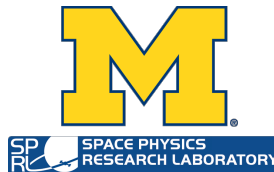


*International Ocean Vector Wind Science Team Meeting*  
*Miami, FL*  
*18-21 May 2026*

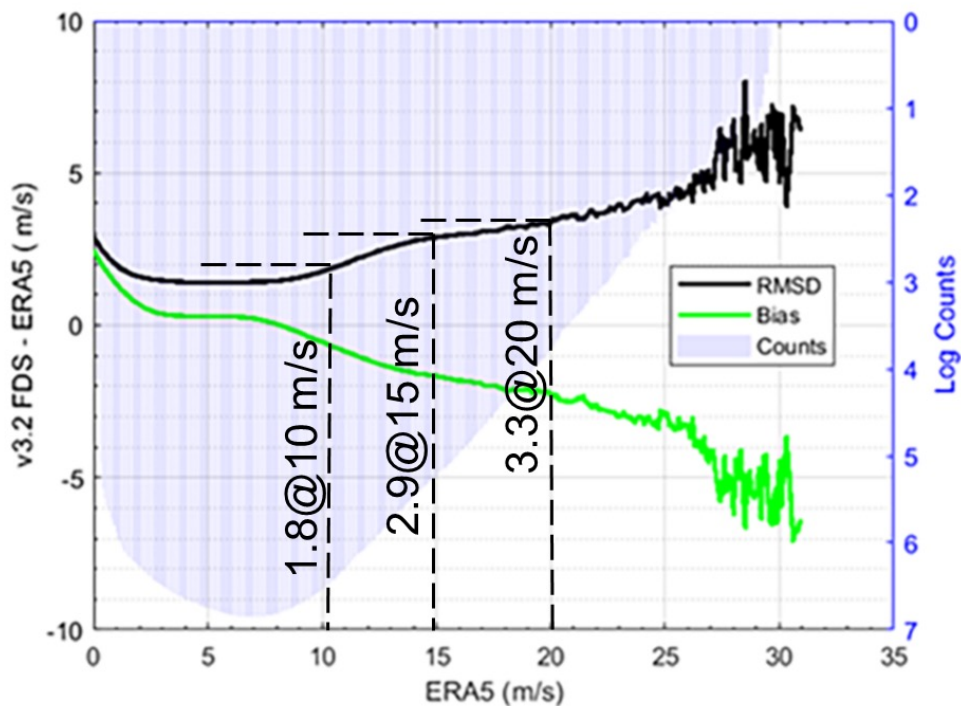
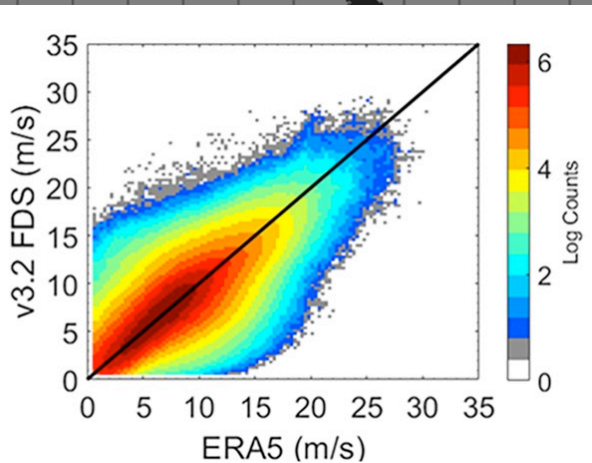
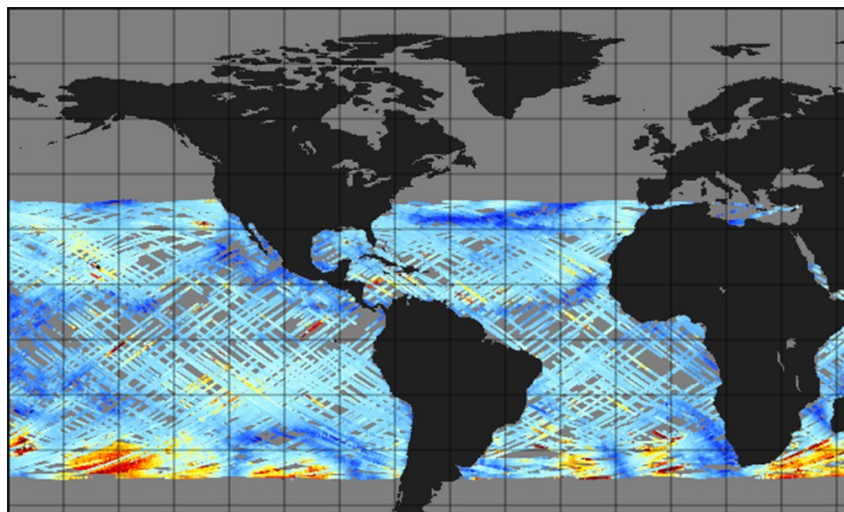
# **Update on CYGNSS Ocean Wind Product – Performance Characterization and General GNSS-R Ocean Wind Properties**

Chris Ruf  
University of Michigan





# CYGNSS Global Surface Wind Speed



**ERA5 comparison to CYG FDS v3.2**  
**RMSD = 1.7 m/s, Bias = -0.2 m/s**



# Wind Speed Assessment Paper

## Sea State Sensitivity of Wind Speed Retrieval

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### ❖ Recent publication assessing CYGNSS wind speed data products

Ruf, C., M. Al-Khaldi, S. Asharaf, R. Balasubramaniam, D. McKague, D. Pascual, A. Russel, D. Twigg, A. Warnock (2024). Characterization of CYGNSS Ocean Surface Wind Speed Products. *Remote Sensing*, 16, 4341, doi: 10.3390/rs16224341.

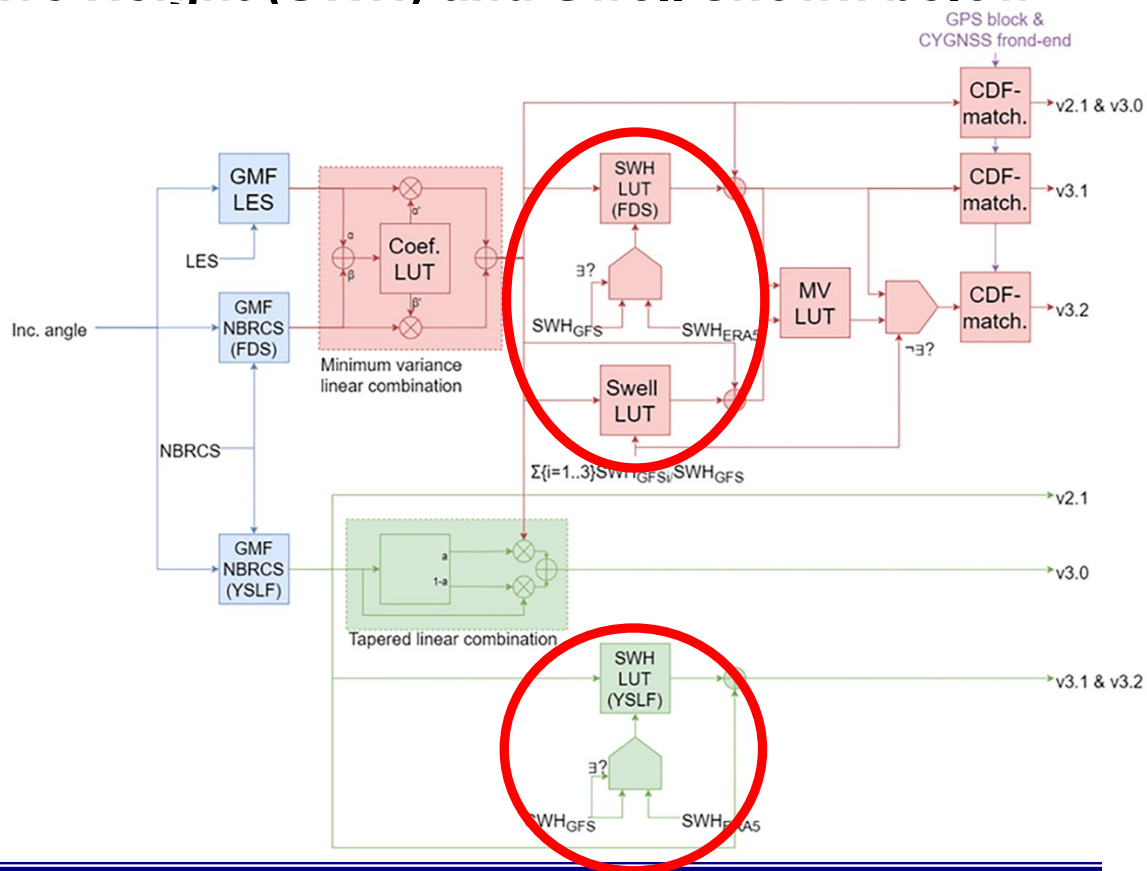
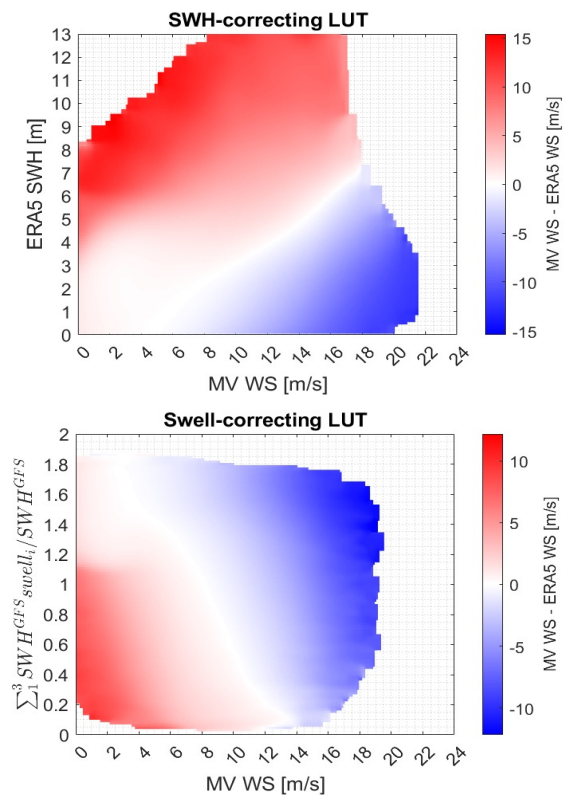
### ❖ Paper outline:

1. & 2. Introduction & Materials and Methods
  3. Results
    - 3.1 Intercomparisons with Reference Wind Speeds
    - 3.2 Triple Colocation Validation
    - 3.3 Sampling Properties
    - 3.4 Sensitivity to Significant Wave Height**
    - 3.5 Sensitivity to Wind Speed Transience**
  4. & 5. Discussion & Conclusions
- 
-



# Correcting for Sea State Dependence of Wind Speed Bias

- ❖ Correction is a lookup table of mean bias vs. wind speed and sea state
- ❖ LUTs for Significant Wave Height (SWH) and Swell shown below

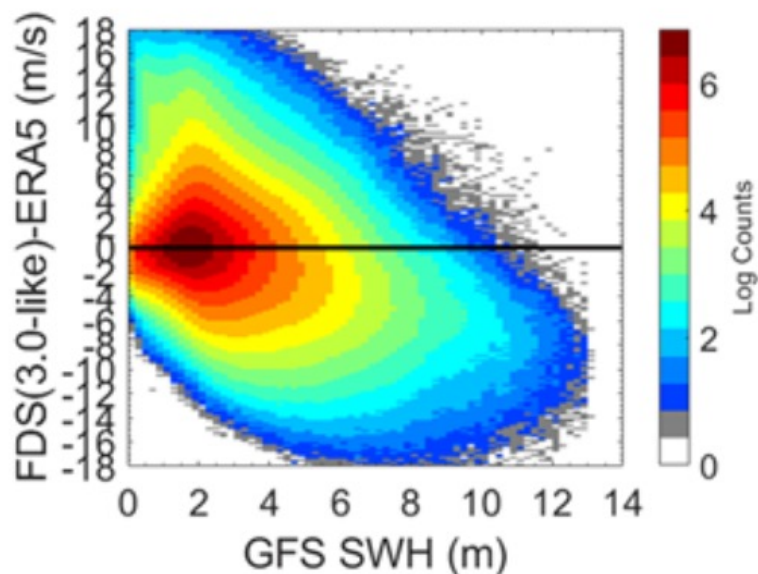




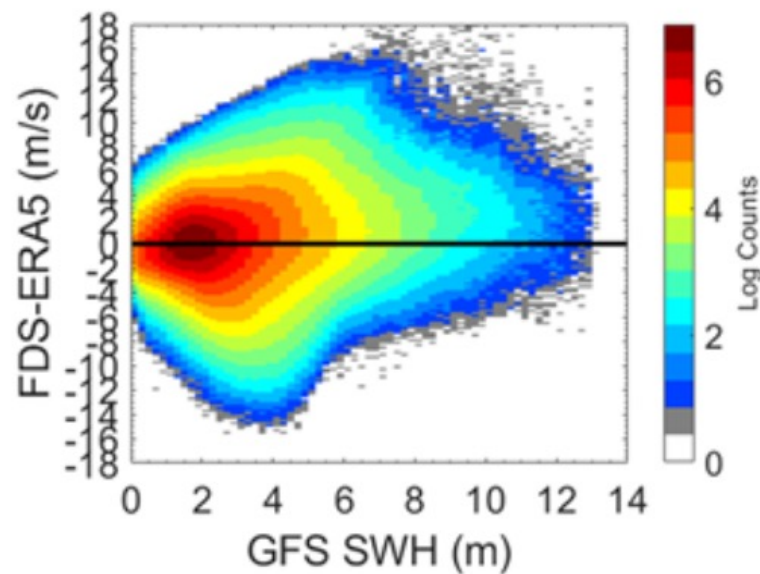
# Effectiveness of Sea State Correction

## ❖ Dependence of CYGNSS wind speed error on SWH

- ❖ (a) FDS wind speed product without correction
- ❖ (b) FDS wind speed product with correction



(a)

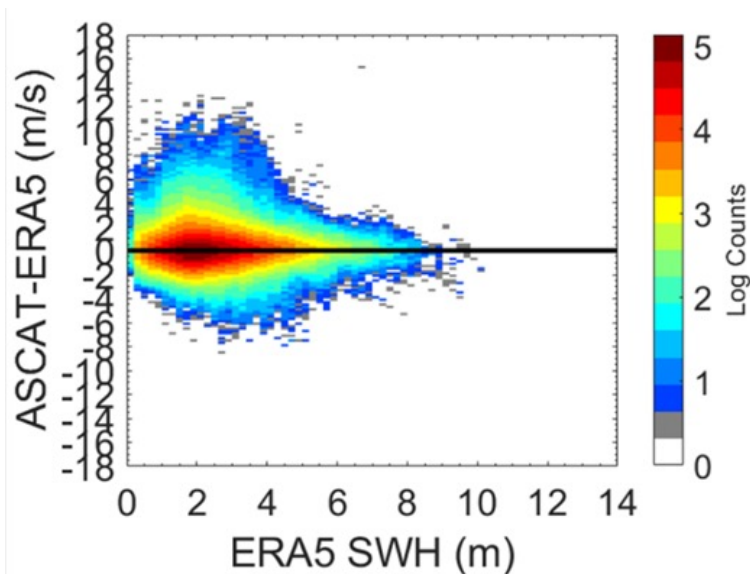


(b)

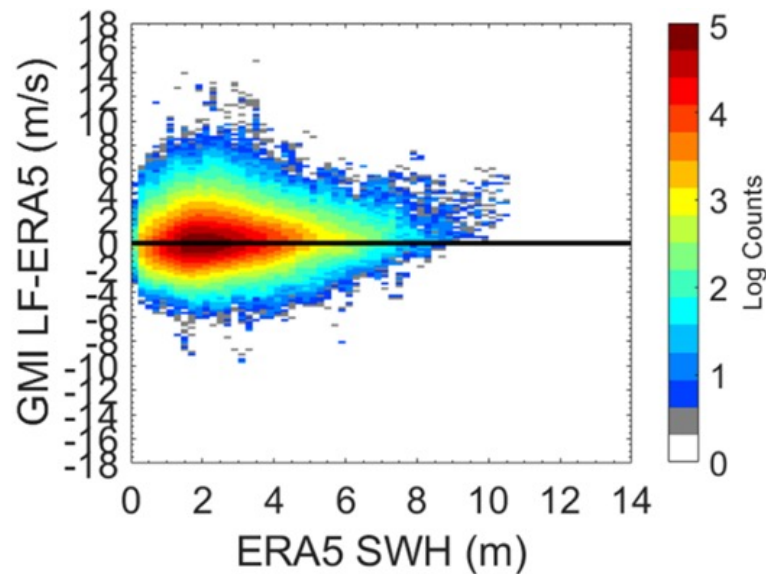


# Sensitivity (or lack thereof) to SWH by other Remote Sensing Modalities

- ❖ Dependence of wind speed bias on SWH for other types of sensors
  - ❖ (a) ASCAT (backscatter radar – Bragg resonant with capillary waves)
  - ❖ (b) GMI (microwave radiometer – fractional foam coverage)



(a)



(b)



# Transient Wind Speed

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- ❖ A young sea state is characterized by an imbalance between the short and long wave portions of the ocean roughness spectrum
- ❖ Young seas can occur when the wind is changing.
- ❖ Wind speed transience is defined to quantify the change in wind speed prior to a remote sensing observation

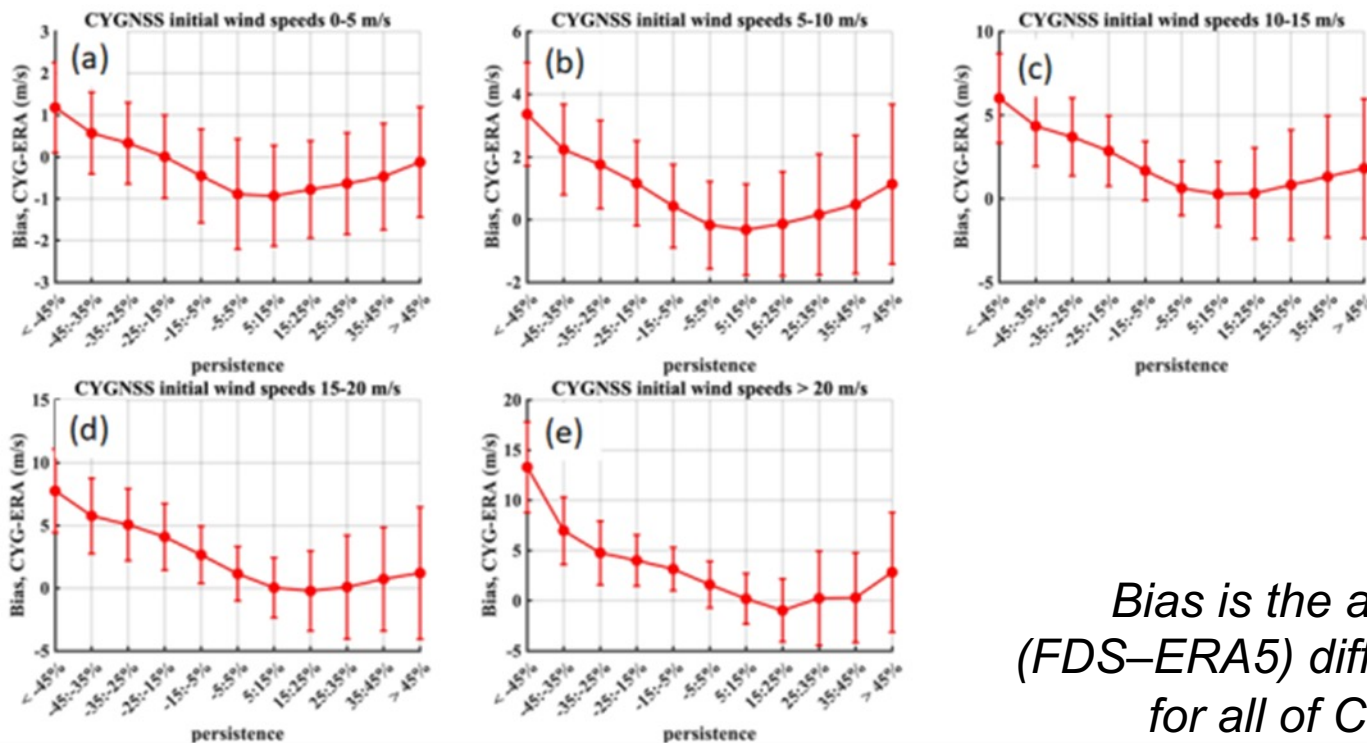
$$\text{transience}(t) = \frac{\text{windspeed}(t) - \text{windspeed}(t - 2\text{hr})}{\text{windspeed}(t)}$$

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# Dependence of GNSS-R Retrieval Bias on Wind Transience

- ❖ Bias in CYGNSS wind speed as a function wind speed transience for wind speed ranges of (a) 0–5 m/s, (b) 5–10 m/s, (c) 10–15 m/s, (d) 15–20 m/s, (e) >20 m/s. Transience < 0 implies prior winds were higher in the past. Error bars are the stdev of samples in each wind speed and transience bin.



*Bias is the average (FDS-ERA5) difference for all of CY2022.*



# Impact of Transience Bias on Global Performance Statistics

- ❖ Dependence of wind speed bias (CYGNSS–ERA5) on wind transience at typical and high wind speeds
- ❖ Note low frequency of occurrence of high wind speeds
- ❖ Note low frequency of occurrence of high transience winds
- ❖ Note high retrieval bias in high wind/high transience corner case

Wind Speed Range (m/s)	5-10 m/s			>20 m/s		
% of Samples	62%			0.02%		
Transience Range	t<-25%	t>-25, t<25%	t>25%	t<-25%	t>-25, t<25%	t>25%
% Samples @Wind Speed (FDS/ERA5 matchup)	3.27%	94.88%	1.85%	2.93%	95.38%	1.69%
FDS – ERA5 Bias (m/s)	2.32	0.00	0.40	9.48	2.05	1.34



# Mission & Sampling Considerations

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- ❖ Scatterometer and passive microwave winds have slightly lower random error and significantly lower sensitivity to secondary sea state conditions
- ❖ GNSS-R sensors are significantly smaller, lighter, lower power, and cheaper
  - ❖ There is roughly a 20x difference in total mission cost
- ❖ Current GNSS-R constellations number ~40 s/c and growing
  - ❖ CYGNSS, Spire, Tianmu, TRITON, Muon, ISRO, HydroGNSS
  - ❖ Atlantic (Spanish AEE), Brazilian AEB, other
- ❖ Global revisit time with 40 GNSS-R satellites is <2 hr
- ❖ There is a strong case for complimentary missions: higher quality anchor sensors + rapid revisit temporal gap fillers

*Thank you*

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