

Analysis and Assimilation of CYGNSS Winds Near Tropical Convection

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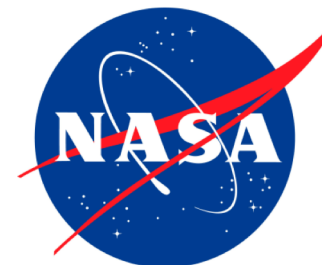
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CYGNSS Science Team Meeting

20 June 2018



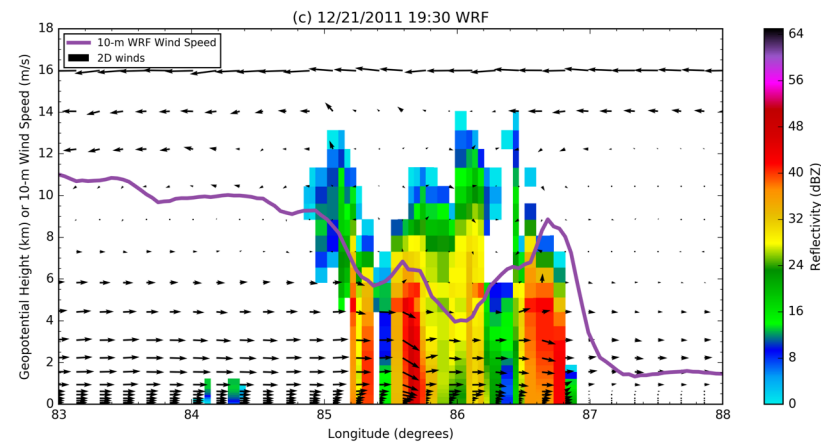
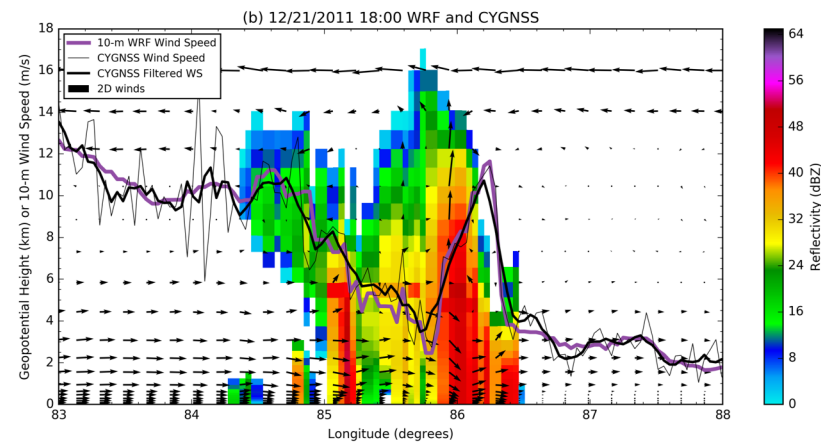
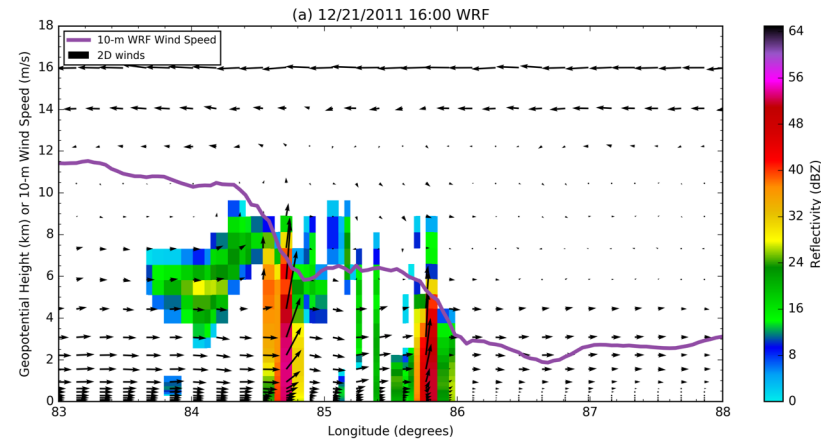
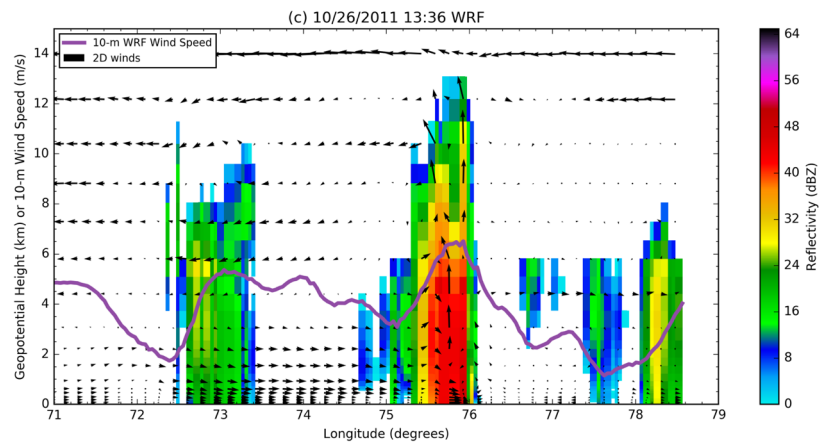
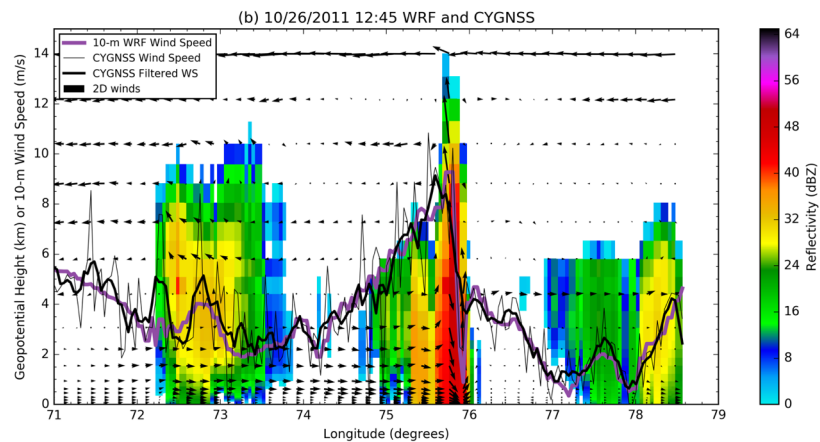
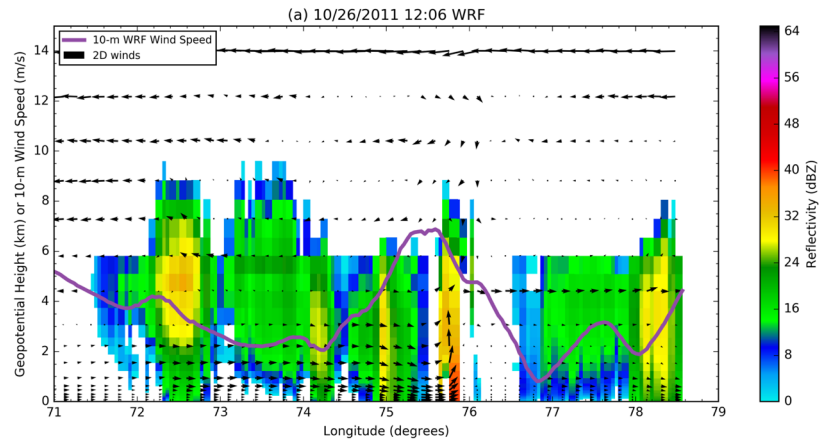
Background and Motivation

- Hoover et al. (2018) predicted that CYGNSS would be able to observe strong wind gradients near tropical convection.
- Ruf et al. (2018) verified that gradients also were observed in on-orbit CYGNSS data.
- CYGNSS v2.1 attempting to improve data quality, and also improved data availability for high-beta periods.

Work is guided by 3 main research questions:

- How does CYGNSS observe MJO convection?
- How does CYGNSS winds compare to ASCAT winds near convection?
- How does CYGNSS affect simulations of post-landfall Harvey (i.e. data assimilation)?

October 2011



December 2011

Air-Sea Heat Fluxes Motivation for Assessing CYGNSS Wind Quality

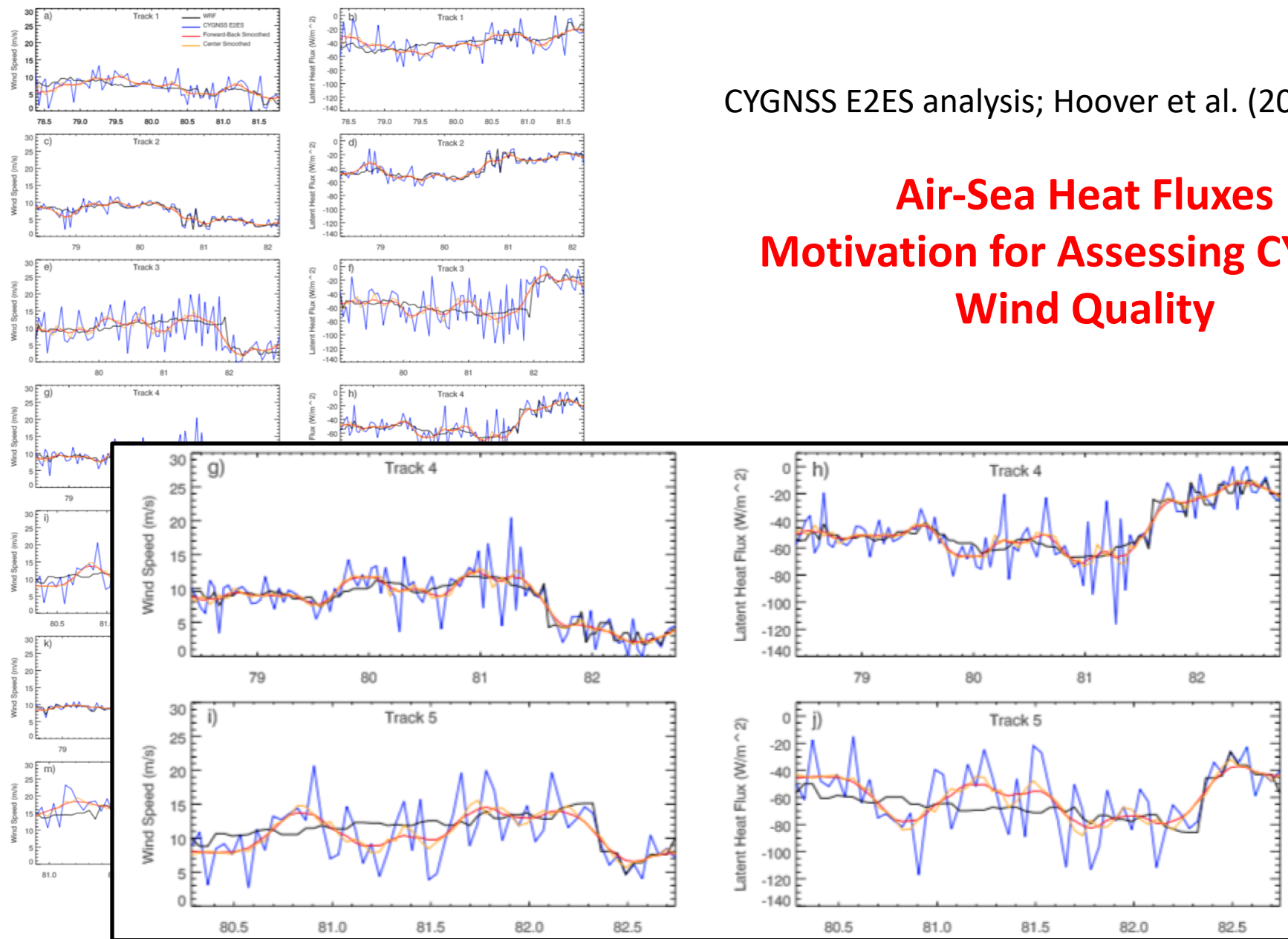
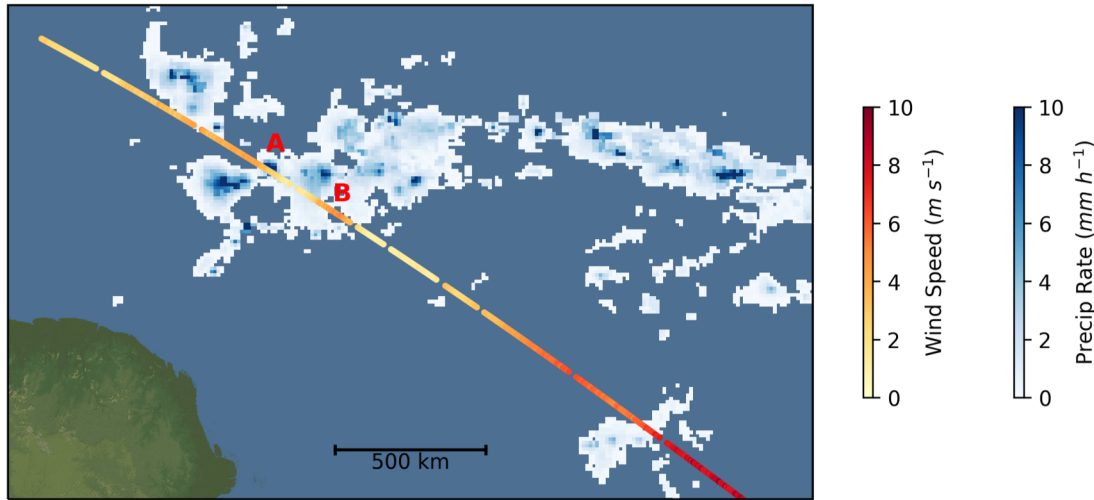
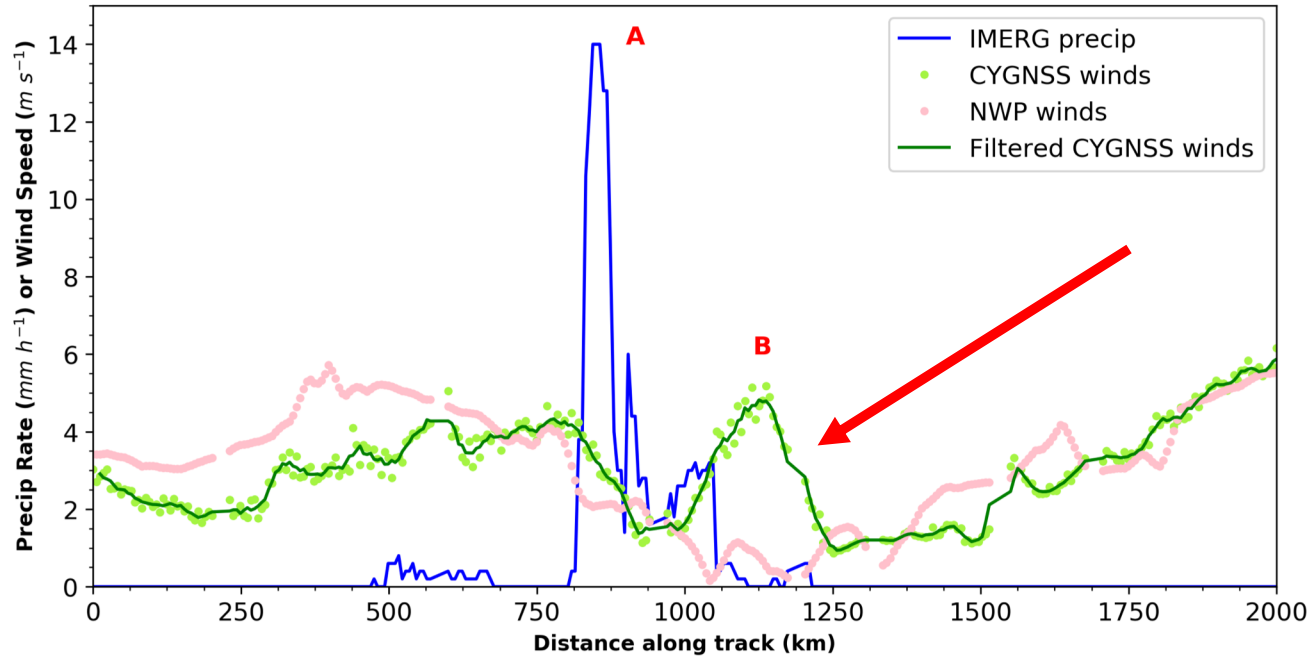


FIG. 11. Wind speed (left) in $m s^{-1}$ and latent heat flux (right) in $W m^{-2}$ with longitude for specular point track 1 (a and b), track 2 (c and d), track 3 (e and f), track 4 (g and h), track 5 (i and j), track 6 (k and l), and track 7 (m and n) on 21 December 2011.

(a) IMERG and CYGNSS Map - 08/28/2017 11:06



(b) IMERG and CYGNSS Time Series - 08/28/2017 11:06

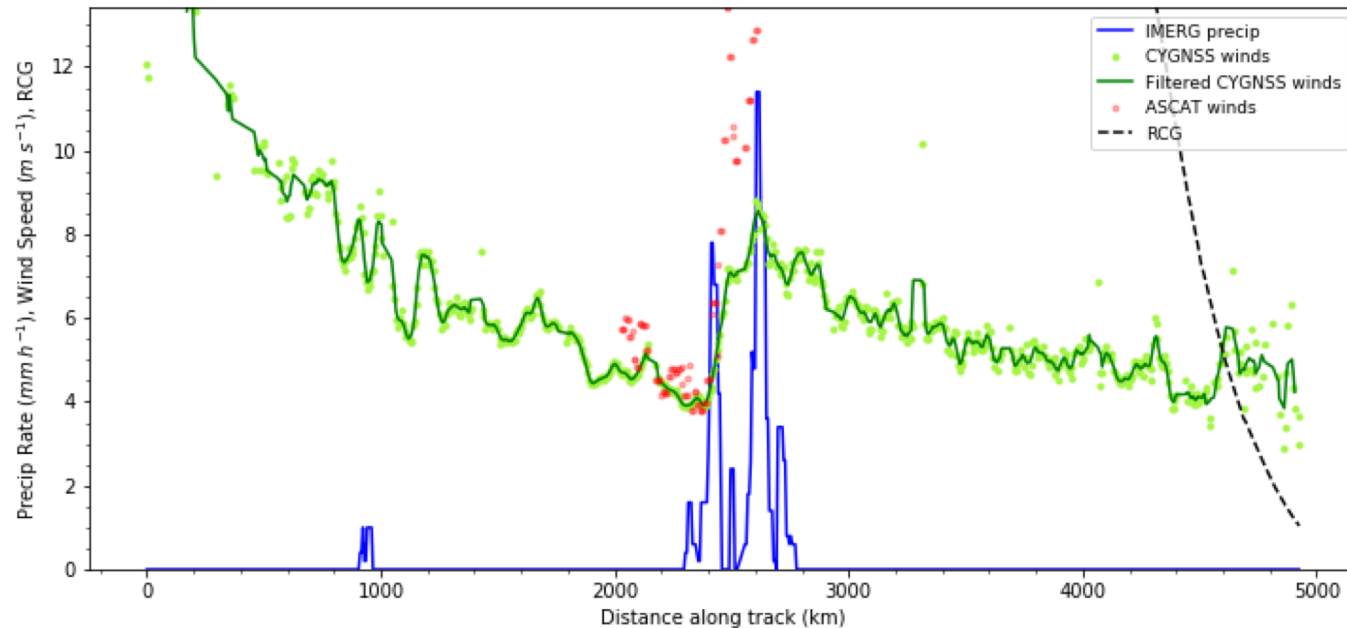
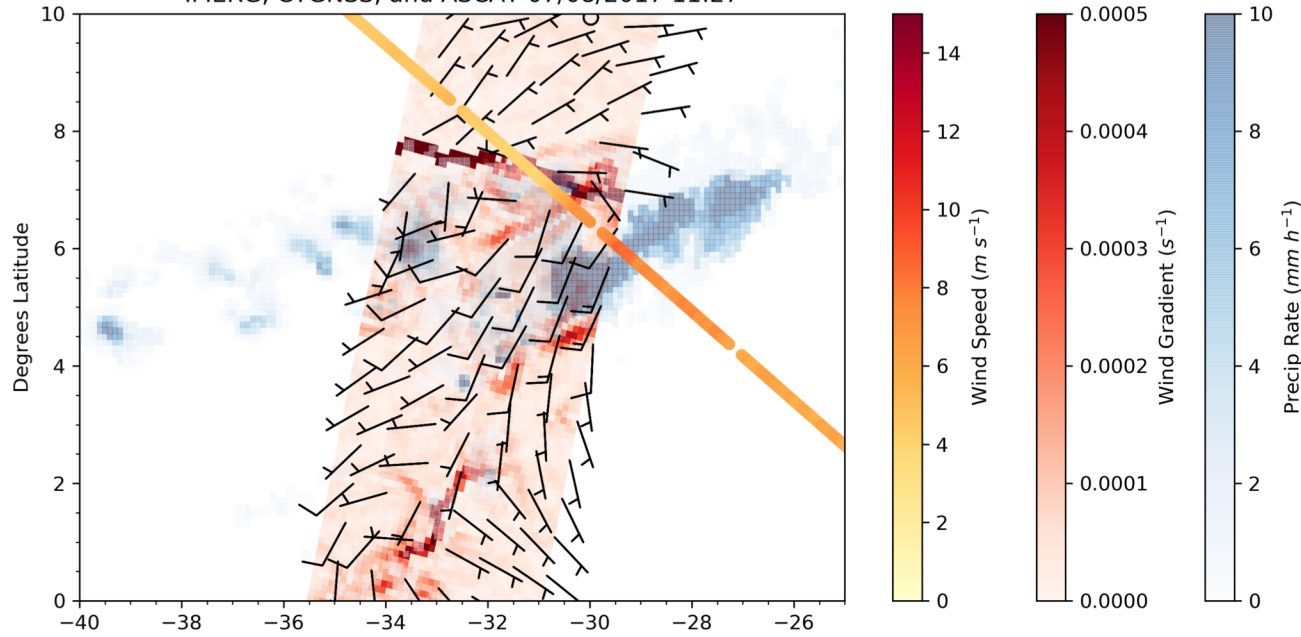


Ruf et al. (2018)

Convective Signatures in CYGNSS Data

- What the real CYGNSS data show, and what is missed by NWP
- Combine CYGNSS specular point tracks with IMERG precipitation
- Have found numerous examples of wind gradients (B) in/near significant convective precipitation (A)
- Gradients not always observed in NWP analyses

IMERG, CYGNSS, and ASCAT 07/08/2017 11:27



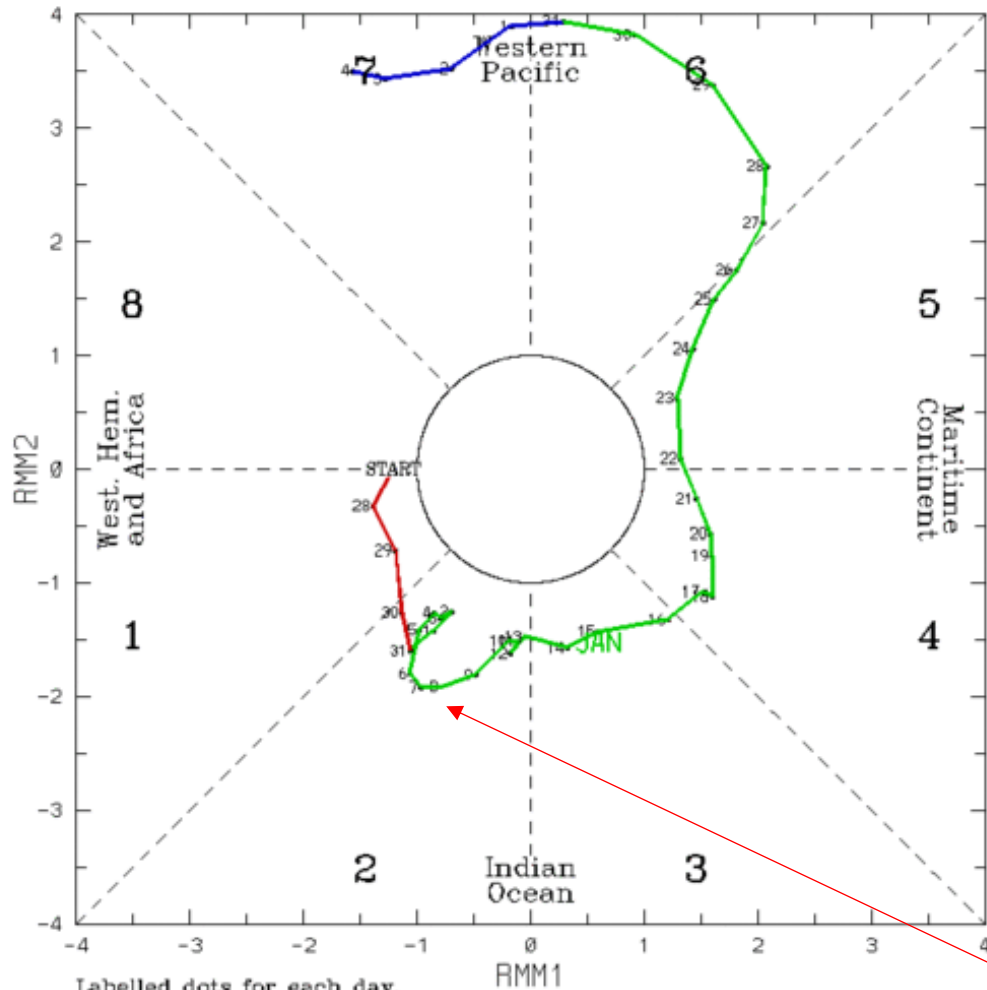
Recent Analysis–ASCAT Comparison

- May 2017 thru January 2018, v2 CYGNSS vs. PO.DAAC 12.5-km coastal ASCAT A/B
- Search for CYGNSS wind gradients – require $>10 \text{ mm h}^{-1}$ and $>3 \text{ m s}^{-1}$ change over 100 km
- ASCAT gradient features commonly found in vicinity of CYGNSS wind gradients
- CYGNSS data demonstrate a relative insensitivity to regions of rainfall
- Automated procedure – Several per day

CYGNSS - ASCAT	Samples	Bias (m s^{-1})	RMSE (m s^{-1})
All	160367	+0.2	2.2
Rain	54552	-0.1	2.7
No Rain	105815	+0.3	1.9

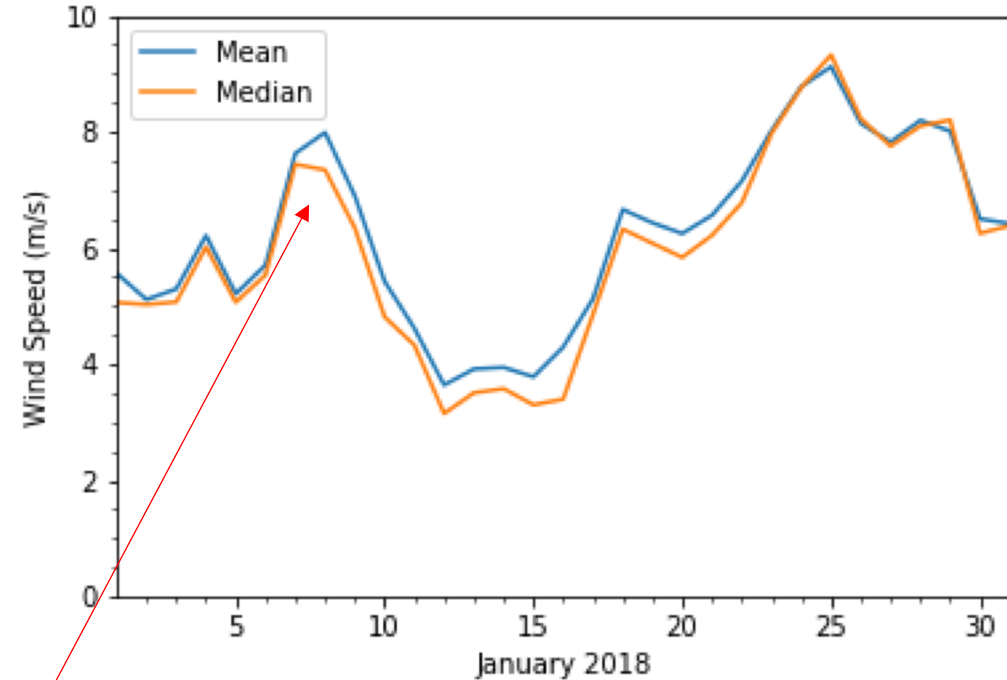
V2.1 Analysis – Finally able to examine early January MJO onset in Indian Ocean

(RMM1,RMM2) phase space for 27-Dec-2017 to 4-Feb-2018



Labelled dots for each day.
Blue line is for Feb, green line is for Jan, red line is for Dec.

CYGNSS average wind speed in 70-80 E, 10-0 S



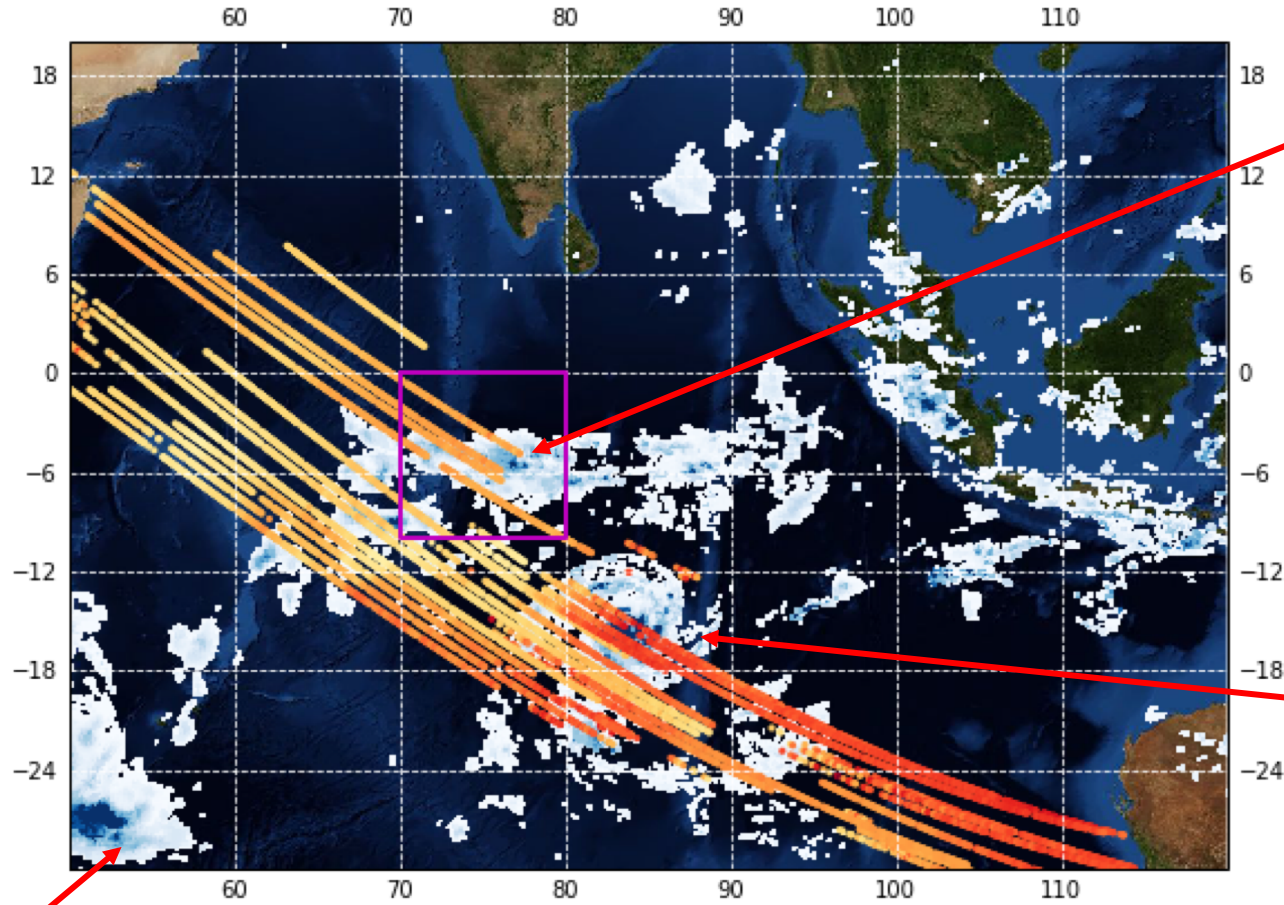
NOAA

- MJO onset: CYGNSS data no longer missing!
- Evidence of WWB

IMERG and CYGNSS

~1 hour of data

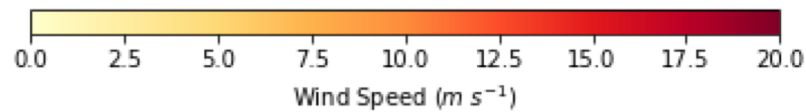
IMERG Late & CYGNSS L2 - 01/07/2018 14:00 UTC



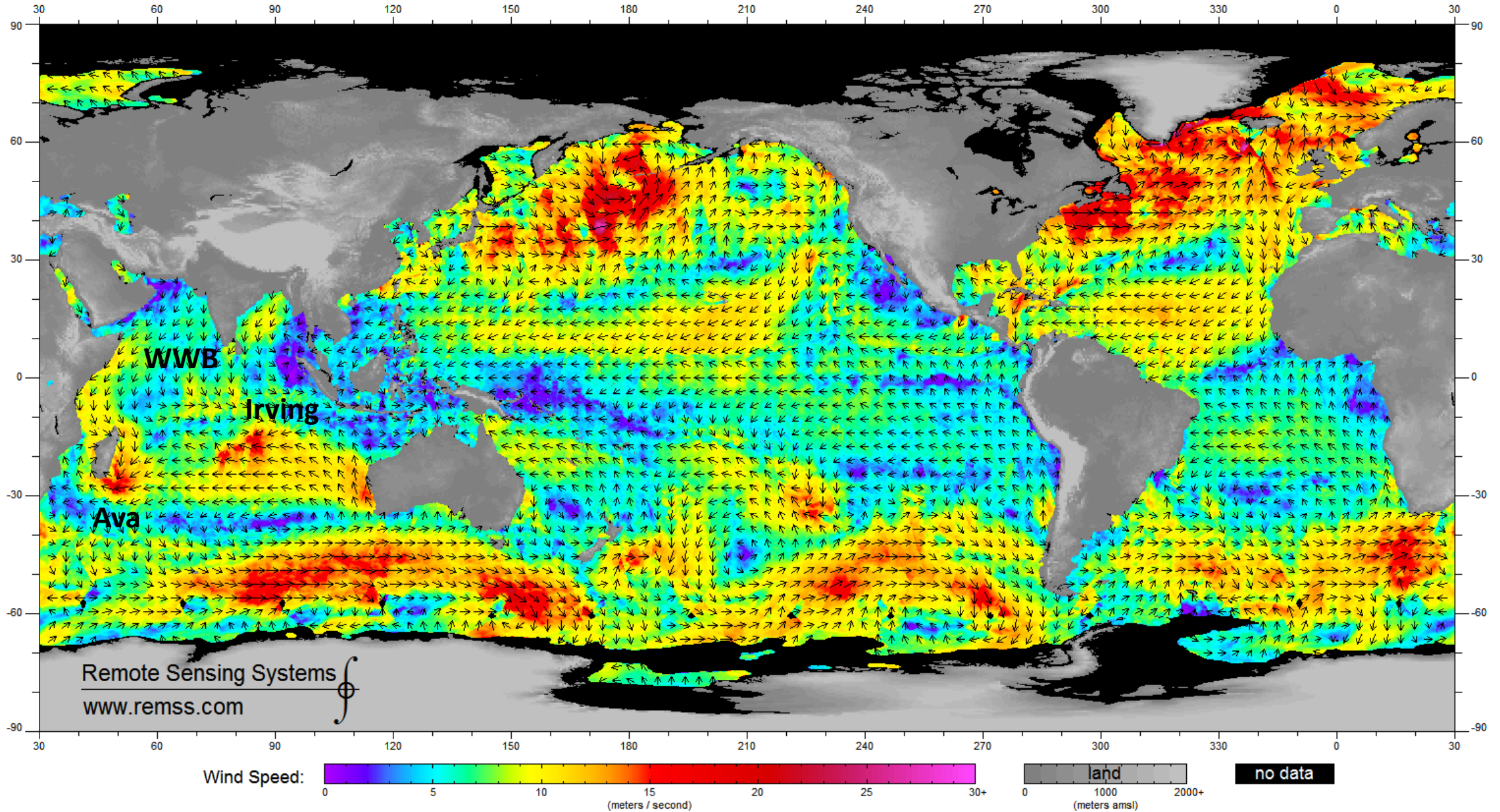
Westerly Wind Burst
(prior slide)

TC Irving

TC Ava

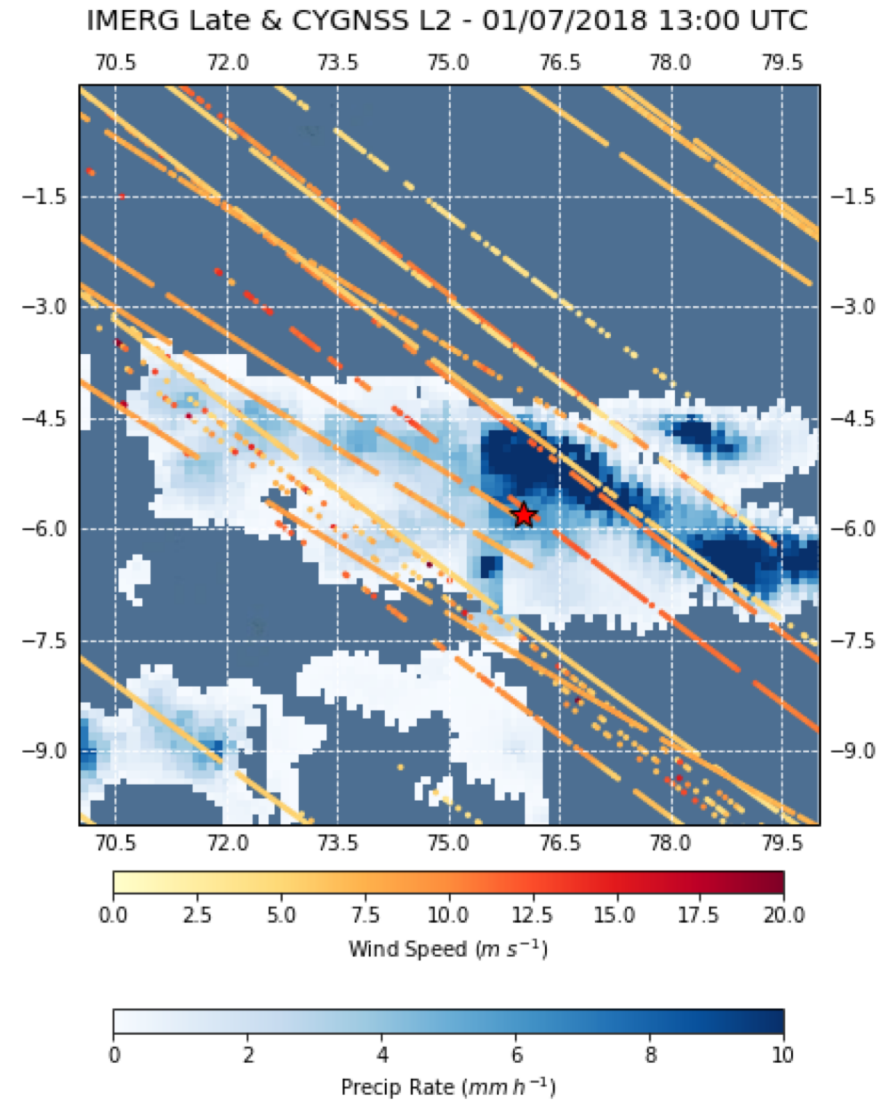
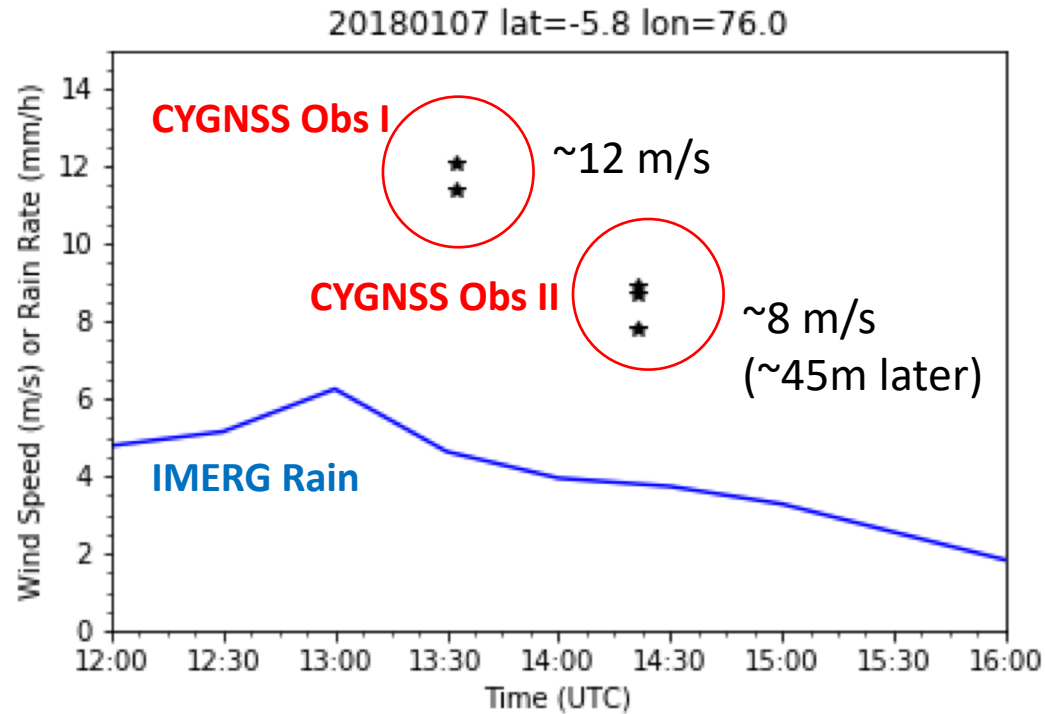


ASCAT v2.1 wind vectors: 3-days ending 2018/01/08 - Global



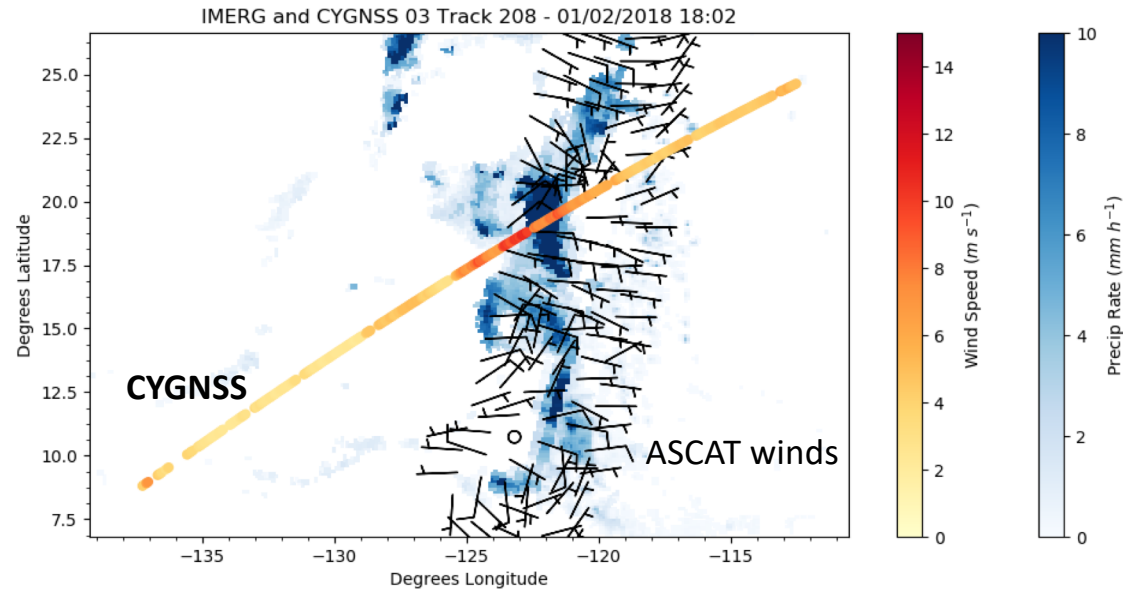
C-2015 ASCAT data are produced by Remote Sensing Systems and sponsored by the NASA Ocean Vector Winds Science Team. Data are available at www.remss.com **ASCAT sees something similar to CYGNSS**

Eulerian Perspective – Watch CYGNSS & IMERG from single location

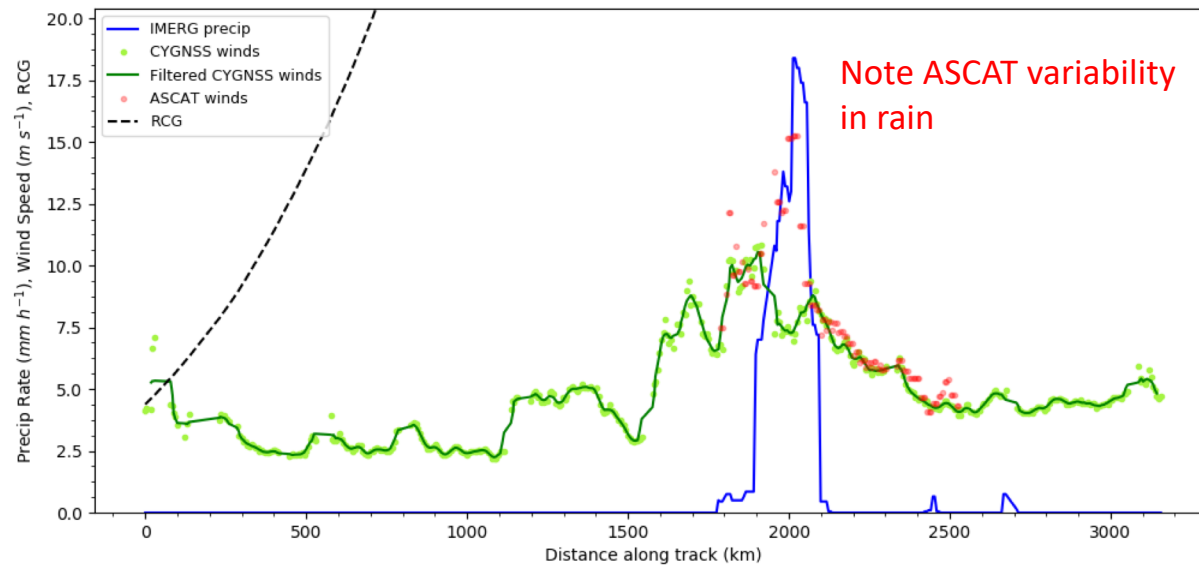


- Evidence for convective variability near rainfall
- Limited samples when Block IIF is excluded
- Impact of calibration offsets between observatories?
- Effects of significant wave heights (SWH)?
- **Difficult to do** – Not enough successive overpasses

V2.1 Comparison with ASCAT

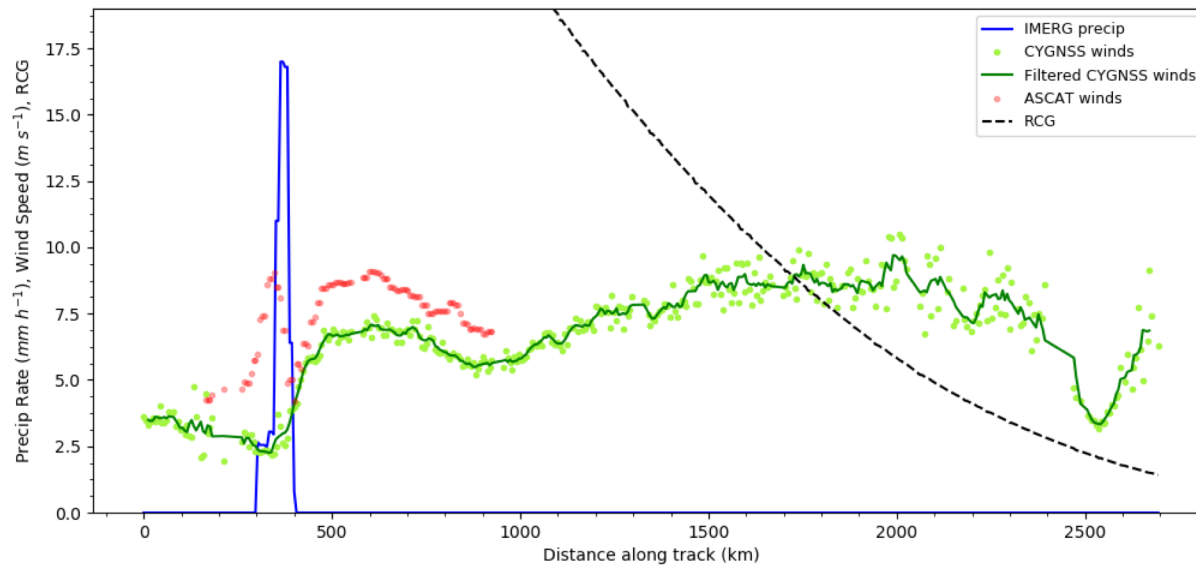
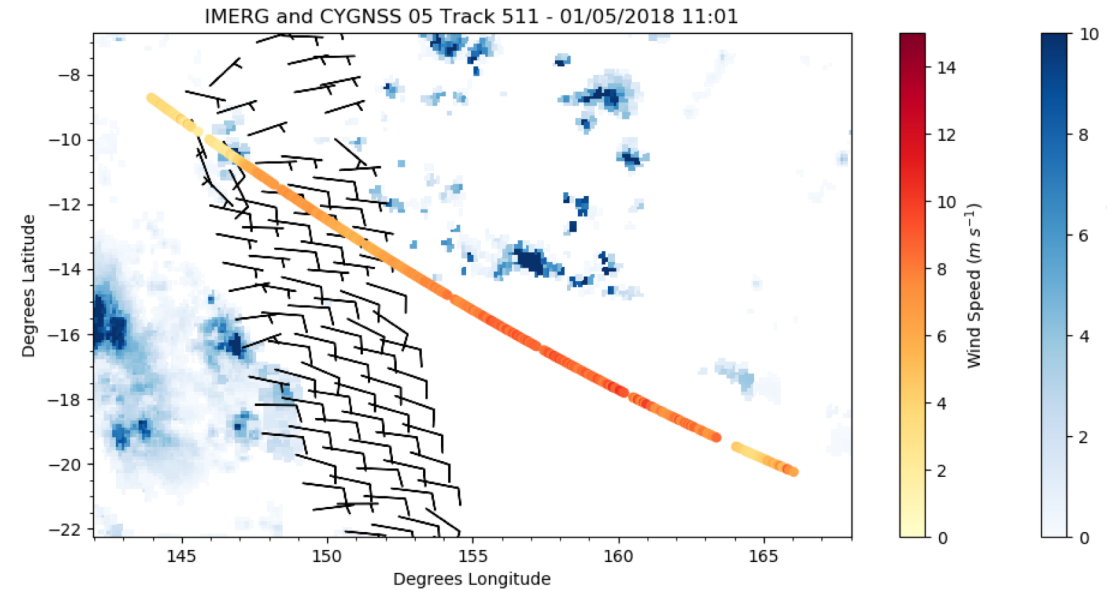


- January 2018 only, global analysis
- Agreement worse, *but not directly comparable to v2.0 analysis due to reduced sample size and addition of previously unavailable early January data.*
- CYGNSS still demonstrates added value under heavy rain



CYGNSS - ASCAT	Samples	Bias ($m s^{-1}$)	RMSE ($m s^{-1}$)
All	19042	-0.3	2.8
Rain	7644	-1.0	3.4
No Rain	11398	+0.2	2.3

Outside rain, ASCAT-CYGNSS comparison is quite good, but not so within rain



More V2.1 Comparisons with ASCAT

- Also see examples of potential miscalibration
- Good correlation outside of rain, but clear offset
- ASCAT stronger than CYGNSS, or visa versa
- May be a calibration offset, or a contribution from significant wave heights

Note: Excluding Block IIF

Note: Focused on track through heavy convection only

Assimilation of CYGNSS data for Hurricane Harvey (2017)

Objectives

1. Assimilation of CYGNSS v2 beta L2 windspeed data & v2.1 L2 windspeed data
2. Done to assess the impact of CYGNSS data on forecasts of Hurricane Harvey (2017), specifically on precipitation and mesoscale processes

LF – "Limited Fetch" Geophysical Model Function (GMF) used for Young Seas

FD – "Fully Developed"

v2 beta data Experiment – Hurricane Harvey

WRFDA hybrid En3DVar

WRF Domain: 9 km resolution (300x250x40)

WRF Simulation: 06 UTC 24 August – 00 UTC 1 September 2017 (before landfall to dissipation period)

Data: CYGNSS L2 wind speed

LF: High winds for young sea around Hurricane Harvey

FD: Fully developed sea other area

DA: v2 beta data: Continuous assimilation of CYGNSS data with 11 DA cycles from:

25 August – 31 August: 06 & 12 UTC August 25,

12 UTC August 27,

06 & 12 UTC August 28, 06 & 12 UTC August 29,

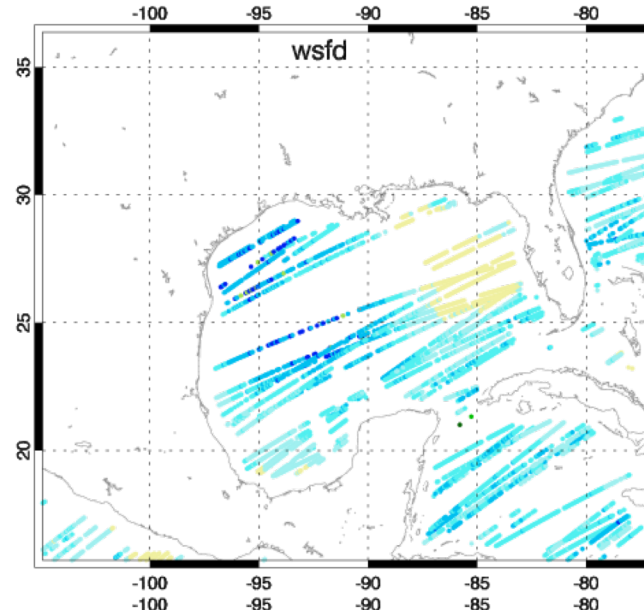
06 & 12 UTC August 30, 06 & 12 UTC August 31

Observational Error: 2 m/s for wind speed < 20 m/s

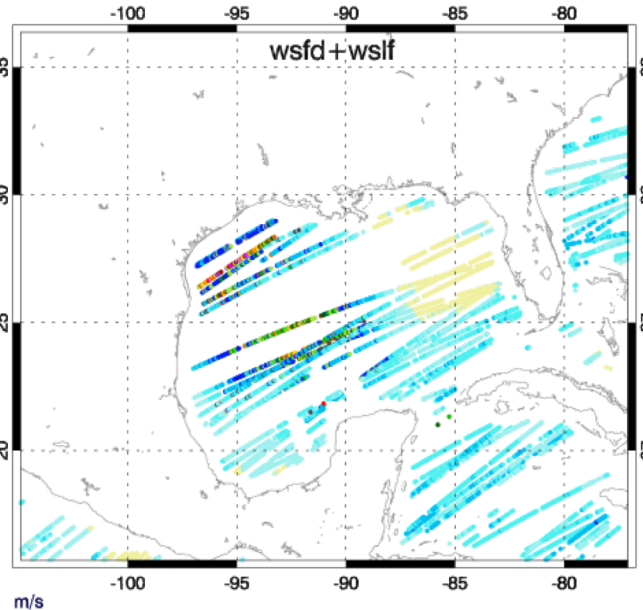
10% for wind speed > 20 m/s

CYGNSS v2 beta data

FD Data



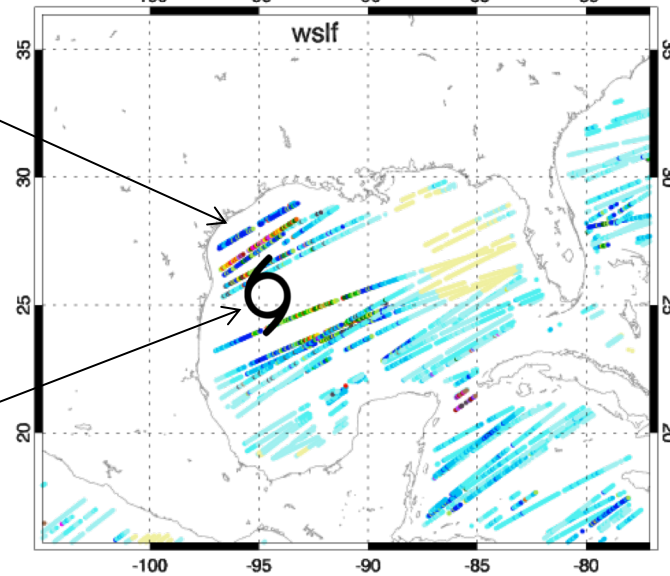
FD+LF Data



Higher wind in LF Data

LF Data

Harvey

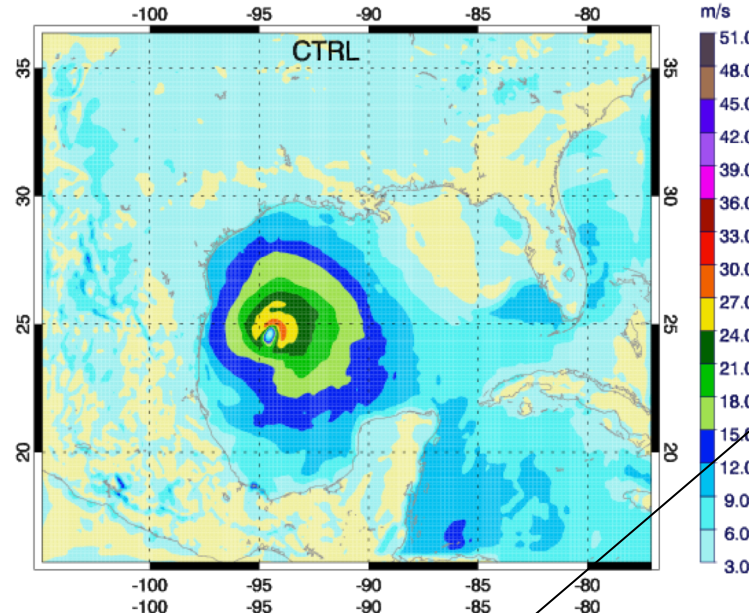


These use different GMF to retrieve winds.

0300-0800 UTC 2017-08-25

Wind speed increment from the 1st DA cycle

Control

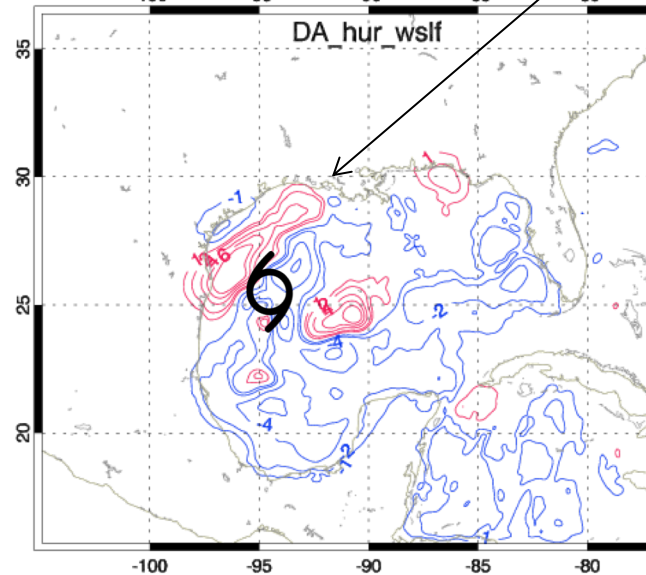


Higher impact has been found when assimilating LF wind around Hurricane Harvey.

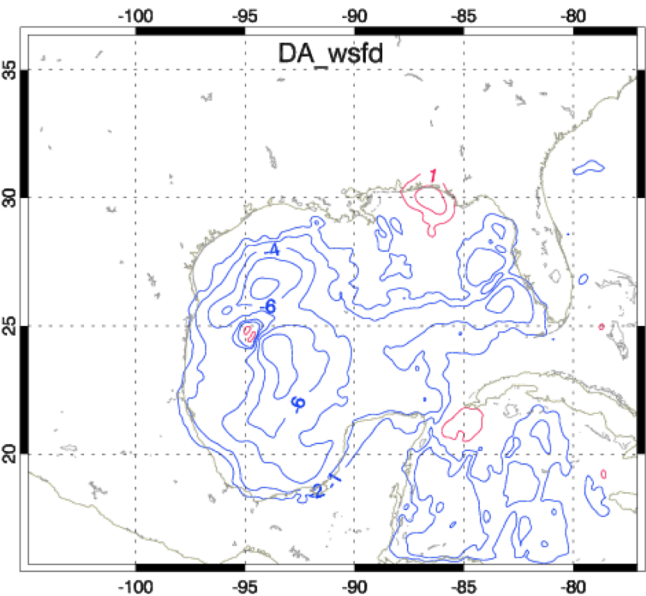
LF data behaving better than FD data

Less impact of assimilating LF data if Harvey was too close to land (obvious)

LF Data

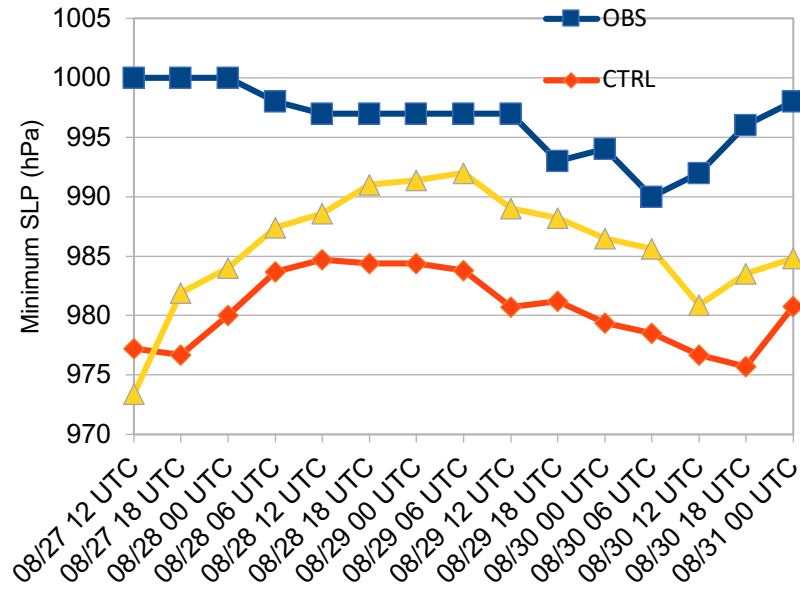


FD Data

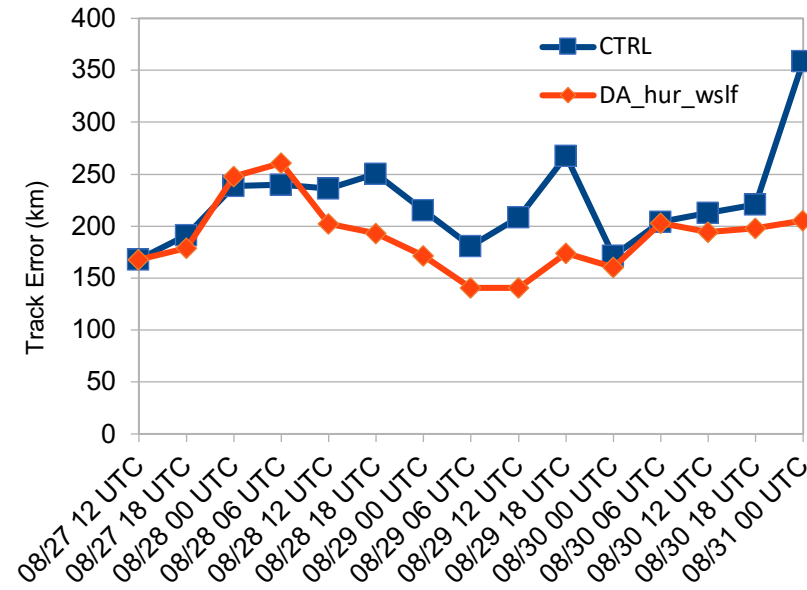


0600 UTC 2017-08-25

v2 beta data impact: Intensity and Track



Minimum Sea Level Pressure (hPa)

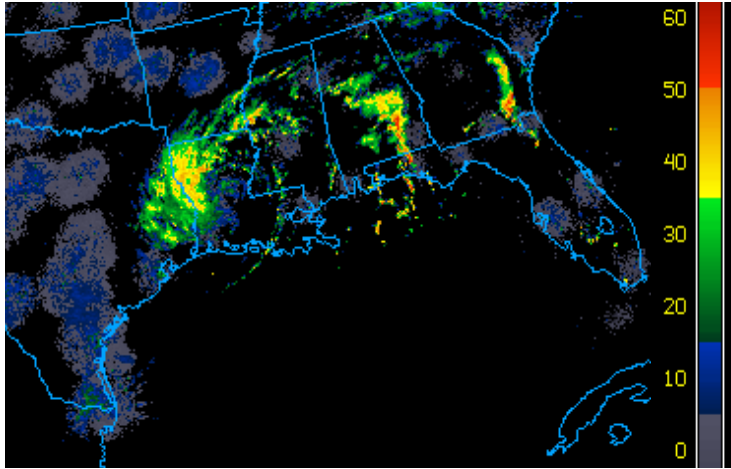


Track Error (km)

- Positive impact from CYGNSS data in intensity forecast.
- Improvement in track forecast after August 28th: ~50 km improvement

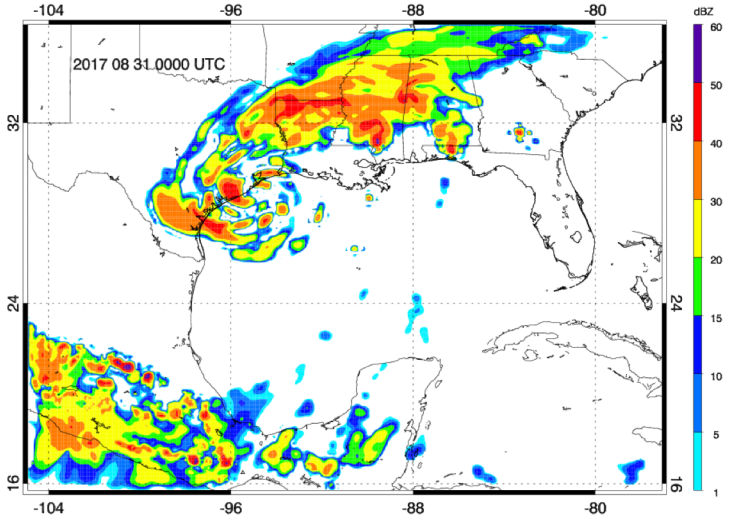
v2 beta data impact: Reflectivity

NEXRAD

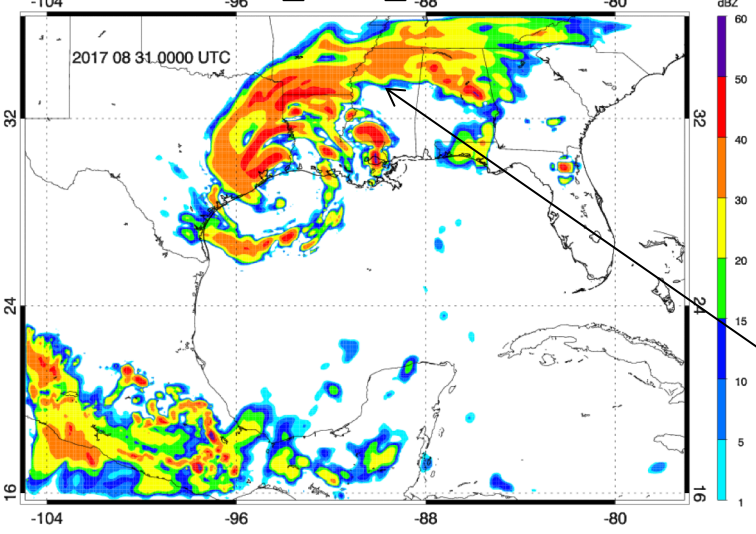


NOAA

CTRL



DA_HUR_WSLF



Less false-alarm rain, yet impact is small by this time

6 Days after CYGNSS DA

00 UTC 2017-08-31

CYGNSS v2 beta data impact: Precipitation

**Threat Scores (threshold = 2 mm/hr)
Against IMERG Rainrate**

Time	CTRL	DA_HUR_WSLF
00 UTC 8/31/2018	0.16	0.18
06 UTC 8/31/2018	0.10	0.11
12 UTC 8/31/2018	0.10	0.12
18 UTC 8/31/2018	0.12	0.18

Positive impact of CYGNSS data in precipitation forecast: 10-15% improvement

v2.1 data assimilation Experiment

WRFDA hybrid En3DVar

Focusing on pre-landfall period with rapid intensity change, using better initial condition at 00 UTC 25 August 2017

WRF Simulation: 00 UTC 25 August – 00 UTC 27 August

v2.1 data + conventional data: 4 DA cycles:

06 & 12 UTC 25 August

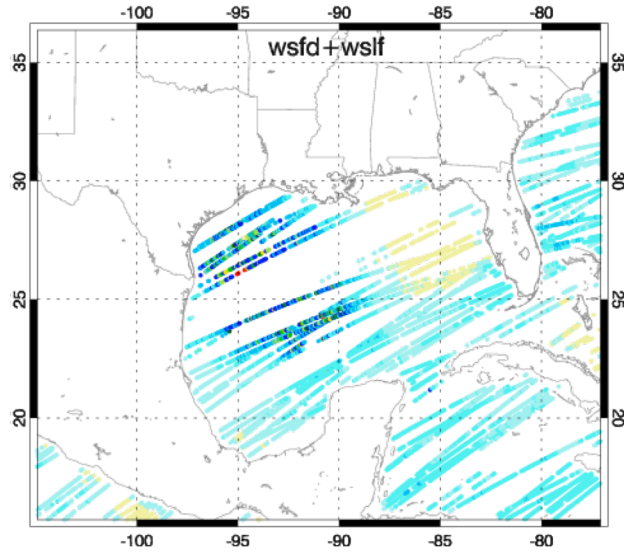
06 & 12 UTC 26 August

Observational Error: 2 m/s for windspeed < 20 m/s

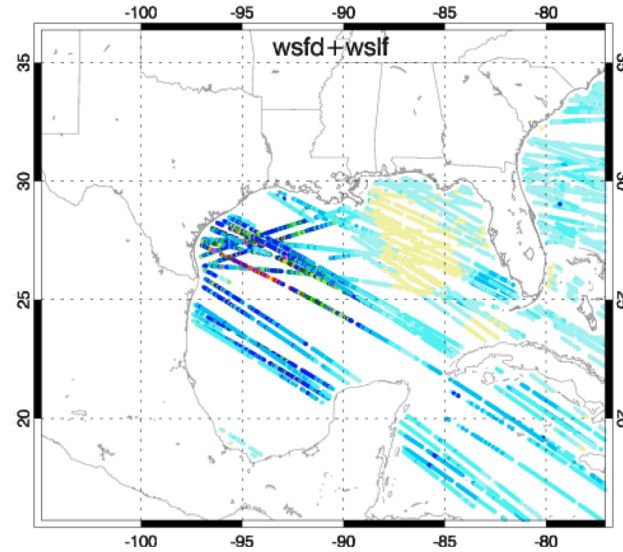
10% for windspeed > 20 m/s

CYGNSS v2.1 data: 2018/07/25 – 2017/08/26

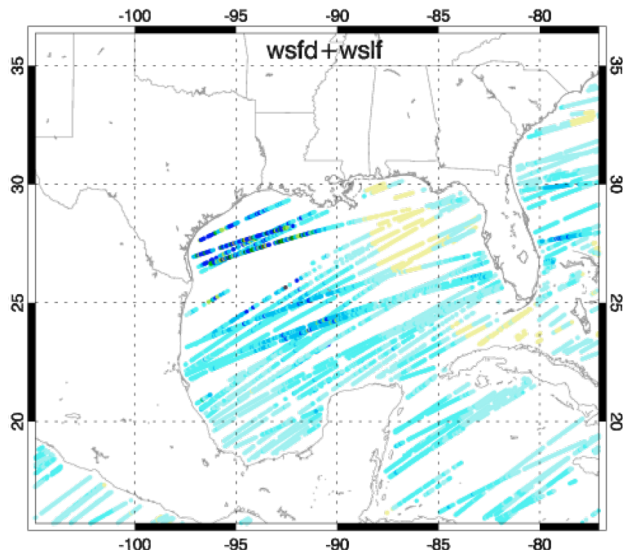
0400 – 0800 UTC 2017-08-25



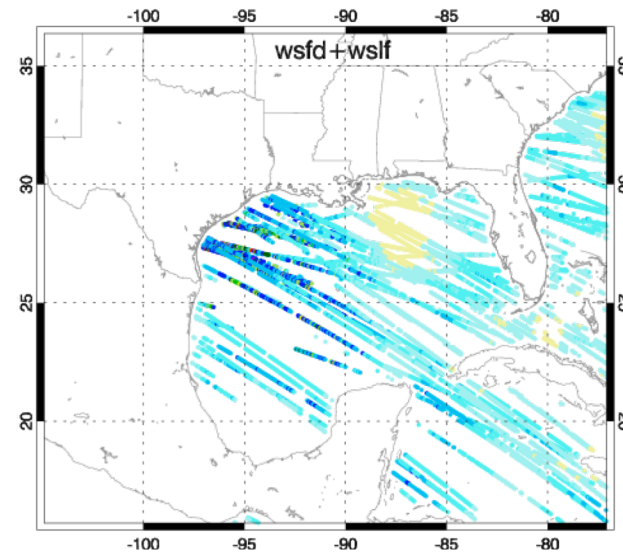
1000 – 1400 UTC 2017-08-25



0400 – 0800 UTC 2017-08-26



1000 – 1400 UTC 2017-08-26

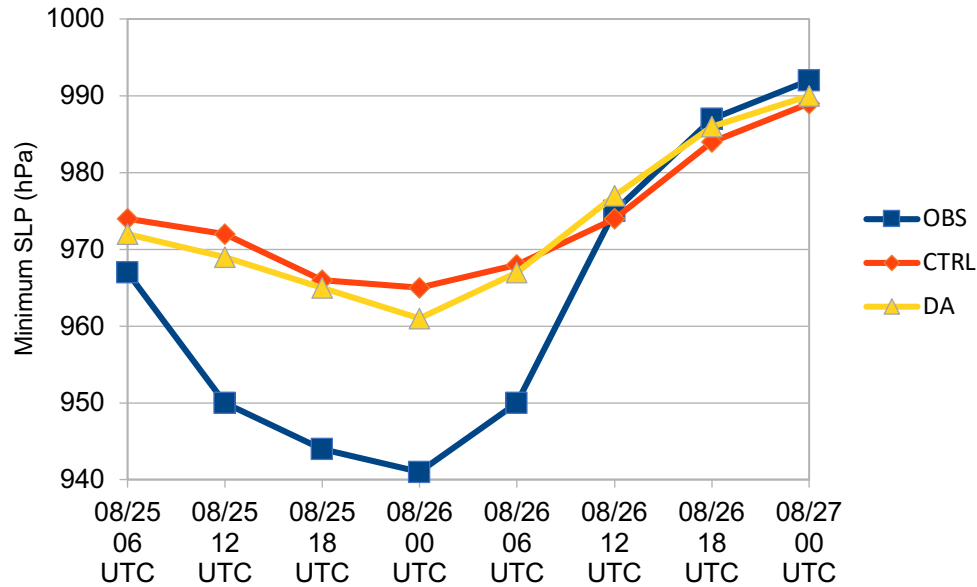


**+/-2 hours around
analysis time**

**CYGNSS LF NBRCS
data assimilated at
these 4 times**

**More data
available
than v2 beta data**

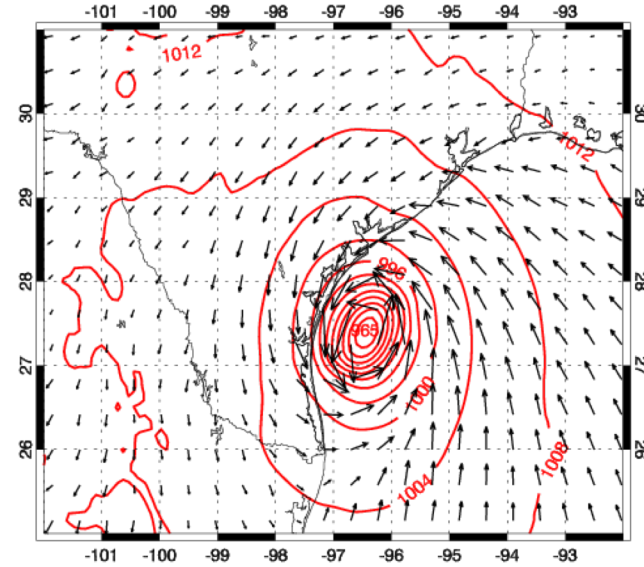
v2.1 data impact: Intensity and Track



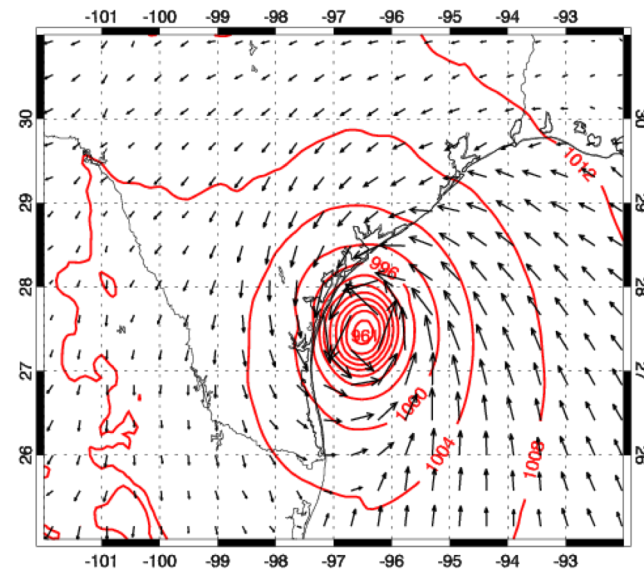
Stronger storm in DA_HUR_WSLF

Small positive impact of CYGNSS v2.1 data in intensity forecast.

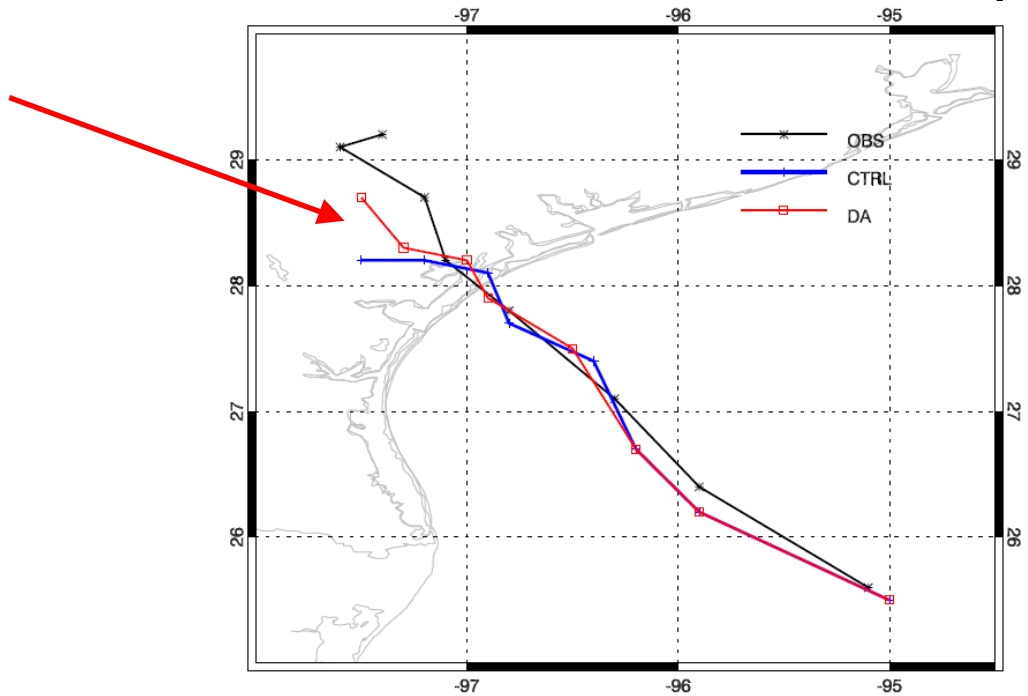
Control on 25th



Data Assimilation

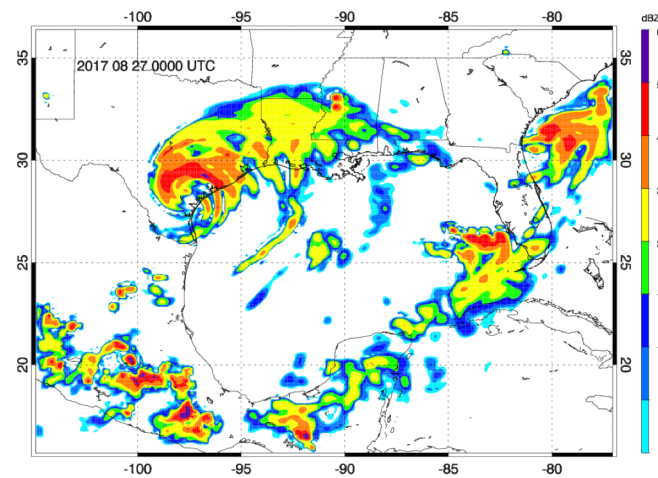
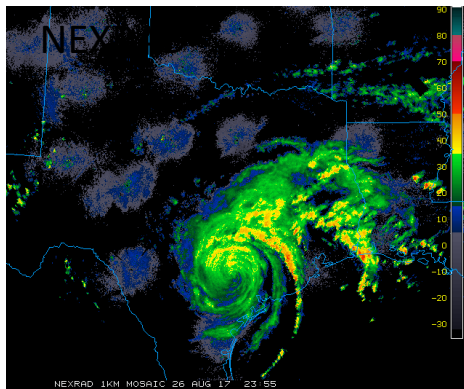


V2.1 data impact: Track and Precipitation

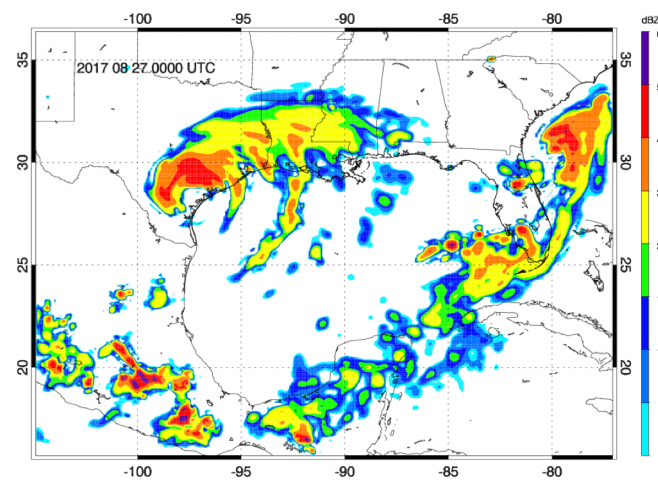


Period of Simulation:
06 UTC 25th to 00 UTC 27th

NOAA



Control on 25th



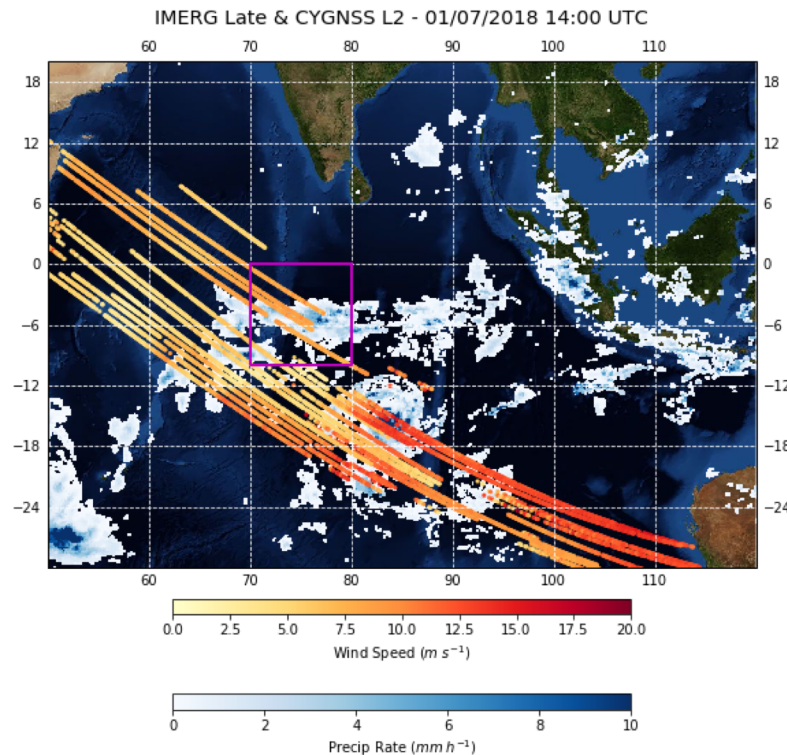
Data Assimilation

Improved track forecast has been found when assimilating v2.1 data

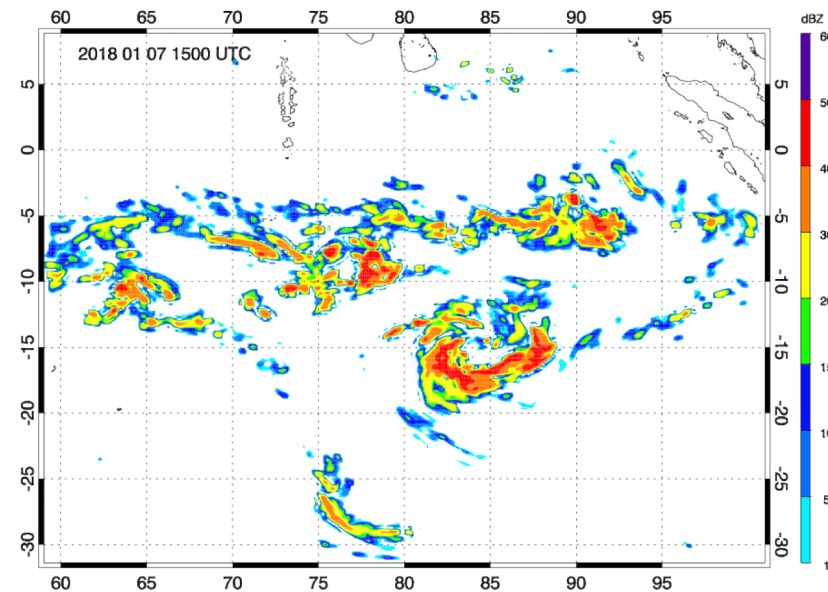
Ongoing and Future Work

- Perform continuous assimilation of v2.1 L2 wind data
- Focus next on the January 2018 MJO event
- Consider WWB on 2018/01/06 – 2018/01/08, and Tropical Cyclone Irving
- Same times as ASCAT–CYGNSS comparison
- CYGNSS wind speed comparisons against buoy wind data

IMERG rain + CYGNSS wind



WRF model precipitation



Summary

- Track-based analysis demonstrates results consistent with pre-launch E2ES predictions
- CYGNSS observes wind gradients in and near heavy rain quite well
- Comparison with ASCAT shows value of CYGNSS in rainfall, and also indicates calibration issues with certain tracks
- Eulerian approach suggests convective variability, but sample numbers significantly limited, especially when excluding Block IIF GPS. Lagrangian appears to be a better way to look at ASCAT–CYGNSS comparison (larger sample sizes, no issues of observatory differences, fewer issues with bias offsets)
- CYGNSS v2.1 data observes January 2018 MJO onset and associated WWB
- v2.1 data improve Harvey simulation, particularly due to increased samples compared to v2
- Use of v2.1 LF wind speed data provide highest impact in WRF En3DVar data assimilation experiments in terms of tropical cyclone intensity and track location