RETRIEVAL OF MEAN SQUARE SLOPES FROM CYGNSS DATA

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Content

- Motivation
- CYGNSS Data and filtering
- Algorithm
- Results and performance evaluation
- Conclusions and ongoing/future work

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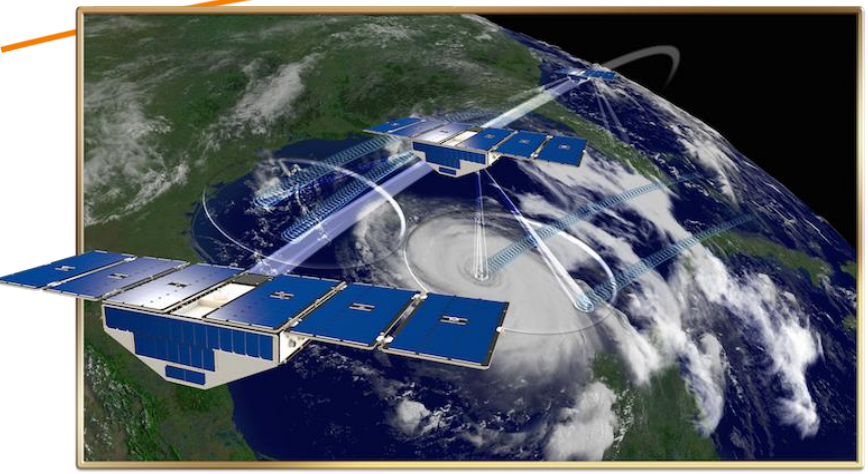
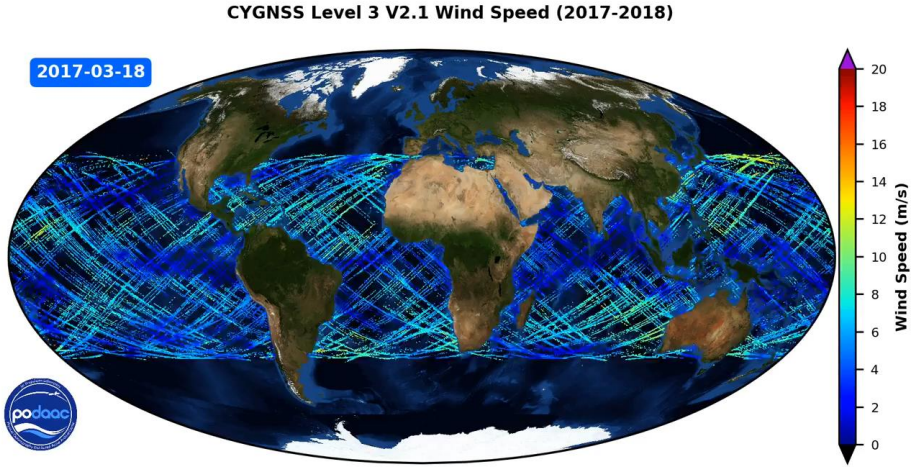
Motivation

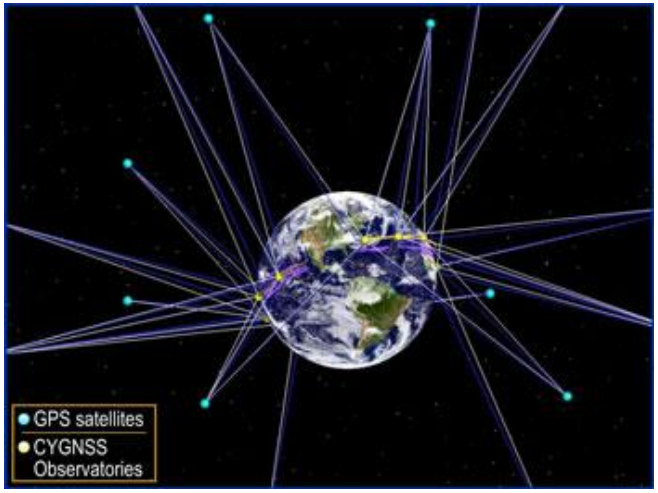




More info on www.cygnss-michigan.org

CYGNSS is about winds….

But don't forget the waves!



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OBSERVABLES USED FOR MSS ESTIMATION

- V 2.1 of CYGNSS Data
- Delay/Doppler Map Average (DDMA) and Leading Edge Slope (LES) observables from the L1 files
- Analysis developed for August-September 2017;

REFERENCE DATA

- Modelled MSS from NOAA WaveWatch 3 or WW3
- Baseline L2 MSS from the CYGNSS L2 product

FILTERS

- Quality control flag = 0
- Truth MSS, and observables > 0;
- Measurements taken when the star tracker is not tracking are discarded (NST flag);
- Range-Corrected Gain (RCG) > 3
- Signals from GPS Block II-F are excluded

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The CDF Matching Method*

If a model function *M* relating MSS *s* to an observable *O* can be defined as *s=M(O)*, then CDF of the observable *O* can be written as:

$$F_O(O') = 1-F_s(s')$$

IMPLEMENTATION STEPS

1.Construct the CDF of the observable and of the MSS $F_O(O')$ and $F_s(s')$ from the training dataset;
2.For each observable value O' find its CDF value $F_O(O') = \beta$
3.Find the MSS estimate s' for which $1-F_s(s') = \beta$

➢***The CDFs are derived from the training dataset, and for individual bins of incidence angle and range-corrected gain (RCG)***

➢***Steps 1 to 3 are used to derive separate MSS estimates from DDMA and LES, and then these two estimates are combined into a MV estimator***

*Freilich, M. and P. Challenor, "A New Approach for determining Fully Empirical Altimeter Wind Speed Model Functions", *Journal of Geophysical Research*, Vol. 99, No. C12, December 1994

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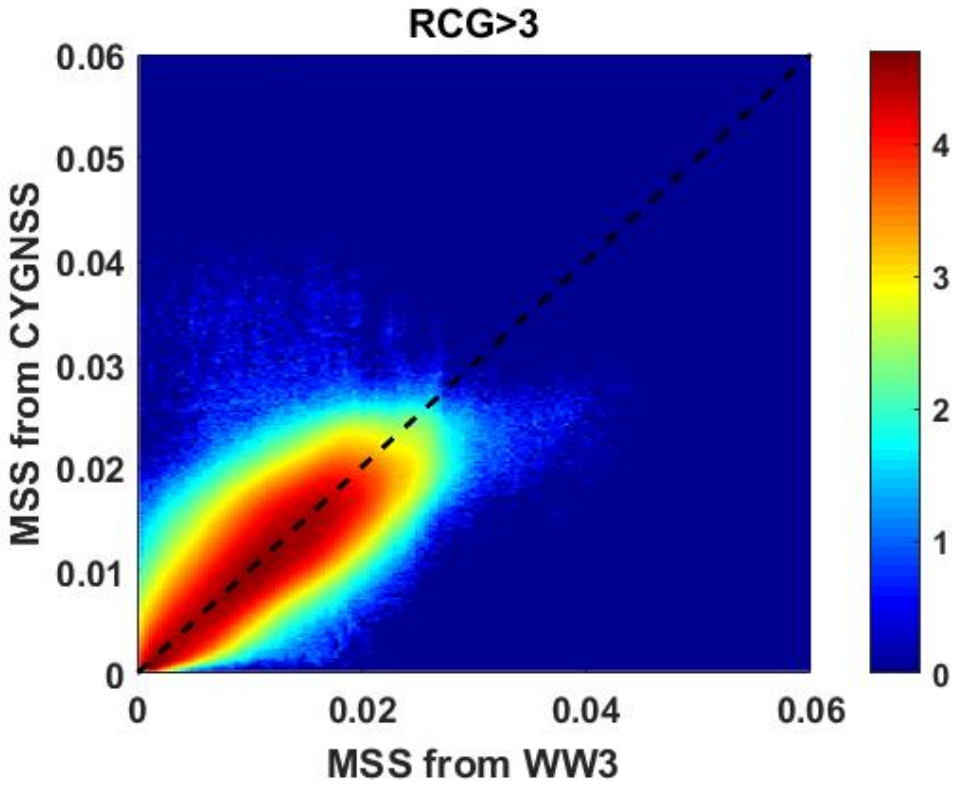
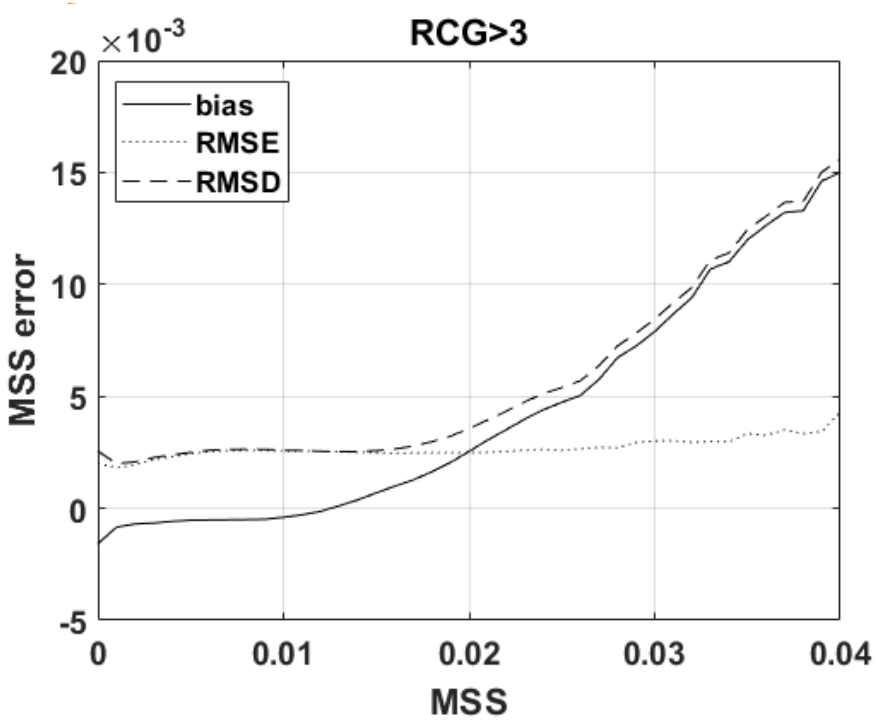
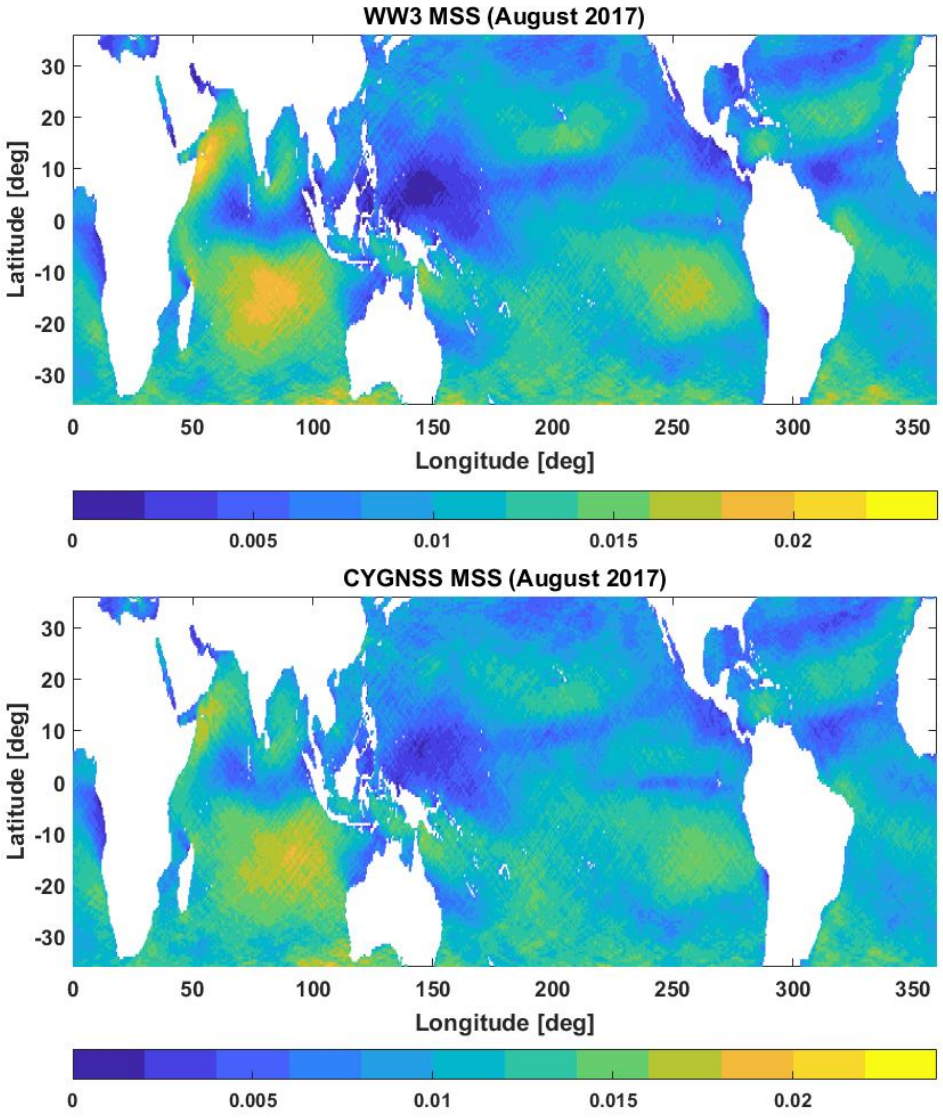
Performance Results

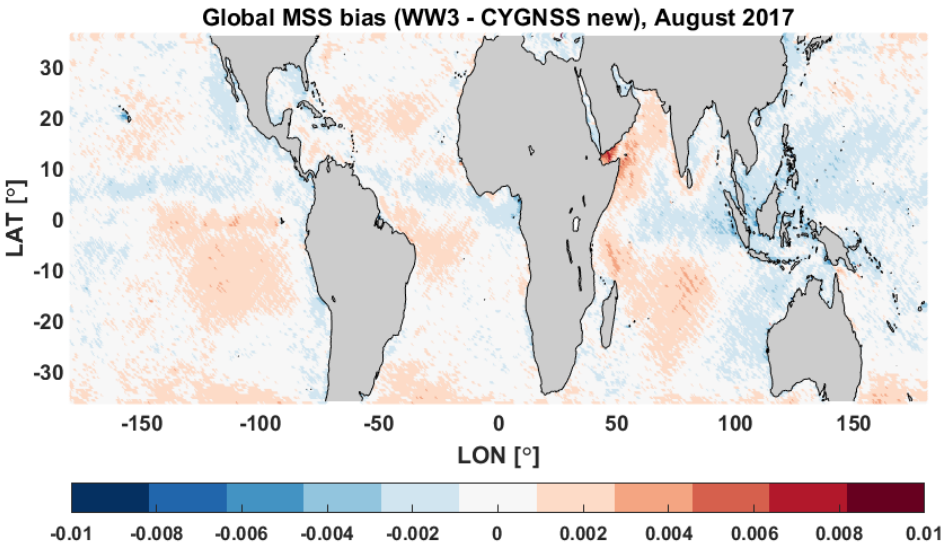




- **Good agreement between WW3 MSS and MSS estimated from CYGNSS**, for the test dataset;
- Issues similar to the wind speed case can be noticed, but possibly **better dependence of the CYGNSS data on MSS than the wind speed case**;
- Error behavior is similar to the wind case: the RMSE is fairly constant, so the bias drives the overall error

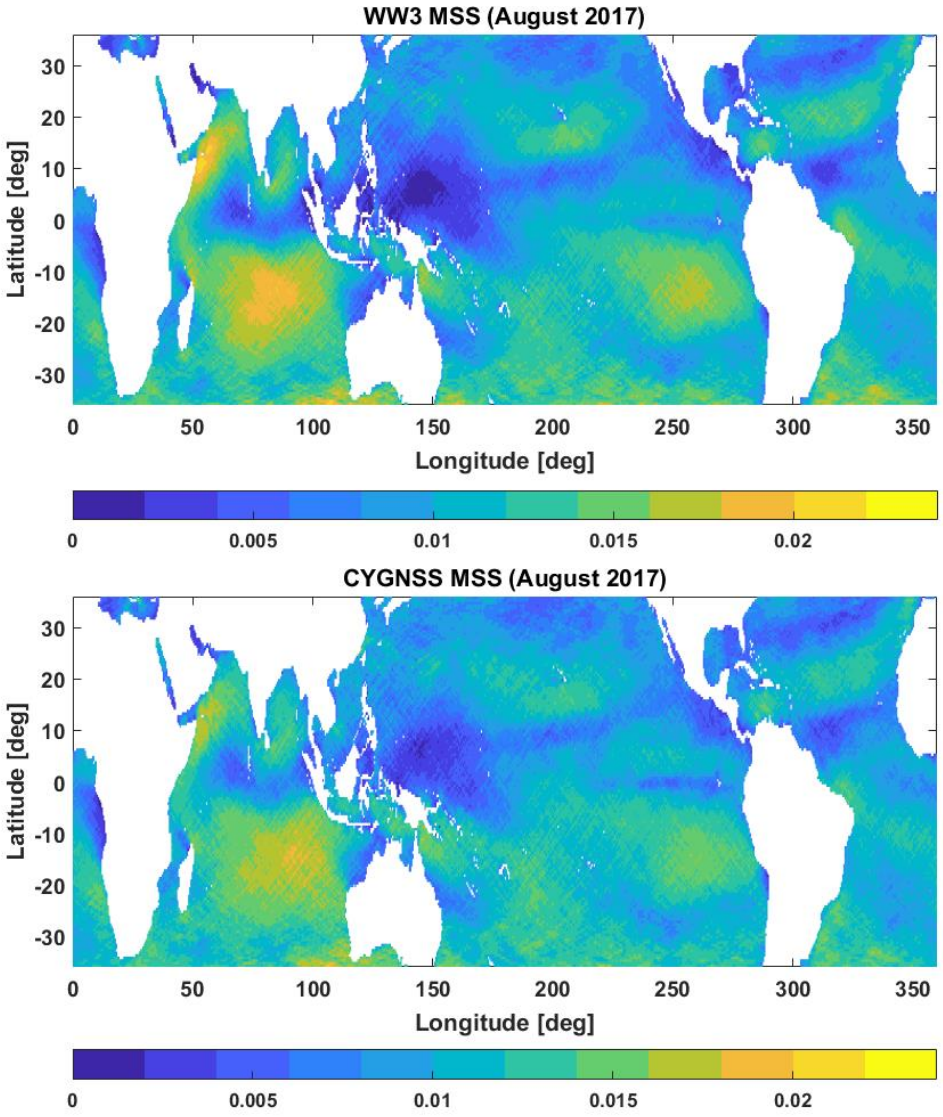
Performance Results (2)



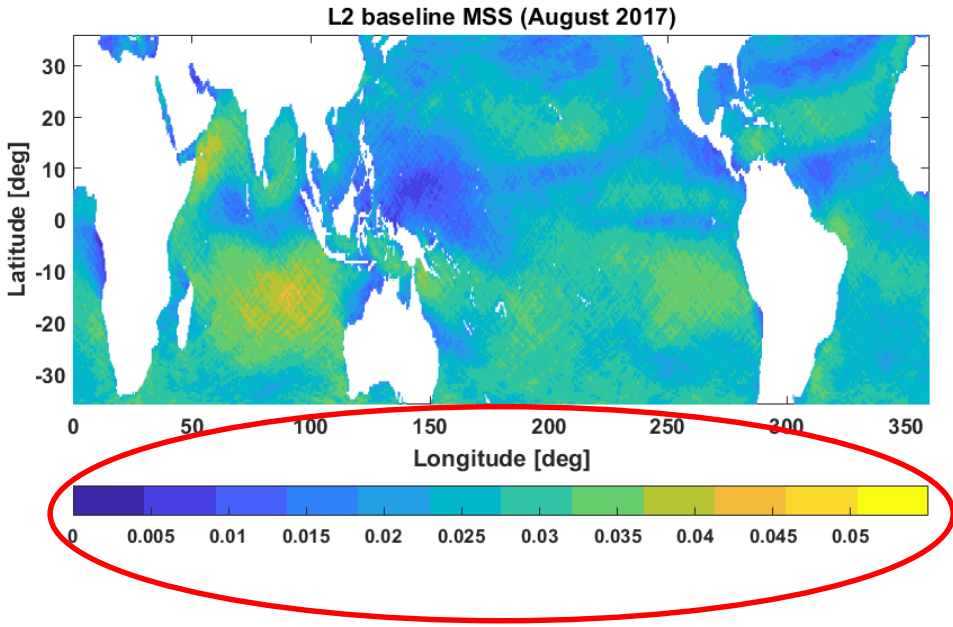


Monthly Averages of MSS

Performance Results (3)

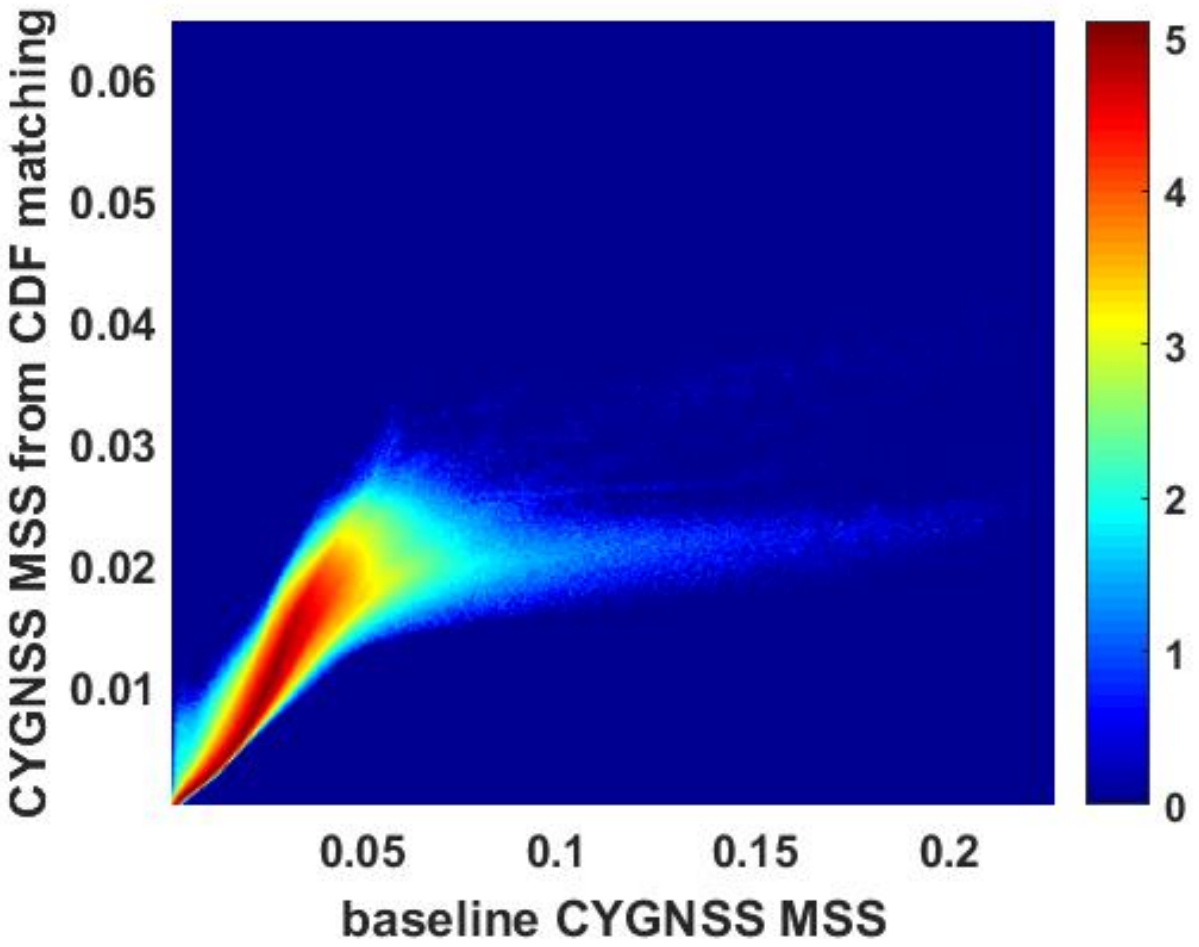


$$MSS_{baseline} = |R_{Fresnel}(\theta)|^2 / \sigma_0(\theta)$$



Performance Results (4)

$MSS_{baseline} = |R_{Fresnel}(\theta)|^2 / \sigma_0(\theta)$



Performance Summary

Stat	CYGNSS new algorithm vs WW3 L2	CYGNSS new algorithm vs WW3 L3 (monthly average)
Bias	0.0000	**0.0000**
RMSE	0.0026	**0.0012**
Corr. Coef.	0.86	**0.95**

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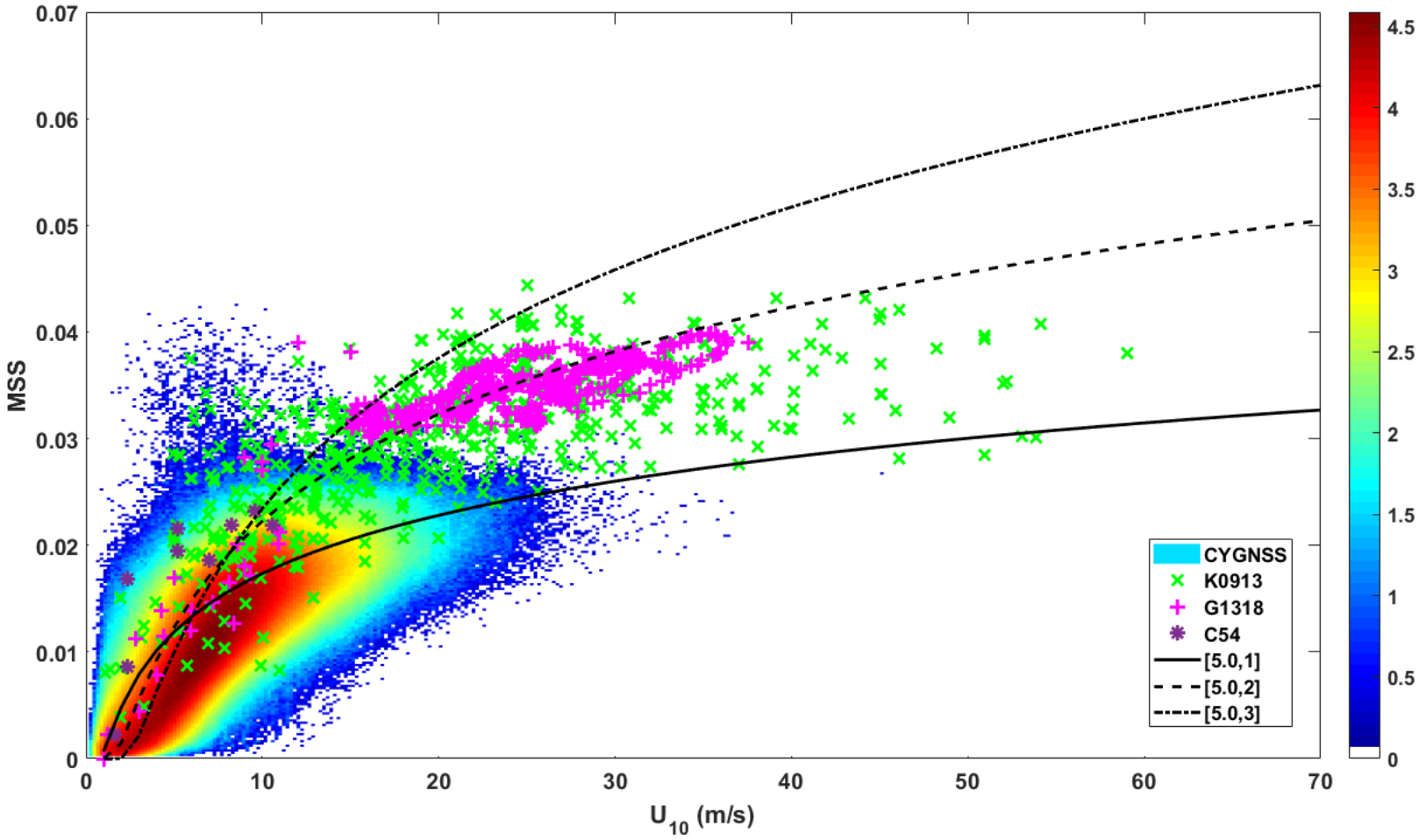
Relationship between MSS and wind speed



- **K0913** are Katzberg's airborne measurements over TCs (2009, 2013);
- **G1318** are Gleason's spaceborne measurements over open ocean and hurricanes (2013, 2018)
- **C54** are MSS from Cox and Munk '54, observed in artificial-slicked water
- **The black lines** are produced using the general surface wave spectrum (G-Spectrum, Hwang et al., JPO, 2017), for a spectral slope of 5, and inverse wave age of 1, 2 and 3.

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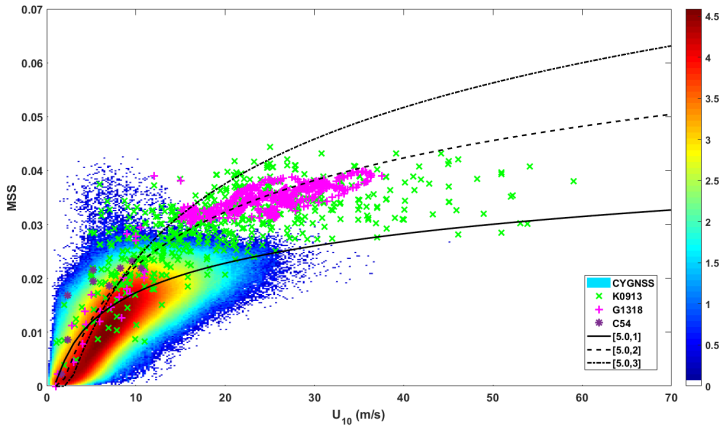
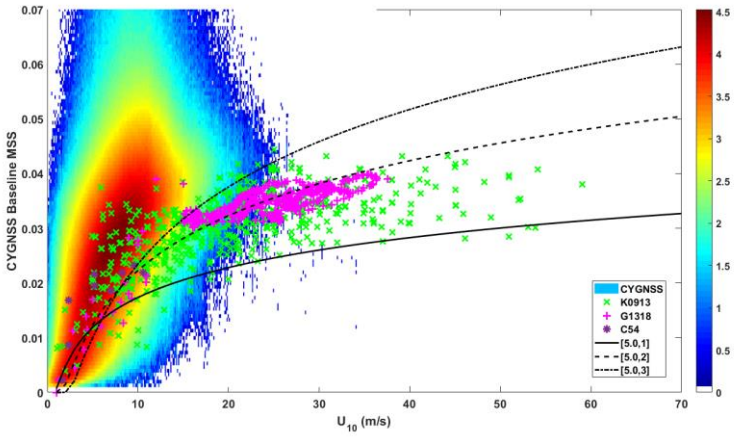
Relationship between MSS and wind speed (2)

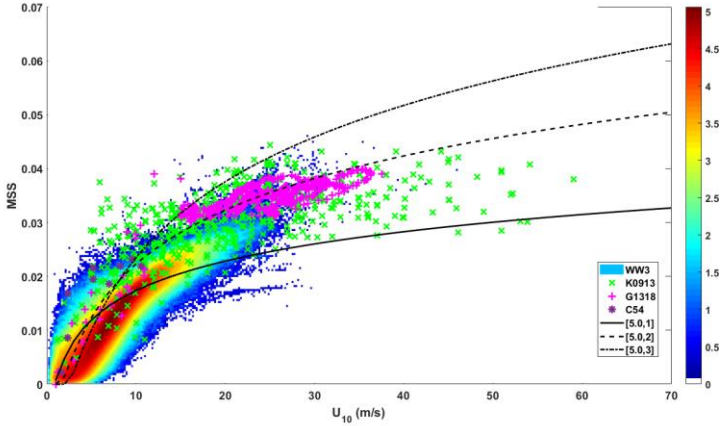
CYGNSS CDF matching



CYGNSS Baseline



WW3



- **Both CYGNSS CDF matching and WW3 predict lower MSS with respect to the expectation from the model and the data**
- **The CYGNSS Baseline predict higher MSS instead, but this might be due to the existing bias in the baseline MSS**

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Conclusions

- **A retrieval approach of MSS from CYGNSS is proposed using the CDF matching method** as an alternative to the current baseline approach

  - The agreement with WW3 is quite good;
  - The comparison with baseline MSS has identified **a possible bias in the existing baseline MSS;**
  - An alternative solution could be to correct the existing $MSS_{baseline}$ by applying the CDF matching to it to derive the correct MSS;

- **The CDF matching requires however knowledge of a CDF of MSS, so is the WW3 MSS the best choice?**
  - Differences have been found in the pdfs of MSS for WaveWatch 3 and for the WAM model, for example
  - Should we use the "corrected" WW3 MSS?
  - how do we validate L-band estimations of sea surface roughness?

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Future Work

- **Extend the dataset** for future analyses
- **use new release (v 3.0) of data** (coming soon!)
- **Understand the best reference data to use**
- **Explore new retrieval algorithm**
  - Regional approaches, neural networks…
- **More validation analysis**
  - Comparison with MSS from other models (e.g. WAM);
  - Comparison with buoy measurements;
  - Further study on the relationship between L-Band MSS and wind speed, using surface wave spectral models and real data

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Thank you!

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