Review of Equivalent Neutral Winds and Stress Equivalent Winds

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Why Calibrate to 'Winds' Rather than Stress

- Radar backscatter was observed to be dependent on wind speed and/or wave height in the 1950s.
- In 1963 Dick Moore had the idea that backscatter could be used to estimate oceanic variables.
- The NASA Sea Surface Stress (S^3) report indicated that scatterometers probably did respond to stress rather than wind.
- The number of stress observations available for calibration was approximately zero. Therefore, it was desirable to calibrate to wind, for which the collocated observations would be plentiful.
- Willard Pierson, Vince Cardone and colleagues found that wind speed could be adjusted to be more consistent with surface stress.
    - Equivalent neutral wind
    - But there was a questionable assumption which brings us to stress equivalent winds

Qualitative Description of Earth-Relative Winds and Equivalent Neutral Winds and Stress Equivalent Winds

- **Earth relative winds** are wind speeds measured relative to the 'fixed' earth
  - **Earth relative winds** are the standard for almost all atmospheric applications:
    - Operational meteorology (forecasts and analyses)
    - Hurricane and marine cyclone analyses
  - Most meteorologists think in terms of **earth relative winds**
- **Equivalent neutral winds** are used to determine (or as a proxy for) surface turbulent stress.
  - They have been designed for very simple conversion to stress.
    - They assume an average (of some sort) air density, which causes systematic errors when converting from a stress to a wind and a friction velocity
      - Air density is about 1.1 kg m^{-3} in the tropics outside of strong cyclones
      - Air density can be 1.4 kg m^{-3} in the in extremely cold air outside of strong cyclones
- **Stress Equivalent winds** correct for this problem, defining a satellite wind speed that does take account of the local air density
  - Which implies that for comparison air density must be used to determine stress-equivalent winds

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Stress – Parameterization with a Drag Coefficient

- The surface turbulent stress (momentum flux density) is usually parameterized as

$$\tau = \rho C_D U_{10}^2$$

- This form can be more accurately written as

$$\boldsymbol{\tau} = \rho C_D \left|\mathbf{U}_{10}\right| \mathbf{U}_{10}$$

- It can be further improved in terms of surface relative wind vectors:

$$\boldsymbol{\tau} = \rho C_D \left|\mathbf{U}_{10} - \mathbf{U}_{sfc}\right| \left(\mathbf{U}_{10} - \mathbf{U}_{sfc}\right)$$

- Does a scatterometer respond to $\mathbf{U}_{10}$ or to $\mathbf{U}_{10} - \mathbf{U}_{\mathrm{sfc}}$?
  - *Cornillon and Park* (2001, *GRL)*, *Kelly et al.* (2001, *GRL*), and *Chelton et al.* (2004, *Science*) showed that scatterometer winds were relative to surface currents.
  - *Bentamy et al.* (2001, *JTech*) indicate there is also a dependence on wave characteristics.
  - *Bourassa* (2006, *WIT Press*) showed that wave dependency can be parameterized as a change in $\mathbf{U}_{\mathrm{sfc}}$ for wind and waves moving in the same direction.
  - Hence, empirical GMFs tuned to $\mathbf{U}_{\mathrm{sfc}}$ incorporate wave (motion) dependency *Portabella et al.* (2009, *JAOT*)

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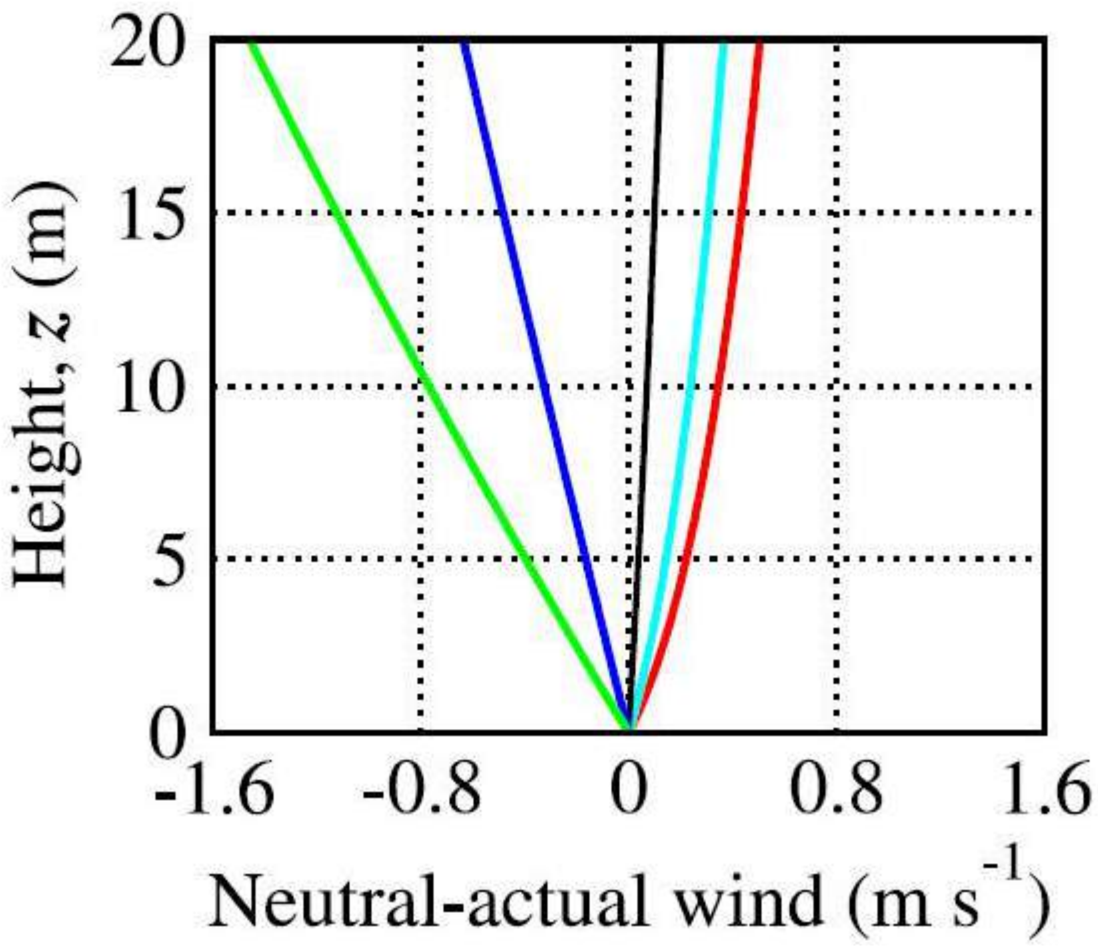
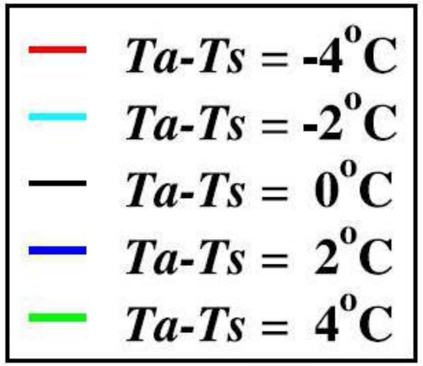
Equivalent Neutral wind speed minus Earth Relative wind speed for $U_{10} = 6\ ms^{-1}$



- For equal and opposite air/sea temperature differences, the change is greater for the stable conditions



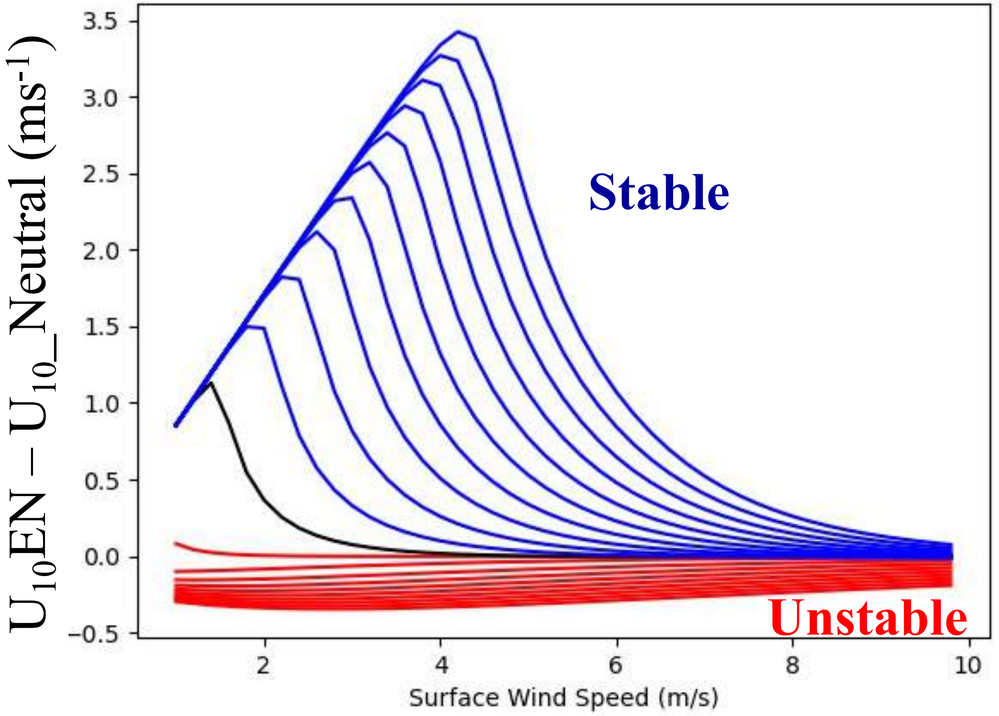
- These results require a roughness length that is dependent on friction velocity. Otherwise, it can change a lot

How To Calculate Equivalent Neutral Winds & Common Errors

- **Correct Approach**
- **Calculate the friction velocity (or stress)**
  - **accounting for atmospheric boundary-layer stability, and**
  - **And using a stress depending roughness length.**

  - **Use these friction velocity and roughness length to determine a wind speed at 10 m height (*z*=10) with zero additional impact from atmospheric stability.**

- Common errors: #1 Neutral winds



- #2 Kara et al. (200xx) found that application of a constant roughness length or a roughness length without a dependency on stress (a Charnock like roughness length results in systematic errors in equivalent neutral winds

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What If Scatterometers Respond to Stress?

- If scatterometers respond in a manner consistent with **equivalent neutral winds**, then they respond to changes in friction velocity (u_*).

$$U_{10EN} = \frac{u_*}{k} \ln\left(\frac{10}{z_o}\right)$$

$$U_{10EN} = \frac{(\tau / \rho)^{0.5}}{k} \ln(10 / z_o)$$

- $\tau = \rho_{air} \, u_*^{\,2}$
- Replace u* in the traditional definition of equivalent neutral winds – write in terms of τ

- If scatterometers respond to stress, then it responds to changes in air density and change in friction velocity!
- If scatterometers respond to stress, then calibrations to **stress equivalent winds** will not depend on actual air mass density (*de Kloe et al.*, 2017, *JSTARS*)

$$\vec{u}_{10s} = \vec{u}_{10n} \sqrt{\frac{\rho_{\text{air}}}{\langle \rho_{\text{air}} \rangle}}$$

$$U_{10S} = \frac{(\tau / \langle\rho\rangle)^{0.5}}{k} \ln(10 / z_o)$$

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