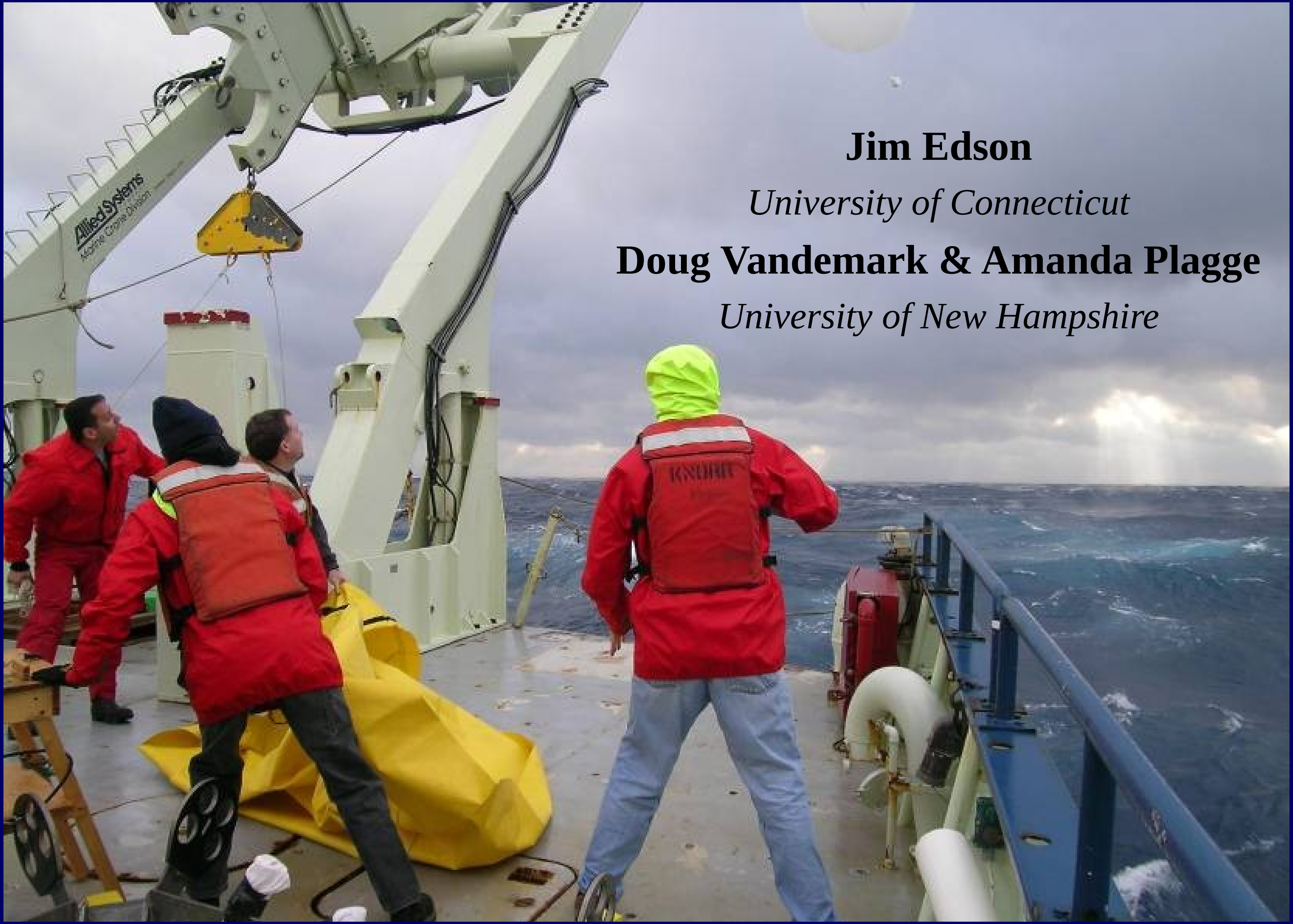
An Investigation of Atmospheric Stability and Its Impact on Scatterometer Winds Across the Gulf Stream



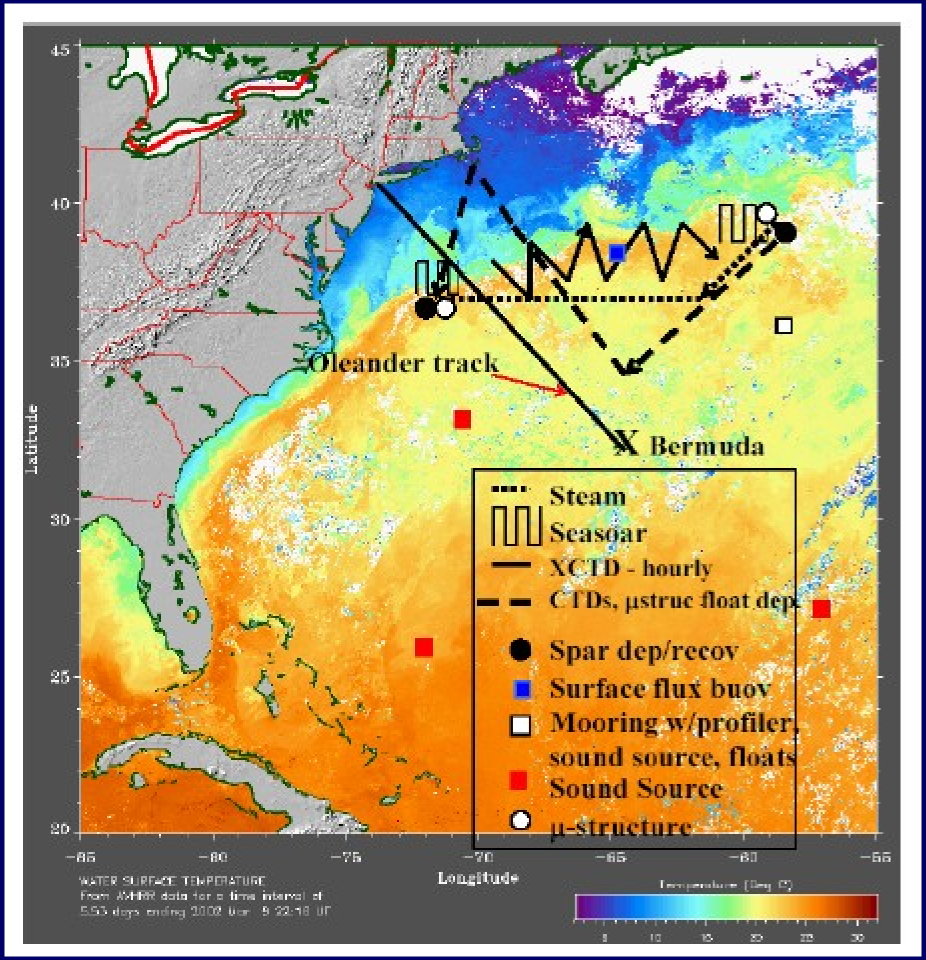
Jim Edson

University of Connecticut

Doug Vandemark & Amanda Plagge

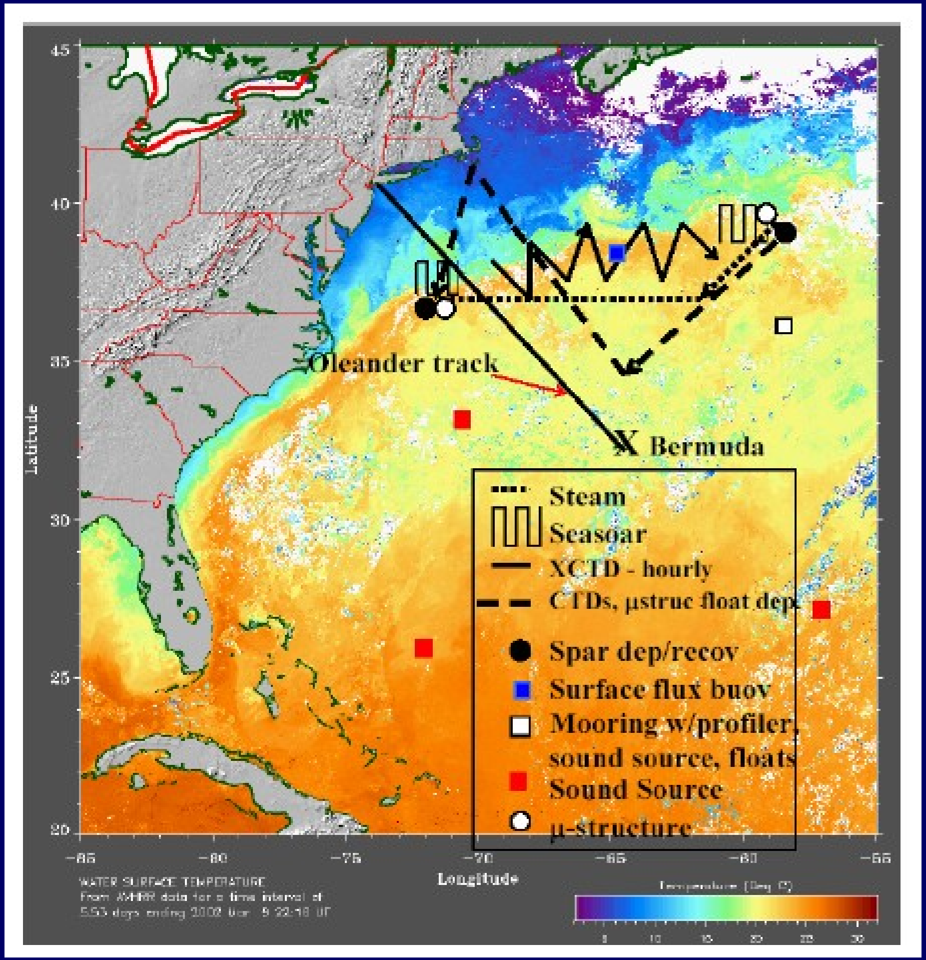
University of New Hampshire

CLIMODE Deployments and Cruises



- November 2005: Mooring & Profiler Deployment Cruise
- January 18-30, 2006: Pilot Experiment, ASIS/FILIS Deployment
- October 2006: Mooring Turnaround Cruise
- February-March 2007: 6-week Main Experiment, ASIS/FILIS Deployments, Microstructure, Surveys.
- November 2007: Mooring Recovery Cruise

CLIMODE Deployments and Cruises



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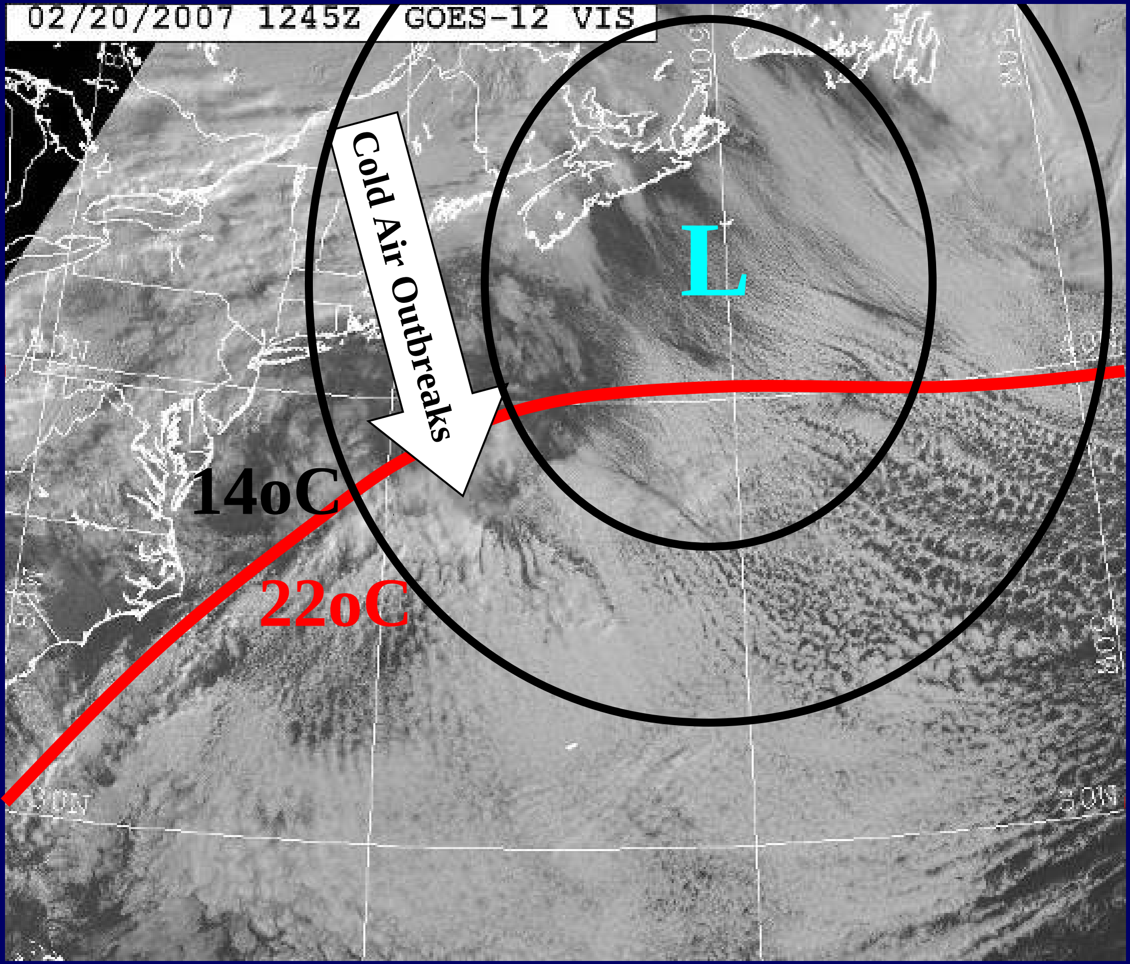
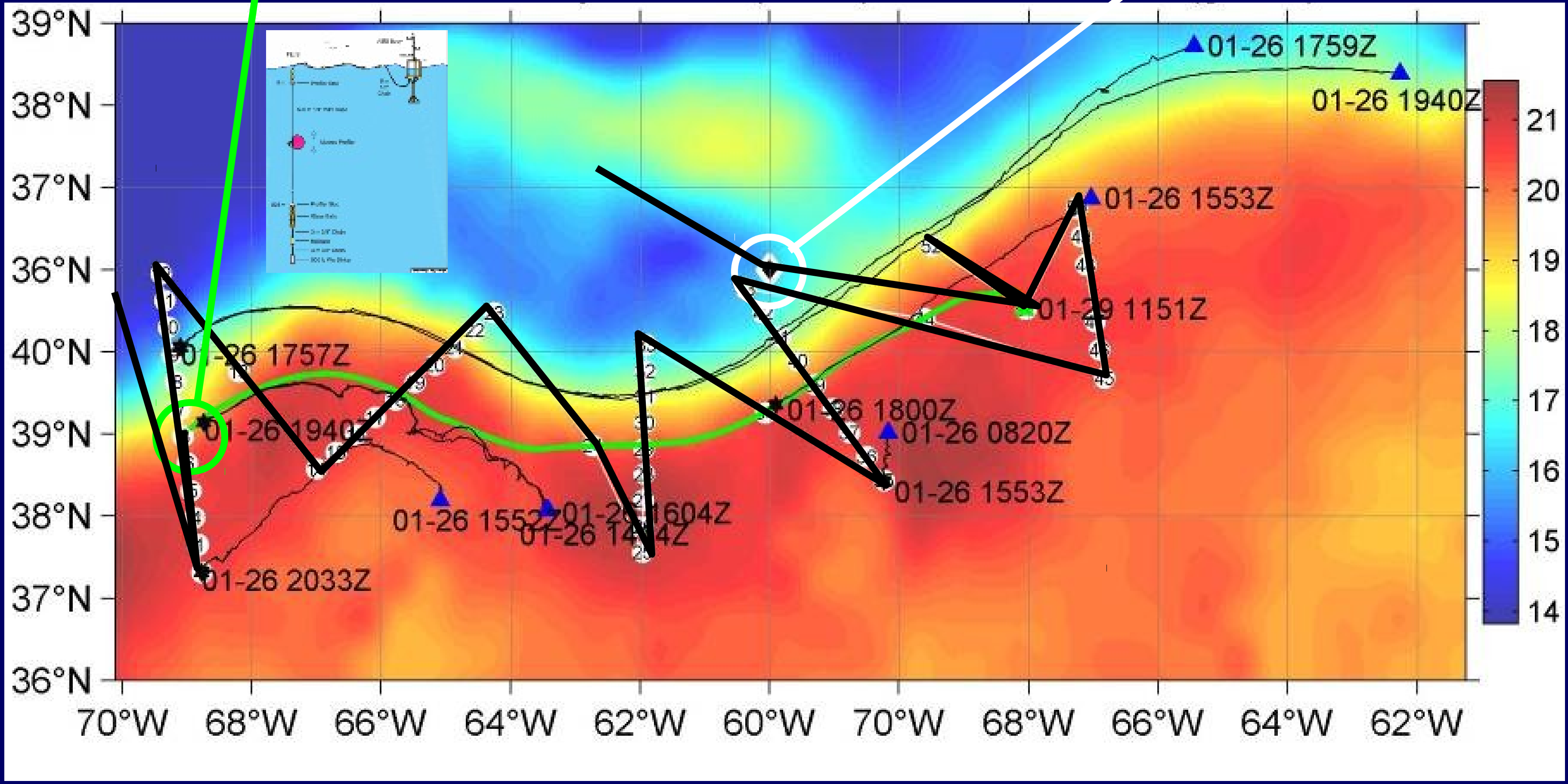
The Gulf Stream



- Cold air outbreaks drive extremely active convection over the region.
- The net winter heat loss in this region is 400 W/m2.

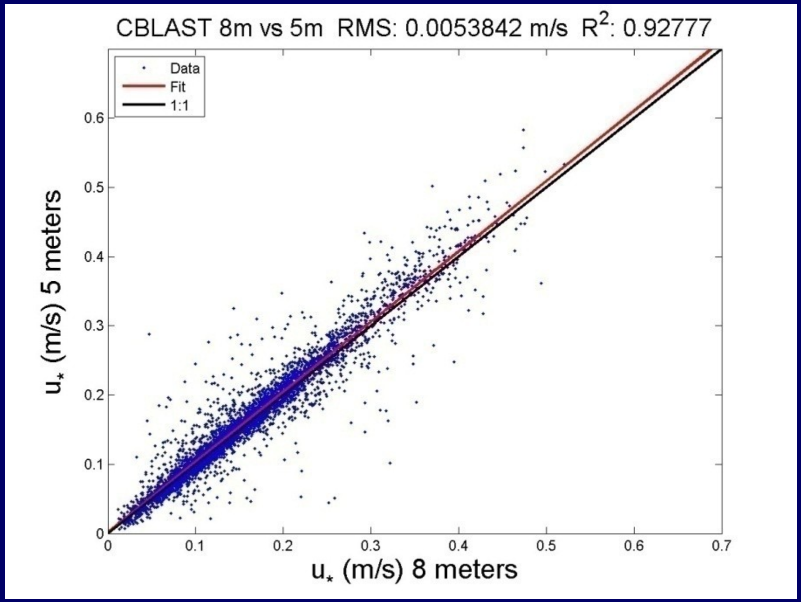
CLIMODE Platforms



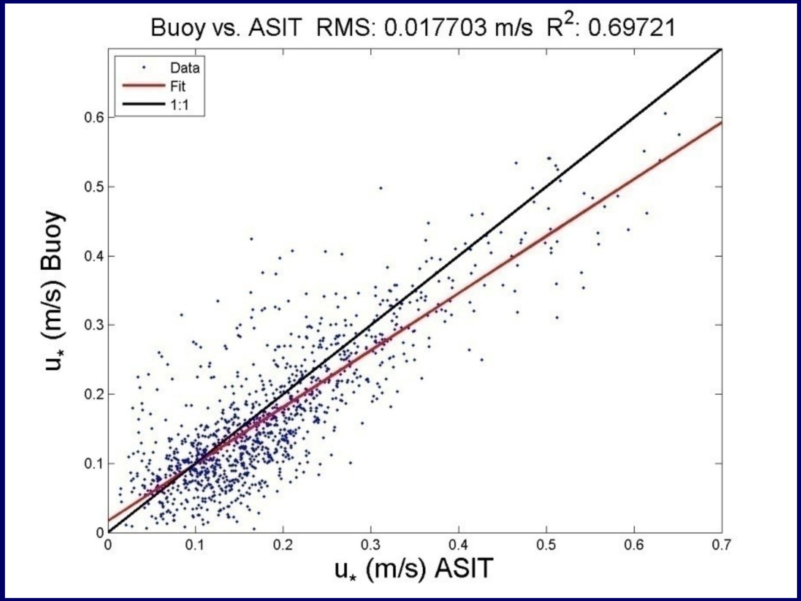
Sensor Packages

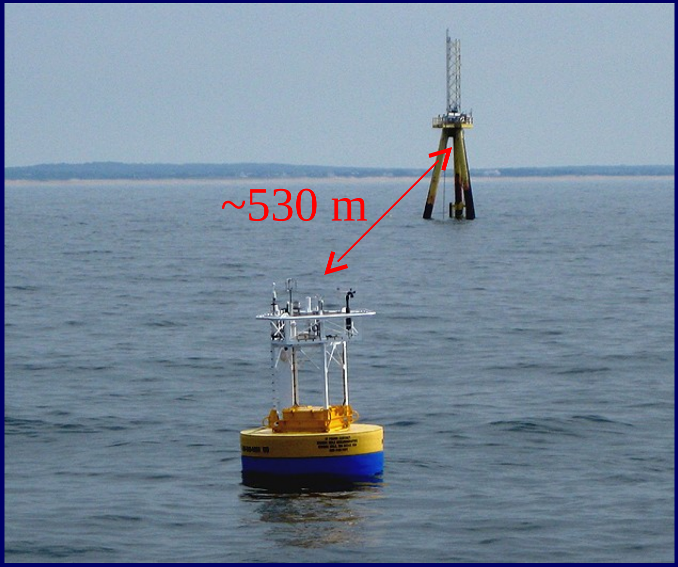
- R/V Atlantis and Knorr
  - 2-3 DCFS (Sonic/MotionPak/Licor)
  - IR and Solar Radiometers
  - IR SST
  - RH/T/P Sensors
  - ShipSystem (Precip, T_{sea}, Salinity, ADCP)
- ASIS
  - DCFS (Sonic/MotionPak/Licor)
  - IR and Solar Radiometers
  - RH/T/P Sensors
  - 6 Wave Wires
  - Subsurface (T_{sea}, Salinity, ADCP, Nortek)
- Discus
  - Low Power DCFS (Sonic/MotionPakIII)
  - Redundant IR and Solar Radiometers
  - Redundant U/RH/T/P Sensors (ASIMET)
  - Subsurface (T/S, Nortek, VACM)

Moving Platform vs. Fixed Tower

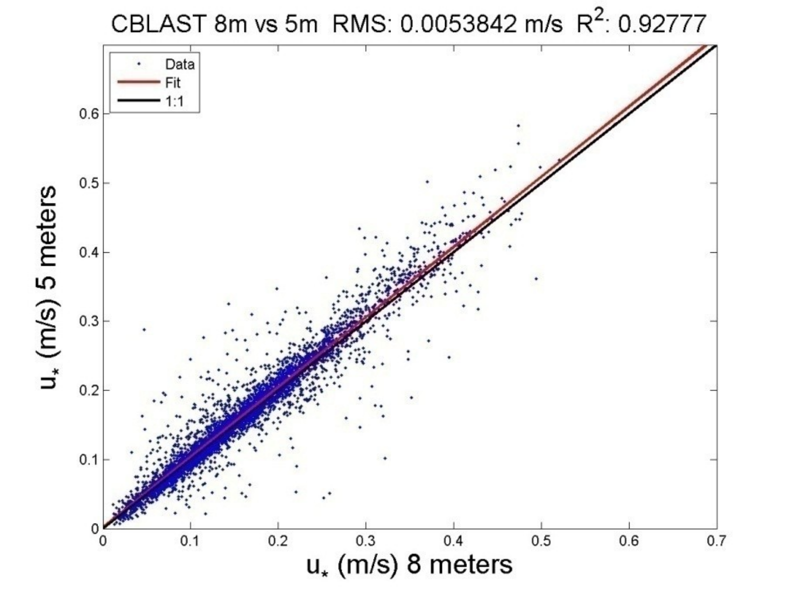


Uncorrected

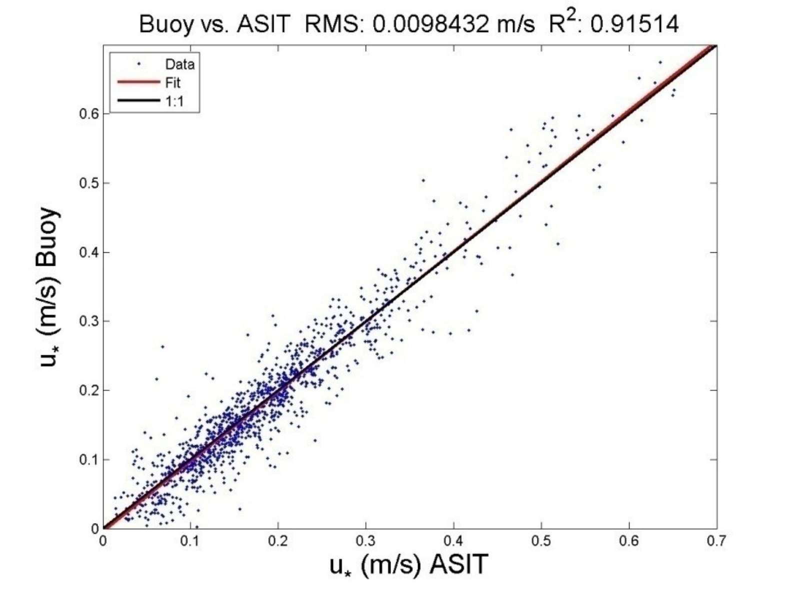


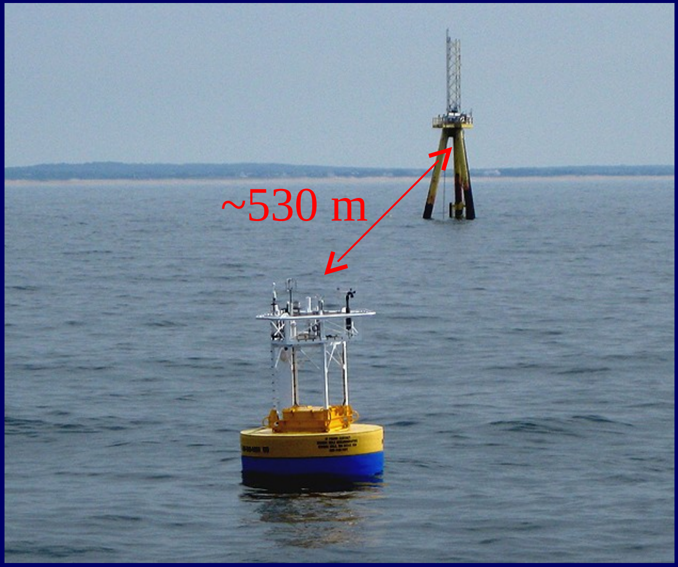


Moving Platform vs. Fixed Tower



Corrected





Bulk Aerodynamic Method

Latent Heat Flux: $\rho\ L_v\ \langle wq \rangle \cong \rho\ L_v C_E\ \Delta U \Delta Q$

Sensible Heat Flux: $\rho\ c_p\ \langle w\theta \rangle \cong \rho\ c_p C_H\ \Delta U \Delta \Theta$

Momentum Flux: $-\rho \langle uw \rangle \quad \cong -\rho\ C_D\ \Delta U^2$

Direct Covariance   Bulk Aerodynamic

Drag Coefficient Formulas

- Semi-empirical

$$C_D(z/z_0, z/L) = \frac{-\overline{uw}}{\Delta U^2} = \left(\frac{\kappa}{\ln(z/z_o) - \psi_m(z/L)}\right)^2$$

Atmospheric Stability

$$C_{DN}(z/z_0) = \left(\frac{\kappa}{\ln(z/z_o)}\right)^2 = \frac{-\overline{uw}}{\Delta U_N^2}$$

TOGA-COARE 4.0

Surface Roughness

- "Empirical"

$$10^3 C_{DN}(U_{10N}) = \begin{cases} 1.2 & 4 \le U_{10N} \le 11\,\mathrm{ms}^{-1} \\ 0.49 + 0.065\,U_{10N} & 11 \le U_{10N} \le 25\,\mathrm{ms}^{-1} \end{cases}$$

Large & Pond (1981)

Wind Speed Dependent

Drag Coefficient Formulas

- Semi-empirical

$$C_D(z/z_0, z/L) = \frac{-\overline{uw}}{\Delta U^2} = \left(\frac{\kappa}{\ln(z/z_o) - \psi_m(z/L)} \right)^2$$

Atmospheric Stability

$$C_{DN}(z/z_0) = \left(\frac{\kappa}{\ln(z/z_o)} \right)^2 = \frac{-\overline{uw}}{\Delta U_N^2}$$

TOGA-COARE 4.0

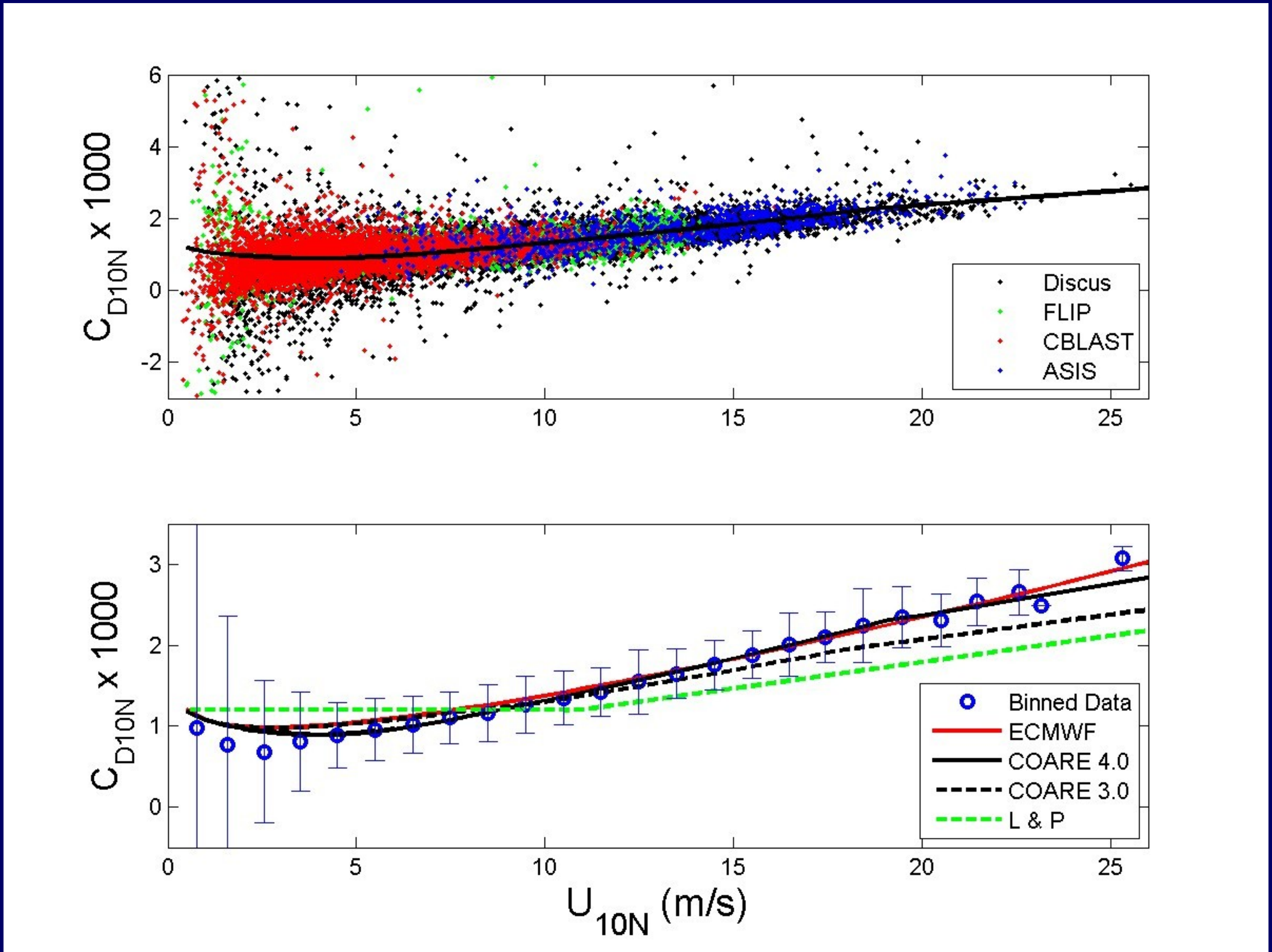
Surface Roughness

- **COARE parameterizes the roughness length as:**

$$z_o = \alpha \frac{\nu}{u_*} + \beta(U_{10}) \frac{u_*^2}{g}$$

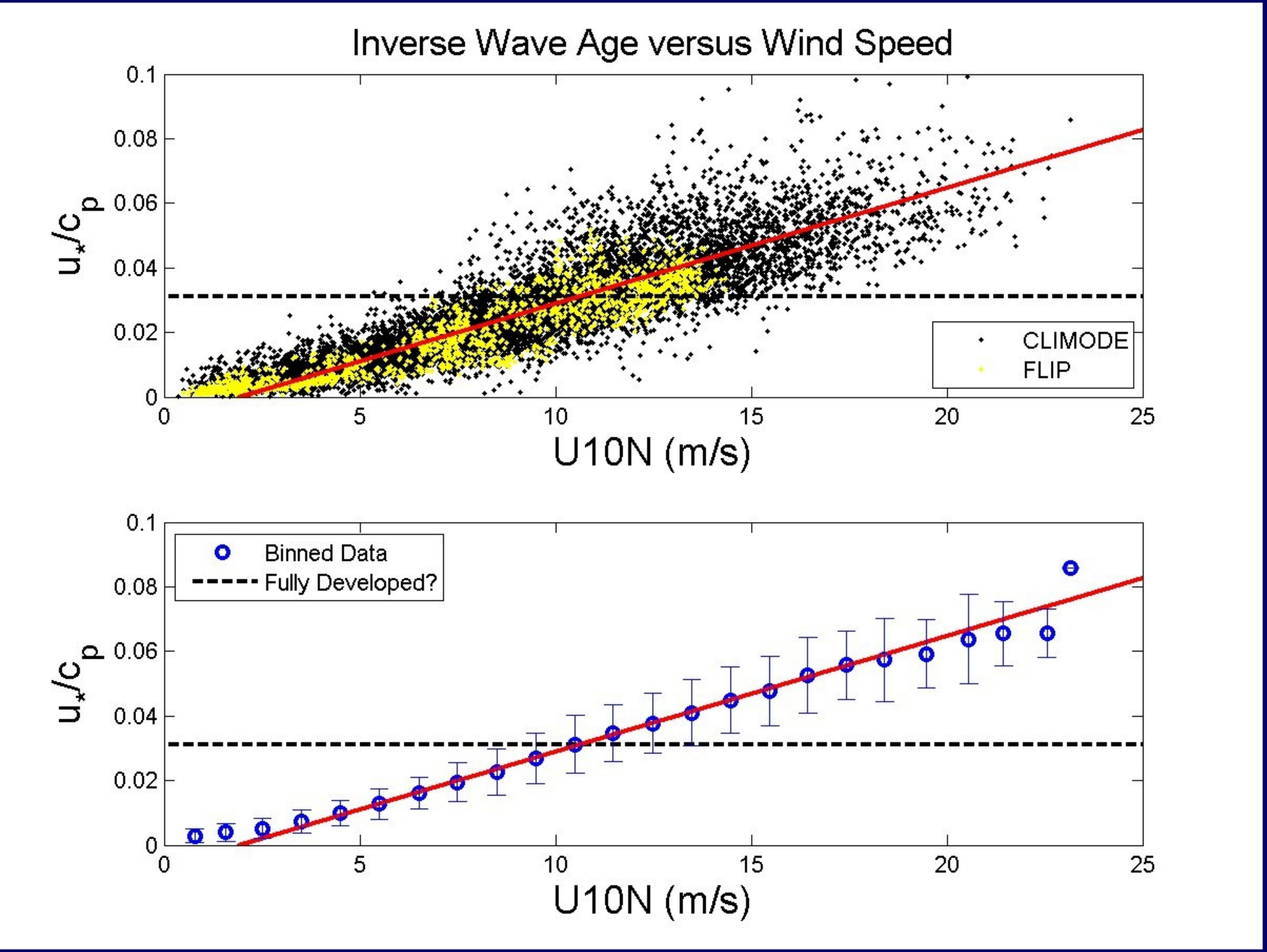
Charnock Parameter

MBL/CBLAST/CLIMODE Drag Coefficients



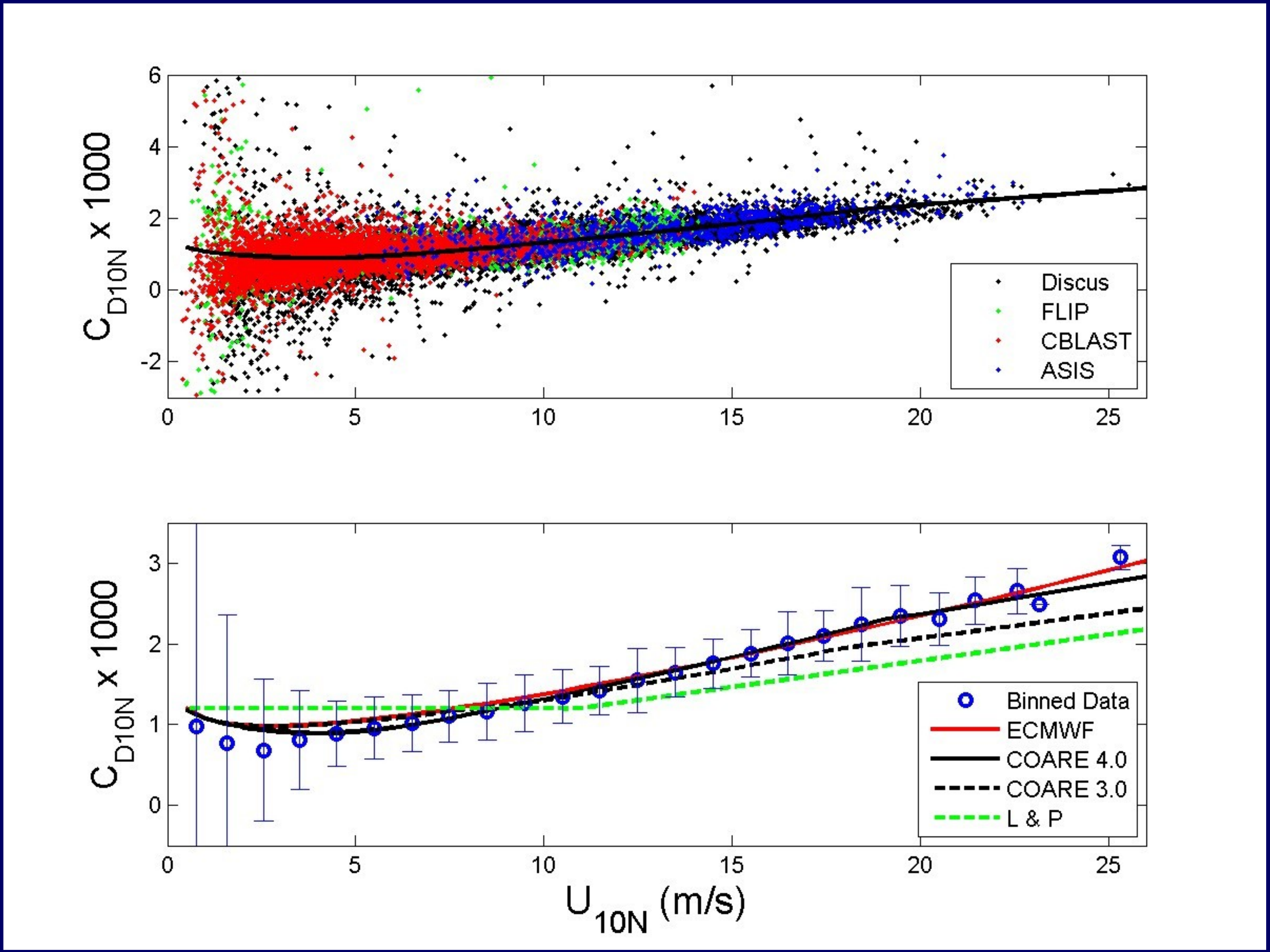
$$z_o = \alpha \frac{\nu}{u_*} + \beta(U_{10}) \frac{u_*^2}{g}$$

Wave Age Dependent Drag



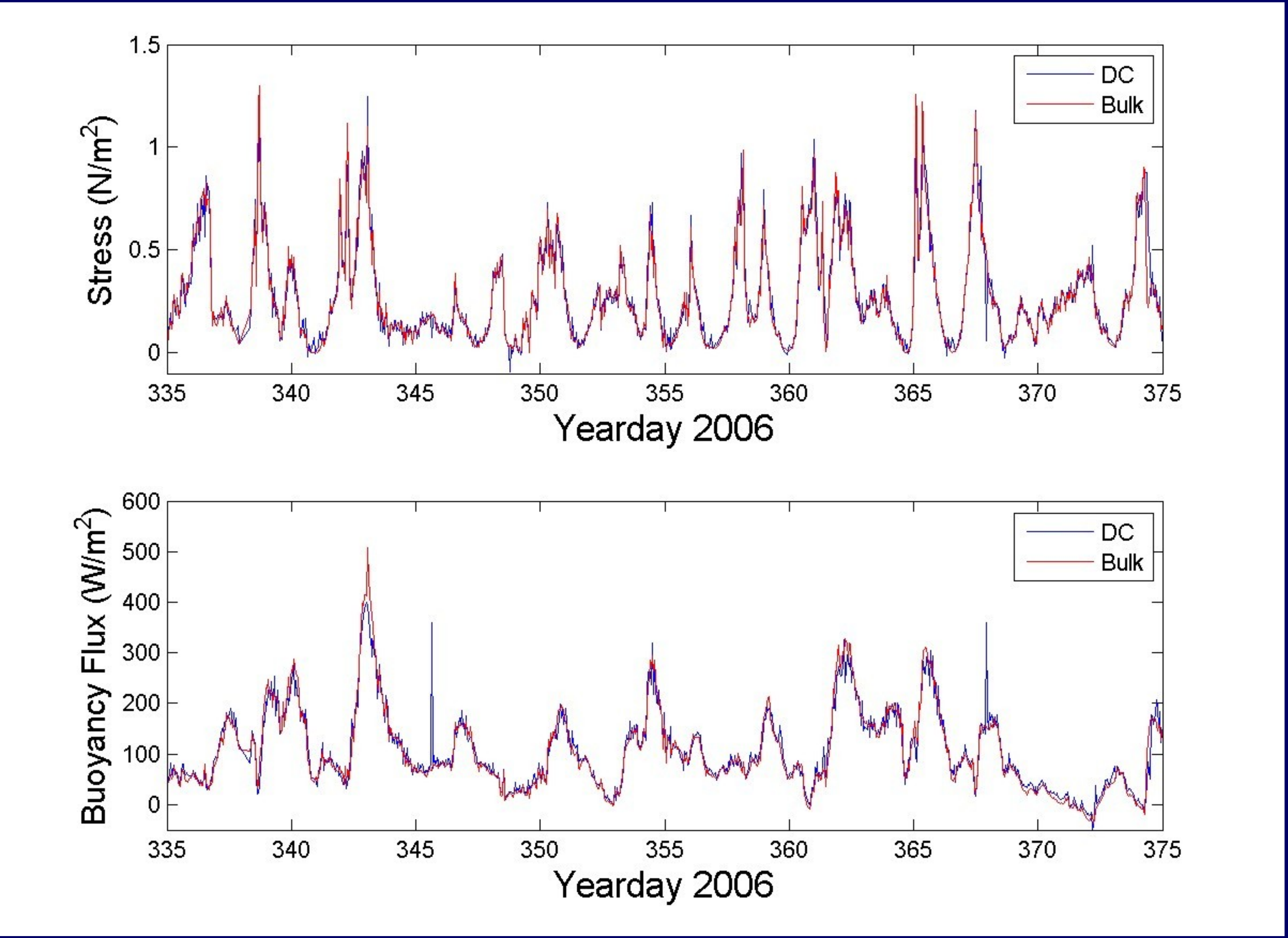
$$u_* / c_p = 0.0036 U_{10N} - 0.007$$

Wave Age Dependent Drag



$\beta = A(c_p / u_*)^{-B}$ plus $u_* / c_p = 0.0036 U_{10} - 0.007$ equals ECMWF

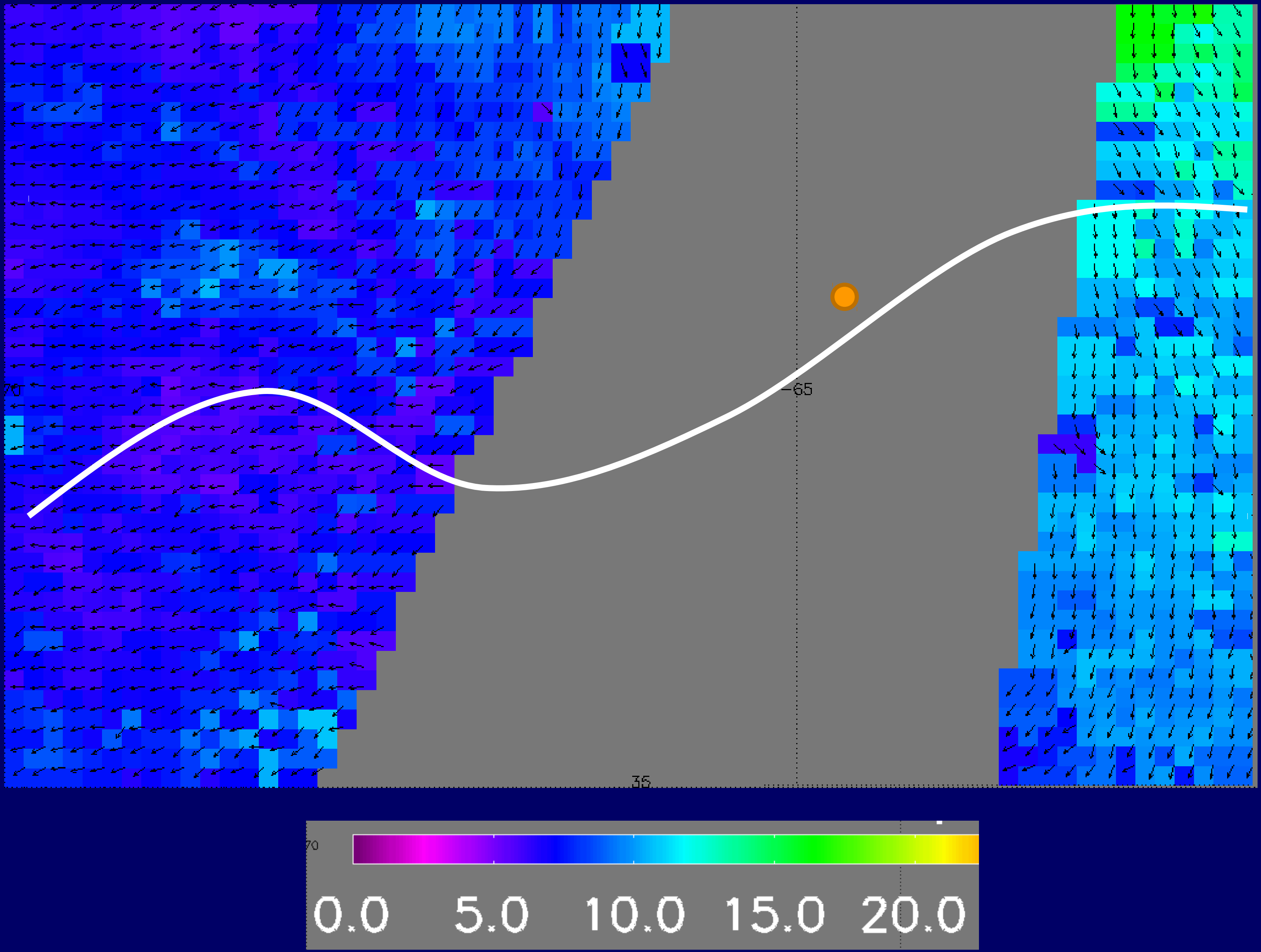
Flux Time Series



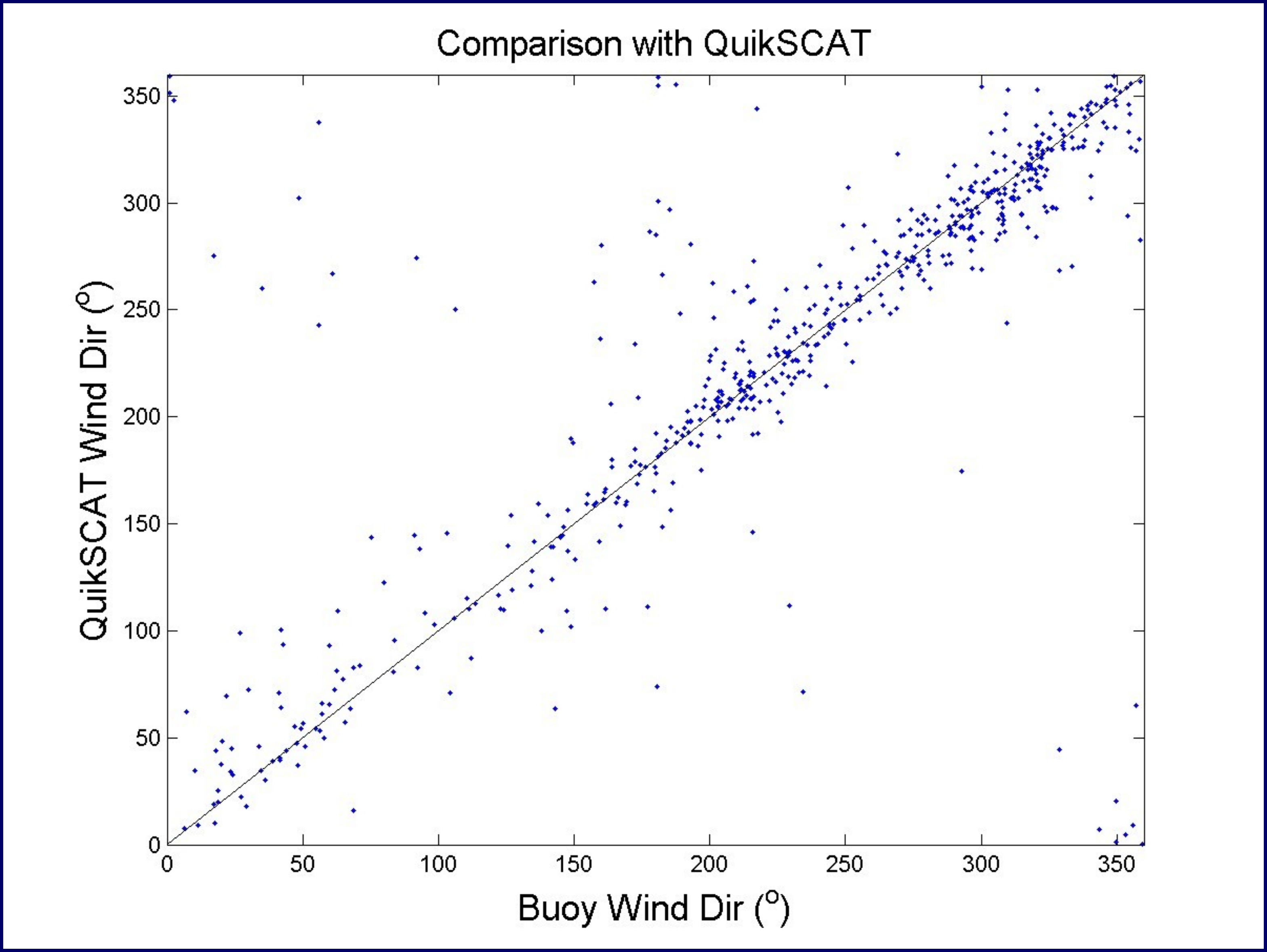
Summary

- A wind speed dependent drag coefficient give good results over a wind range of sea-states/wave-ages.
  - This requires a wind speed dependent Charnock variable
  - Numerous investigations have shown that the Charnock variable is dependent on wave-age.
  - However, these findings can be reconciled since observed wave ages over the coastal and open ocean are clearly associated with wind ranges.

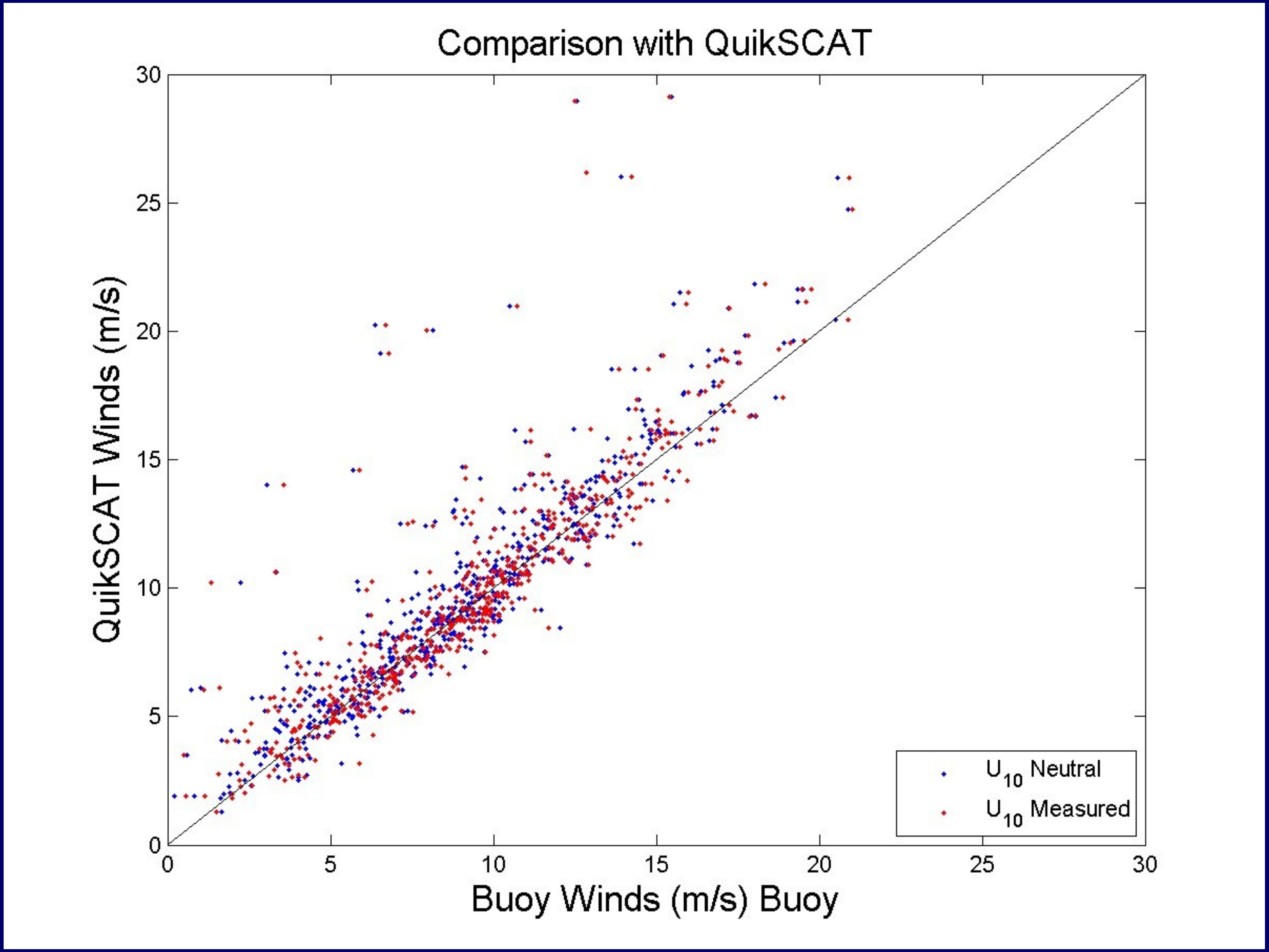
QuikSCAT Wind Speeds



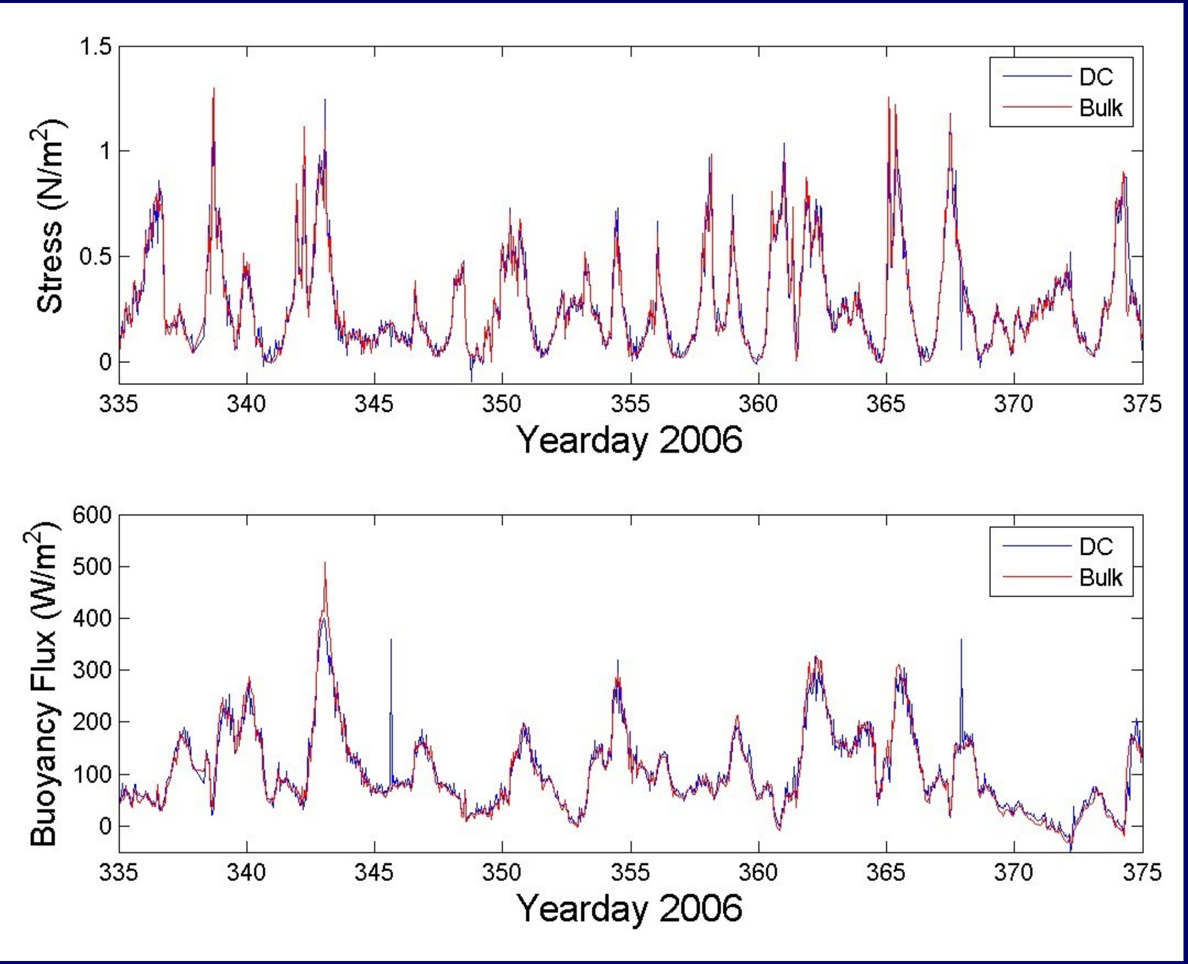
QuikSCAT vs. Buoy Wind Direction

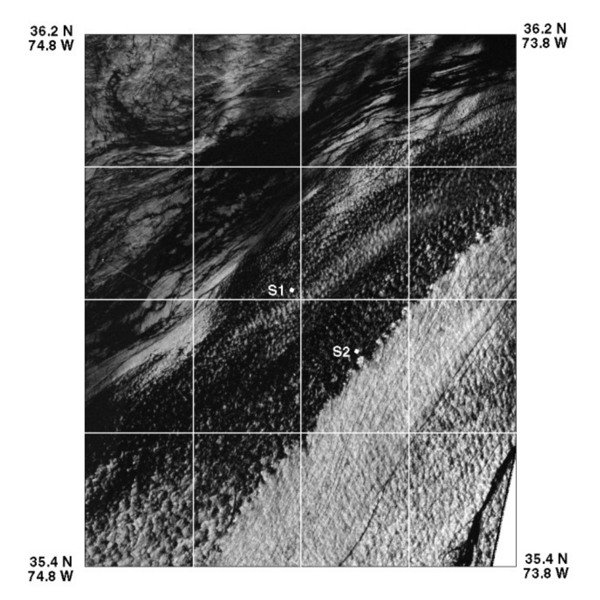


QuikSCAT vs. Buoy Wind Speeds

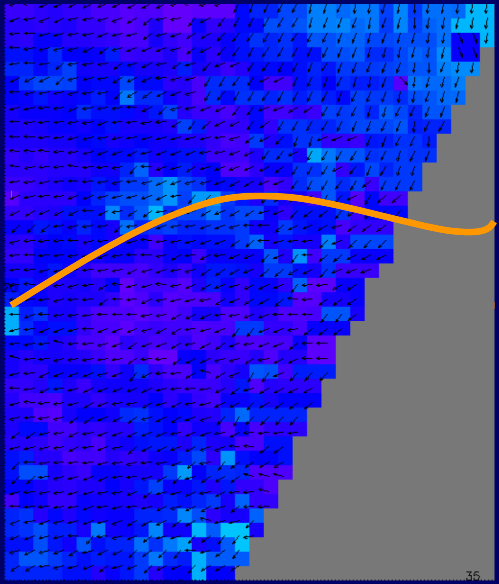


Atmospheric Forcing





Sikora et al. (1995)



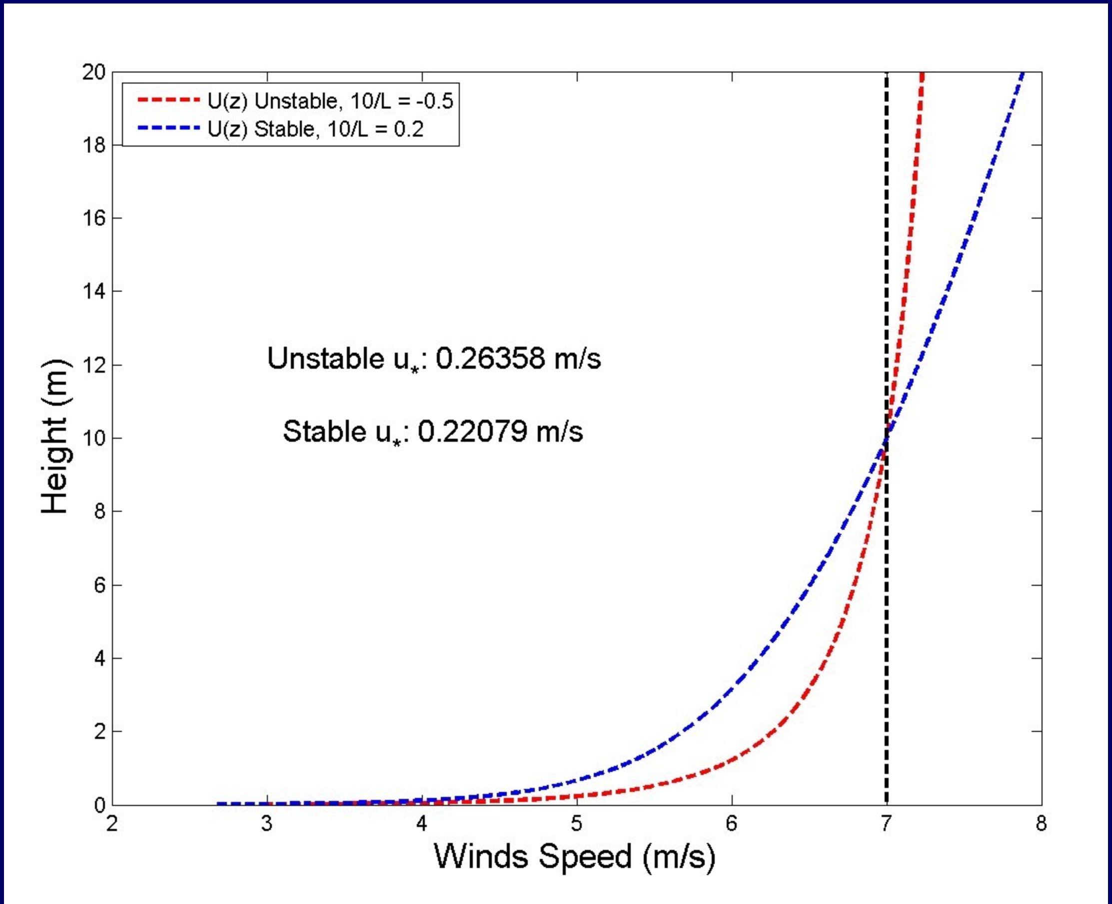
PO.DAAC

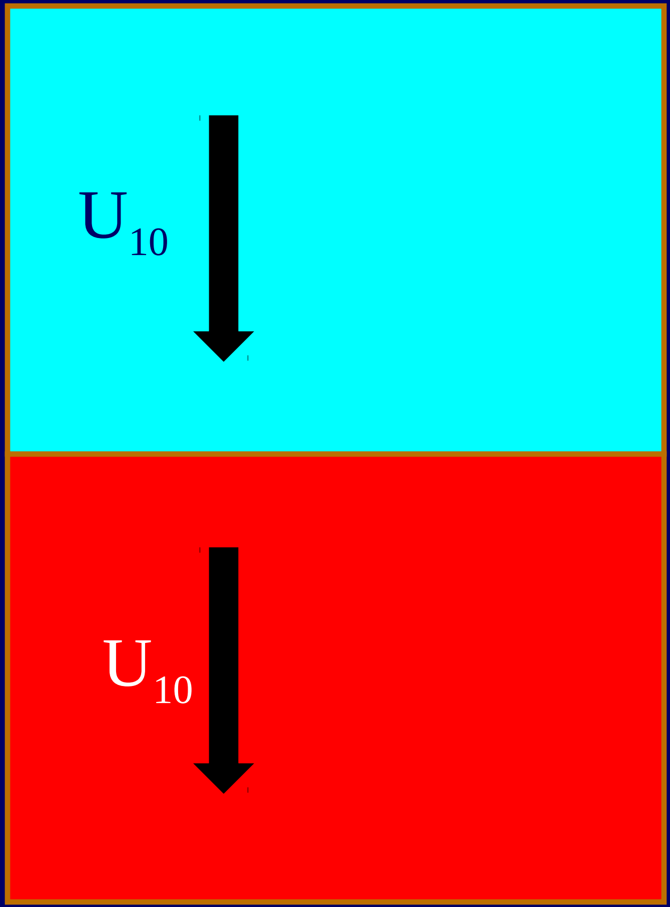
Stability Effects Near SST Fronts

- Boundary Layer Adjustment
  - Baroclinic adjustment to horizontal temperature gradients.
  - Acceleration/deceleration of surface winds.
- Surface Layer Adjustment
  - 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
- Mesoscale Adjustment to SST fronts
  - Combination of both?

QuikSCAT vs. Buoy Wind Speeds

"Surface Layer Adjustment"

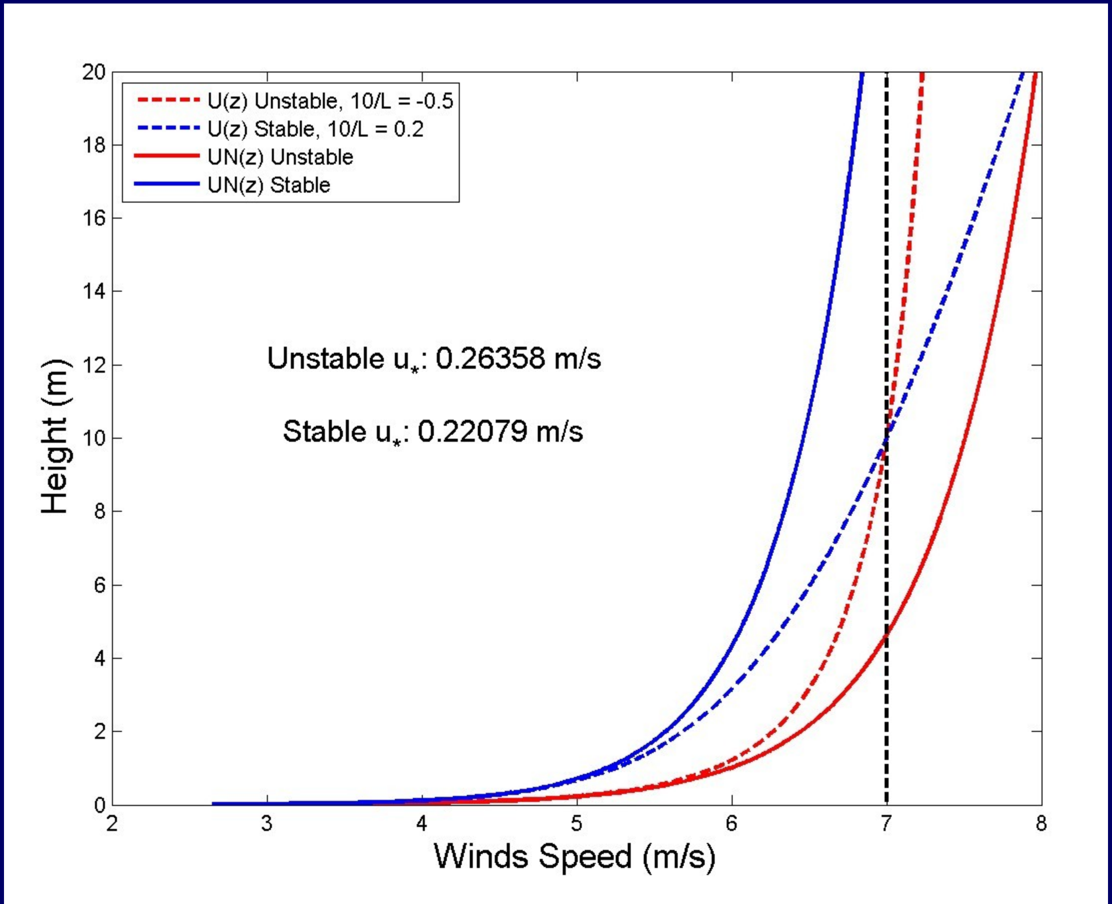


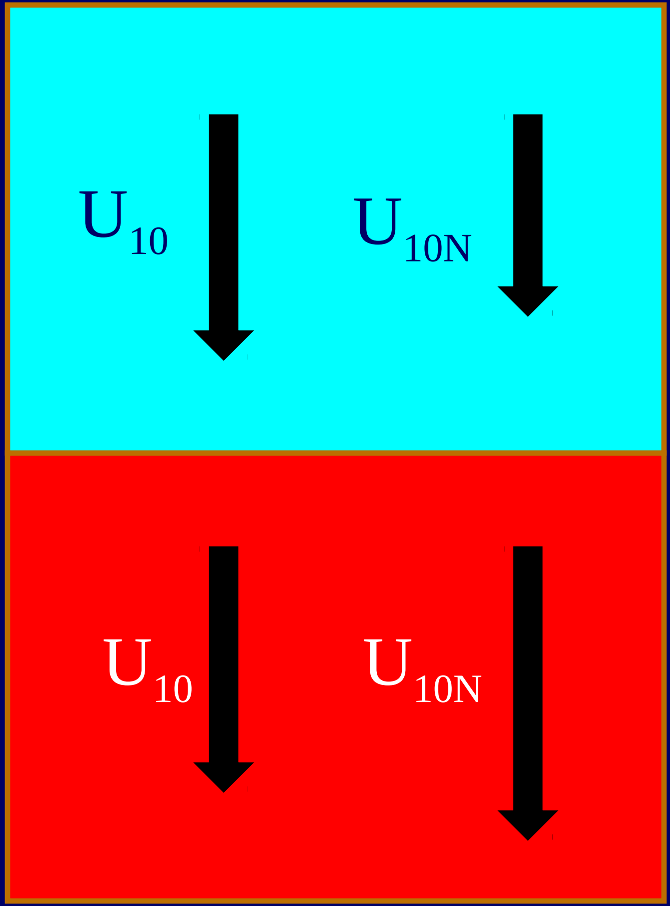


$$U(z) = u_*/\kappa[\ln(z/z_o) - \psi_m(z/L)]$$

QuikSCAT vs. Buoy Wind Speeds

"Surface Layer Adjustment"





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

QuikSCAT vs. Buoy Wind Speeds

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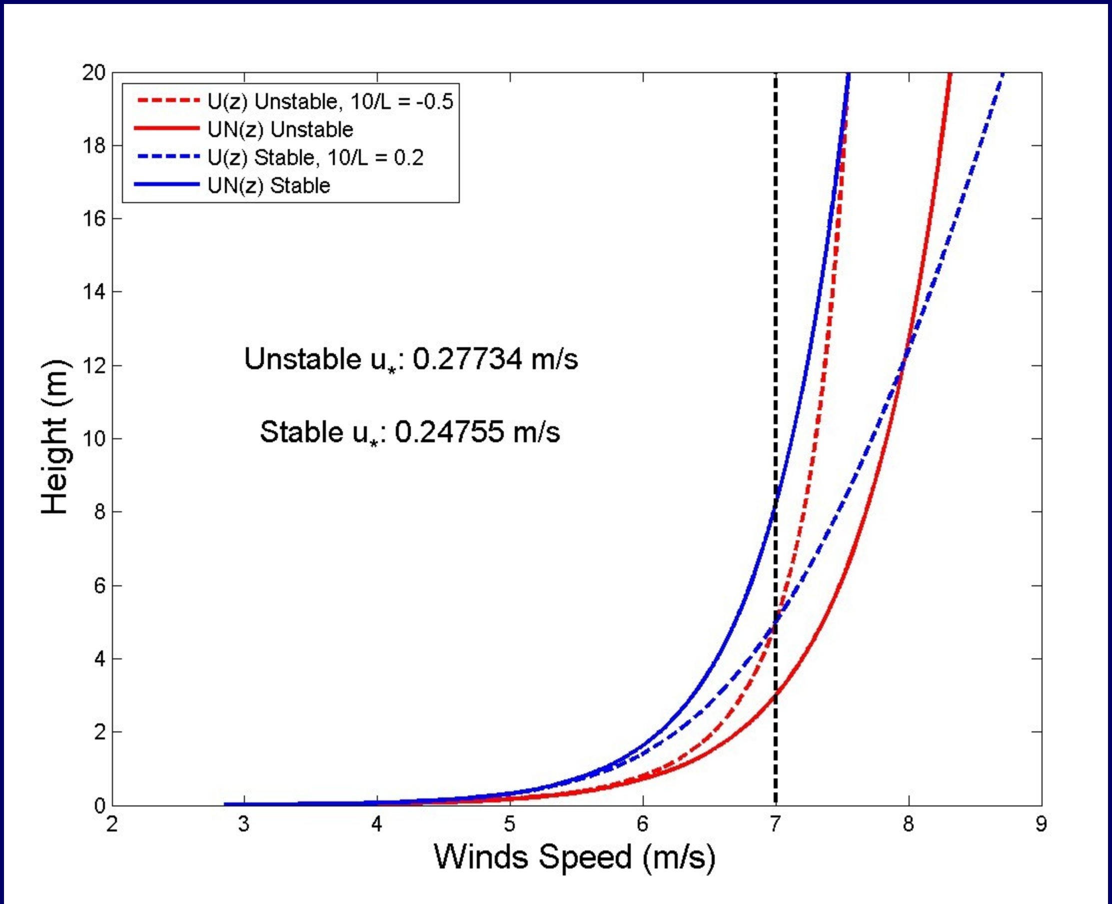

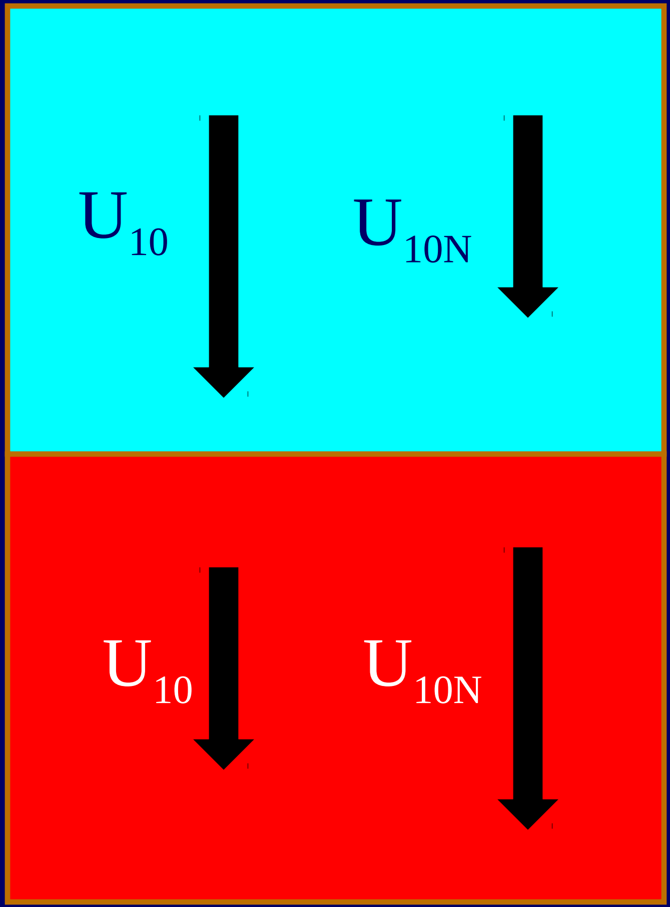

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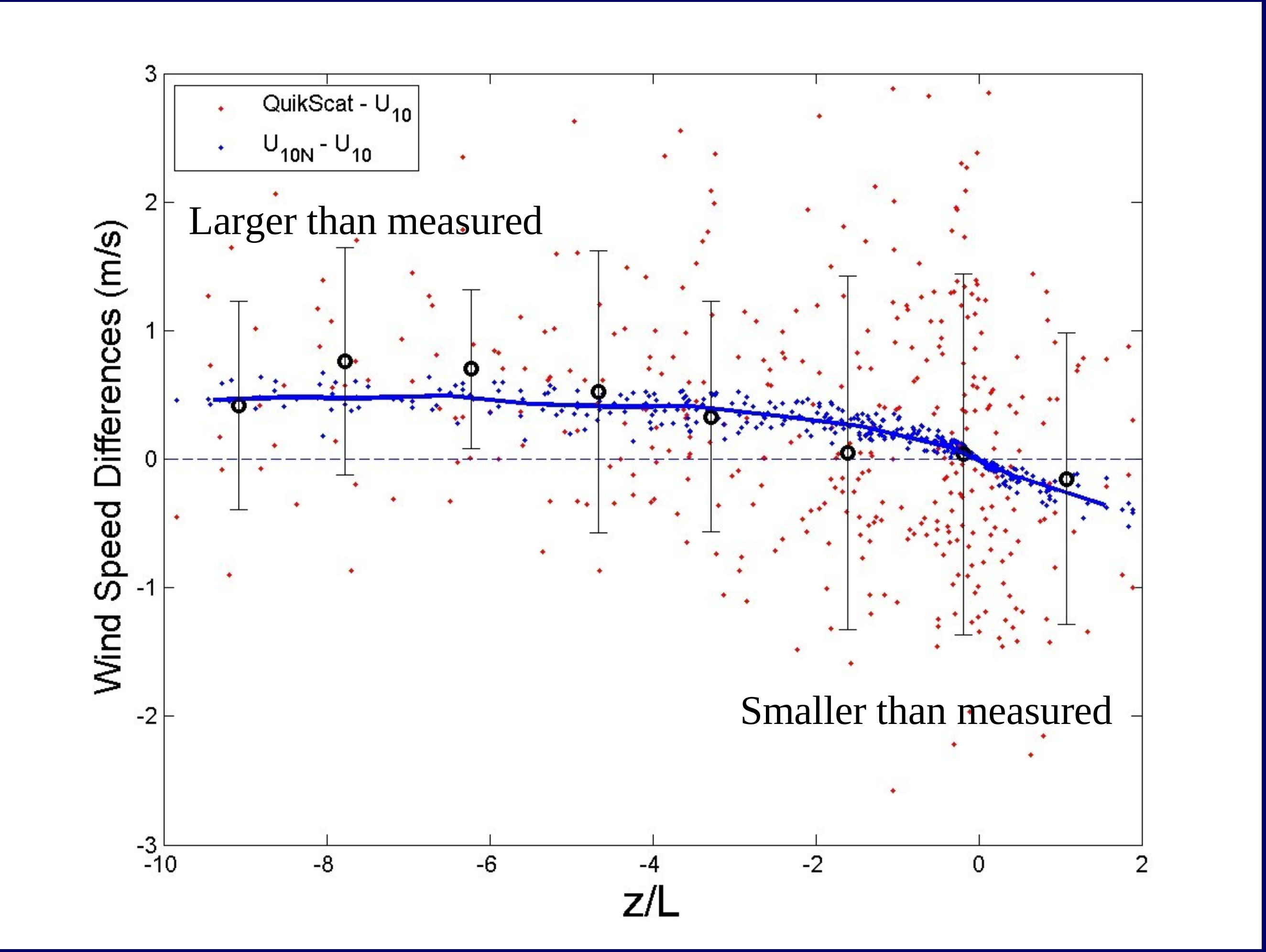

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QuikSCAT vs. Buoy Wind Speeds

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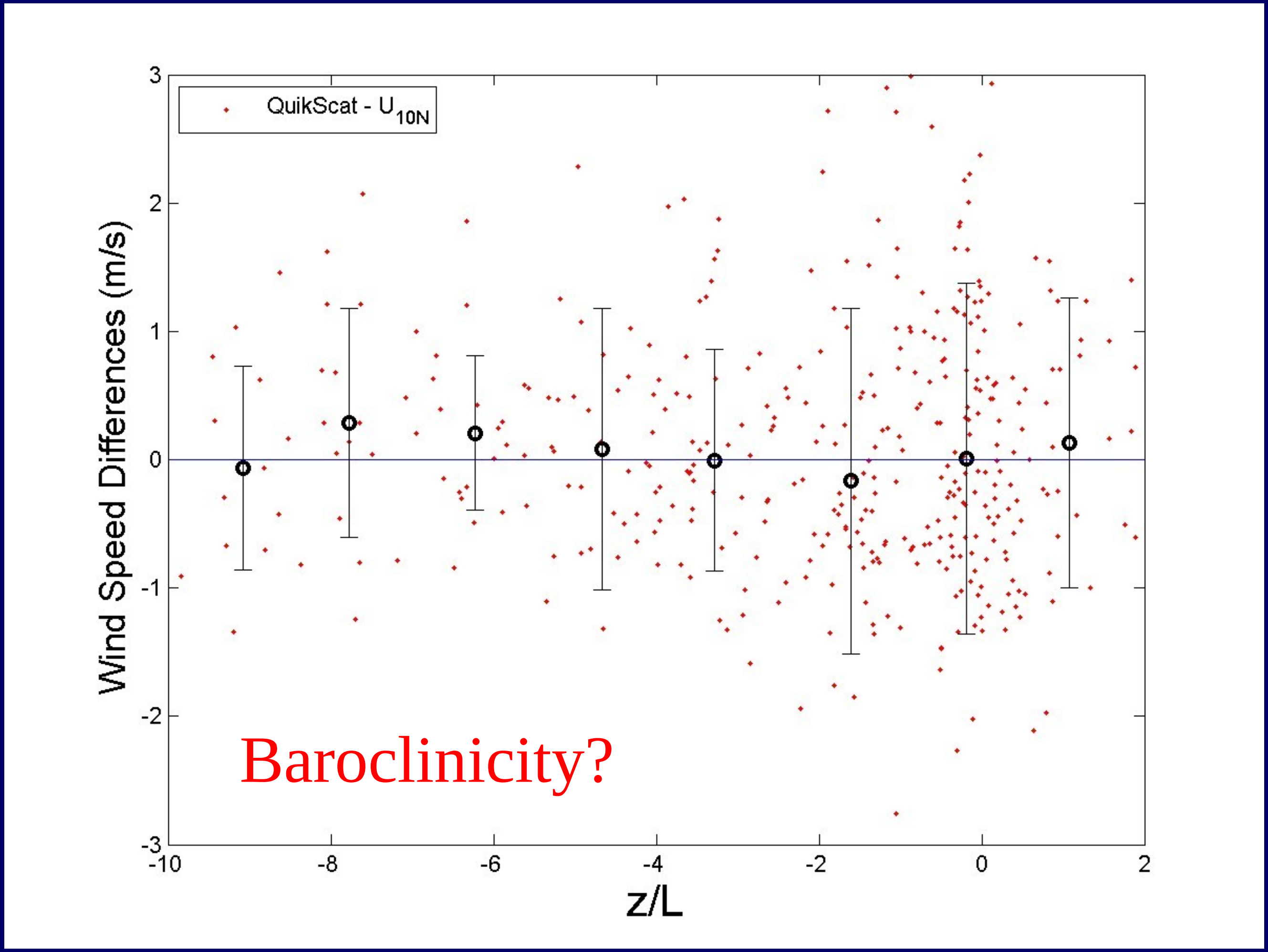

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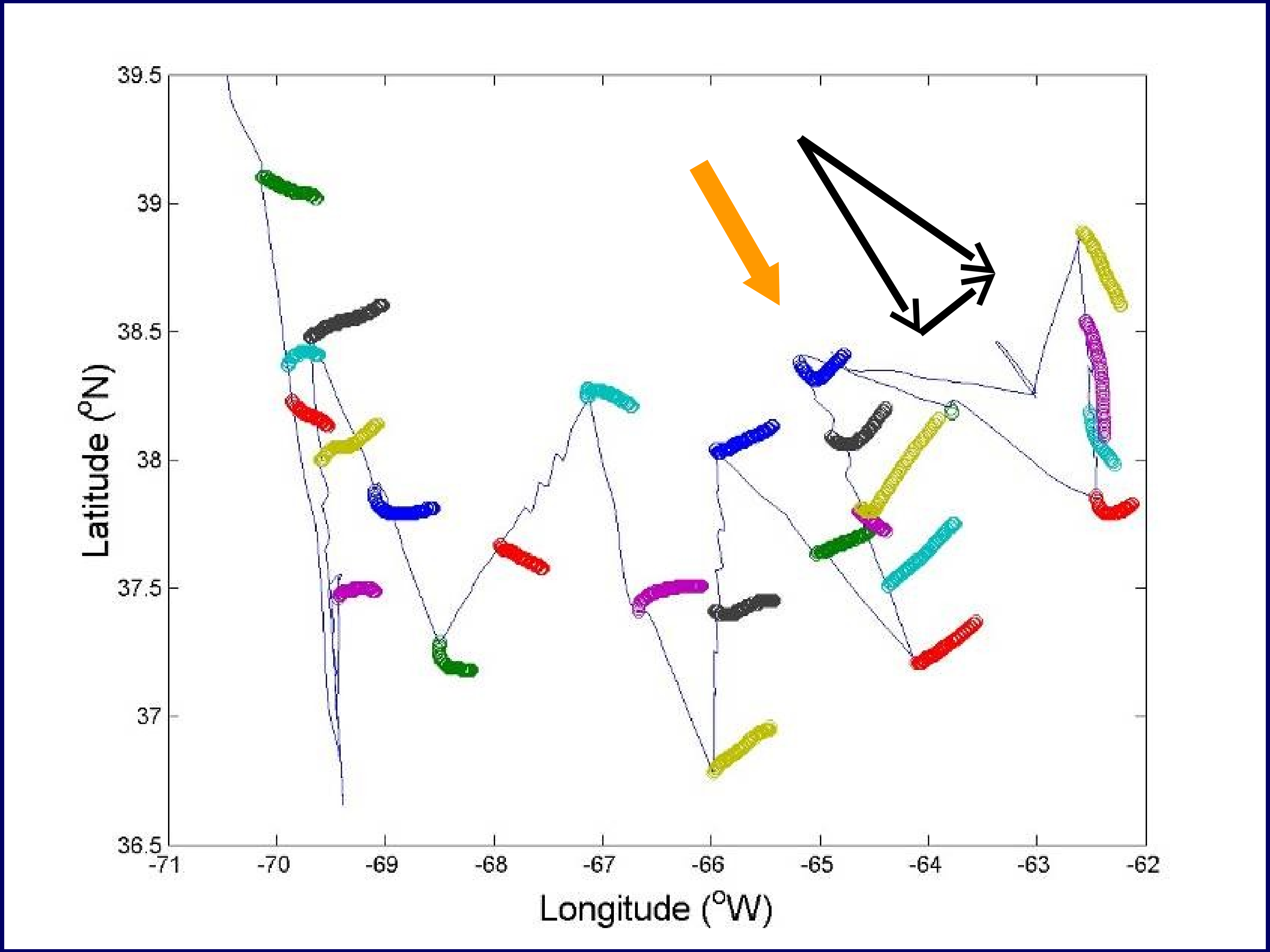
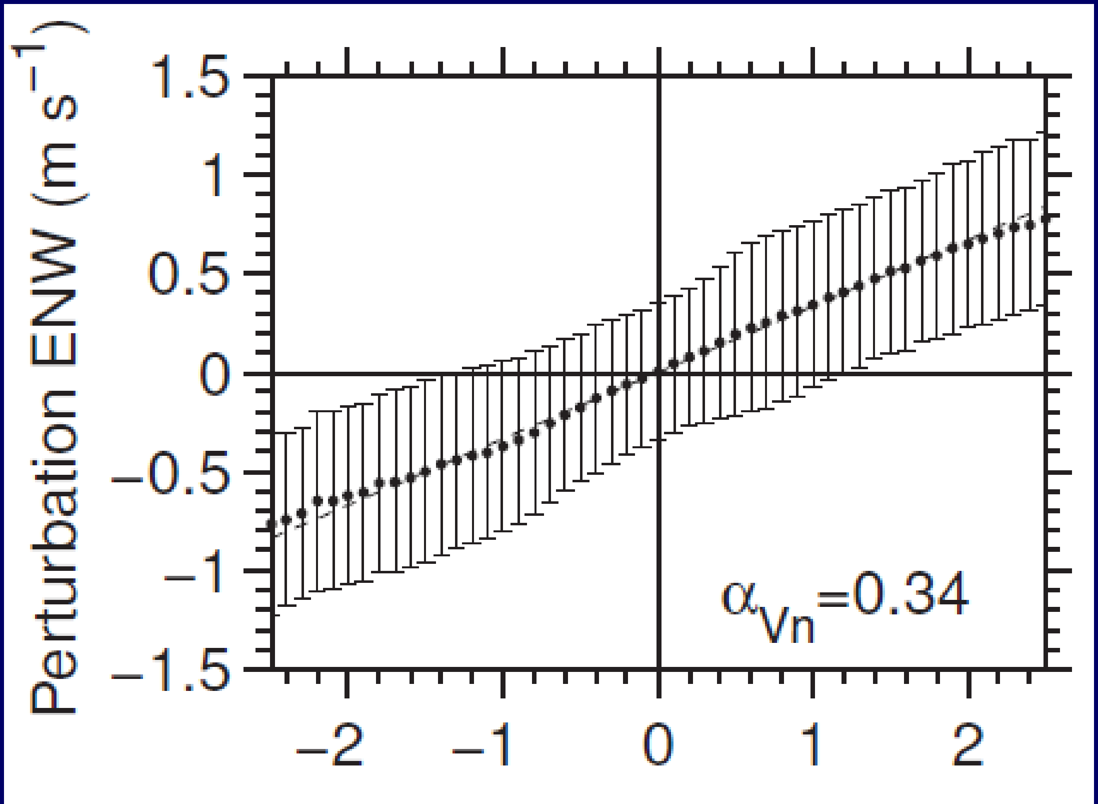
QuikSCAT vs. Buoy Wind Speeds

"Boundary Layer (Baroclinic) Adjustment"

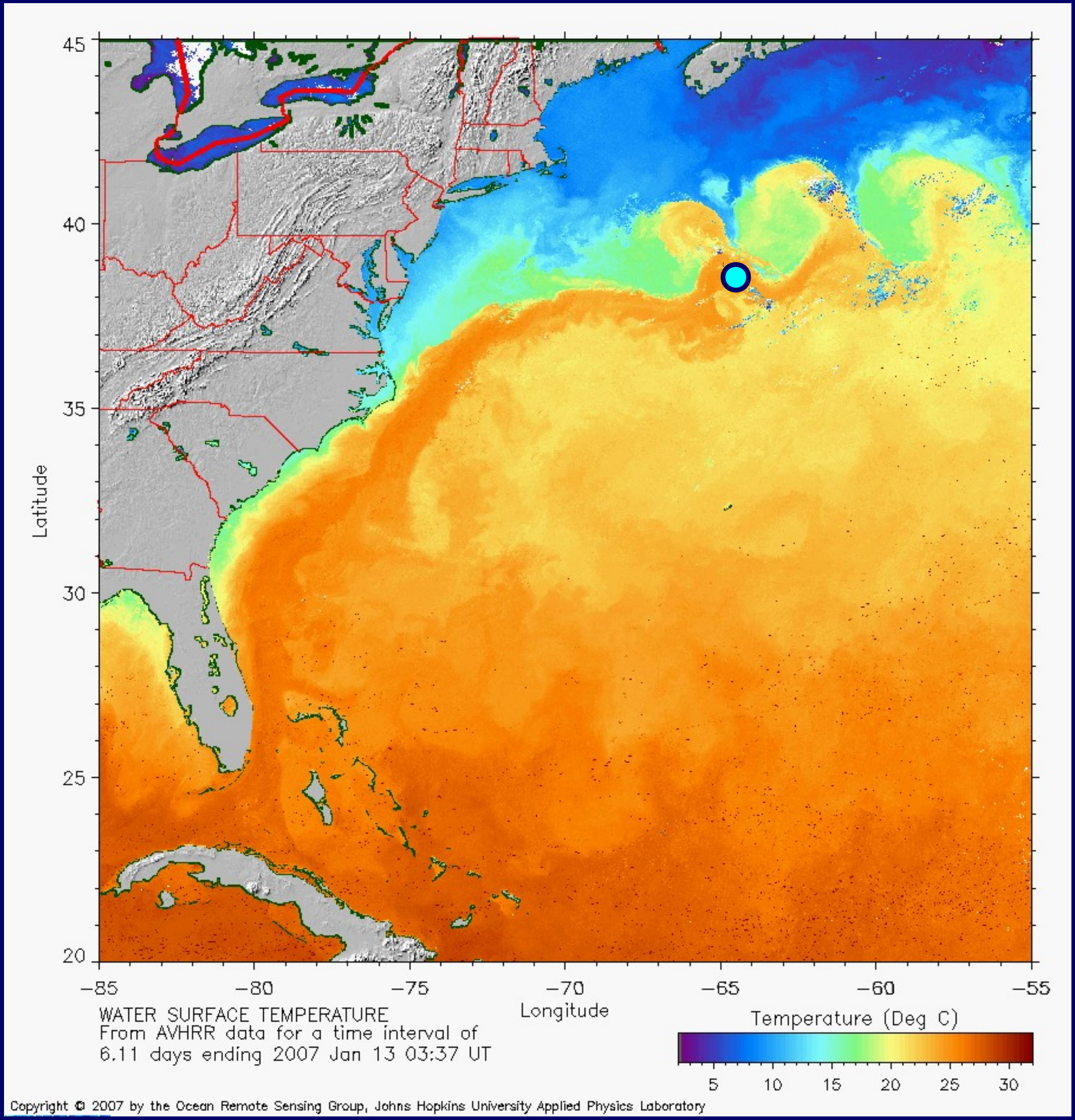


Coupling Coefficients



O'Neill et al. (submitted)

30 Day Perturbations



Courtesy of JHU/APL

QuikSCAT vs. Buoy Wind Speeds

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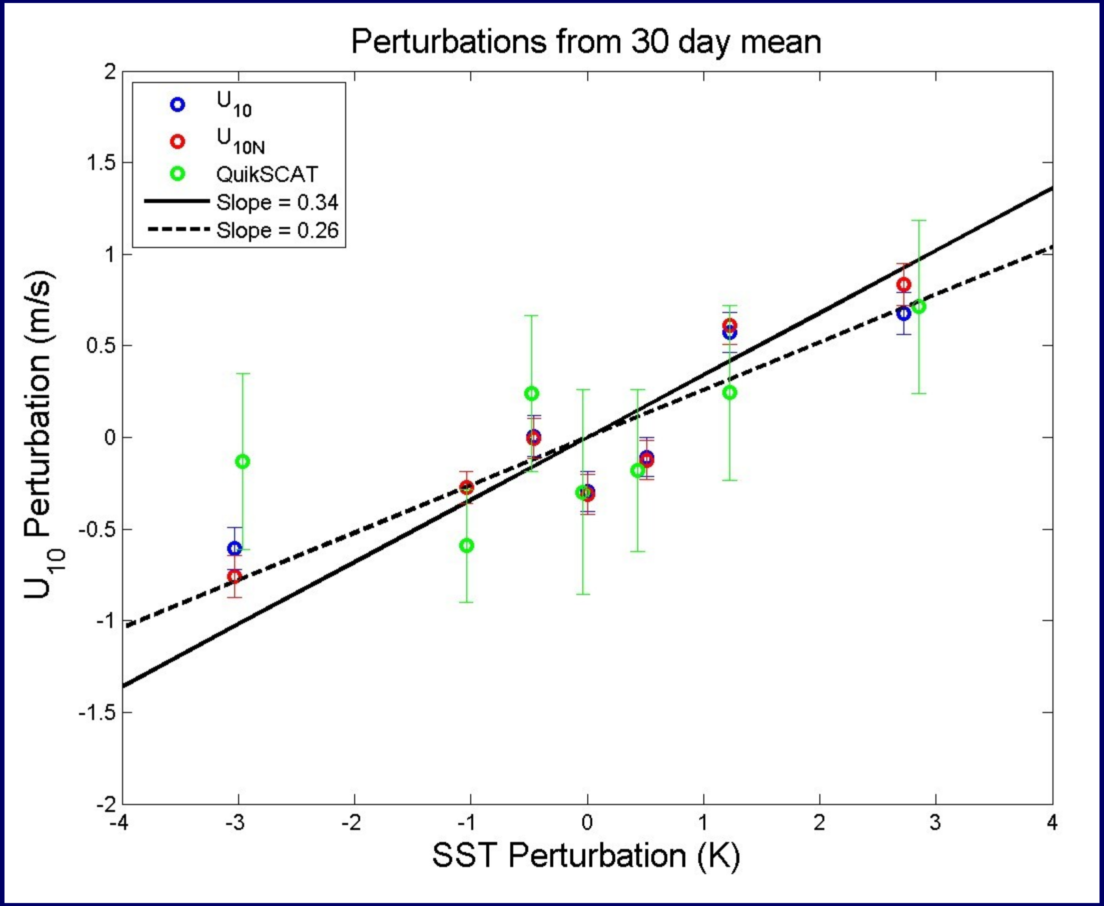

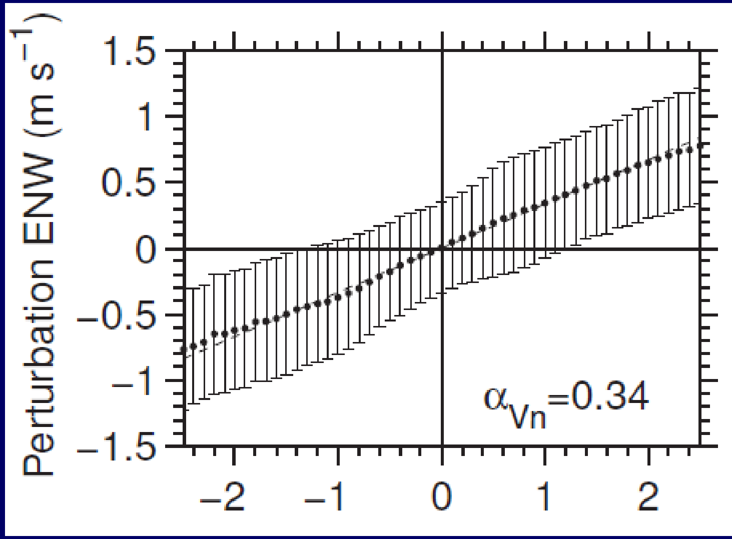

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QuikSCAT vs. Buoy Wind Speeds

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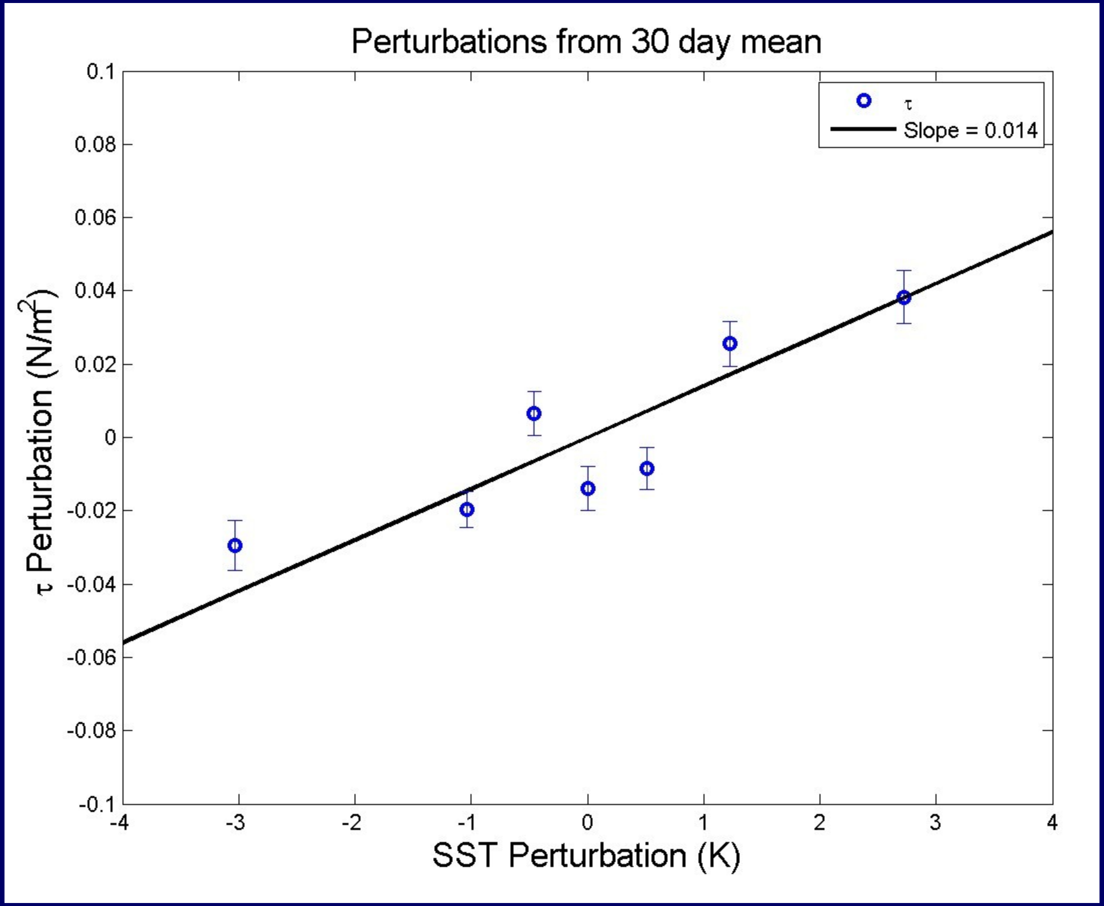

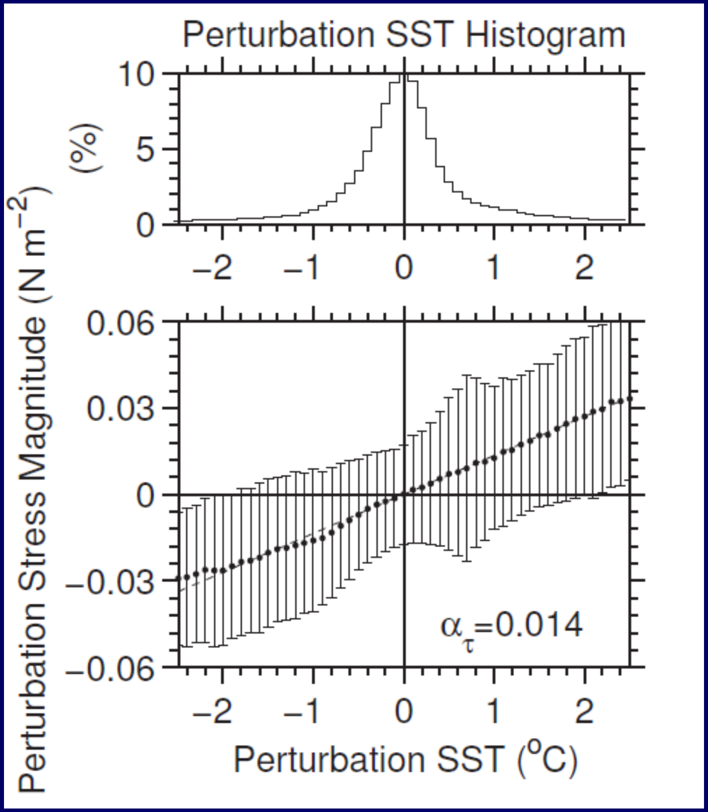

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QuikSCAT vs. Buoy Wind Speeds

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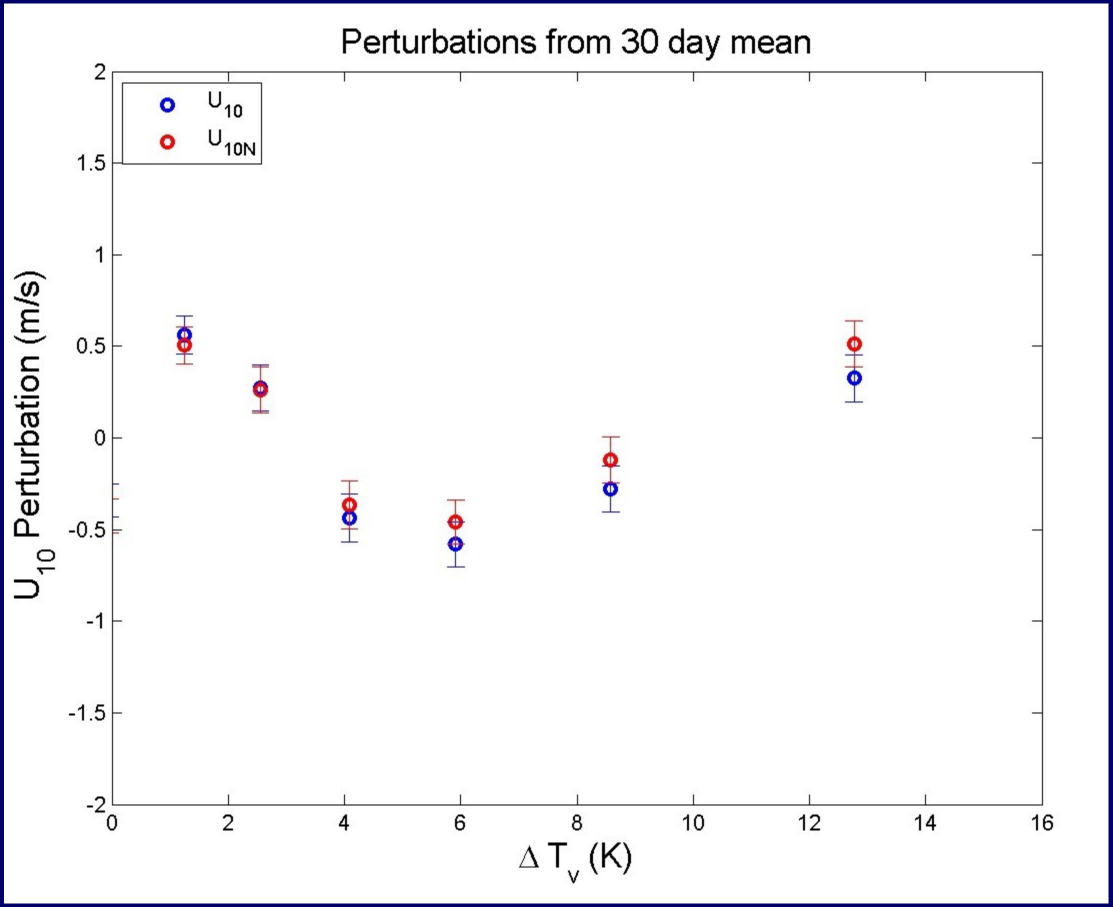
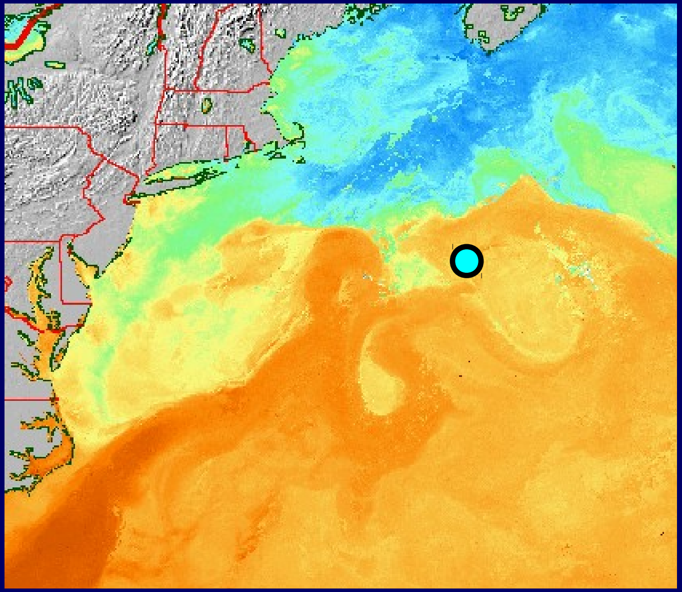
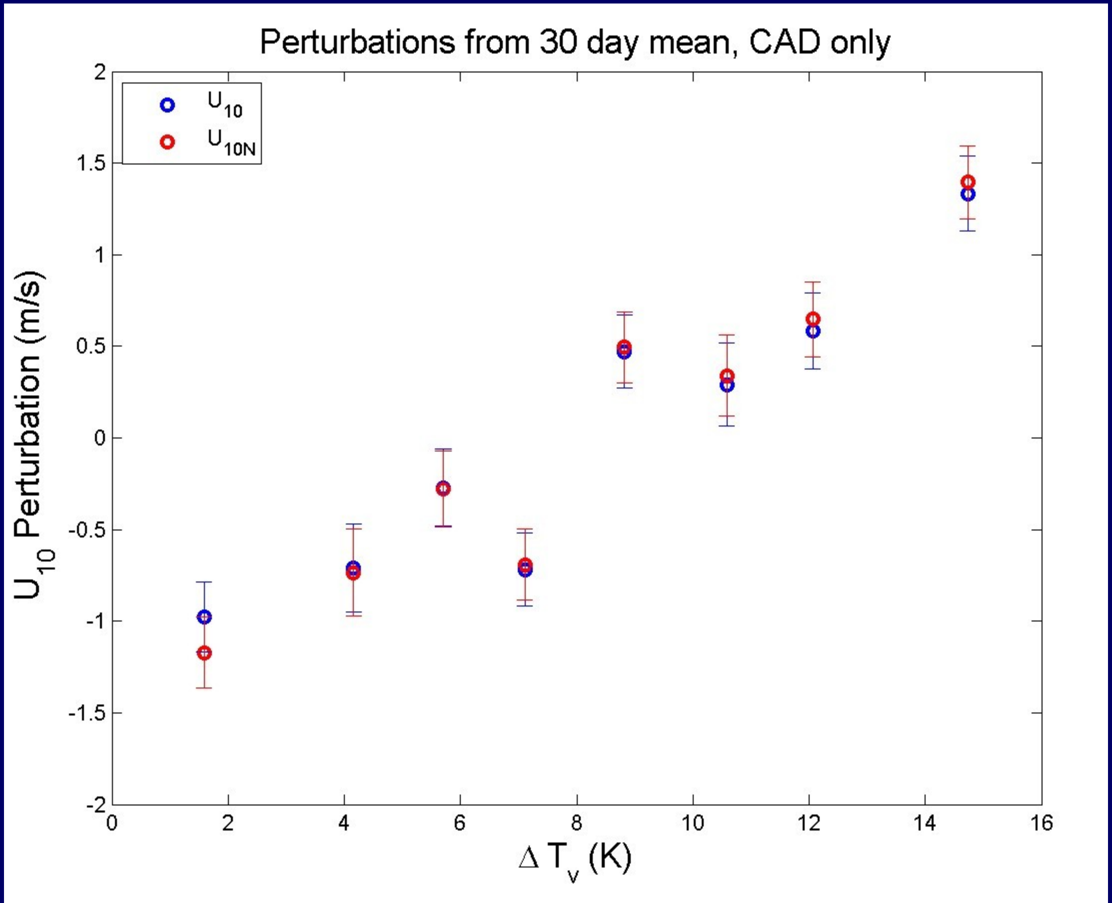


No obvious trend in perturbations when computed versus sea-air virtual temperature difference.

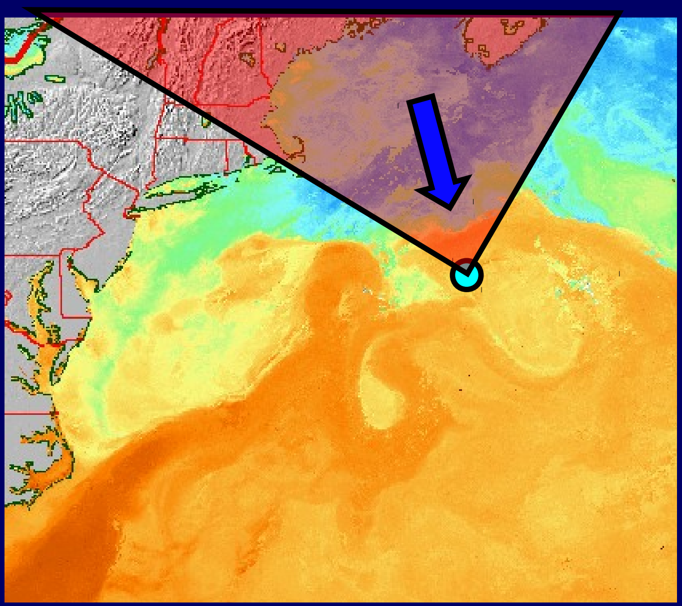


QuikSCAT vs. Buoy Wind Speeds

"Boundary Layer (Baroclinic) Adjustment"



However, it becomes more obvious when you only look at cold/cool air advection.



JHU/APL

QuikSCAT vs. Buoy Wind Speeds

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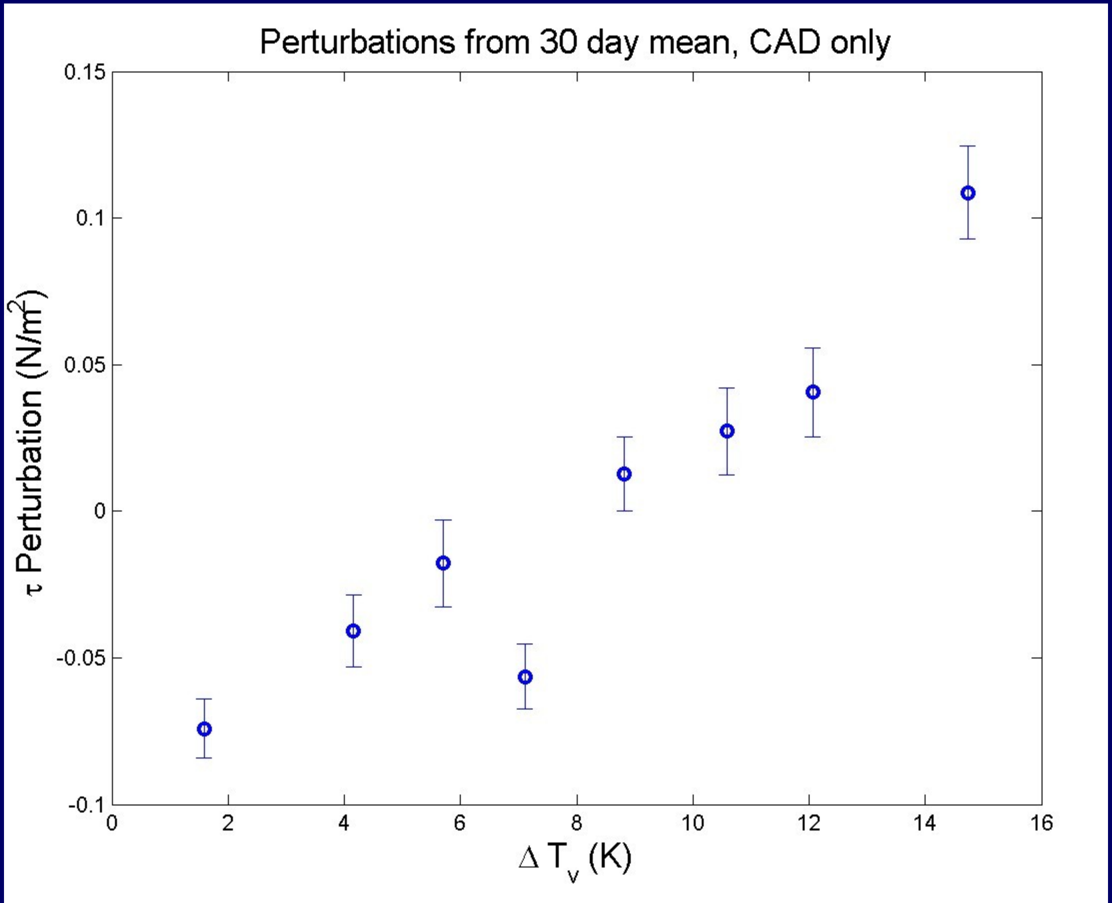

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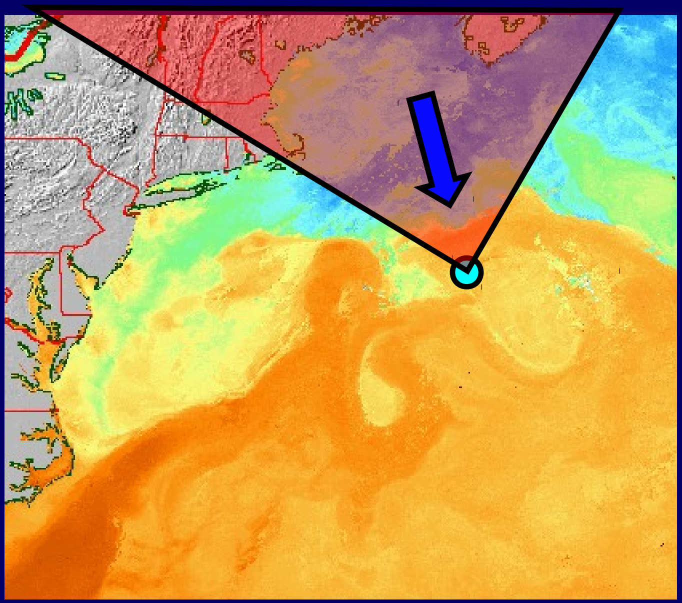


JHU/APL

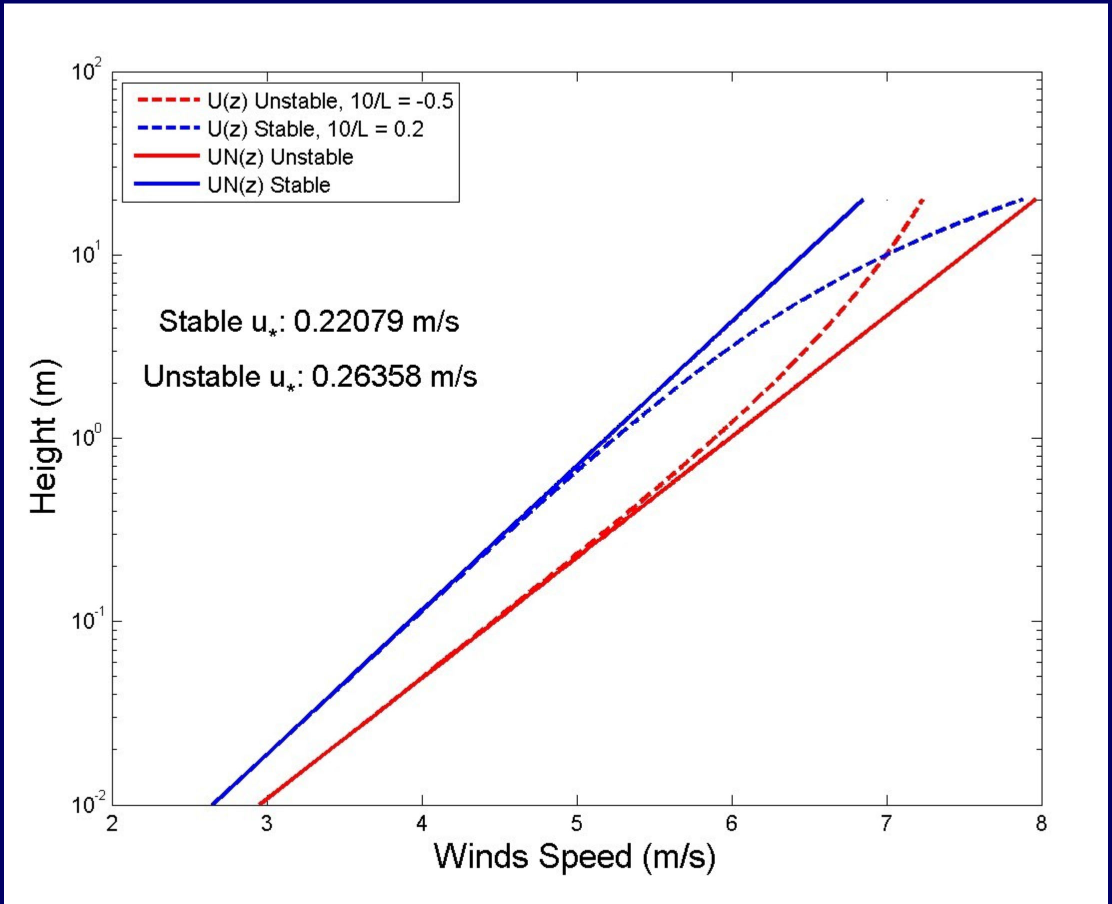
Summary

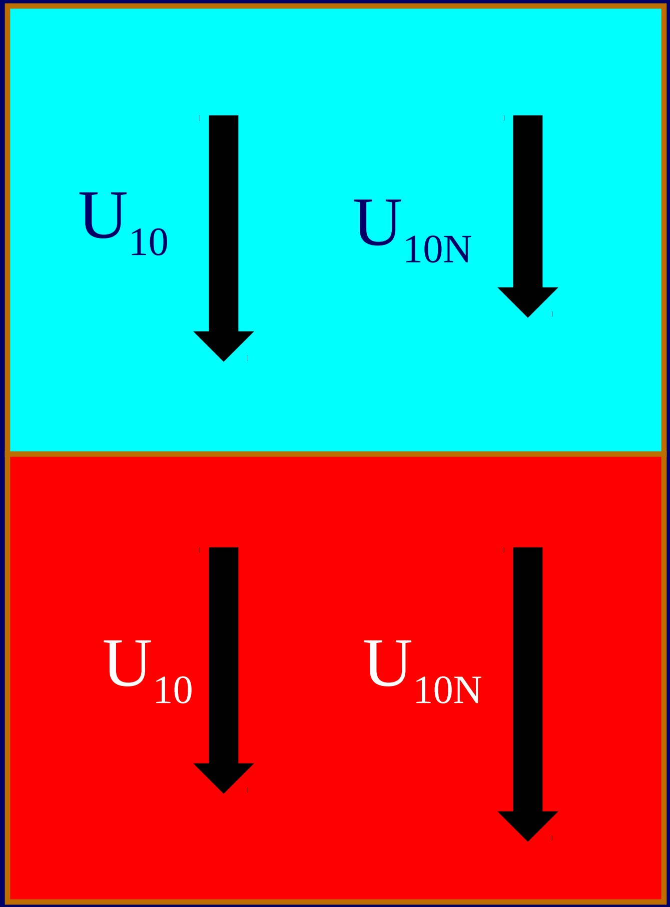
- A wind speed dependent drag coefficient give good results over a wind range of sea-states/wave-ages.
  - This requires a wind speed dependent Charnock variable
  - Numerous investigations have shown that the Charnock variable is dependent on wave-age.
  - However, these findings can be reconciled since observed wave ages over the coastal and open ocean are clearly associated with wind ranges.
- Some of the variability in the QuikSCAT winds is due to adjustment of the neutral wind to changes in stratification and not changes in the actual wind speeds.
  - This variability obeys MO-Similarity in the mean.
  - This effect enhances the gradient in neutral winds but not actual.
  - 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 neutral wind, measured wind, and directly measured stress.
  - The physical processes responsible for this correlation is …
- Compare stress!

Thanks to NSF and NASA for supporting this research.

QuikSCAT vs. Buoy Wind Speeds

"Surface Layer Adjustment"





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