Zero Current Equivalent Wind (U_{zc}): Adjusting ERA5 Windspeeds for Currents

Gopal Sundaram, University of Michigan, CLaSP

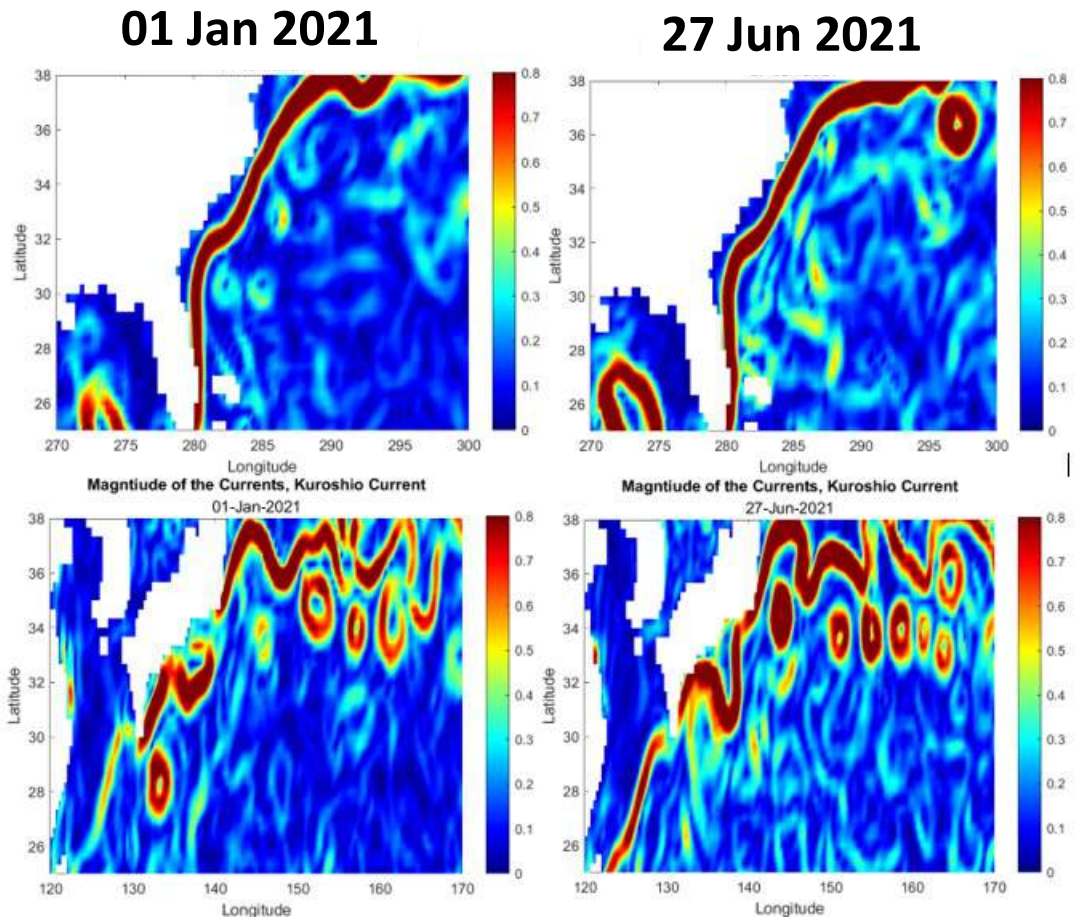
Chris Ruf, University of Michigan, CLaSP

Summary of Presentation & Some Questions

- Radiometers, scatterometers and bistatic radars (GNSS-R) are all sensitive to the relative motion between water and air (i.e. the stress equivalent wind)
- Reanalysis and forecast models report “true” wind (i.e. air motion relative to an Earth-fixed coordinate system)
- True winds are used to
  - Tune empirical forward models used by remote sensing retrieval algorithms
  - Assessment performance of remotely sensed winds
- A zero current equivalent wind ($U_{zc)}$ is considered as a proxy for the stress equivalent wind
- The bias in remotely sensed winds is reduced if with respect to U_{zc}
- QUESTIONS:
  - Should forward models be tuned to U_{zc} instead?
  - Should retrievals include a current correction to convert retrieved wind to true wind?

Ocean Currents Affect Air/Sea Relative Motion

- Gulf Stream and Kuroshio Currents are shown for January (left) and June (right)
  - Western Boundary Current (WBC) for North Atlantic (Gulf Stream) and North Pacific (Kurushio)
  - Gulf Stream alignment is consistent between winter and summer
  - Kurushio has significant variability between seasons
- Other major currents associated with the ITCZ are the North and South Equator Currents (EC)

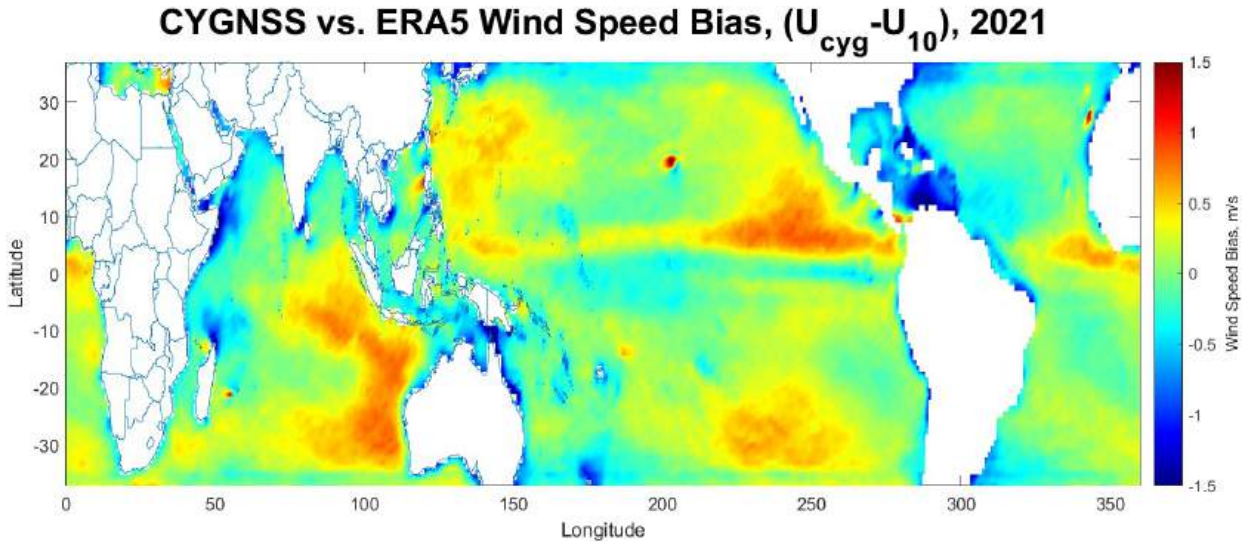


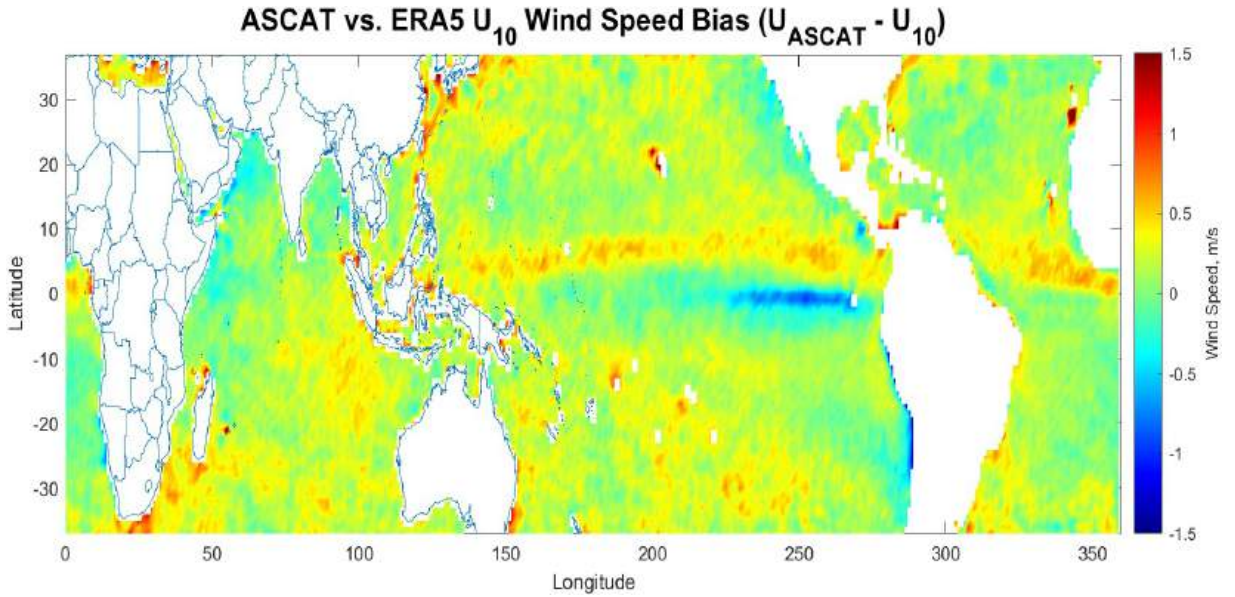
Remotely Sensed Wind Speed Products Considered

Sensor/Satellite	Start Op.	Active or Passive	Product details	Instrument type
DDMI/CYGNSS	2017	Active	L3 Gridded, Daily	GNSS-R Receiver
ASCAT/MetOP	2007	Active	L3 Gridded, Daily	Scatterometer
GMI/GPM	2014	Passive	L3 Gridded, Daily	Microwave Radiometer

Examples of Apparent Wind Speed Bias

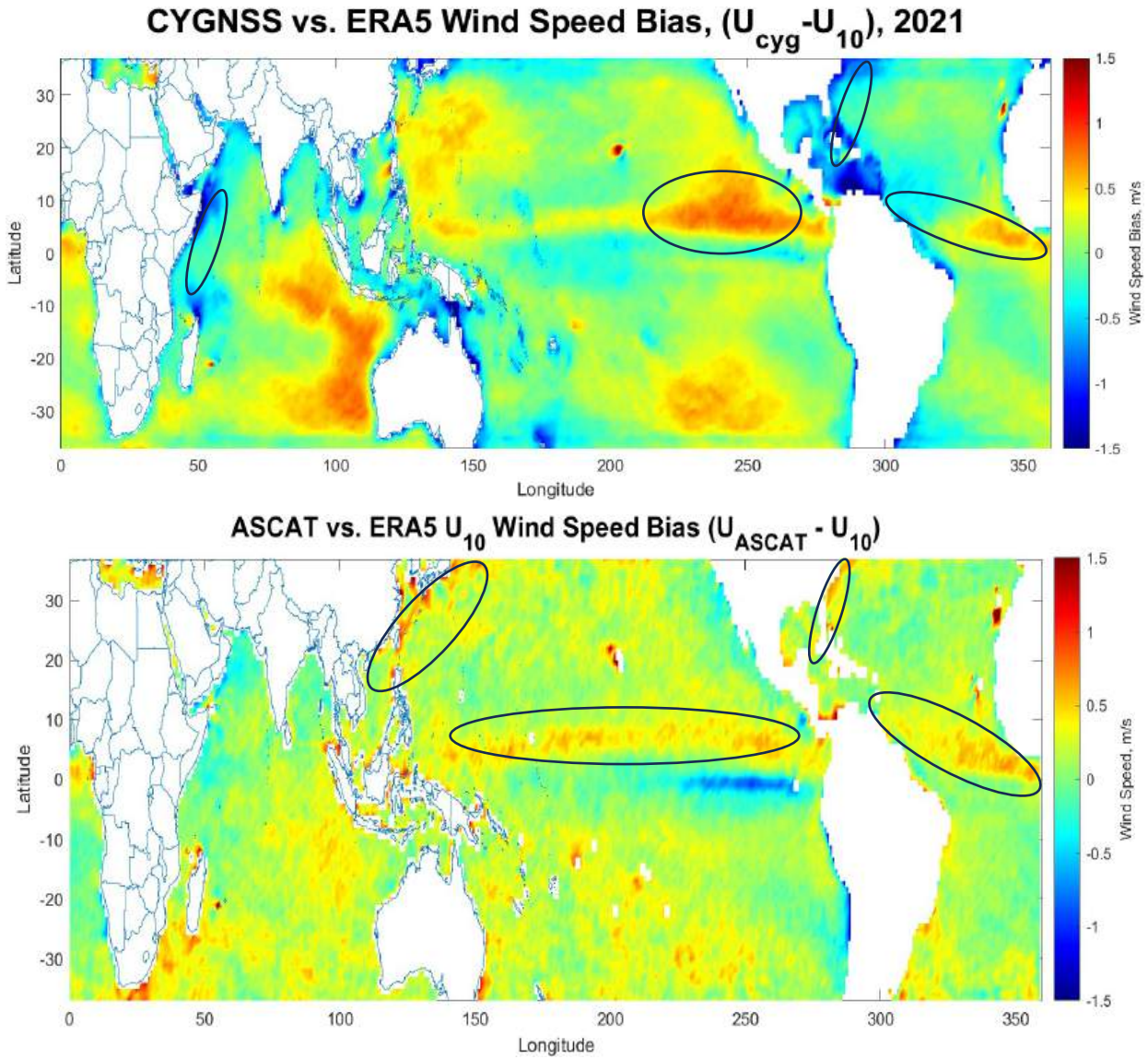
- Mean annual difference between CYGNSS or ASCAT and ERA5 U_{10} shown





Examples of Apparent Wind Speed Bias (2)

- CYGNSS has areas of high wind speed bias around the Gulf Stream, Eastern Pacific ITCZ & East African Current
- ASCAT displays high wind speed bias around the Pacific and Atlantic ITCZ, Kuroshio Current and the Gulf Stream



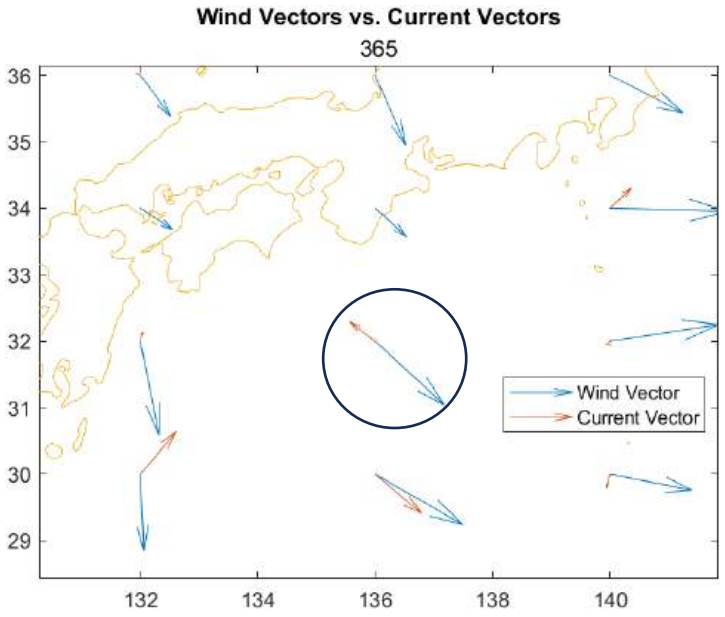
Zero Current Equivalent Wind, U_{zc}

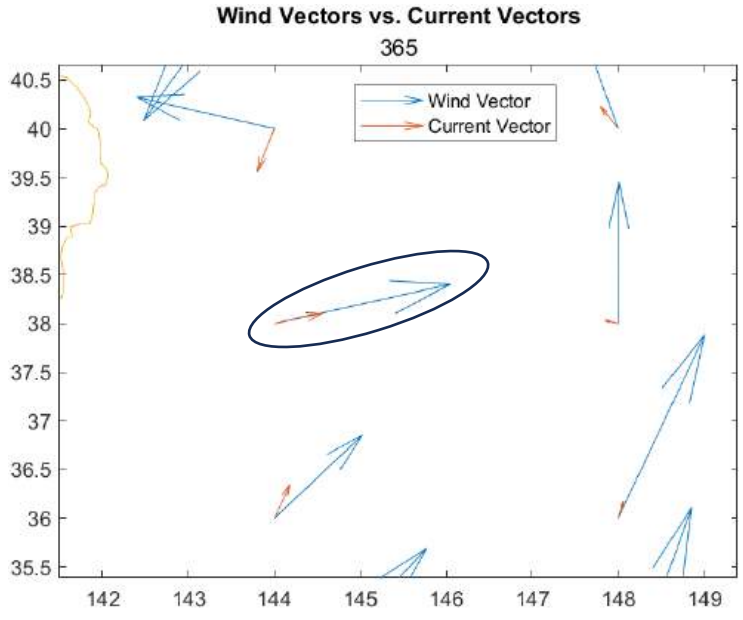
- U_{zc} is a modification made to ERA5 reanalysis data to account for the surface currents, (Wind-Current = Relative motion)
- Subtraction is done vector-wise

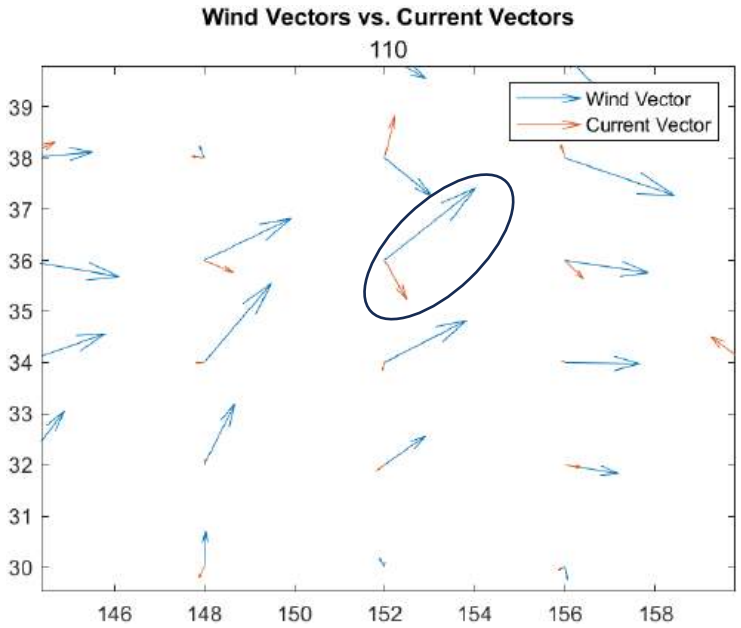
$$U_{zc} = |\boldsymbol{U}_{ERA5} - \boldsymbol{U}_{OSCAR}|$$

- U_{ERA5} represents the uncorrected ERA5 Neutral Wind Speed (NWS) at 10-meter height, and U_{OSCAR} is the Ocean Current Vector from the Ocean Surface Current Analysis Real-Time (OSCAR) database

Wind Speed vs. Current Vectors





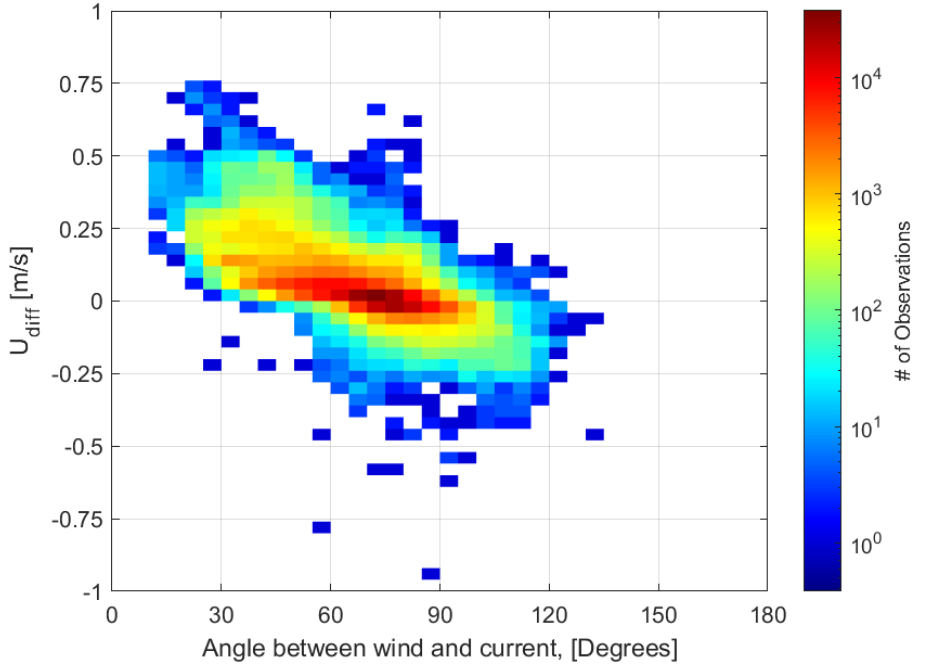


- Antiparallel wind and current vectors
- Parallel wind and current vectors
- Orthogonal Wind and Current Vectors

- Visual Representation of the vector subtraction
- Angle between wind and water plays an important role in determining strength of correction
- Orthogonality does not mean zero effect, that is at ~60 degrees
  - Angle with zero difference will vary with relative magnitudes of U_{ERA5} and U_{OSCAR}

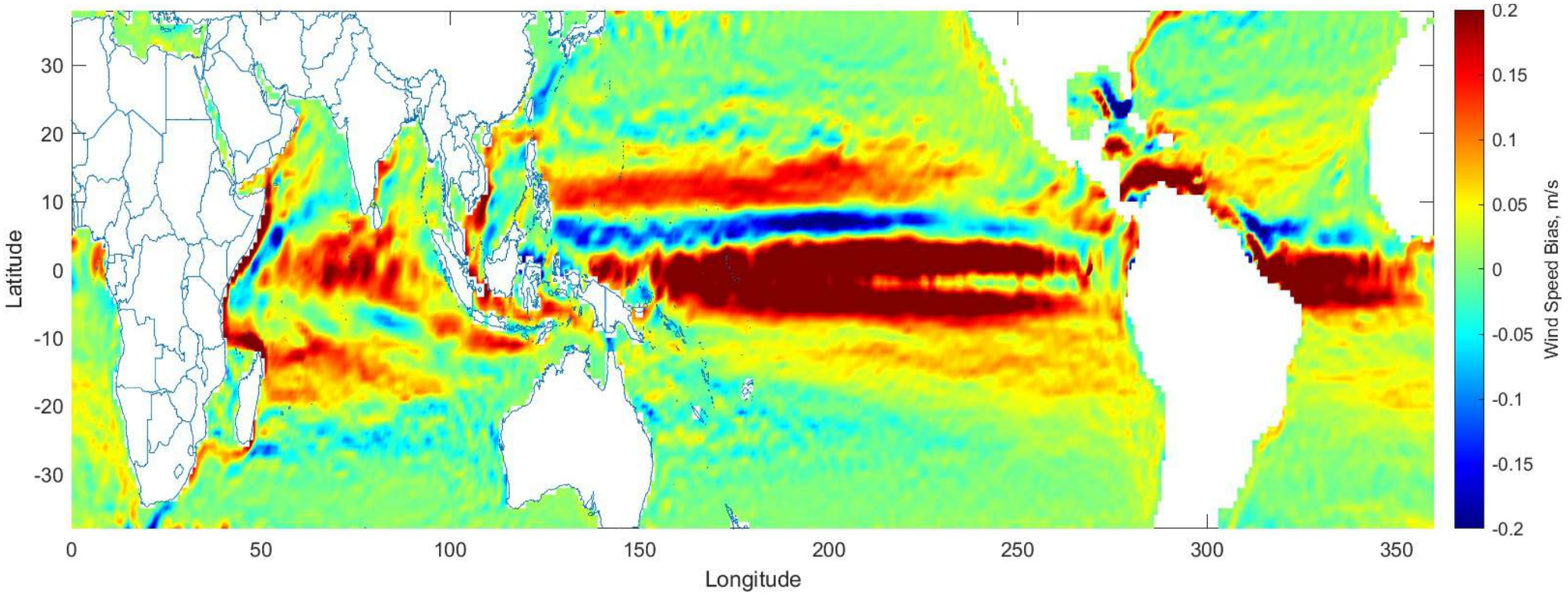
Effect of Angle Between Wind and Current

- Udiff = $U_{10} - U_{zc}$, the difference in the wind speeds
- Density scatterplot of Udiff vs. Angle globally for all of 2021



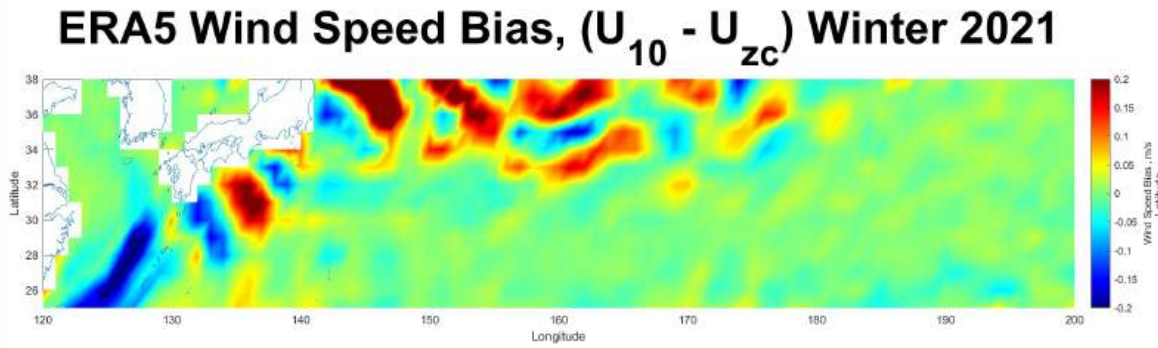
- Max positive difference when wind and current are parallel
- Max negative difference when wind and current are anti-parallel
- Zero difference when wind and current are ~30-90 deg apart

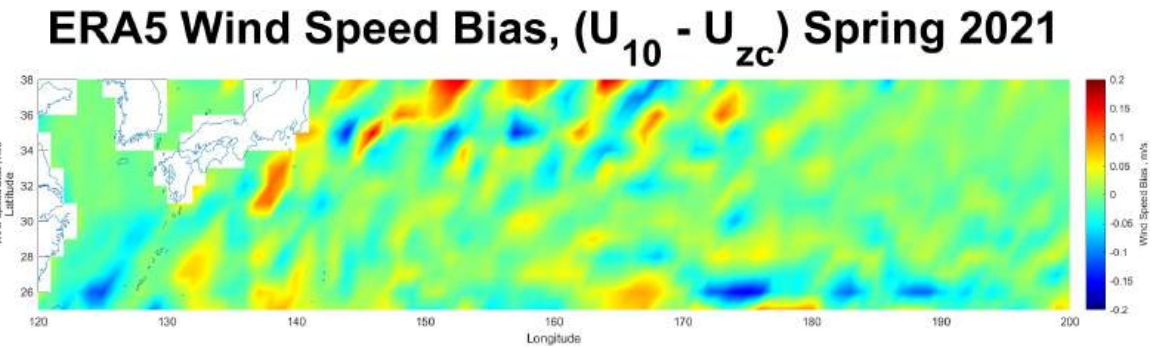
Annual Average (2021) $U_{diff} = U_{10} - U_{zc}$

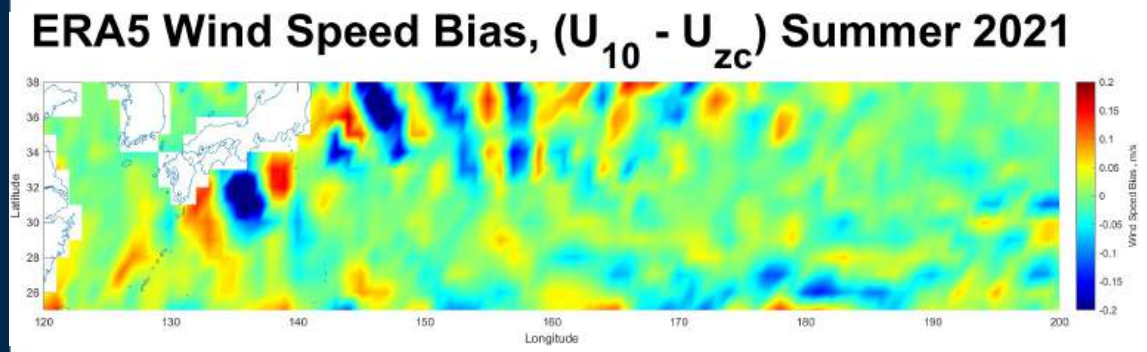


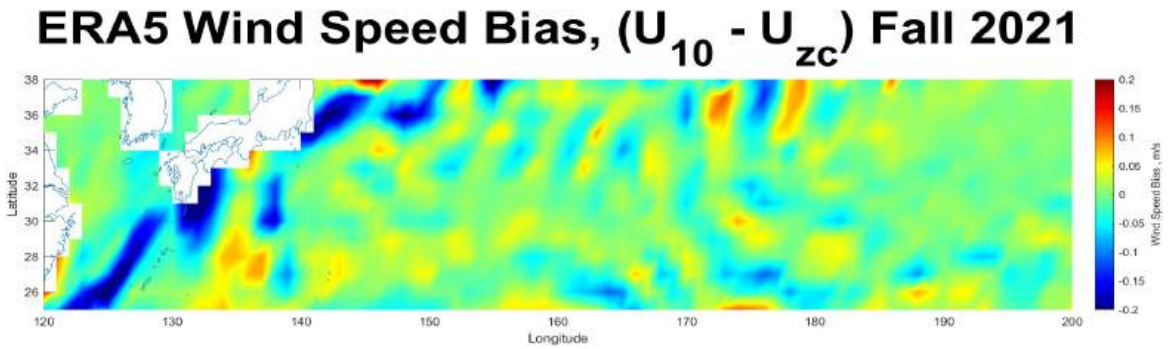
- Wind Speed Difference between the ERA5 U_{10} and the ERA5 Current Corrected U_{zc}
- WSD tracks the Equatorial Currents, but is not consistent with other large currents
  - Gulf Stream and East African Current are present, but not the Kuroshio
- Currents are not the only factor, but the angle between the wind and the current also affects magnitude of difference

Wind Speed Difference Zoom In, Kuroshio









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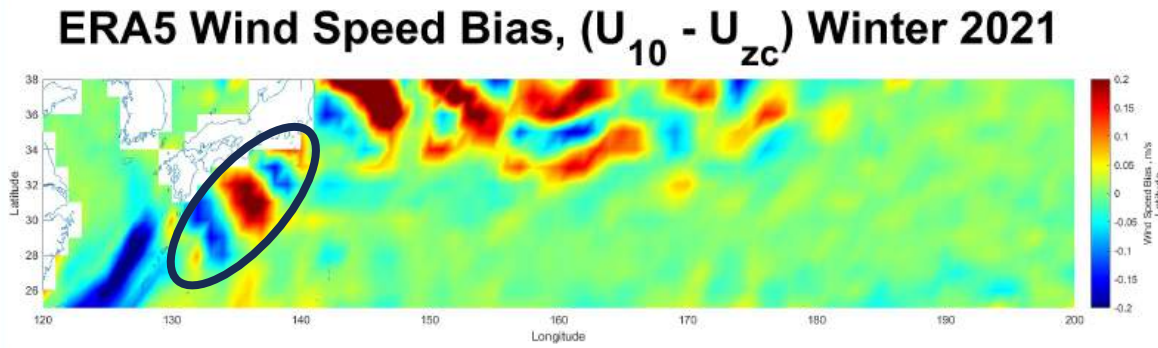
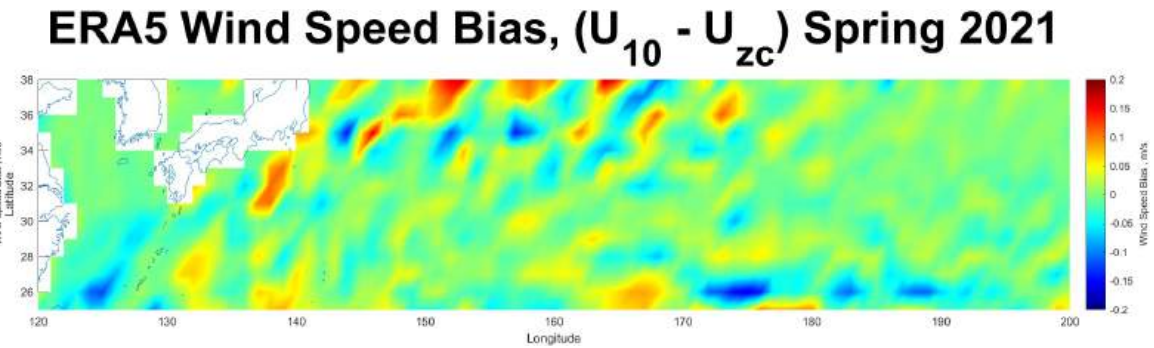
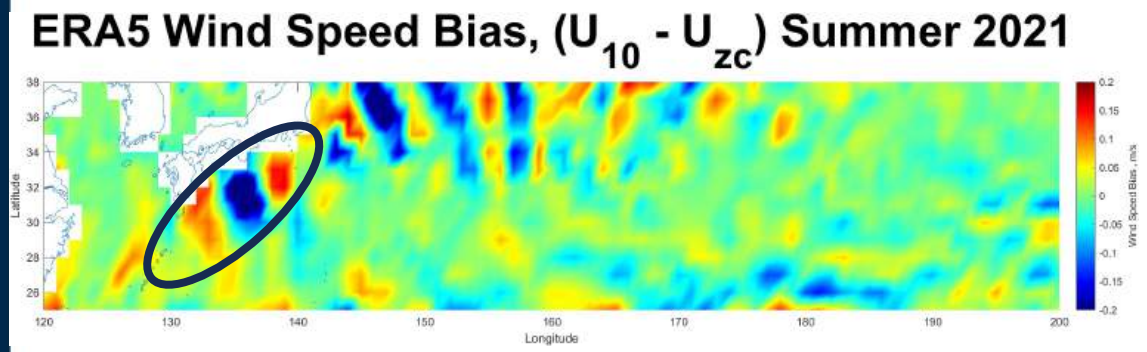
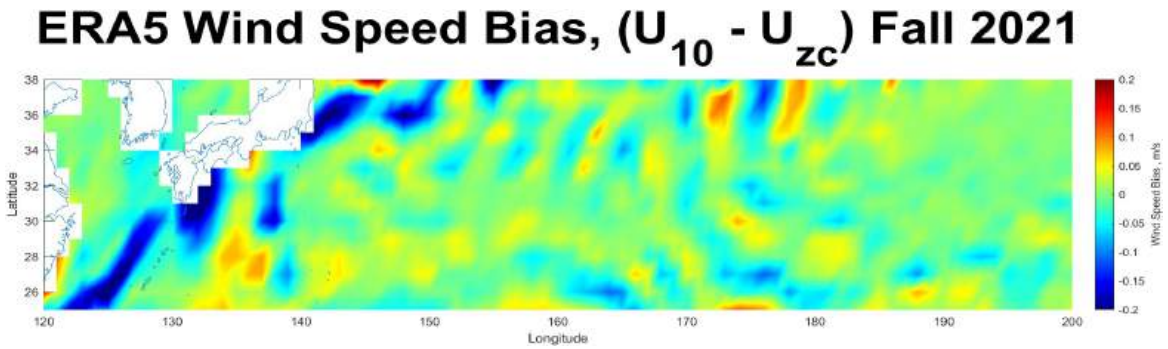
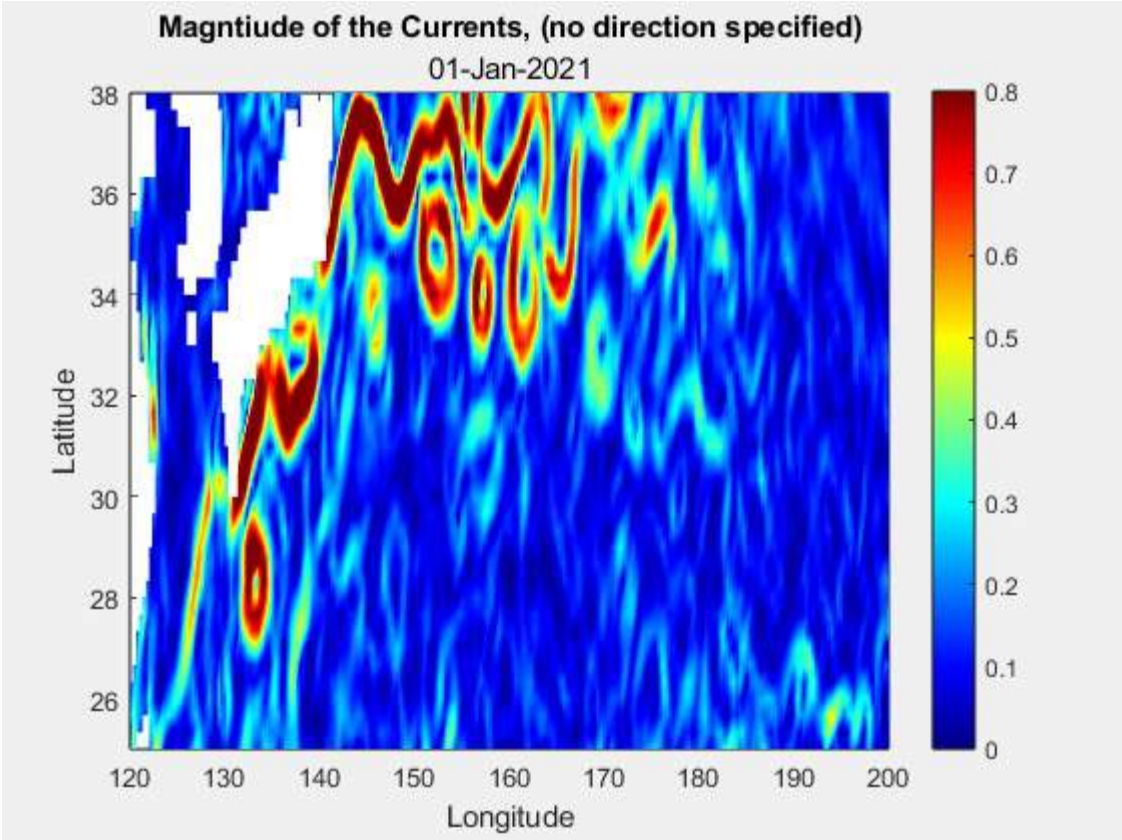


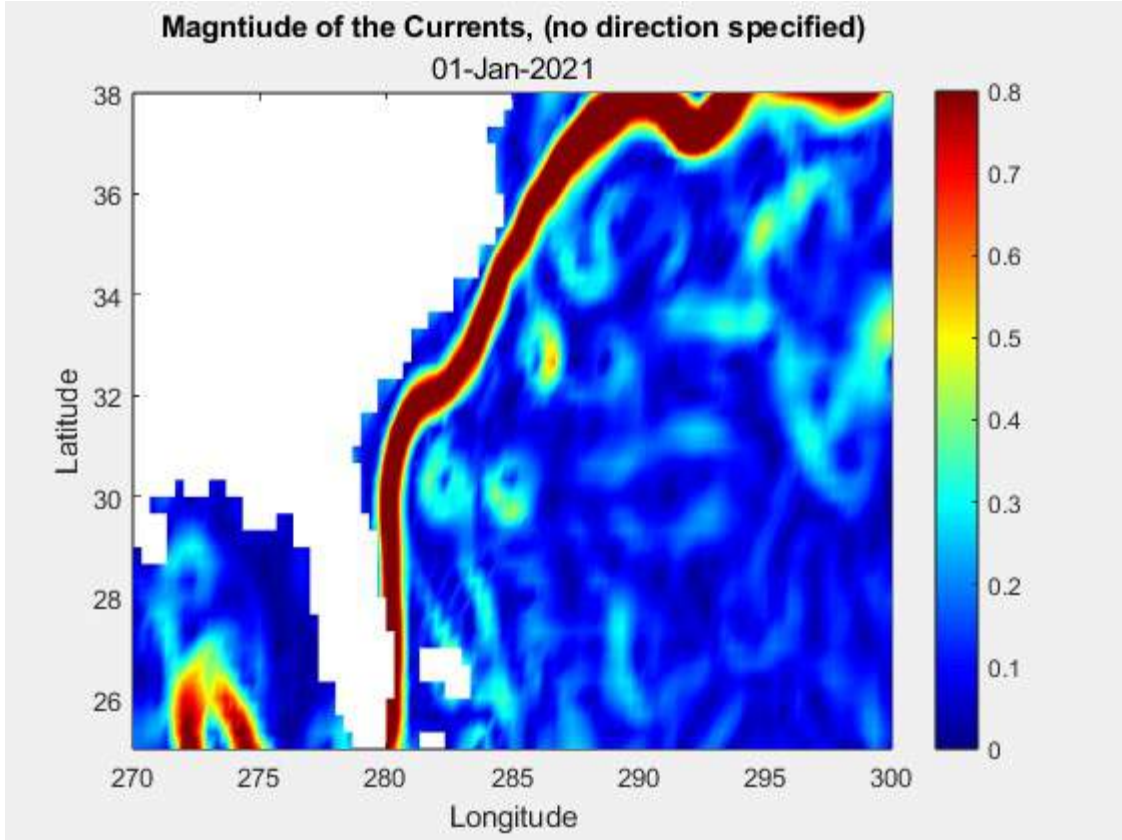






Consistency is Key



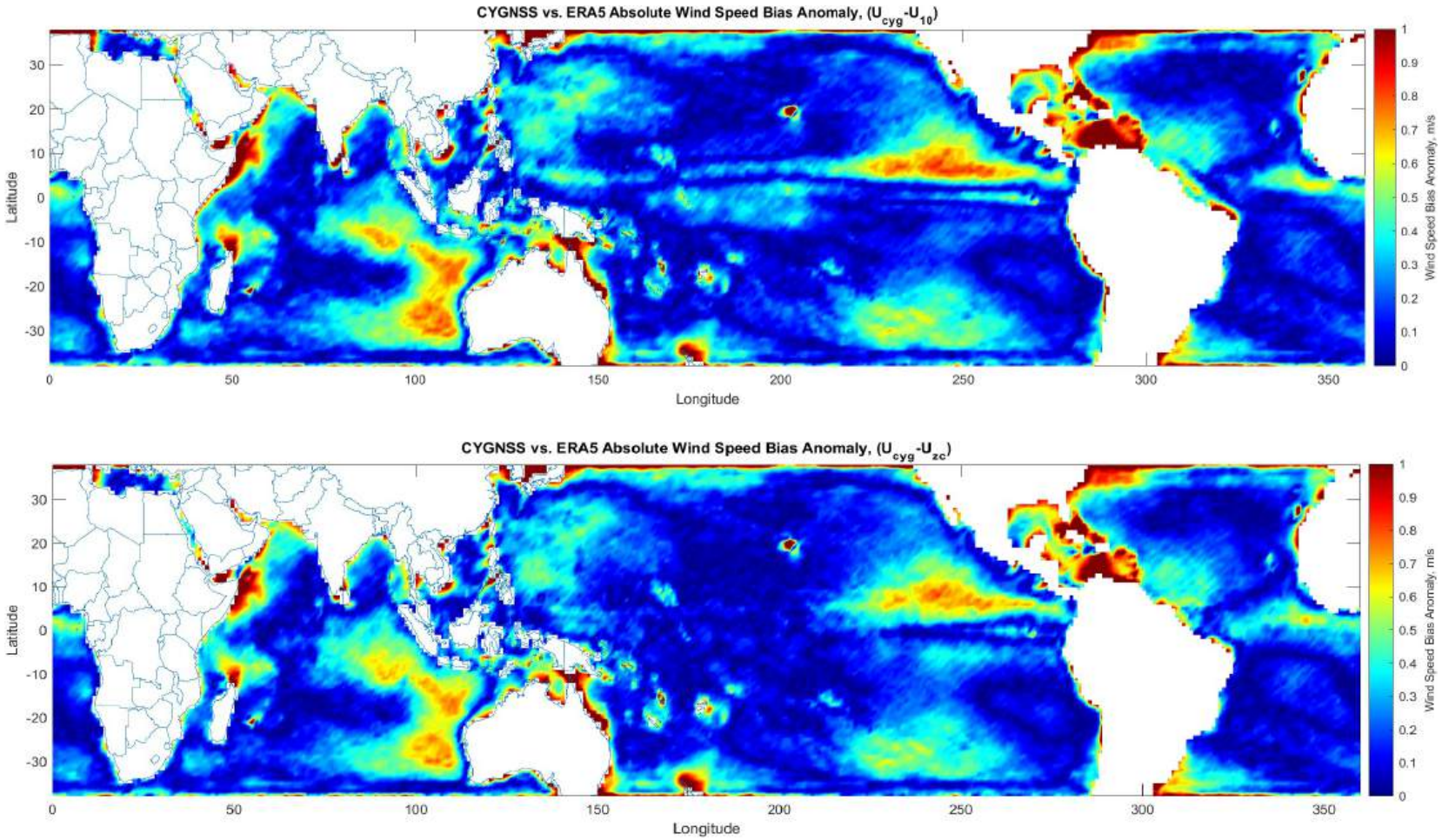


Statistical Comparison

- Many satellite wind products are tuned to ERA5 winds, so doing a direct wind speed bias comparison will lead to results that show the standard ERA5 as the less biased product in any circumstance
- Instead of using pure wind speed bias, Absolute Wind Speed Bias Anomaly (AWSBA) is used to show where the biases diverge apart from the tuning
- AWSBA is helpful, plots will further demonstrate where the changes from U_{10} to U_{zc} are the most prominent

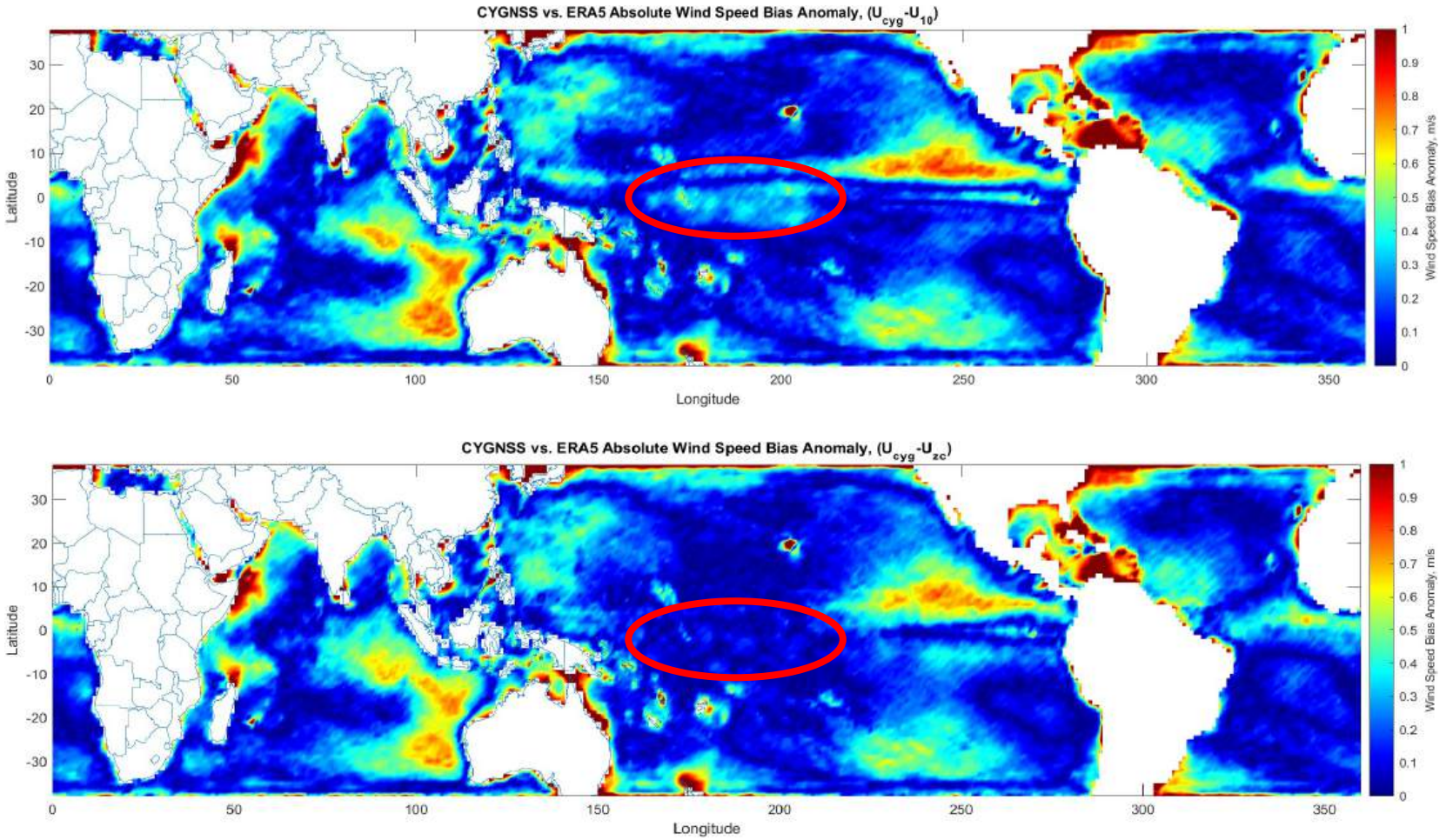
$$|U_{AWSBA}| = |U_{bias} - mean(U_{bias})|$$

U_{zc} vs. U Absolute Bias Anomaly, 2021 CYGNSS



- CYGNSS vs. ERA5 Current Corrected (bottom) and CYGNSS vs. ERA5 NWS (top)
- Improvements in bias anomaly can be seen in the central Pacific, and there's very few area where bias anomaly increases from NWS to U_{zc}

U_{zc} vs. U Absolute Bias Anomaly, 2021 CYGNSS



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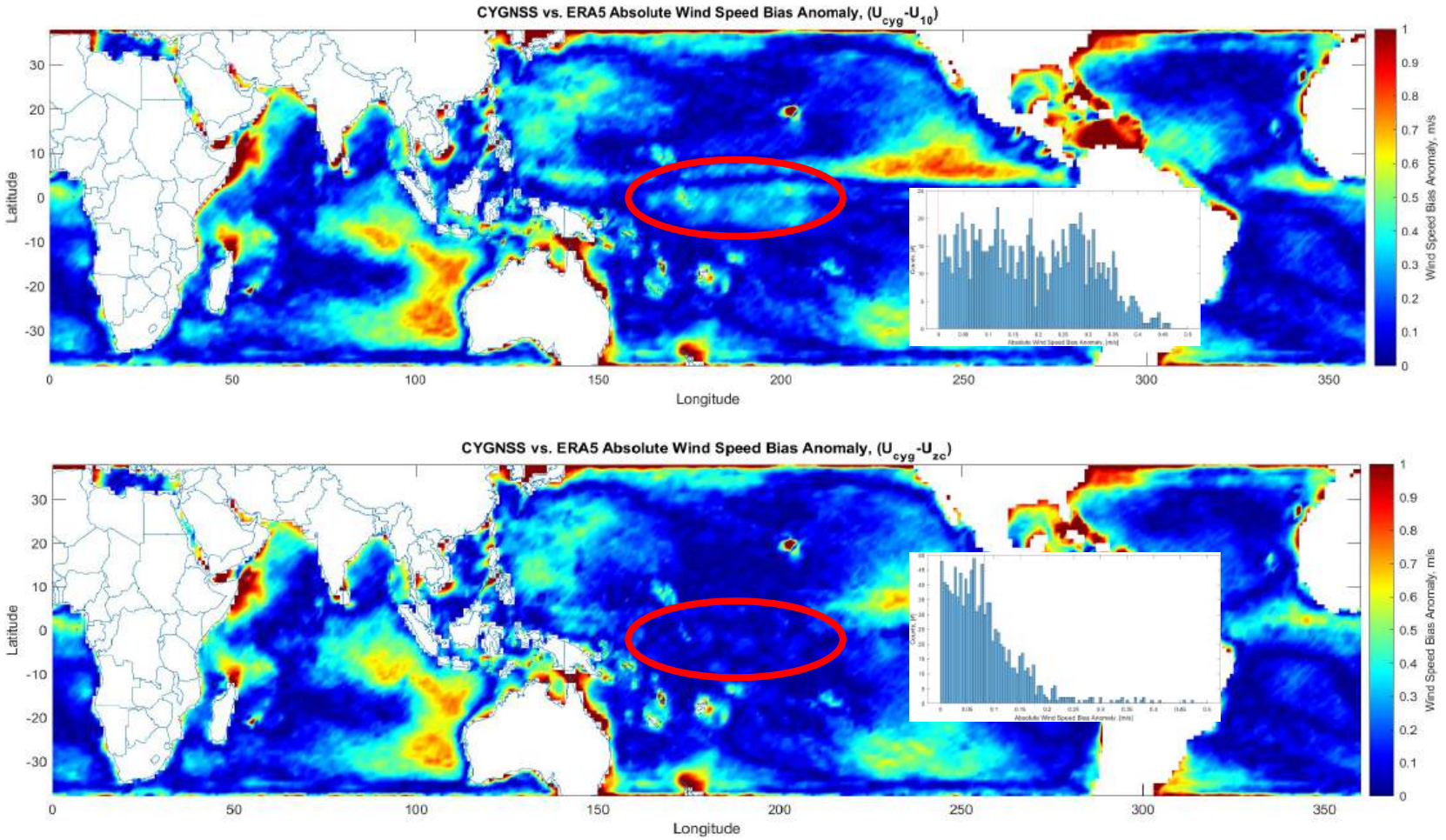

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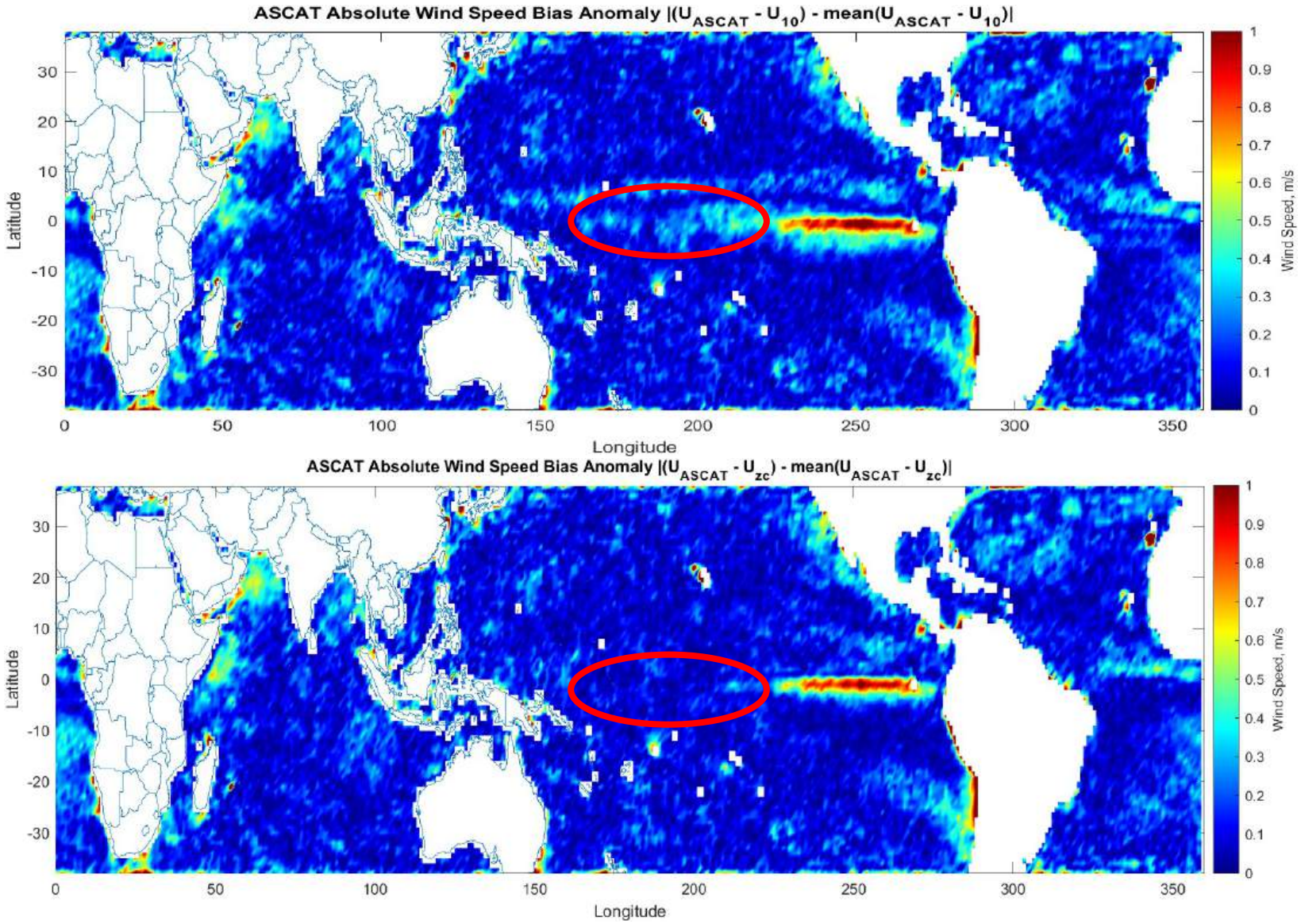
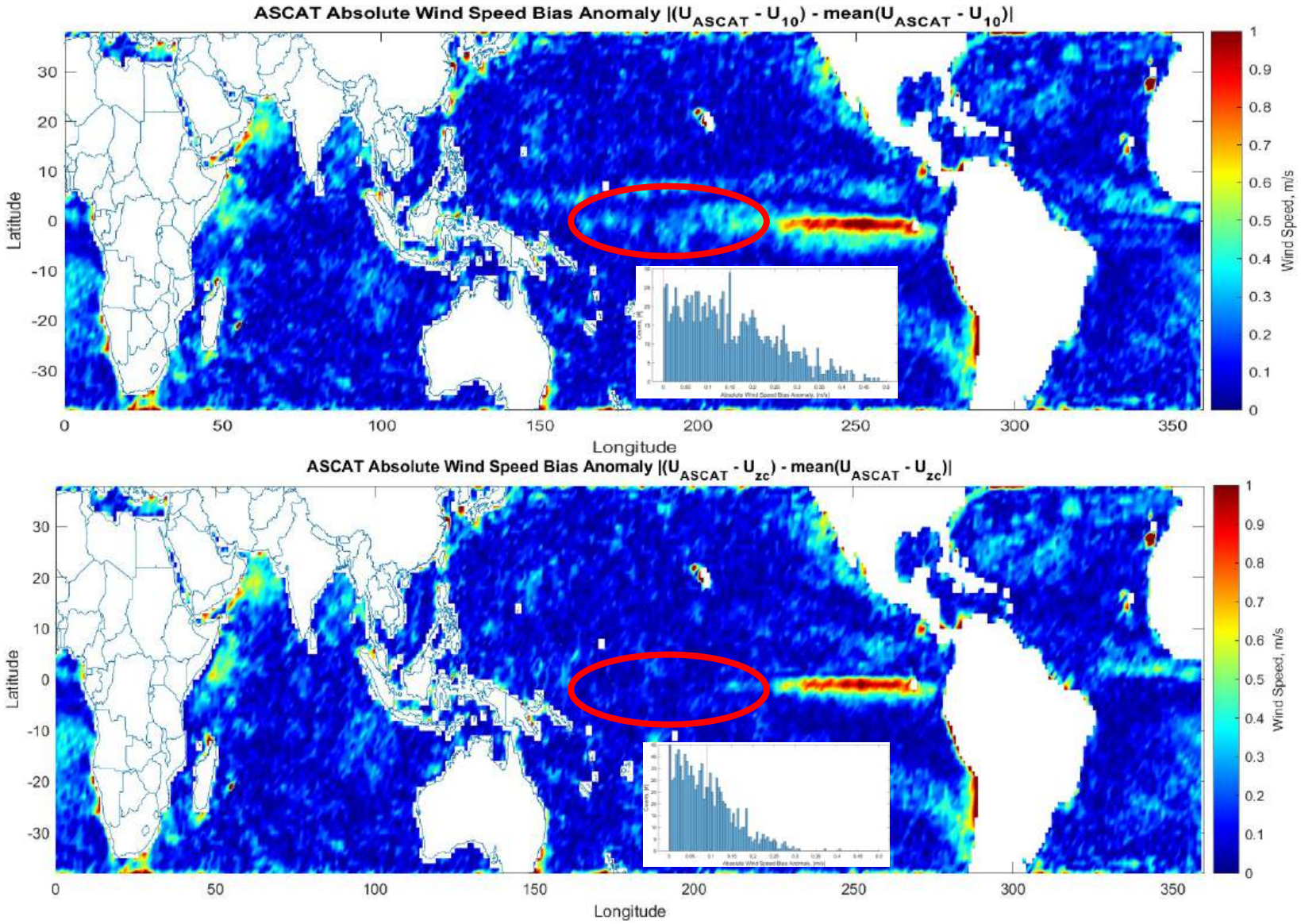
U_{zc} vs. U Bias Anomaly, 2021, ASCAT



- ASCAT vs. ERA5 NWS (top) and GMI vs. ERA5 Uzc (bottom)
- Extremely low Absolute Bias Anomaly which indicates that the wind speed is finely tuned to ERA5 model data
- AWSBA improves from 0.21 m/s to 0.19 m/s

U_{zc} vs. U_{10} Bias Anomaly, 2021, ASCAT



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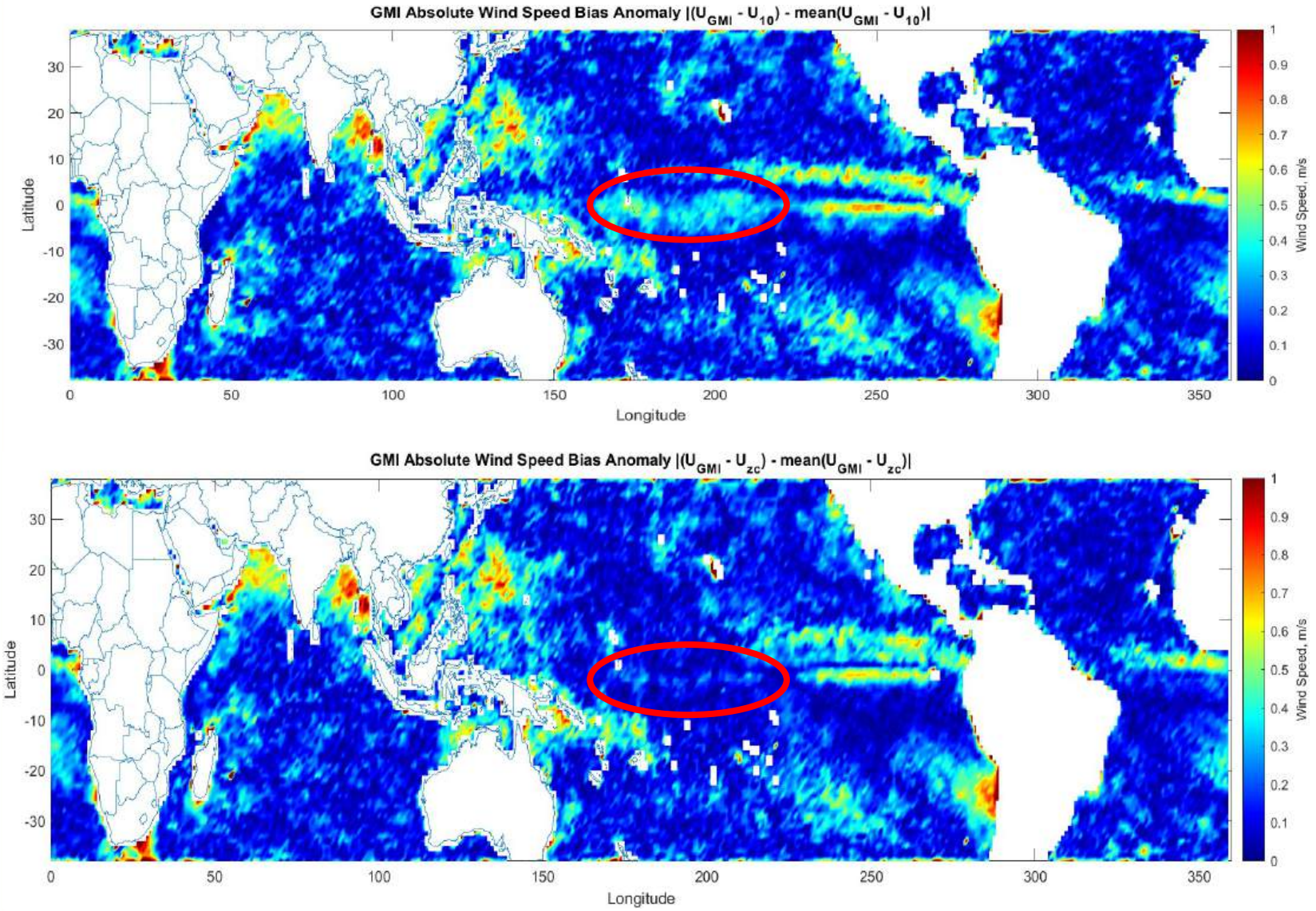
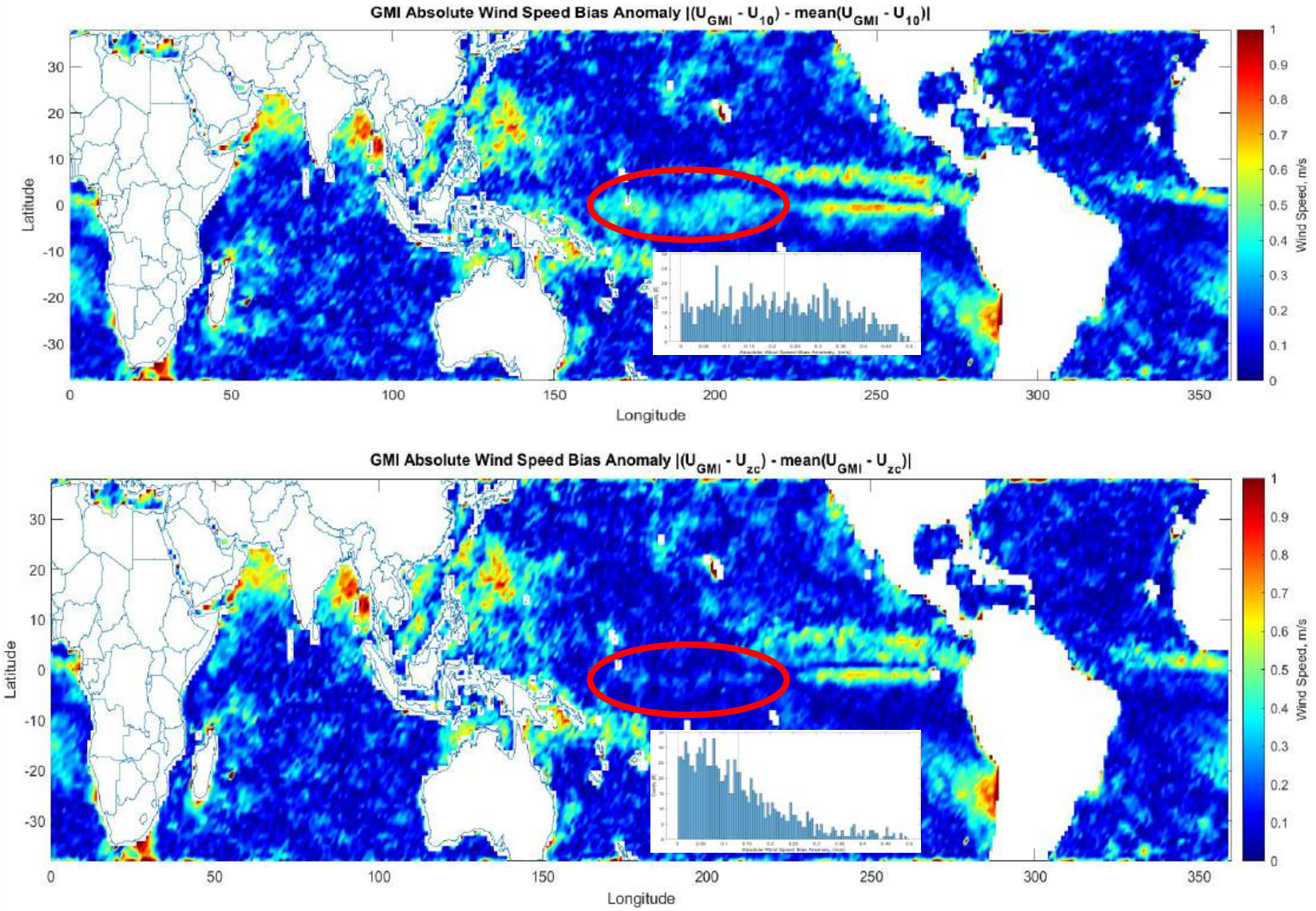
U_{zc} vs. U Absolute Bias Anomaly, 2021 GMI



- GMI vs. ERA5 NWS (top) and GMI vs. ERA5 Uzc (bottom)
- Improvements in bias anomaly can be seen in the central Pacific, and there's minimal areas where bias anomaly increases from NWS to U_{zc}
- AWSBA improves from 0.26 m/s to 0.25 m/s
- High impact region goes from 0.5 m/s to 0.1 m/s

U_{zc} vs. U Absolute Bias Anomaly, 2021 GMI



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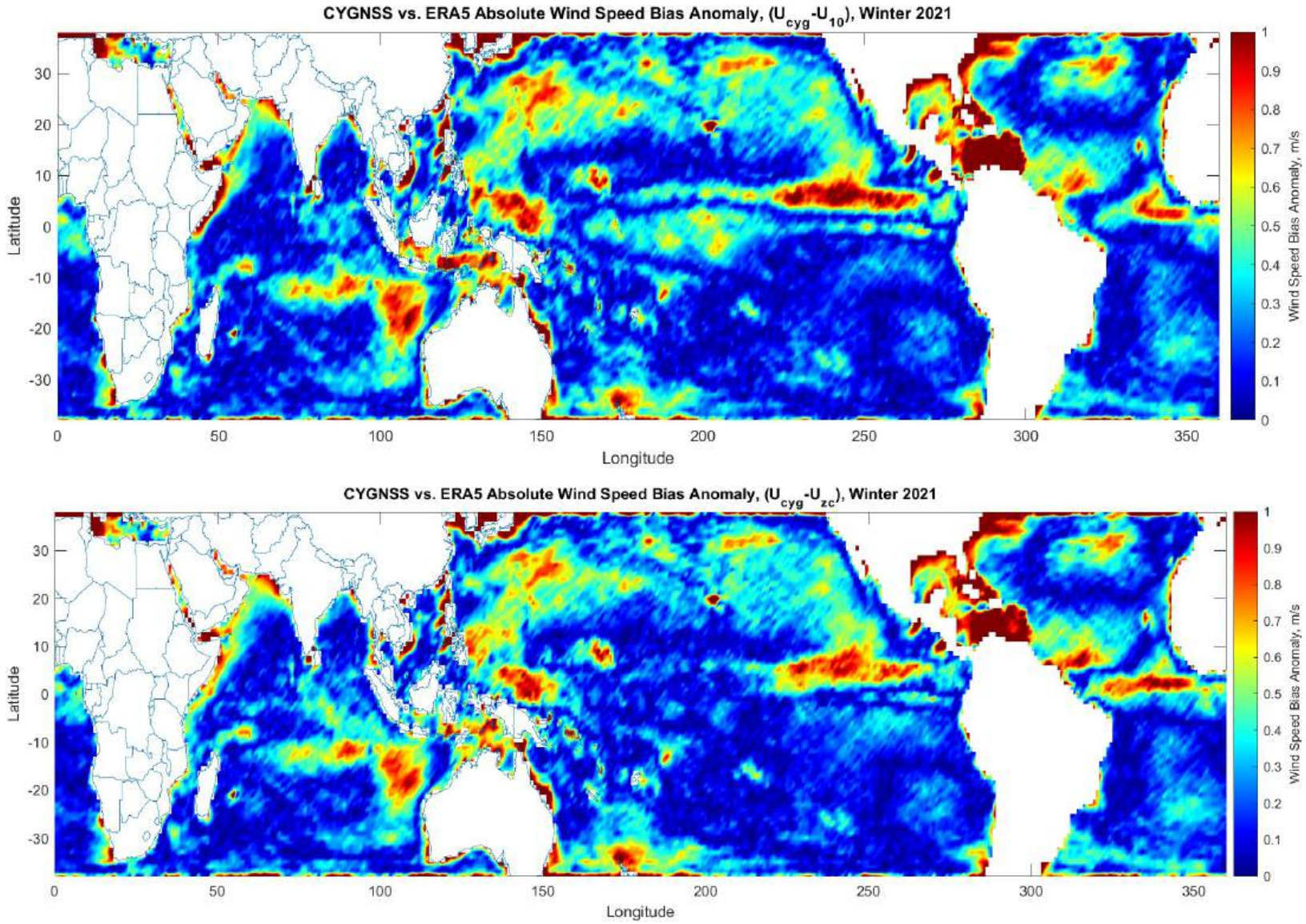
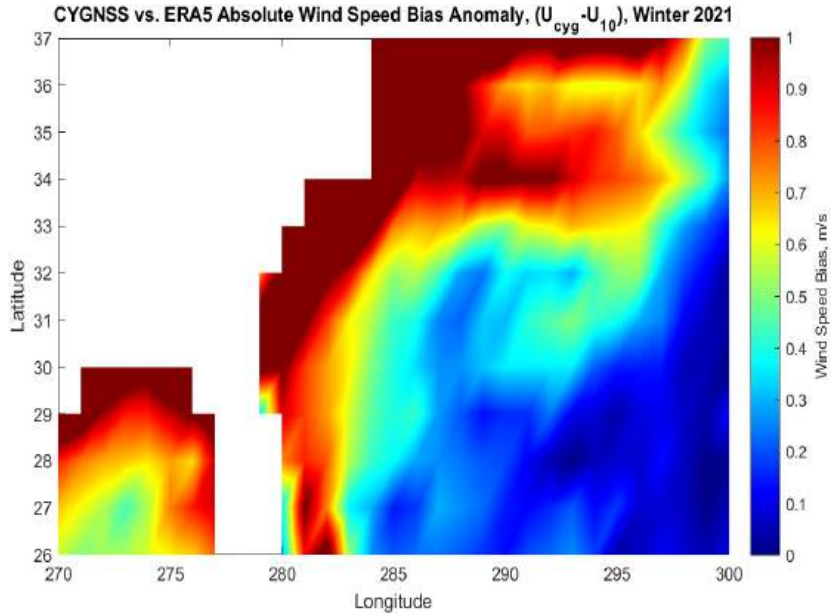
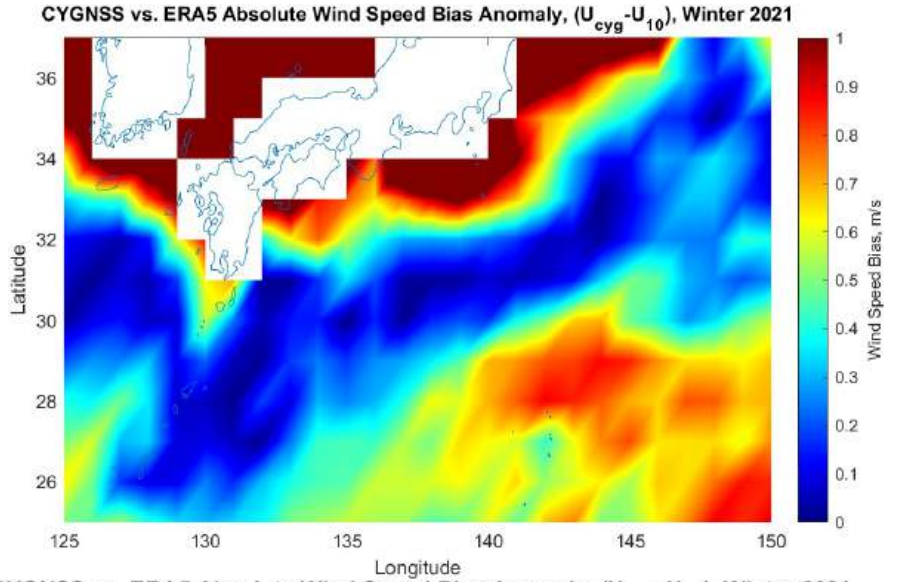
U_{zc} vs. U Absolute Bias Anomaly, 2021 Winter, CYGNSS

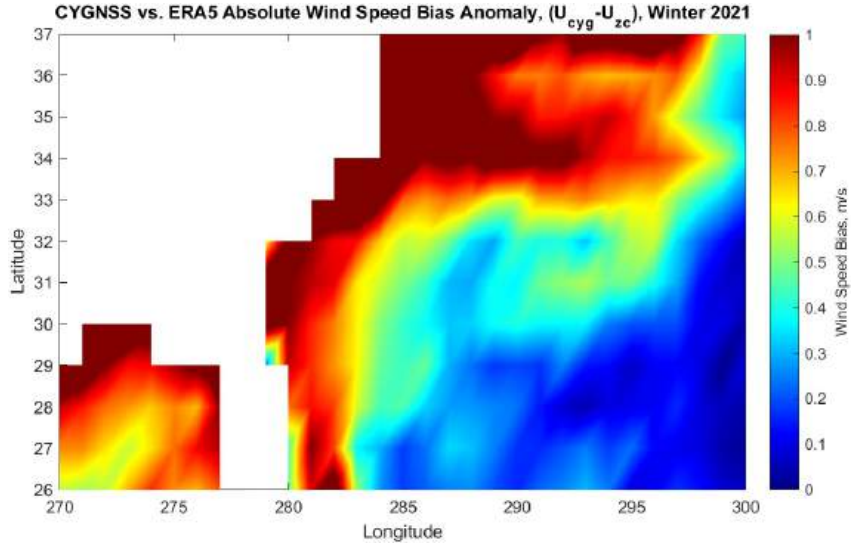


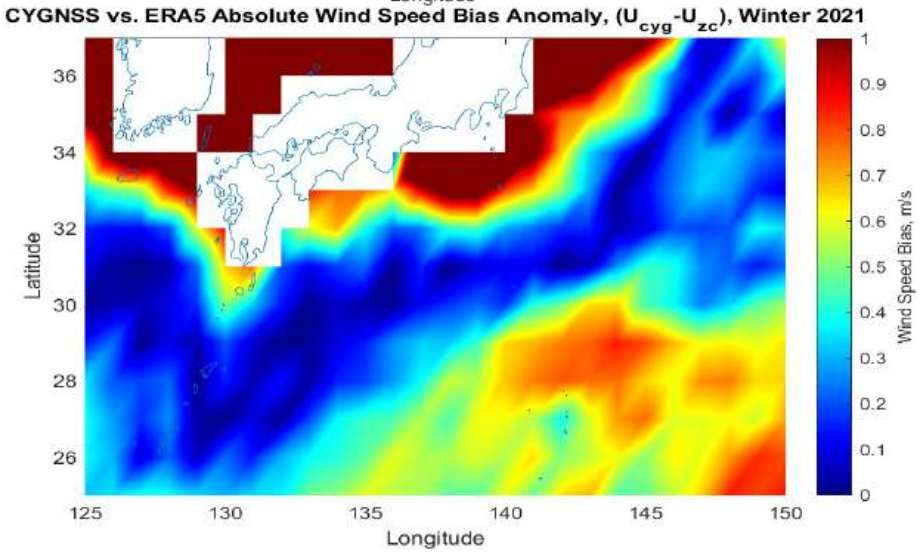
- CYGNSS vs. ERA5 Current Corrected (top) and CYGNSS vs. ERA5 NWS (bottom)
- Improvements in bias anomaly can be seen in the central Pacific, and there's no area where bias anomaly increases from NWS to U_{zc}

CYGNSS Zoom In on Kuroshio and Gulf Stream

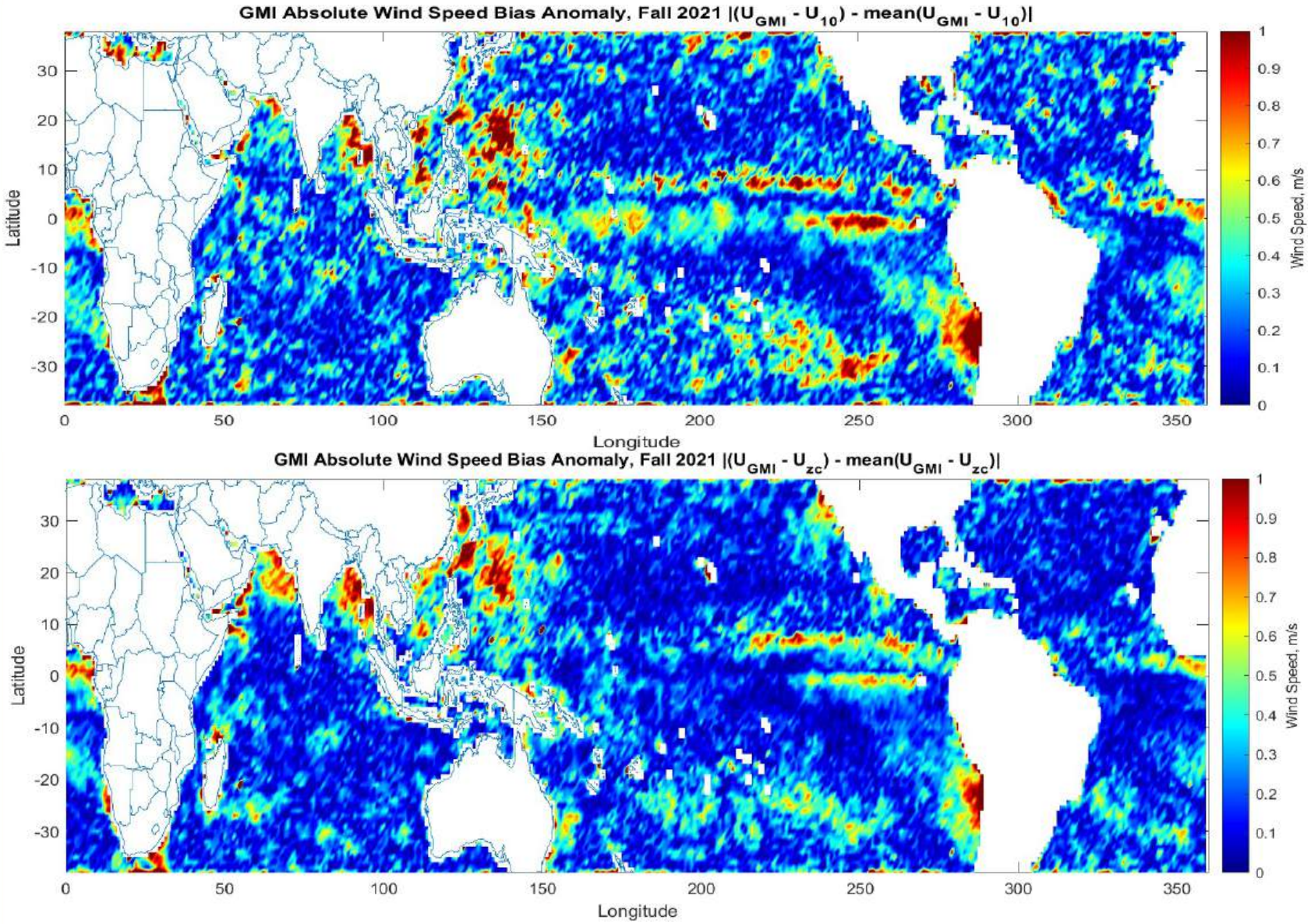






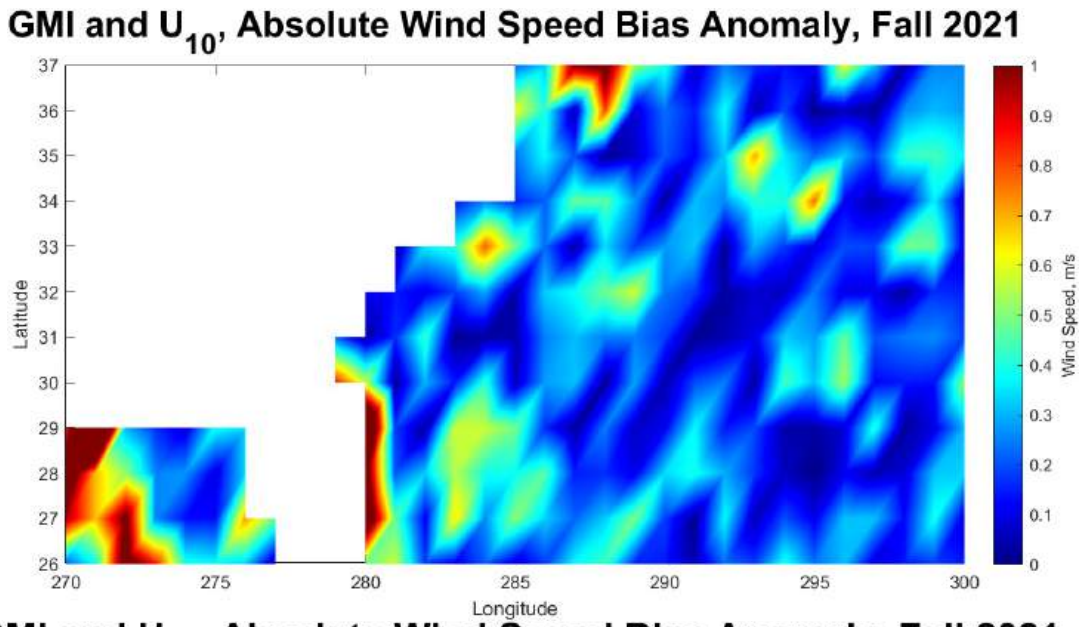


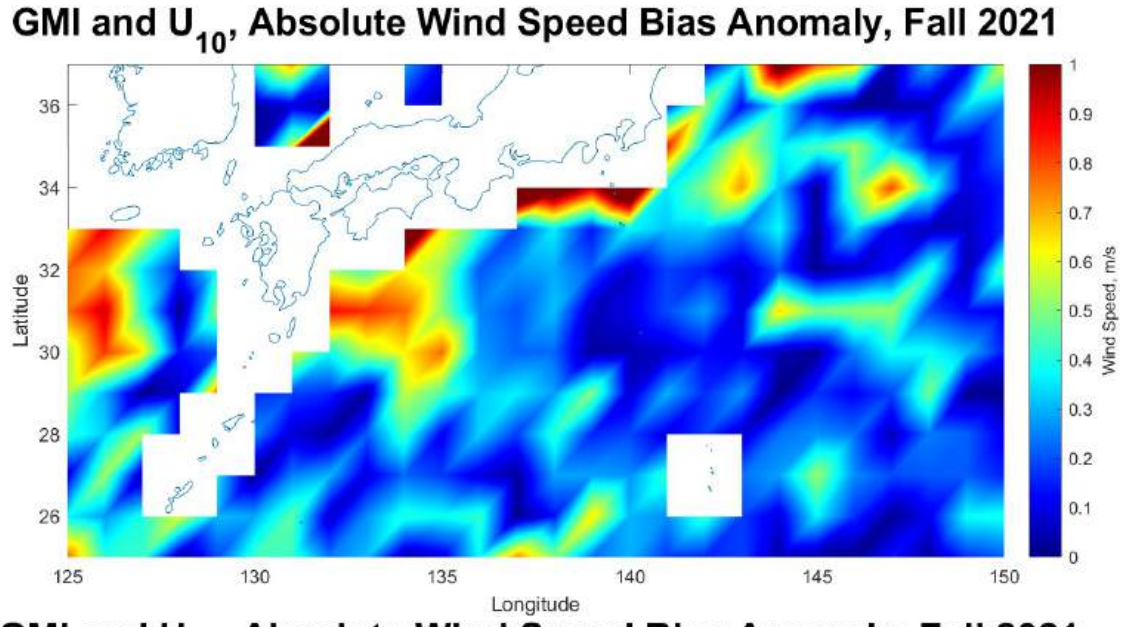
U_{zc} vs. U Absolute Bias Anomaly, 2021 Fall, GMI

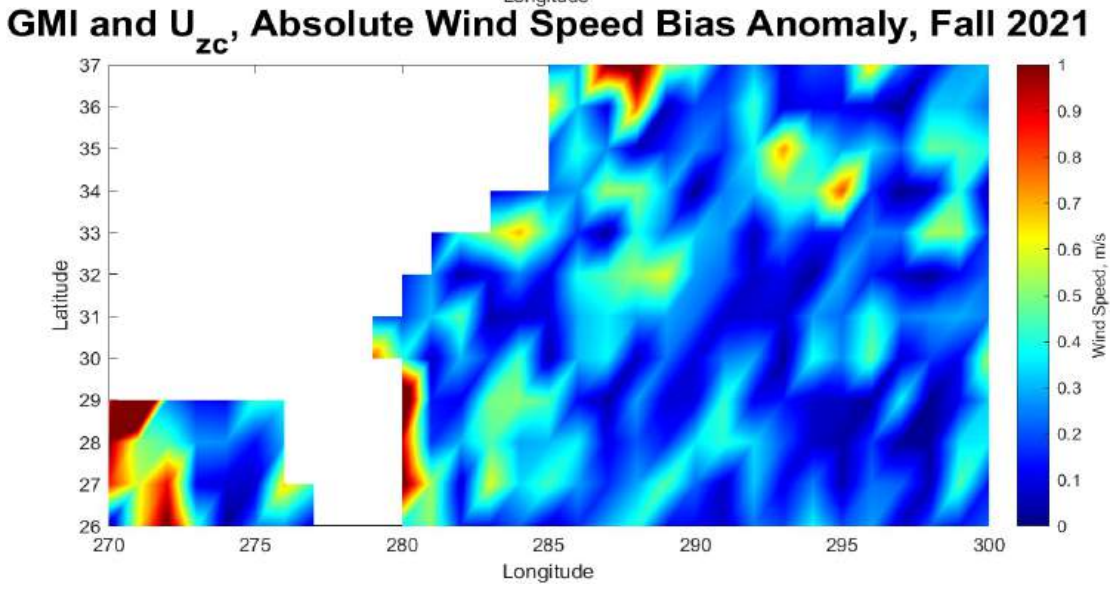


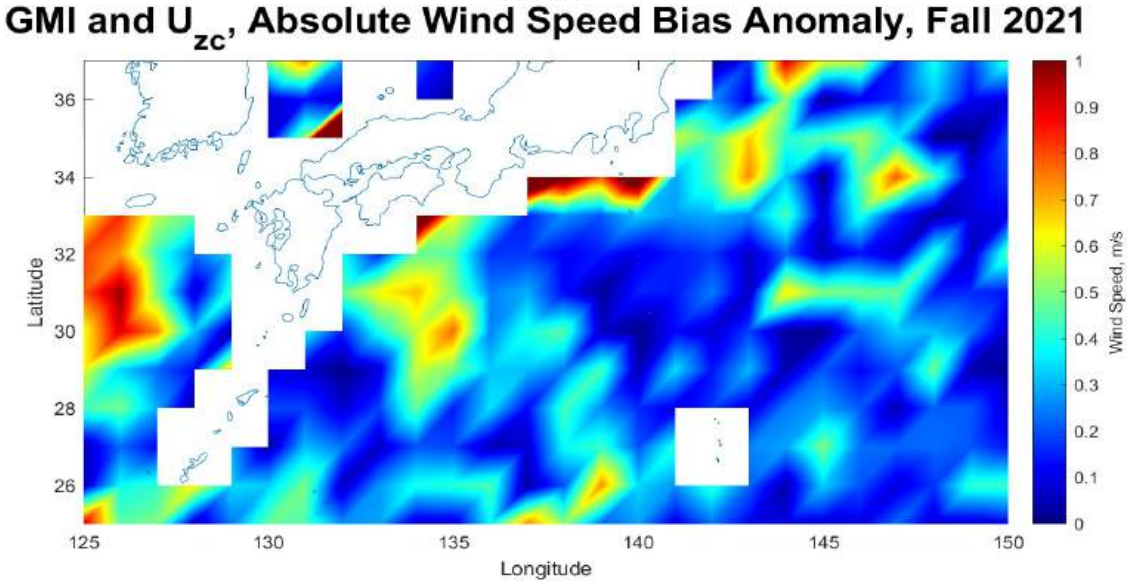
- GMI vs. ERA5 NWS (top) and GMI vs. ERA5 Uzc (bottom)
- Improvements in bias anomaly can be seen in the central Pacific, and there's no area where bias anomaly increases from NWS to U_{zc}

GMI Zoom in on Kuroshio and Gulf Stream

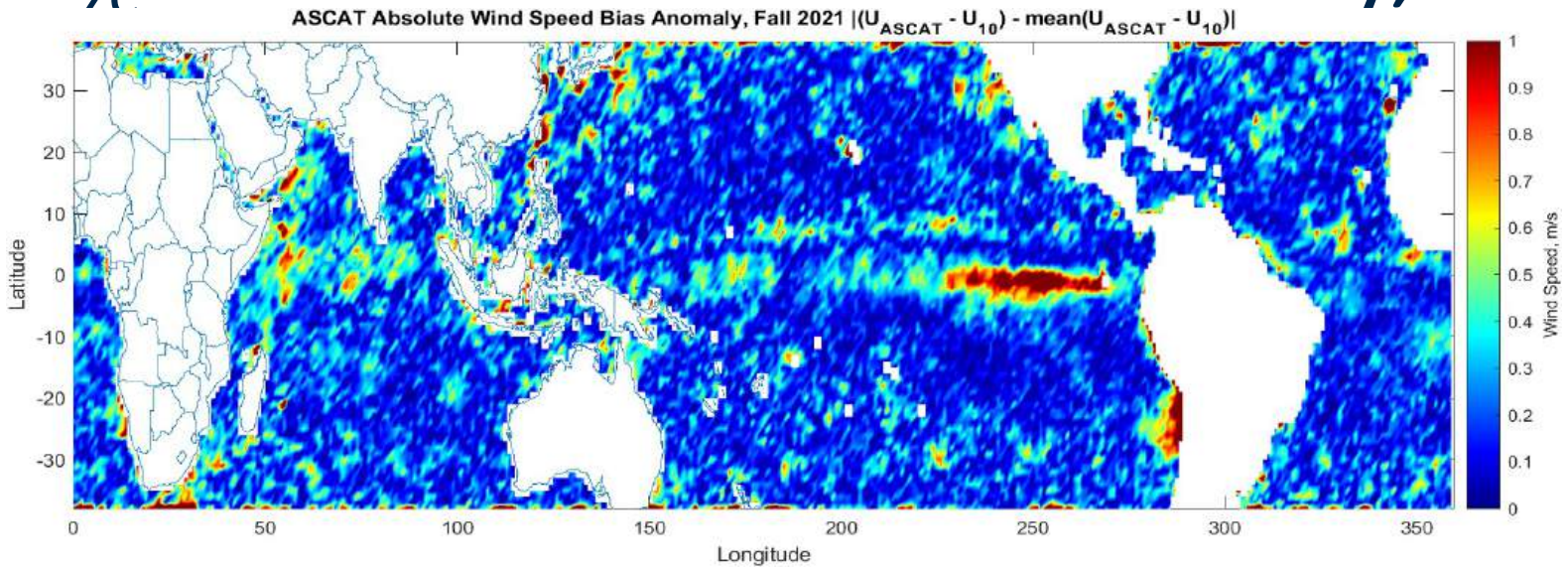


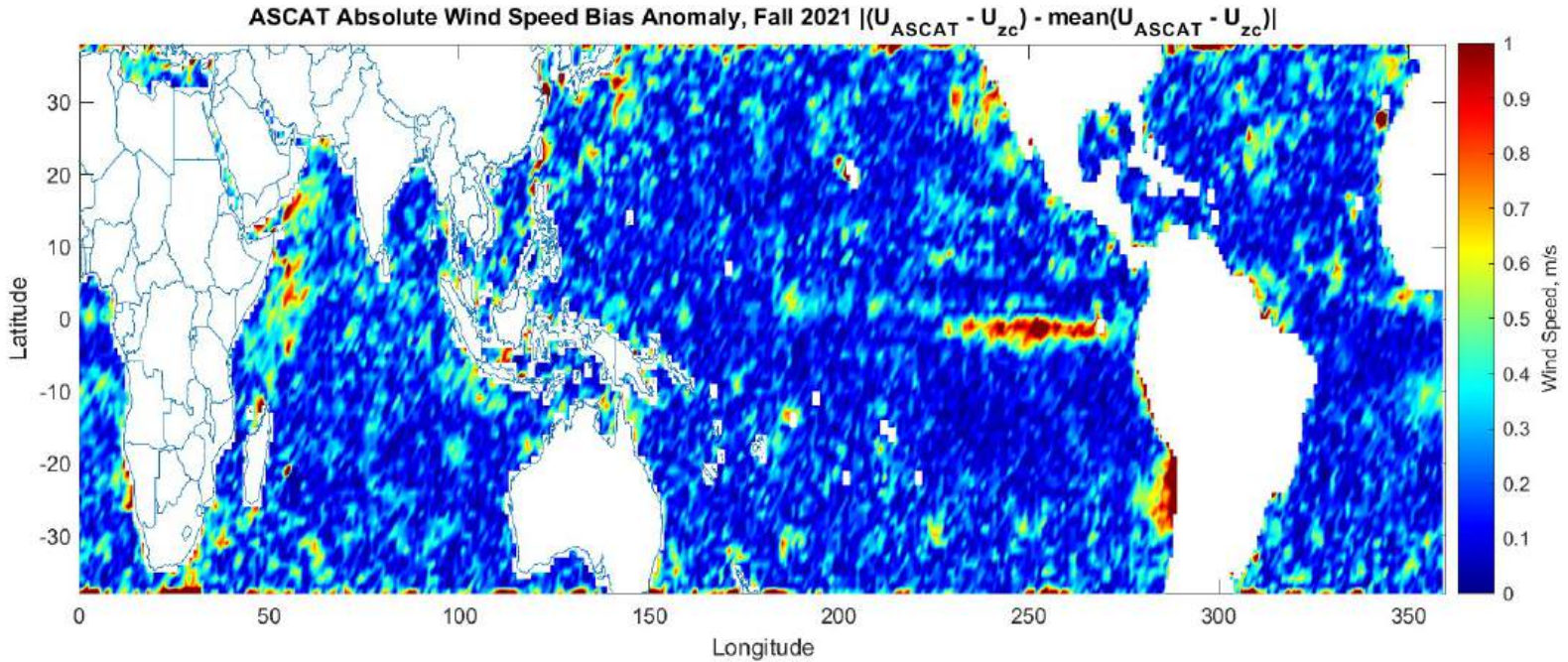






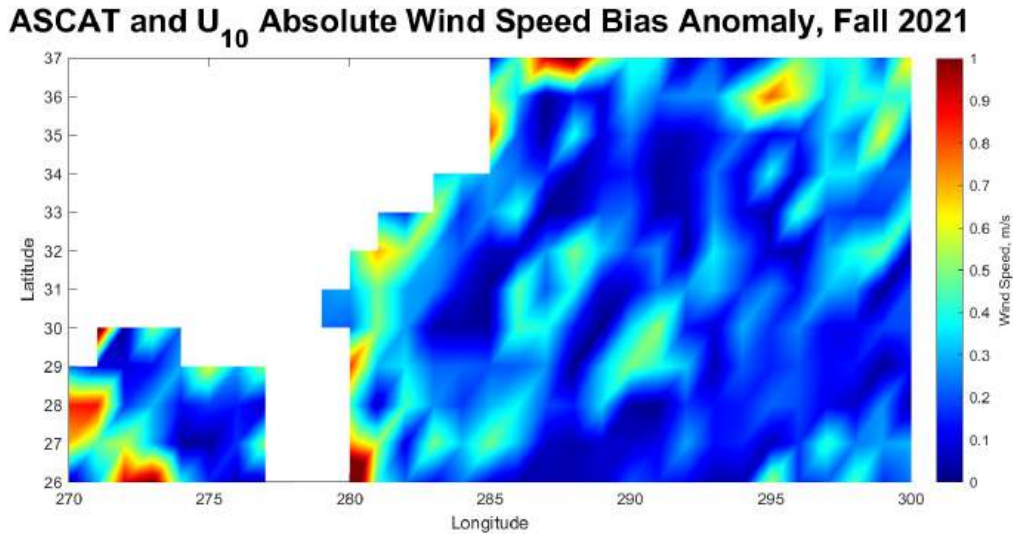
U_{zc} vs. U Absolute Bias Anomaly, 2021 Fall, ASCAT

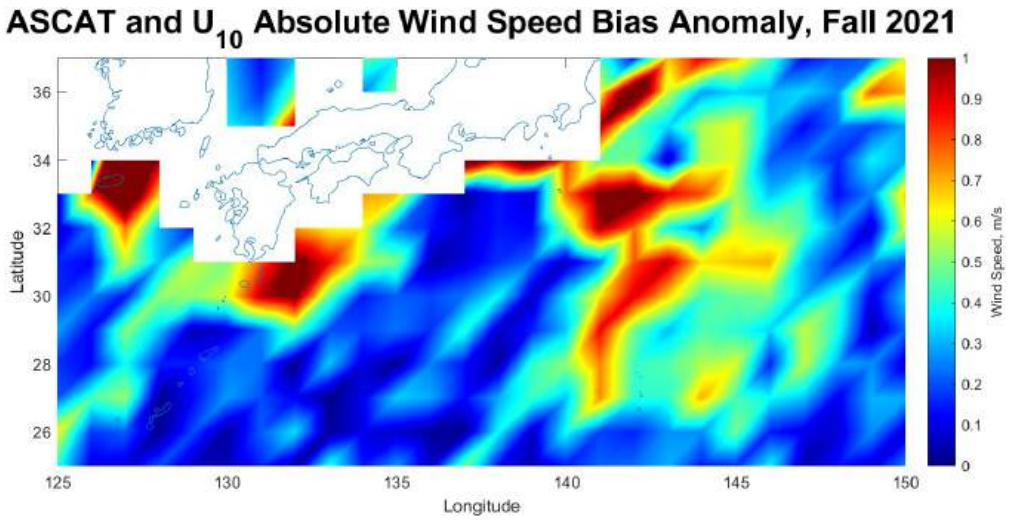


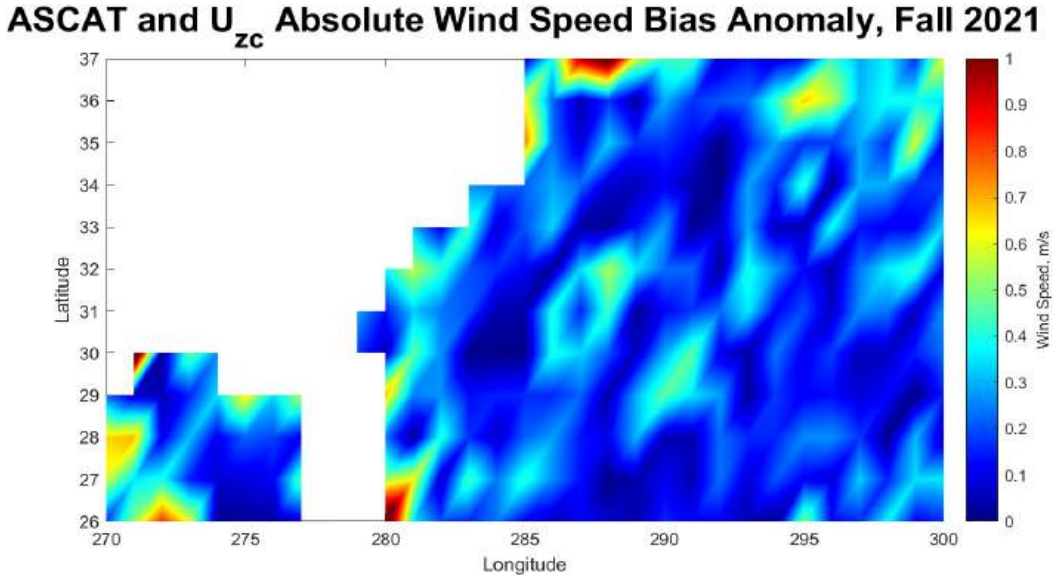


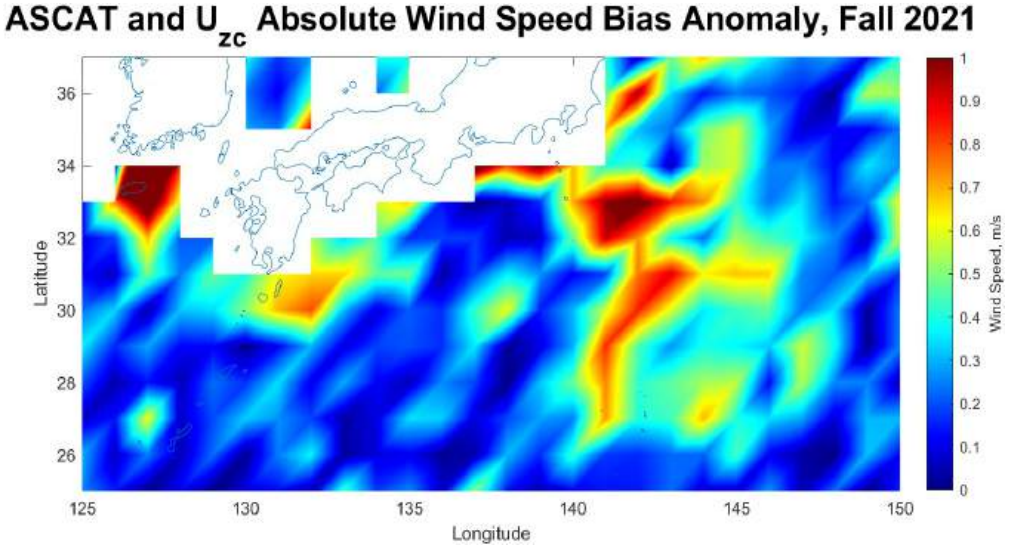
- ASCAT vs. ERA5 NWS (top) and ASCAT vs. ERA5 Uzc (bottom)
- Improvements in bias anomaly can be seen in the central Pacific, and there's no area where bias anomaly increases from NWS to U_{zc}

ASCAT Zoom In on Kuroshio and Gulf Stream









Conclusions & Questions

- Satellite wind speed products show a decrease in wind speed bias anomaly from the standard ERA5 neutral wind speed product to the modified zero current equivalent wind product.
  - Matters most in West Pacific ITCZ
- Even though the change in wind speed is relatively small (order of 0.1 m/s), this can influence other geophysical parameters that use wind speed, such as Latent Heat Flux.
- QUESTIONS:
  - Should forward models be tuned to U_{zc} instead?
  - Should retrievals include a current correction to convert retrieved wind to true wind?