There are two related goals:

1. Use dropsonde profiles of wind speed, air temperature, and moisture to determine (1) log profile parameters for each profile, including impacts of non-neutral boundary layer stability, (2) use this information to determine air-sea fluxes and transfer coefficients for each profile, and (3) compare our wind speeds (u+10) to NOAA's estimates based on the lowest 150 m of winds (WL150) adjusted for the height range.

2. Model the influences of sea spray on stress, fanning ocean waves, and on stress felt by the atmosphere.

Both goals have implications on the calibration of scatterometer and radiometer winds.

By a physically better definition of 10 m winds.

- Showing that the stress felt by the atmosphere can differ from the stress felt by ocean waves.

What do we calibrate if we’re an Oceanographer?

- Traditionally we calibrate to a 10 m equivalent neutral wind speed. Equivalent neutral means that applying a neutral drag coefficient will result in the correct stress (it does not mean we assume neutral conditions).

The ten-meter wind is defined as the horizontal wind speed at a height 10 m above the displacement height.

- This displacement height is small under most conditions.

Wave tank observations indicate that it is not zero (Bosshard et al. 2021).

- Spray can make the displacement height (d) substantially above the traditional surface (d = 5-20 m) according to Wallace et al.’s dropsonde profile analysis.

- To calibrate to a 2 m wind we would need to know the displacement height (d) based on the inference on an unforced stress.

Since we base our equivalent neutral winds on an ocean stress, this (by itself) is not a serious problem for oceanographers trying to use scatterometer winds to force an ocean model.

What do we calibrate if we’re a Meteorologist?

- Equivalent neutral assumes that scatterometers respond to ocean stress.

Atmospheric Stress = Ocean Wave Stress + Spray

- Spray extracts momentum from the air, reducing the stress felt by the ocean surface.

The atmosphere experience more stress than the ocean if spray extracts momentum from the air.

- Suggesting that scatterometer equivalent neutral winds will underestimate the wind speed if spray extracts momentum from the air.

What do we do that makes sense physically and operationally?

- The answer to this question depends on the relative importance of the momentum extracted by spray.

- If relatively little momentum is extracted, then we don’t need to change our approach to stress, but we might still have issues with displacement height modifying the wind speed.

- If spray extraction of momentum is non-negligible, then we might need to rethink our approaches to estimating wind and stress.

Three Assessments of the wind speeds for which spray matters

1. We use the observed drag coefficient as one guide to identifying the wind speed above which spray has a significant impact on momentum.

2. Early work by Powell et al. Suggests that the dependence of the drag coefficient on wind speed changes around 40 to 50 m s⁻¹.

3. Hoffmeister et al. (2022) and Richter et al. (2021) suggest this change occurs around 30 m s⁻¹.

4. Our dropsonde-based analysis is more consistent with Richter et al. (2021) and Hoffmeister et al. (2022).

5. Comparisons can also be made between our dropsonde-based 10 meter wind speed and wind speeds estimated by the WL150 method. This tests to see if our estimated wind speeds are loosely consistent with estimates from NOAA’s Research and Development Division, and if there might be a problem with calibrating remotely sensed winds to dropsonde-based WL150 winds (assuming there aren’t other issues like beam filling and sensitivity to rain).

Comparisons (see figures) are

- remarkably similar up to 35 ms⁻¹.

- noticeably shift a little from 35 to 50 ms⁻¹, and

- Suggest that winds > 55 ms⁻¹ are underestimated.

Modeling Reduction of Momentum Due to Spray

Modeling Reduction of Momentum Due to Spray

- The total stress in the spray layer is assumed to be comprised of three additive components:

  - Form drag of surface waves

  - Bag stress, or the airflow resistance to the microsails

  - The droplet stress, or the momentum gained due to the droplet production

The wave component is based on a Beaverskmarkt parameterization for roughness due to gravity waves (Beaverskmarkt 1999), which has a drag coefficient that increases linearly with wind speed. This drag is used to remove momentum from the air.

Spray removes momentum from the air

- reducing the stress on the ocean surface,

- reducing the roughness of waves,

- Causing surface winds to increase.

- Causing a net decrease in atmospheric stress.

- Decreasing the drag coefficient

The model for stress from bags and drops seems to work well for U∗ ≤ 35 ms⁻¹.

- Very minor changes in the parameterization can remove the increase in drag for U∗ > 35 ms⁻¹.

- But how does this parameterization work?

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Modelled stress (left) and drag coefficient (right) as a function of 10 meter wind speed (U10). The black line shows an increase in stress and the drag coefficient as wind speed increases, as expected if modeling that works well for U∗ ≤ 20 ms⁻¹ applies at stronger wind speeds. The red line shows the wave stress and CD same model modified to include the extraction of momentum by spray, adapted from Troitskaya et al. (2017) with minor tuning to improve the results for U∗ > 35 ms⁻¹. The blue line shows the spray-modified stress and CD for the atmosphere for the model used to determine the red line.