as far as possible.

Thanks to NASA and NSF for supporting this research.

QuikSCAT vs. Buoy Wind Speeds

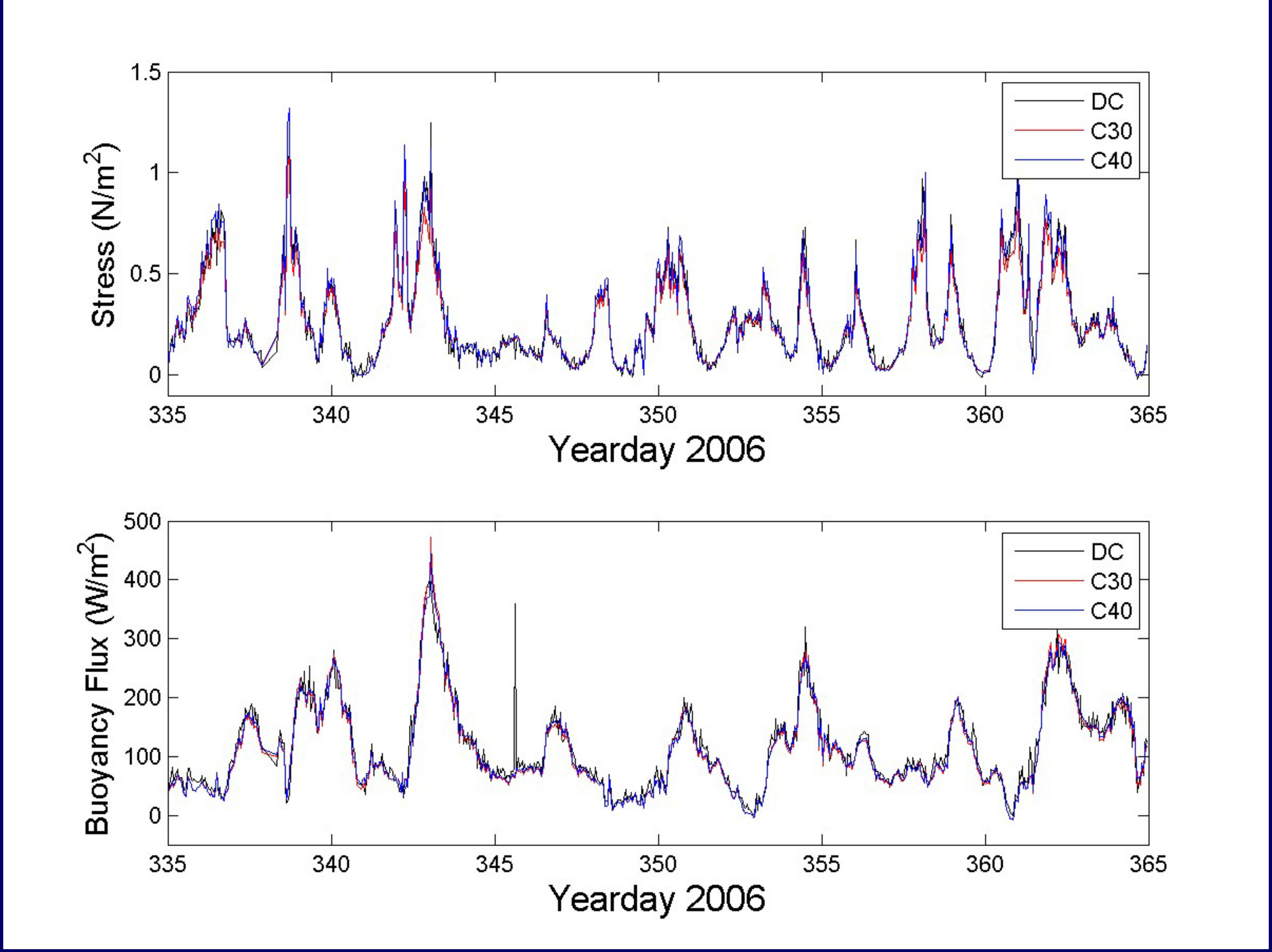


Discussion Slide



$$\tau = \rho_a C_{DN} U_{Nr}^2$$

Discussion Slide



Discussion Slide