Overview of Wind Stress Working Group

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Motivation

Motivation for the working group can be found in a recent ocean flux remote sensing survey paper by Bourassa et al. (2010 TOS):

- *Recent studies find that scatterometers, and presumably other wind-sensing instruments, respond to stress rather than wind, accounting for variability due to wind, buoyancy, surface currents, waves, and air density.*
- *It is anticipated that scatterometer-derived stresses will soon be available from reprocessed QuikSCAT observations, with regional and seasonal biases proportionally smaller than for stresses determined previously.*
- *This is a tremendous advantage for improved accuracy in other turbulent fluxes because wind stress is more closely related to fluxes than wind: stress observations are believed to account for all sea-state-related variability in surface fluxes of momentum, heat, and moisture.*
- *Because sea state is not well observed from space, this approach should remove one source of error in studies of climate change.*

Background

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- *The basis for this is that radar backscatter is proportion to surface roughness, and we generally assume that surface roughness is most closely correlated with wind stress, τ.*
- *Wind stress is most closely correlated with the equilalent neutral wind speed (squared) relative to the sea surface, U_{rN}. Since wind speed varies with height, the neutral wind speed is typically computed at a height of 10-m, U_{r10N}.*
- *The relationship between U_{r10N} and τ given found using a neutral drag coefficient C_{D10N}:*

$$\vec{\tau} = \rho_a C_{D10N} \left| \vec{U}_{r10N} \right| \vec{U}_{r10N}$$

- *Therefore, the stress can be estimated from scatterometer-derived winds through a drag coefficient without the need for stability corrections.*

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- *Geophysical Model Functions (GFMs) are typically derived using equivalent neutral winds from buoy and model data using MO similarity scaling:*

$$U_{r10N} = U(z_b) - U_0 + \frac{u_*}{\kappa}\left[\ln\left(\frac{10}{z_b}\right) + \psi_m\left(\frac{z_b}{L}\right)\right] \Rightarrow u_*^2 = \left|\frac{\vec{\tau}}{\rho_a}\right| \quad \& \quad \frac{z}{L} = -\frac{z\kappa g}{T_v}\frac{\overline{wT_v}}{u_*^3}$$

Preliminary (TDB) Charge

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The primary objectives of the IOVWST Wind Stress Working Group (WSWG) are:

- Improved estimates of wind stress derived from scatterometer estimates of the equivalent neutral wind via a WSWG recommended drag coefficient.
- Investigate the need for more direct estimates of wind stress from scatterometer measurements of surface roughness.

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$$\vec{\tau} = f(\vec{\sigma}_0, \ldots)$$

1. WSWG recommended bulk formula.
2. Direct covariance measurements.

I have a dream . . .

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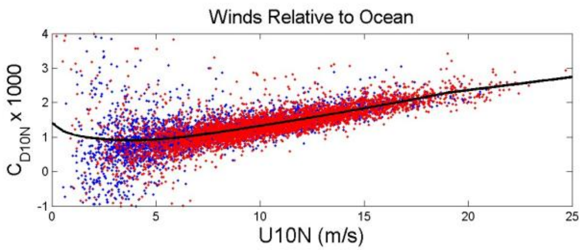
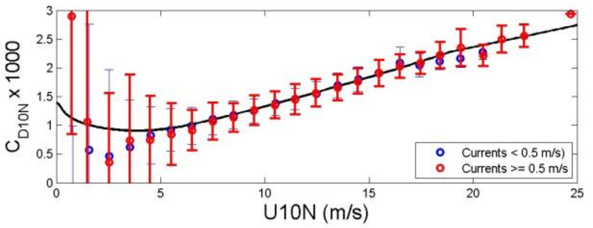
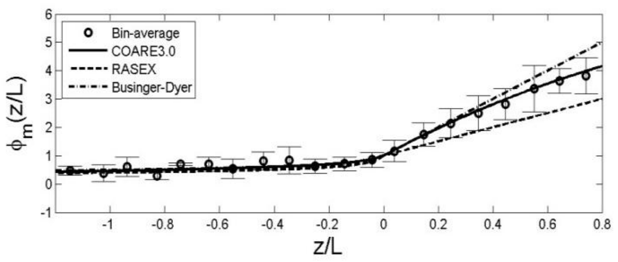
Summary of Potential Research Issues

The following issues have all been considered by the IOVWSTs. The IOVWSTs have a good handle on some of them and significant disagreement or overall lack of understanding exists with other.

- Currents and stability corrections and consideration
- Dependence of surface stress on air density.
- Drag coefficient and surface roughness formulations.
- Sea-state dependent drag coefficients.
- Geophysical model function based on surface stress
- Noise and non-linearity
- Physical models of scattering and relation to surface stress.
- Water temperature dependency of surface characteristics (e.g., viscosity, density and tension effect on gravity-capillary waves)
- Extreme wind conditions







$$U_{r10N} = \sqrt{\frac{<\rho_a>}{\rho_a}}\, U_{r10N}^{retrieval}$$

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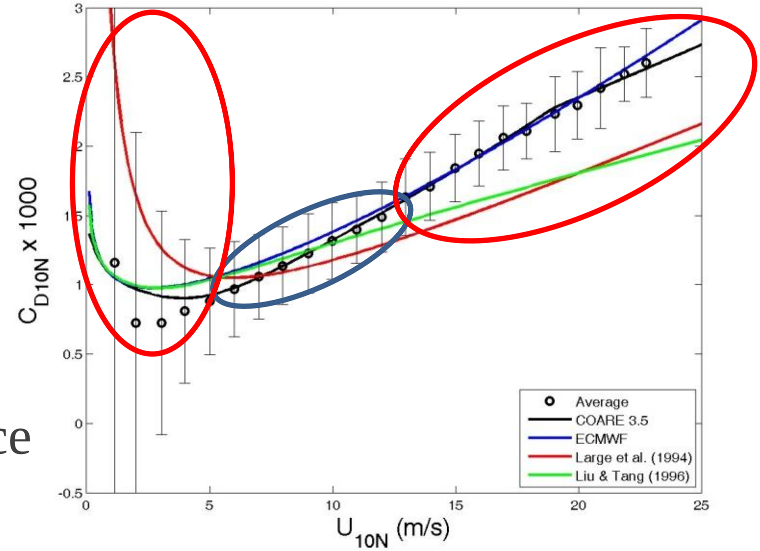

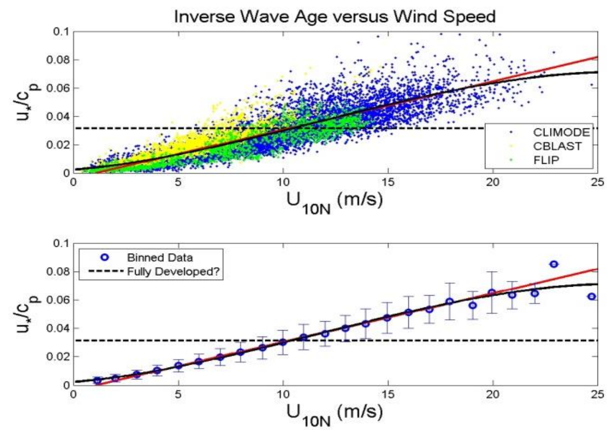

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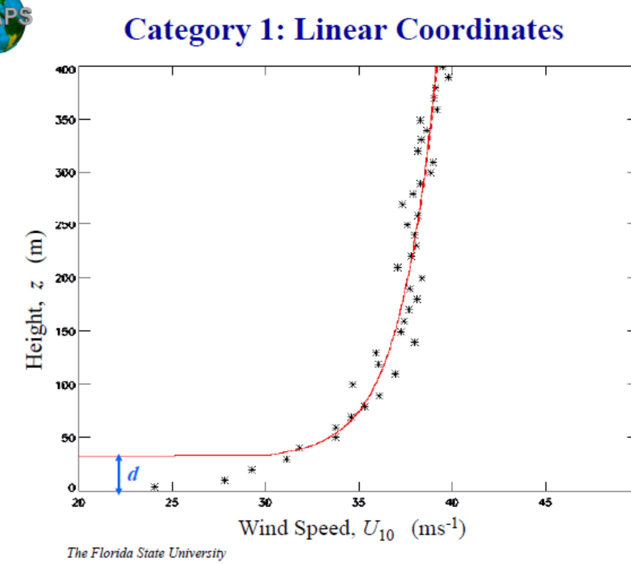
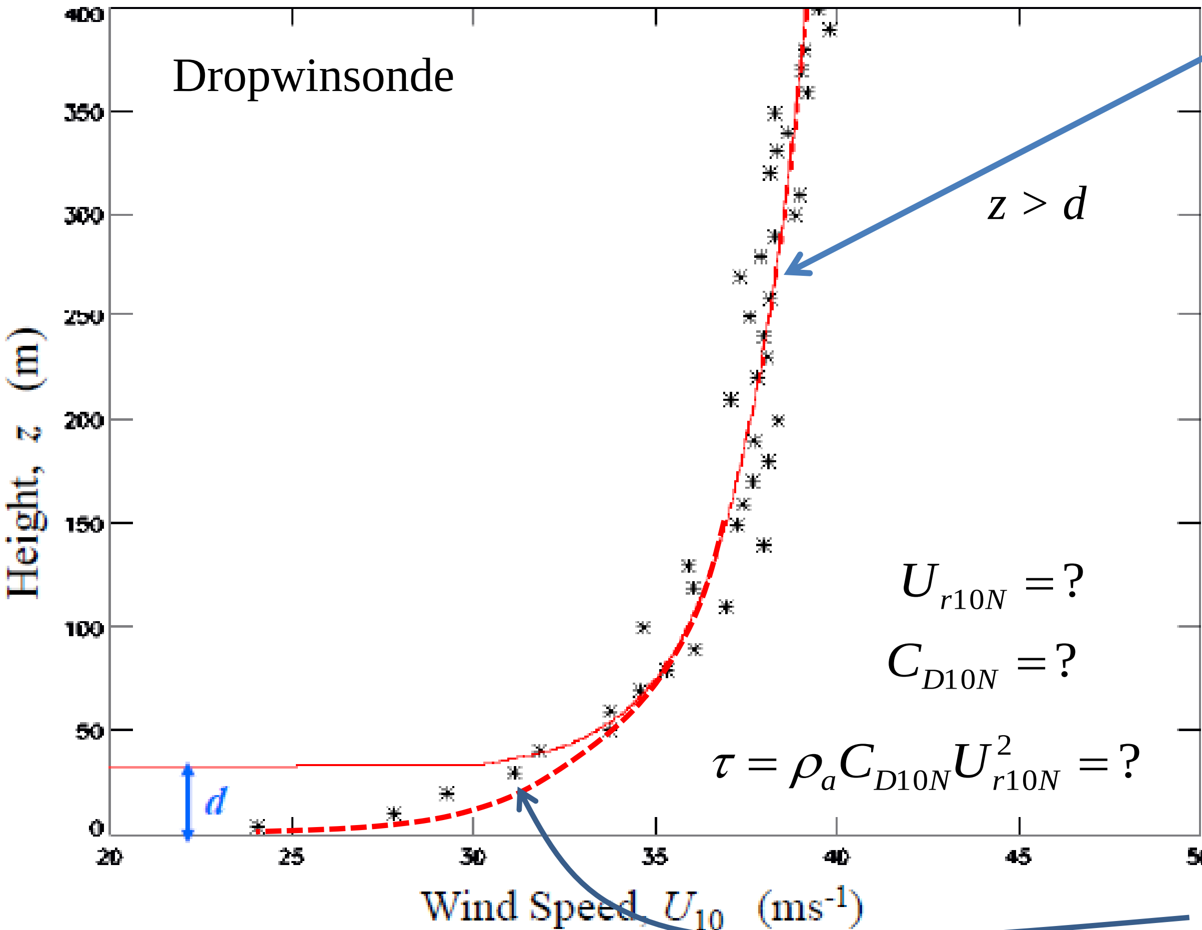


Measured wind profiles in high-wind conditions from dropwinsondes.

3rd Talk in Session
Liu et al., Retrieving Hurricane Scale Wind and Stress from Scatterometers

Extreme Wind Conditions



The Florida State University

Velocity Deficit

$$U_N(z) - U_0 + \frac{u_*}{\kappa}\ln\left(\frac{z-d}{z_0}\right)$$

$d \approx 30\text{m}$

$$\tau = \rho_a u_*^2$$

WSWG

Physical Processes?

- Wave Boundary Layer

$$\tau = \rho_a \overline{uw} = \rho_a\left(\overline{u'w'} + \overline{\tilde{u}\tilde{w}}\right)$$

$\tau \approx \rho_a \overline{u'w'}$ $\quad z > d$

$\tau \approx \rho_a \overline{\tilde{u}\tilde{w}}$ $\quad z = 0$

? $\quad 0 < z < d$

- Sea-spray?
- Breaking wave/Flow separation?

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Where does this leave us?

- The drag coefficient (C_D) and roughness length (z_o) cannot be accurately determined
- Displacement height is highly sensitive to U_{sfc} if z_o is large (and it will be for a tropical cyclone), so it is also impractical to estimate

- On the other hand, the estimate of friction velocity (u_*) is
  - only weakly depending on U_{sfc}, and
  - weakly depending on d if $z >> d$.
- Therefore, it is possible to get a relatively good estimate of u_*.
  - How good depends on the number and quality of observations that are close to the surface but well above the wave height
- Given friction velocity and air density, an reasonably accurate stress could be calculated
- Tests with the Powell et al (2003) data indicate robust values for u_*