Estimating Atmospheric Wind from Scatterometer Equivalent Neutral Winds

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Abstract

Ocean vector winds estimated by scatterometers represent the Equivalent Neutral Wind. The EN wind has units of wind speed, but is modulated like wind stress. When compared against in-situ or model winds, the EN wind has been shown to have regional biases on the order of 1 m/s in areas with strong surface currents or large air-sea temperature differences (Belmonte Rivas 2019). Oftentimes, these areas are climactically important and drivers of large-scale weather, like the western boundary currents, the ICTZ, and ACC. Accurately determining and projecting trends requires we properly represent the wind.

EN wind biases can be corrected to the extent that required ancillary data is available and reliable. In this work, we introduce a method for adjusting the EN wind measured by scatterometers to represent the "atmospheric" wind. The resulting data will be available as a new variable in the upcoming MEASURES JPL scatterometer climate data record for ASCAT-A, ASCAT-B, QuikSCAT, and ScatSat.

Our results show improvement in bias and RMS error to ERA5 winds, with large improvements in regions where scatterometers are known to traditionally show biases.

Background

Ocean vector winds estimated by scatterometers represent the Equivalent Neutral Wind (Bourassa 2019). The EN wind has units of wind speed, but is modulated like wind stress, according to:

$$U_{EN}(z) = \frac{\sqrt{\tau}}{\sqrt{\rho}k}[\ln\frac{z}{z_o} + \phi] + U_s,$$

where $U_{EN}(z)$ is the equivalent neutral wind speed, τ is the wind stress, ρ is the density of air, k is a constant. The logarithmic term represents the structure of wind speed over height, scaled by z0, the roughness length. Effects due to atmospheric stability are represented by ϕ, which is itself a function of wind speed, air temperature, sea surface temperature, humidity, and sea state (among other parameters). Finally, Us are the surface currents, making the measured EN wind relative to the moving ocean.

Numerous solvers exist for estimating parameters in Eq 1. COARE 3.5 (Edson 2013) is a common choice, which we used to estimate the stability adjustment (Fig. 1, top left).

Each additional panel shows the change in EN to ATM wind adjustment when the selected parameter is changed. Changing the relative humidity from 60% to 100%, causes an O(0.1) m/s change in the adjustment due to effects on atmospheric stratification. The air temperature has a similar order effect when varied over 20 degrees C, due to changes in air density and drag coefficient. This variability is representative of the difference in tropics and polar regions.

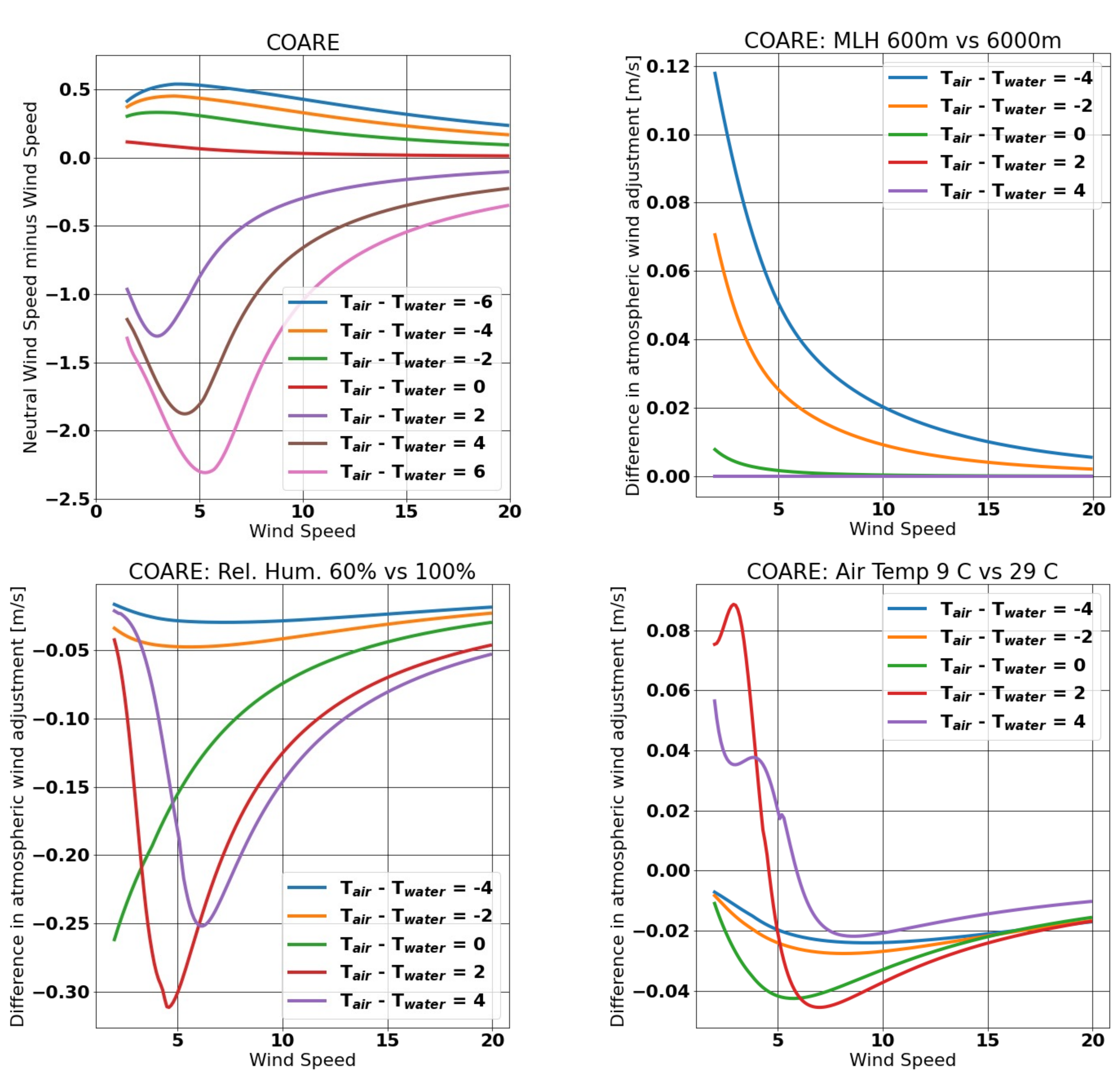

Figure 1: COARE base stability adjustment (top left) and sensitivity of the adjustment to parameter choices (other panes).

Methods

Atmospheric stability:

The COARE 3.5 algorithm was used to adjust scatterometer measured EN winds for atmospheric stability, using ancillary inputs of ERA5 sea surface temperature, air temperature, boundary layer height, and relative humidity.

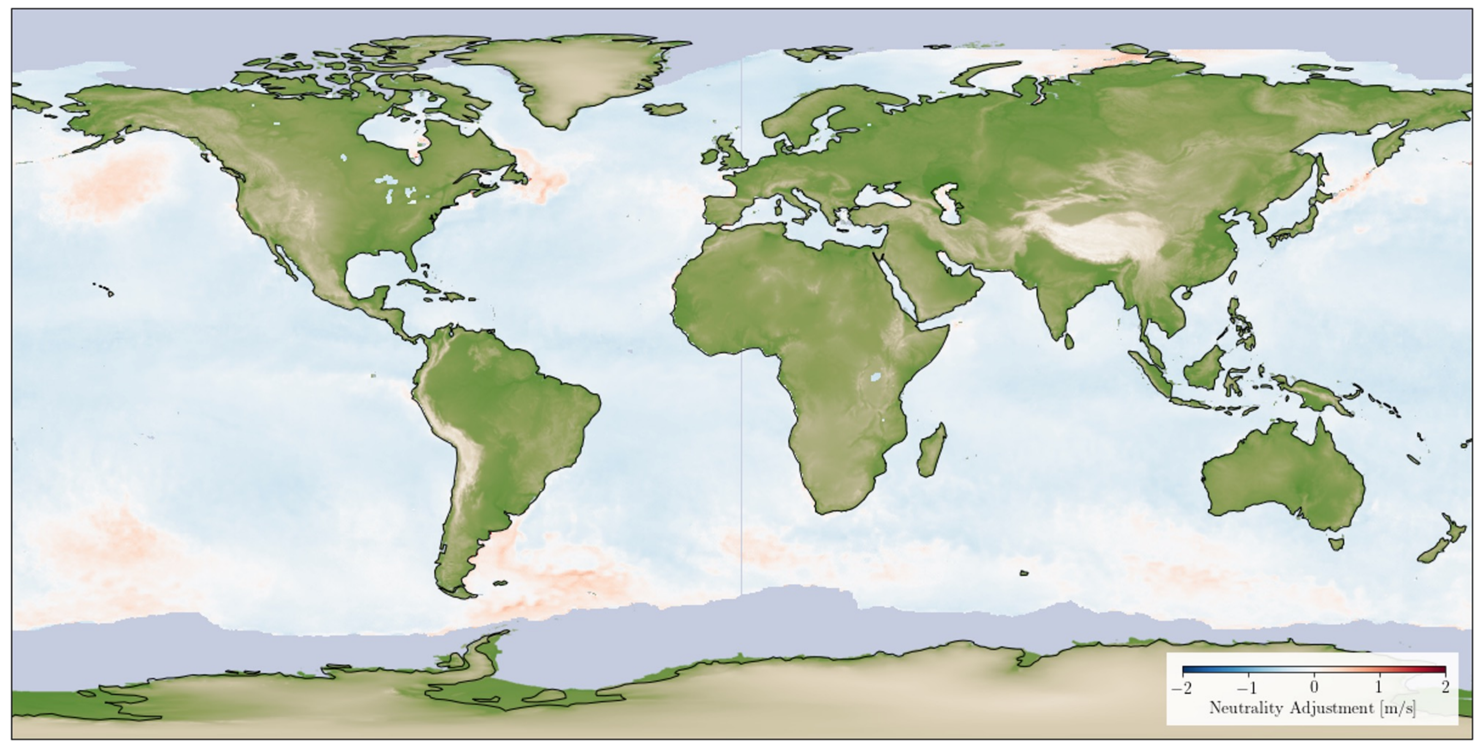

Figure 2: One-week average of the stability adjustment from January 2008.

Surface currents:

Scatterometer-co-located Globcurrent surface current data was used to adjust the current-relative scatterometer winds to Earth-relative atmospheric winds. We use a product made up of geostrophic, Ekman, and stokes currents.

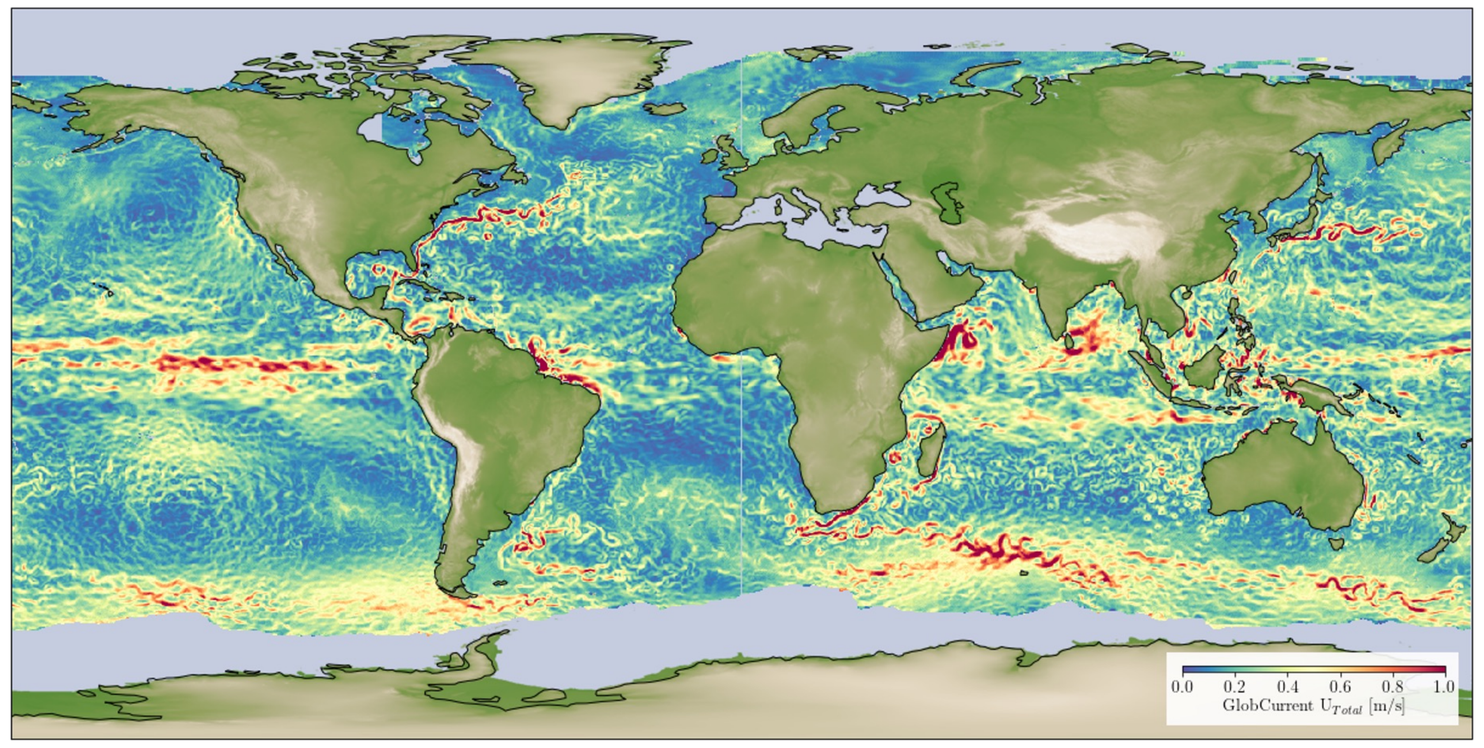

Figure 3: One-week average of the surface current adjustment in January 2008.

Total Adjustment

The wind speed is adjusted using COARE 3.5, with no change in direction. The components are then summed with surface current components to form an Earth-relative wind. The largest adjustments occur in the southern ocean, western boundary currents, and anomalous "heat blobs," one of which is apparent near Alaska.

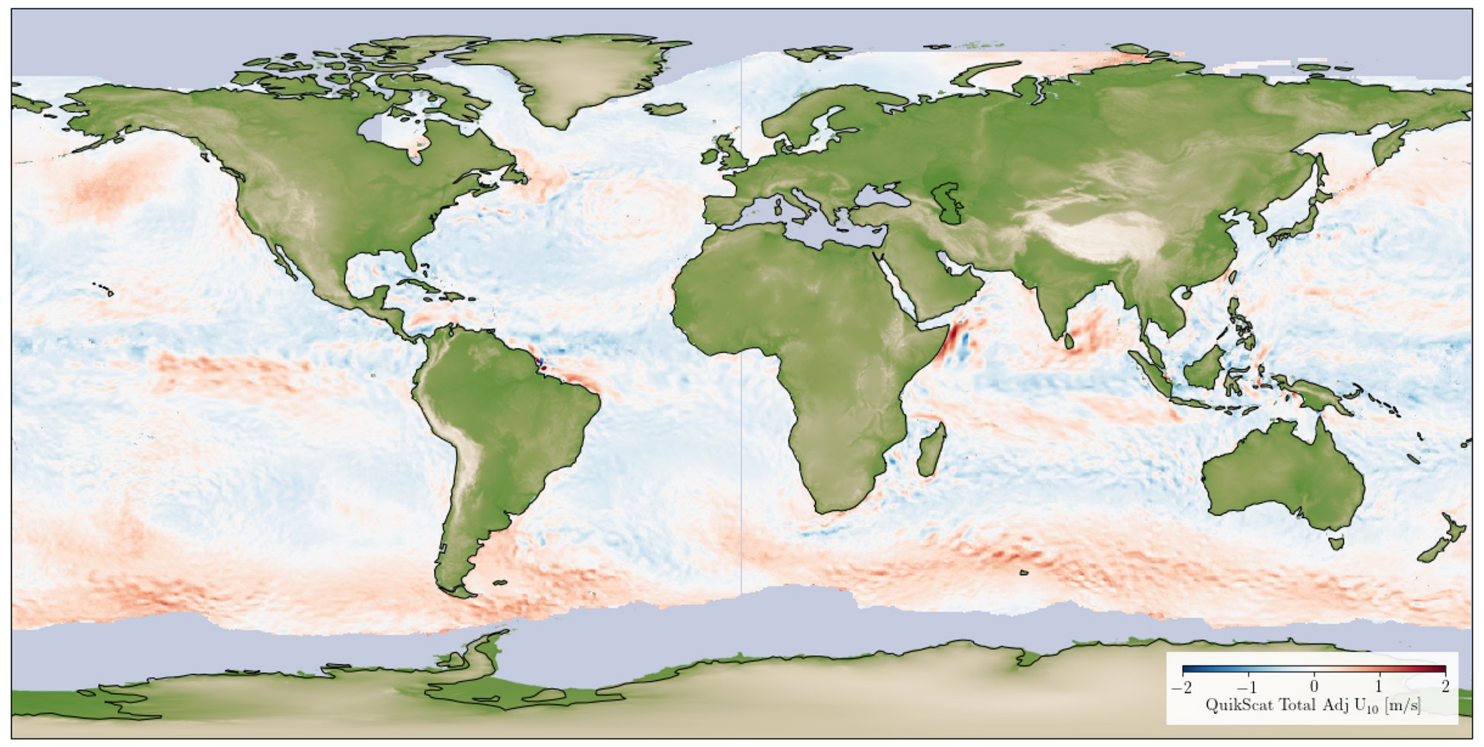

Figure 4: One-week average of the total EN wind adjustment in January 2008.

Results and Validation

Figure 4 shows the adjustment for one-week during January 2008. These results show that the adjustment can very often reach >1 m/s, with large-scale regional effects.

Figure 5 shows the latitude-dependence of the U and V component differences from ERA5 for the EN winds in red and the adjusted atmospheric wind in blue. In the zonal averages, the bias is consistently closer to zero, except near the equator where surface current estimates are very poor. Biases in the southern ocean are almost completely eliminated.

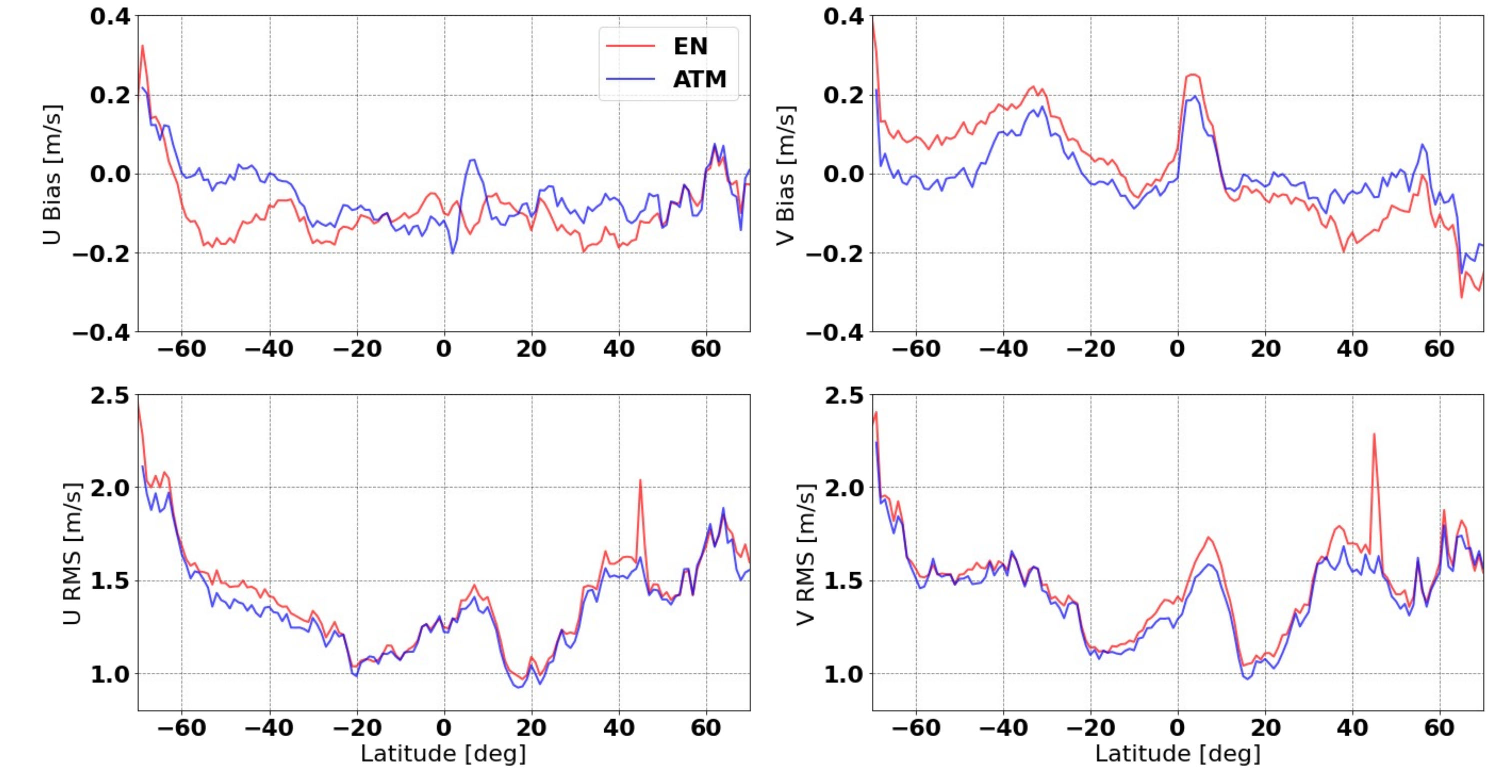

Figure 5: Zonal averages of the bias and RMS of the EN/ATM winds relative to ERA5. Data for JPL processed ASCAT-A for the year 2008.

Figure 6 shows the distribution of errors relative to ERA5 for U, V and wind speed. Overall, the effect is a ~0.1 m/s reduction in bias and standard deviation. These relatively small changes, however, mask the significant regional effects.

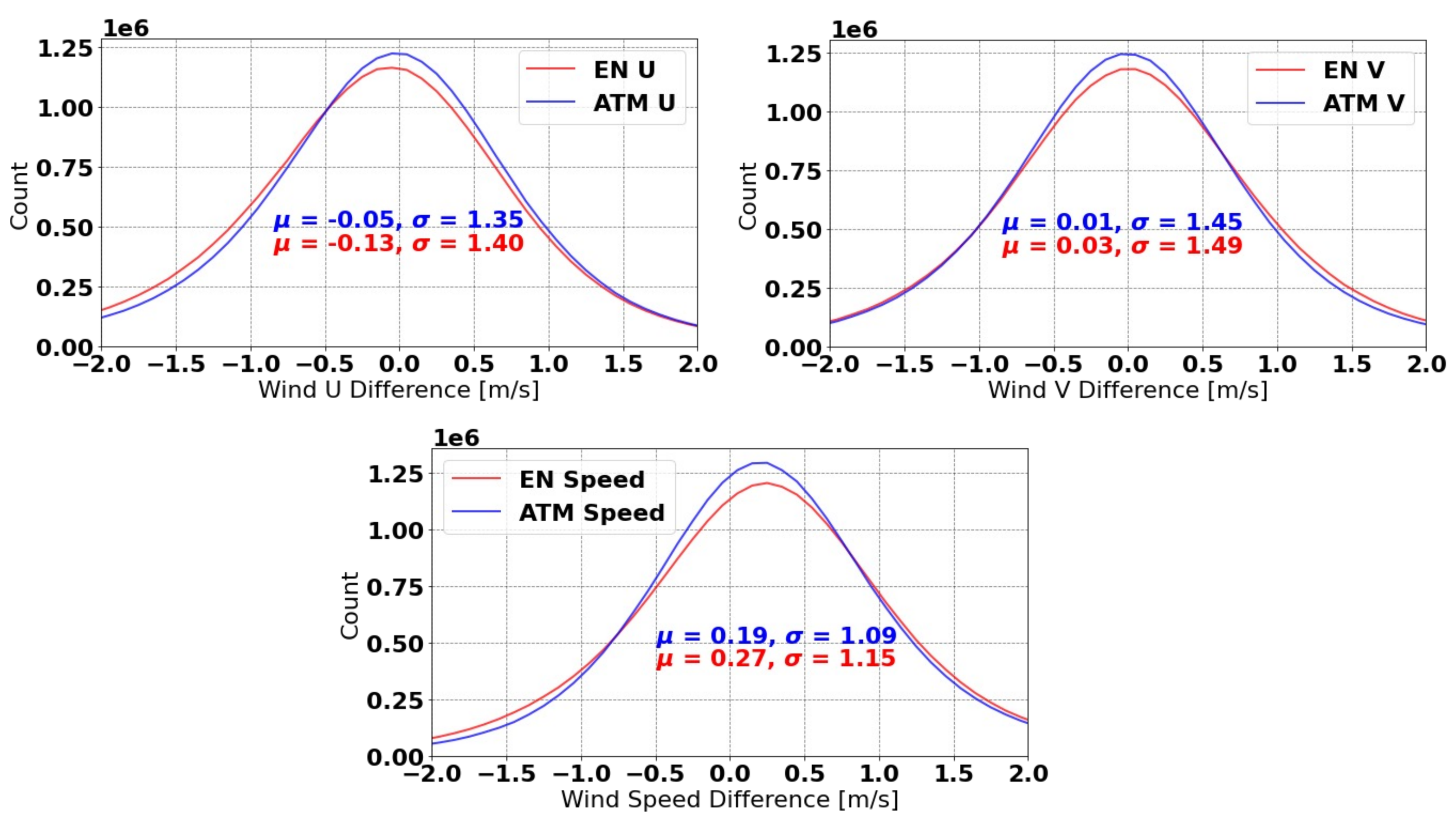

Figure 6: Distribution of errors for U,V, and wind speed relative to ERA5. Data for JPL processed ASCAT-A for the year 2008.

Conclusions

Using ERA5 reanalysis ancillary data, Globcurrent surface currents, and COARE 3.5, we have produced a climate data record of atmospheric winds based on scatterometers.

- Compared to ERA5, the global bias and standard deviation is reduced by ~0.1 m/s relative to the standard scatterometer EN winds.
- Regionally, biases are reduced substantially by up to 1-2 m/s.
- Our adjustment almost completely removes large scale biases in the Southern Ocean.
- Equatorial biases remain likely due to poor Equatorial surface current estimates.

These data will be available in the MEASURES JPL scatterometer dataset for ASCAT-A, ASCAT-B, QuikSCAT, and ScatSat.