Exploring the utility of the planned CYGNSS mission for investigating the initiation and development of the Madden-Julian Oscillation

Timothy J. Lang, John Mecikalski, Xuanli Li, Themis Chronis, Tyler Castillo, Kacie Hoover, Alan Brewer, James Churnside, Brandi McCarty, Paul Hein, Steve Rutledge

Background

One of the most distinctive signals of the Madden-Julian Oscillation (MJO) is the upscale development and organization of convection in the Indian Ocean.

Dynamics of the MJO (DYNAMO) campaign occurred in late 2011 – early 2012 to investigate this genesis stage. One of the best non-satellite wind datasets ever obtained over the ocean.

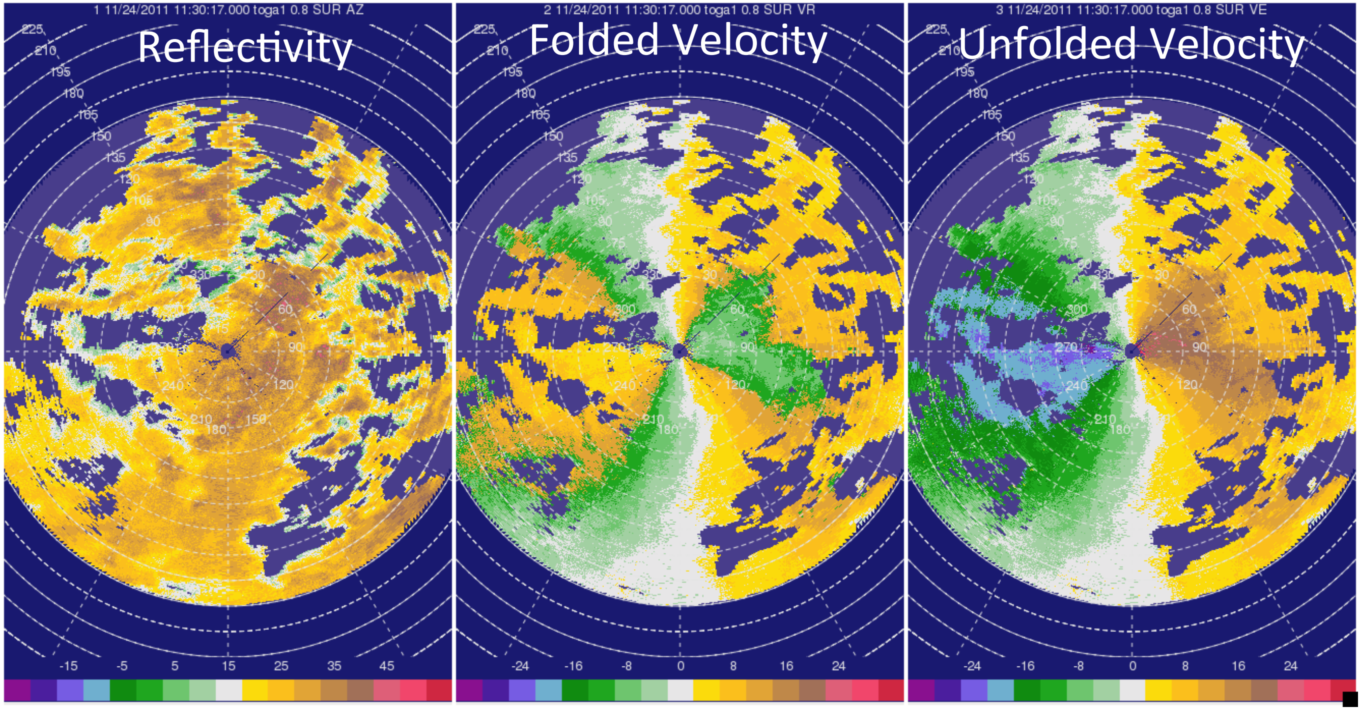
The Cyclone Global Navigation Satellite System (CYGNSS) mission can exploit this dataset to better understand the performance of the satellite constellation in regions of deep convection, in particular for characterizing the MJO.

Three Scientific Objectives

1. Produce a high-resolution surface wind dataset for multiple MJO onsets using WRF-assimilated winds and other data from DYNAMO.

2. Use the DYNAMO datasets, along with available scatterometer observations, to study the causes and impacts of wind variability at spatial and temporal scales finer than those planned to be provided by CYGNSS, and the implications of these processes for CYGNSS observations.

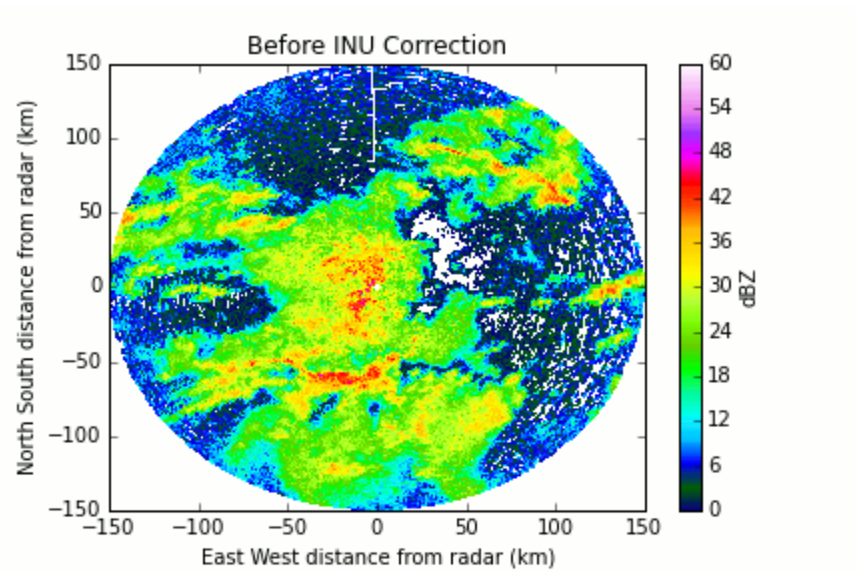
3. Using a simulated CYGNSS dataset for the MJO, perform observing system simulation experiments to determine the benefits of CYGNSS for improving scientific understanding and forecasting of the MJO, particularly its genesis over the Indian Ocean.

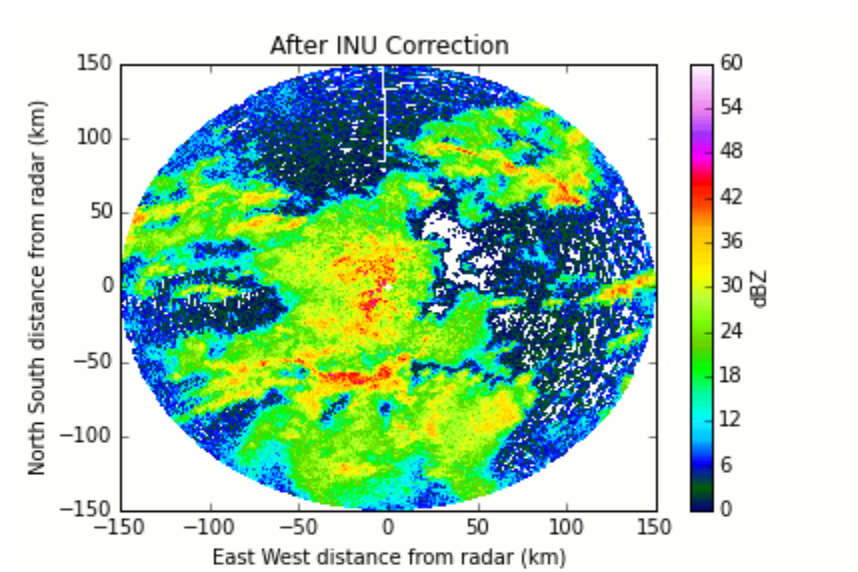


TOGA Radar QC

On *Roger Revelle* during DYNAMO

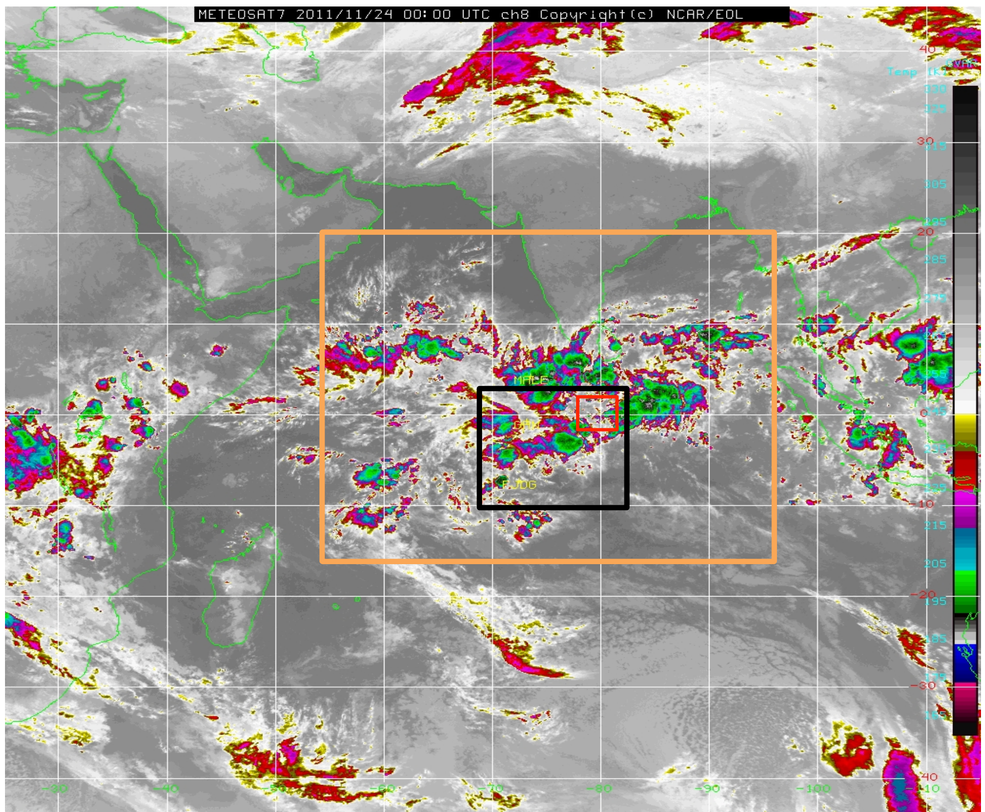
Velocity dealiasing and INU error correction





WRF Model Setup

- Advanced Research WRF
- A: 9-km resolution Indian Ocean domain
- B: 3-km DYNAMO quadrilateral domain
- C: 1-km high-resolution domain focused on Revelle
- 40 sigma levels (more levels in lower troposphere)
- Nested 9-3-1 km runs, plus separate 3- and 1-km runs
- Background runs successfully resolve mesoscale features for MJO events
- Focus on late October, late November, late December 2011 MJO onsets

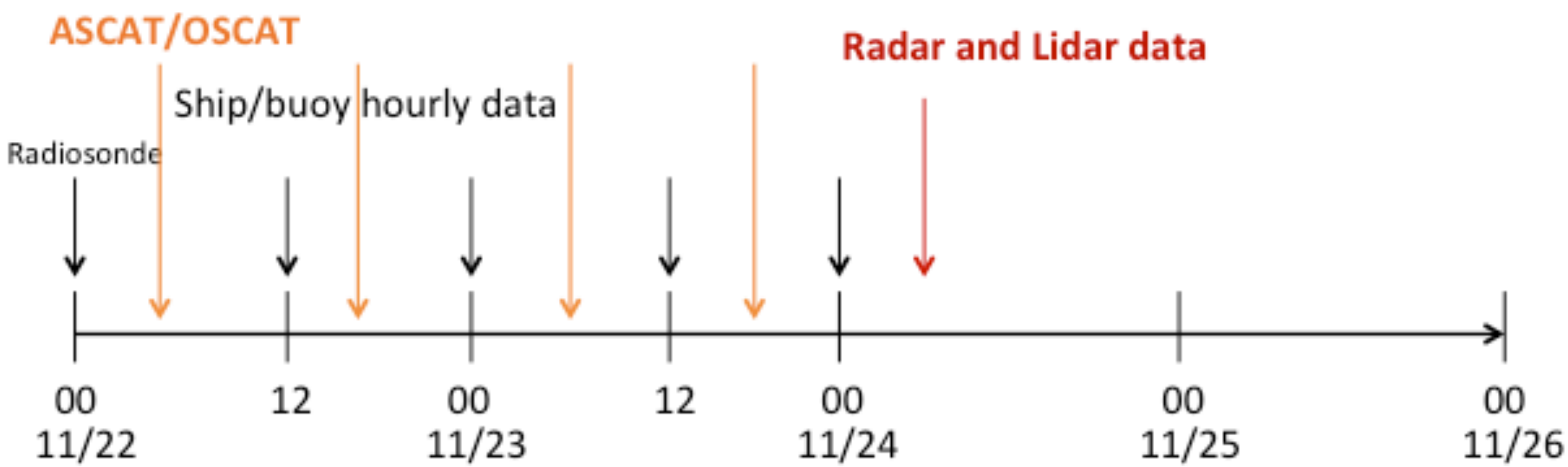


WRF 3DVAR Progress

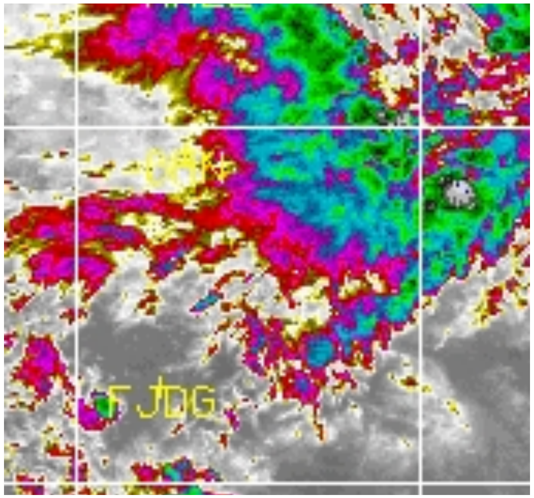
- Finalizing WRF runs for B/R matrices generation
- Assimilation tests underway

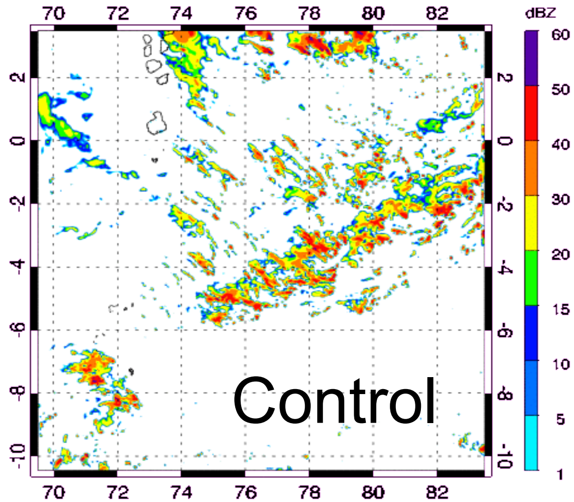
Assimilation Datasets

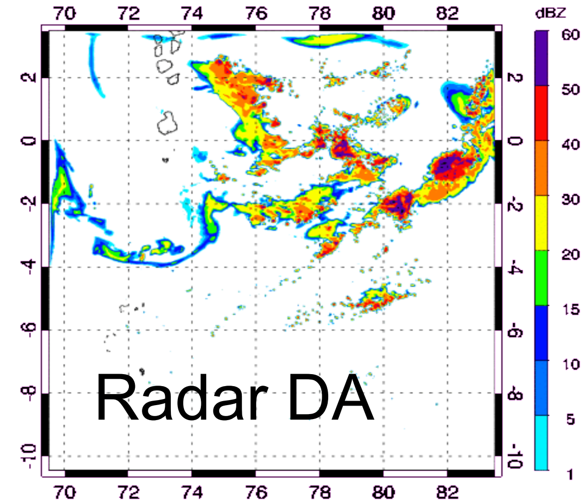
- Radars - TOGA, Mirai, S-PolKa
- Soundings
- Surface, Ship, and Buoy observations
- ASCAT/OSCAT
- HRDL



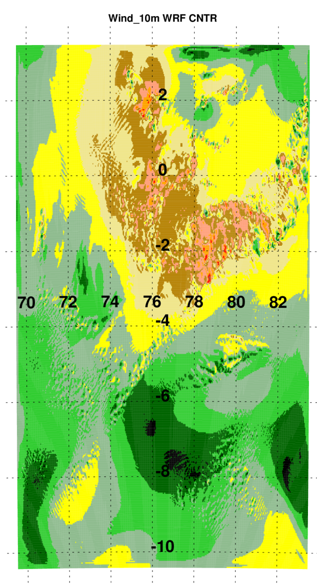
Preliminary Radar Data Assimilation Results
2011-11-24 0800 UTC

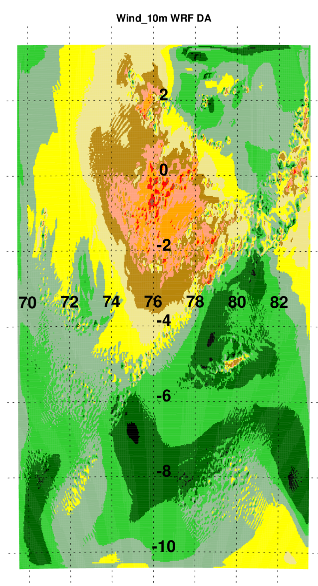


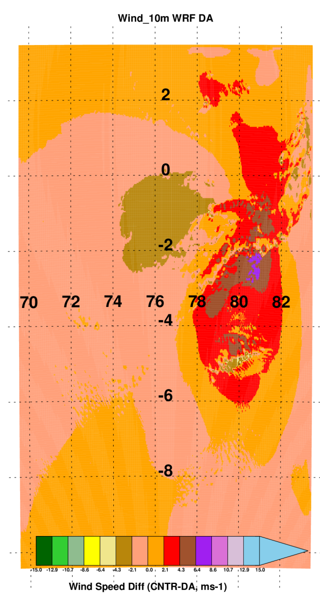




- Results suggest large impacts from assimilating just TOGA data
- Improvements in precip system structure seen



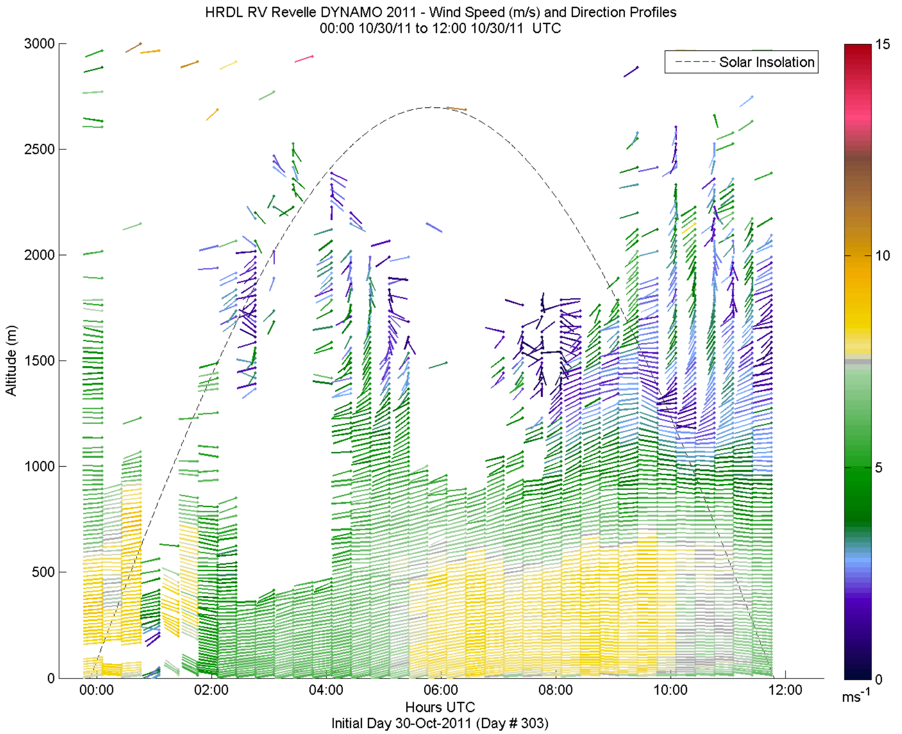




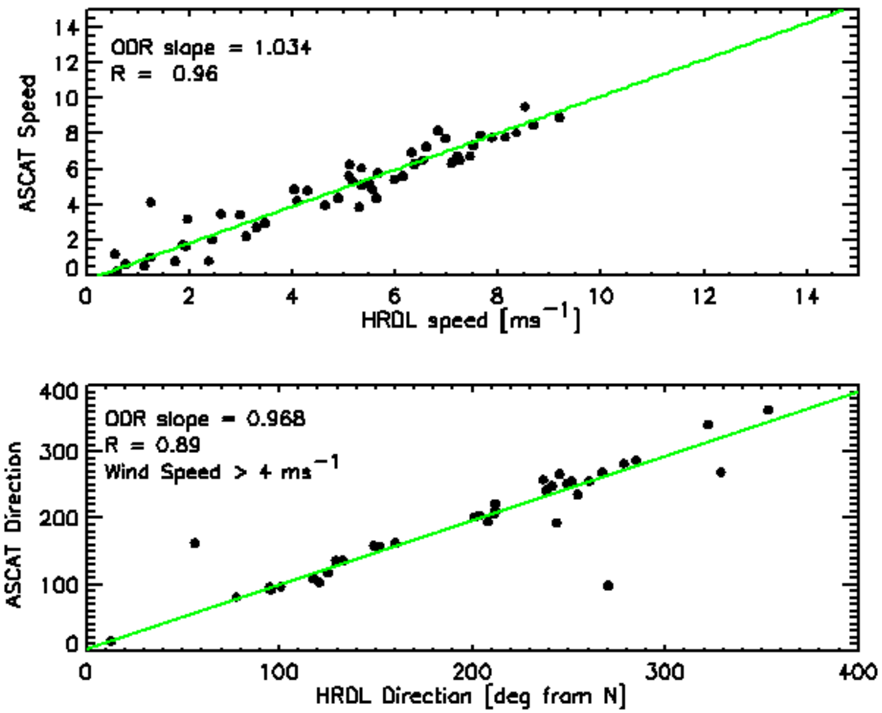
NOAA High-Resolution Doppler Lidar (HRDL)

- On Revelle for Cruises 1-3 (1 September - 6 December 2011)
- HRDL scanning ability provided 20-min averaged vertical profiles of wind speed and direction from 12.5 m to ~2000 m
- 12.5-m gate used to compare HRDL to scatterometers (OSCAT and ASCAT)
- Examine relationship between winds and mean square slope as Richardson number varies

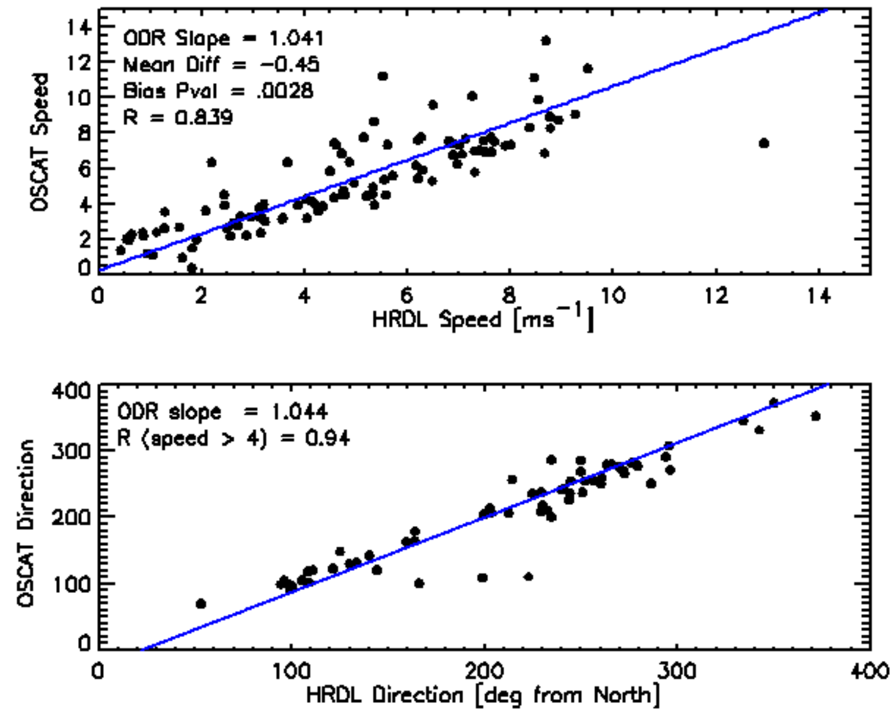
$$Ri = \frac{g\left(T_a - T_w\right)z}{T_w U_z^2},$$



ASCAT/HRDL



OSCAT/HRDL



Preliminary Results

- Richardson number always negative for DYNAMO (unstable)
- ASCAT matches HRDL better than OSCAT

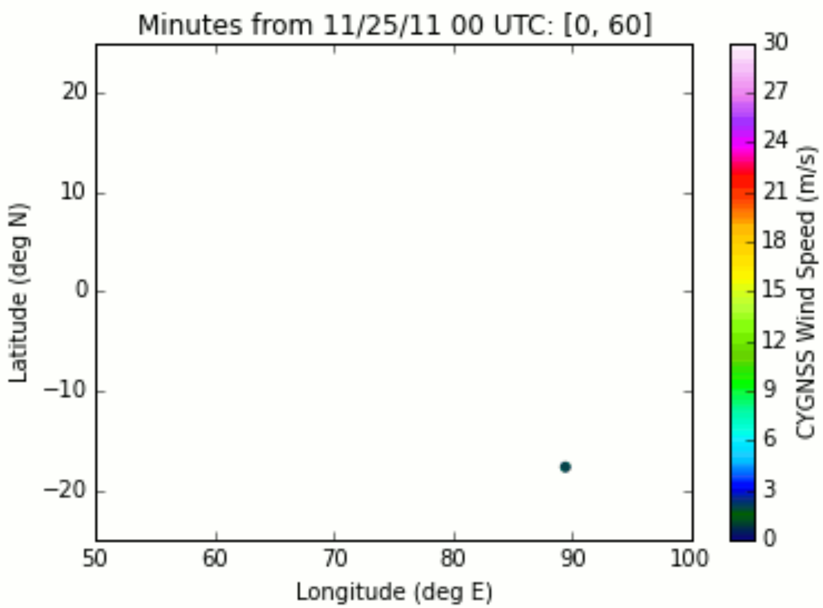
CYGNSS E2ES Test Run

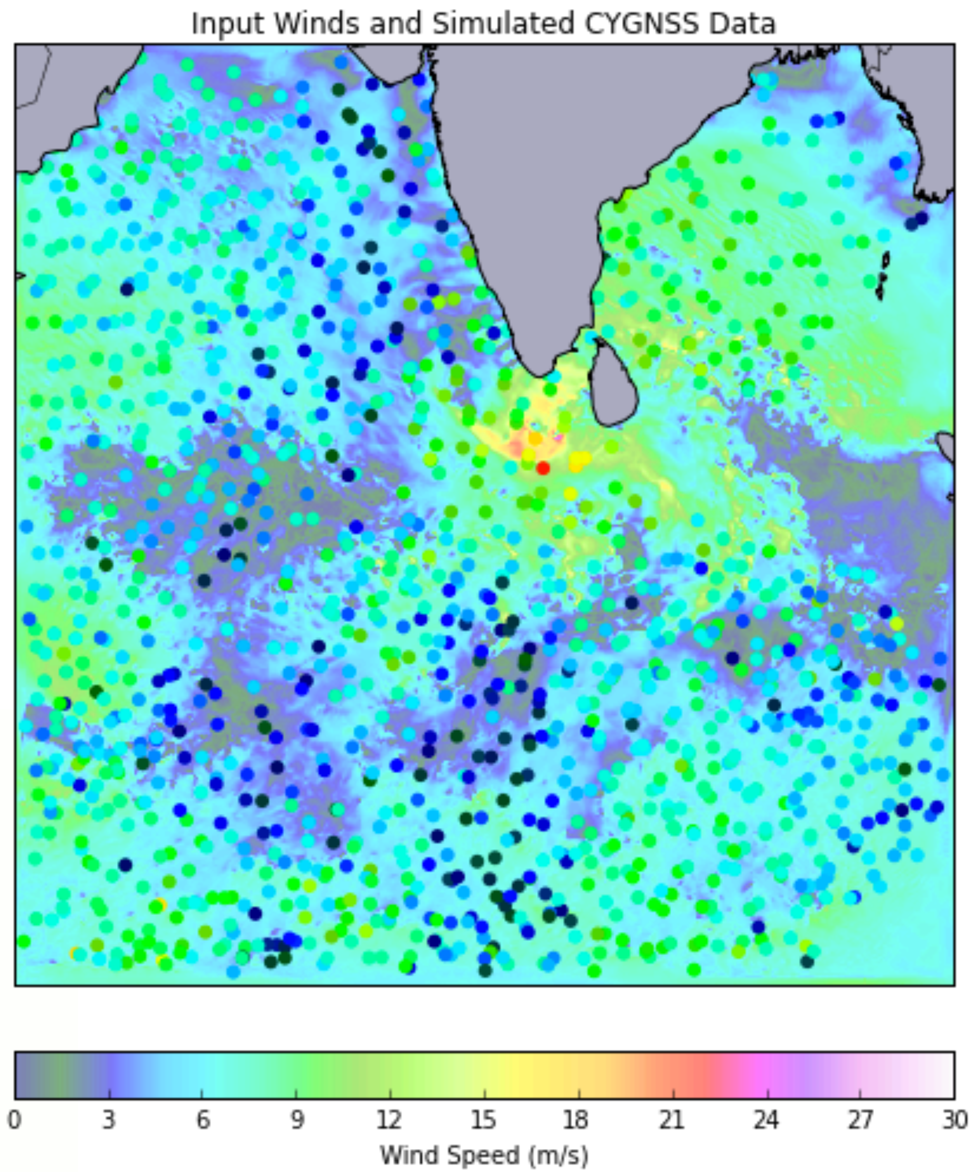
WRF simulation of November 2011 MJO onset

11/25/2011 Background 10-m Winds

View of soon-to-be JWTC Tropical Storm 05A

24-h, 1-min resolution



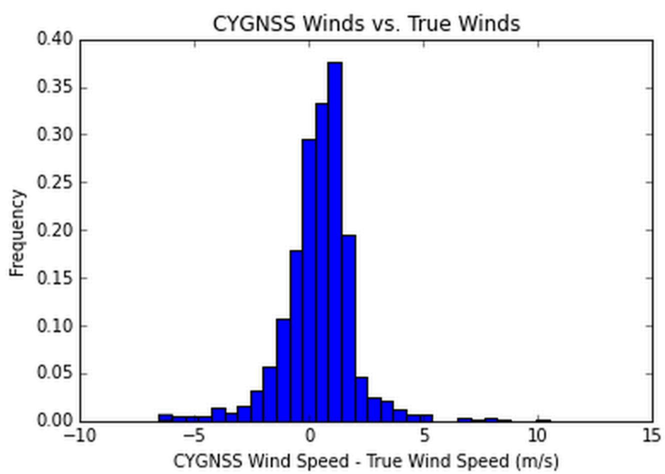


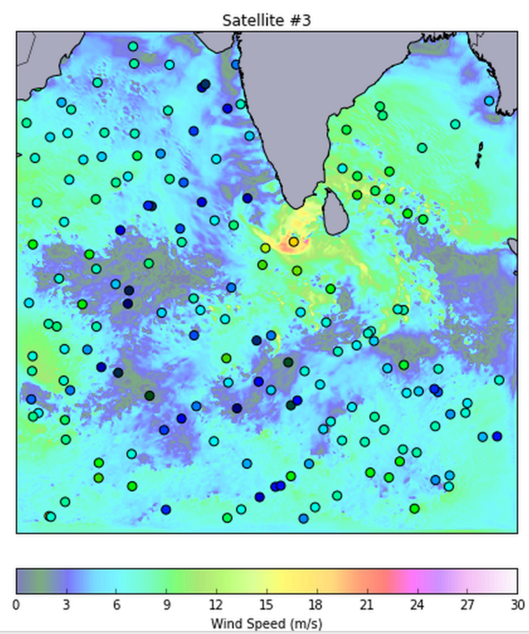
CYGNSS E2ES Python Toolkit

- Supports reading/analyzing/plotting of E2ES input and output data
- Complex plots and analyses in just a few lines of code
- Can isolate single satellites or specific time periods
- Object-oriented, scalable
- Model for Python-based analysis of future CYGNSS data?

In [17]:
```
lgist = lighten_cmap(plt.cm.get_cmap('gist_ncar'))
fig = plt.figure(figsize=(8,8))
input_display = pygnss.InputWindDisplay(input_files[11])
m = input_display.basemap_plot(title='Satellite #3', cmap=lgist)
ss_display = pygnss.CygnssL2WindDisplay(merged_data.satellites[2])
ss_display.specular_plot(cmap='gist_ncar', colorbar_flag=False, edge_flag=True,
                         title_flag=False, basemap=m)
```

In [18]:
```
merged_data = pygnss.CygnssMultiSat(output_L2_files)
display = pygnss.CygnssL2WindDisplay(merged_data)
display.histogram_plot(bins=30, axis_label_flag=True)
```





Summary and Future Work

- DYNAMO dataset nearly prepped for assimilation into WRF.
- WRF domains established and preparatory 3DVAR assimilation matrices nearly finalized.
- Initial assimilation testing suggests realistic background runs receive large impacts from radar data.
- HRDL/scatterometer comparison suggests good overall performance, with ASCAT (C-band) better than OSCAT (Ku-band). Continue examining Richardson number relationship to MSS.
- E2ES working on WRF output, Python module developed.
- Objective #3 (OSSEs focused on MJO) – Work planned latest this year into next. MJO Nature Run?