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

Timothy J. Lang (NASA MSFC)

John Mecikalski, Xuanli Li, Themis Chronis (UAH)

Alan Brewer, Jim Churnside, Brandi McCarty (NOAA ESRL)

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.

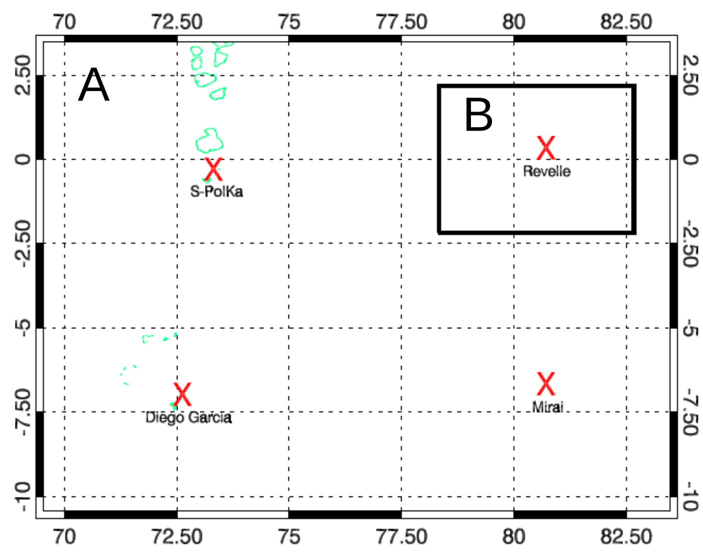
2. Use the DYNAMO datasets, along with available scatterometer observations, to study the causes and impacts of wind variability at spatial and temporal scales finer than those planned to be provided by CYGNSS, and the implications of these processes for CYGNSS observations.

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.

WRF Model Simulation and Assimilation of DYNAMO Data

WRF model

- Advanced Research WRF v3.5.1
- A: 3-km resolution DYNAMO domain
- B: 1-km high-resolution smaller domain
- 40 sigma levels (more levels in lower troposphere)
- Separate runs for domains A and B
- Mesoscale features for MJO events



WRF model domain setup

WRF 3DVAR

Solve for Cost Function:

$$J = \frac{1}{2}\left(X - X_b\right)^T B^{-1}\left(X - X_b\right) + \frac{1}{2}\left(Y - H(x)\right)^T R^{-1}\left(Y - H(x)\right)$$

Background Error Matrix: NMC Method

$$\overline{[X^f(T+24) - X^f(T+12)][X^f(T+24) - X^f(T+12)]^T}$$

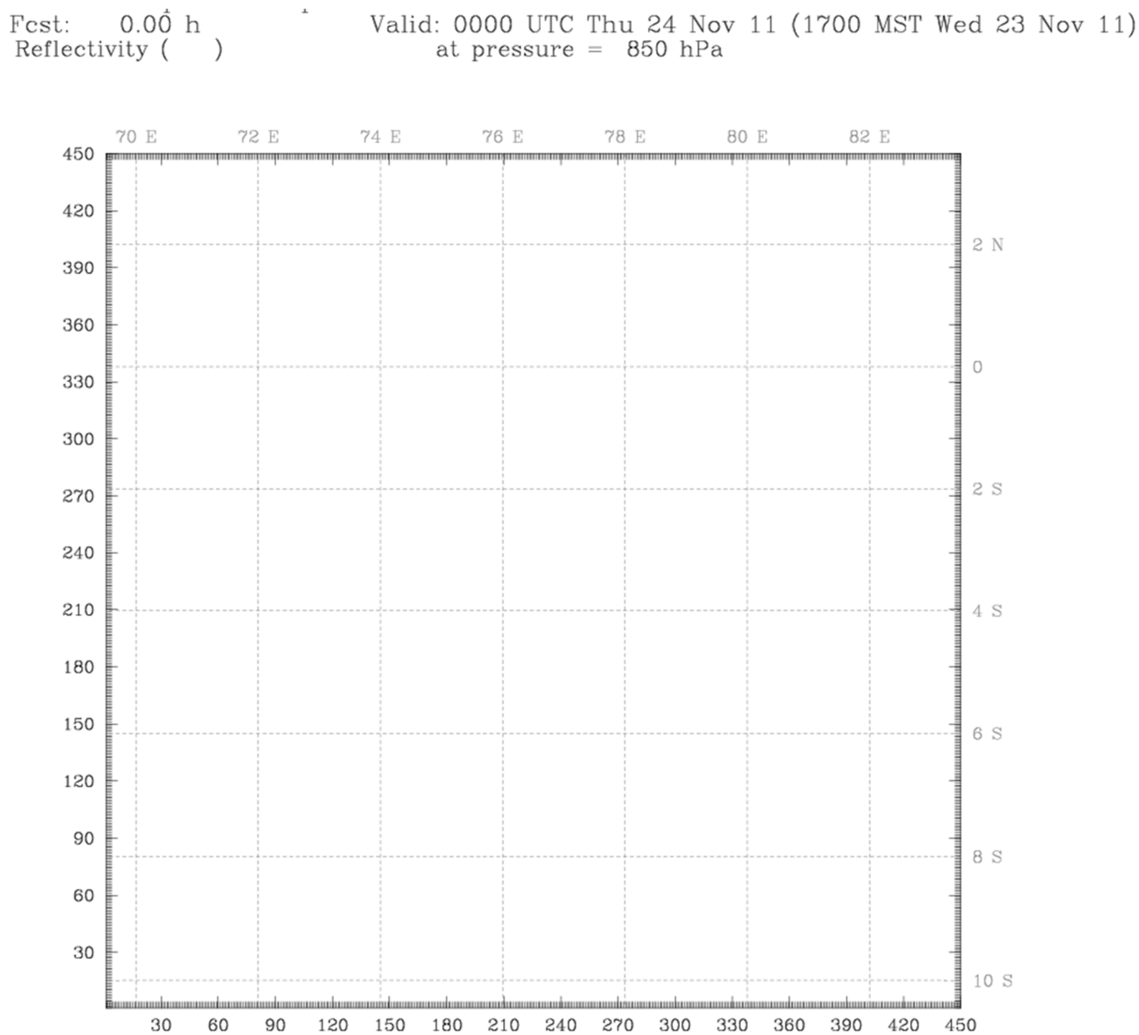
Assimilation Plan:

- Cycled assimilation of available sounding, dropsonde, surface, buoy, radar, lidar, scatterometer data into both domains using WRF 3DVAR

Progress:

- Conducting WRF runs for B matrix generation
- Processing the observational data and prepare for assimilation

WRF Simulation on 3-km grid (2011-11-24)

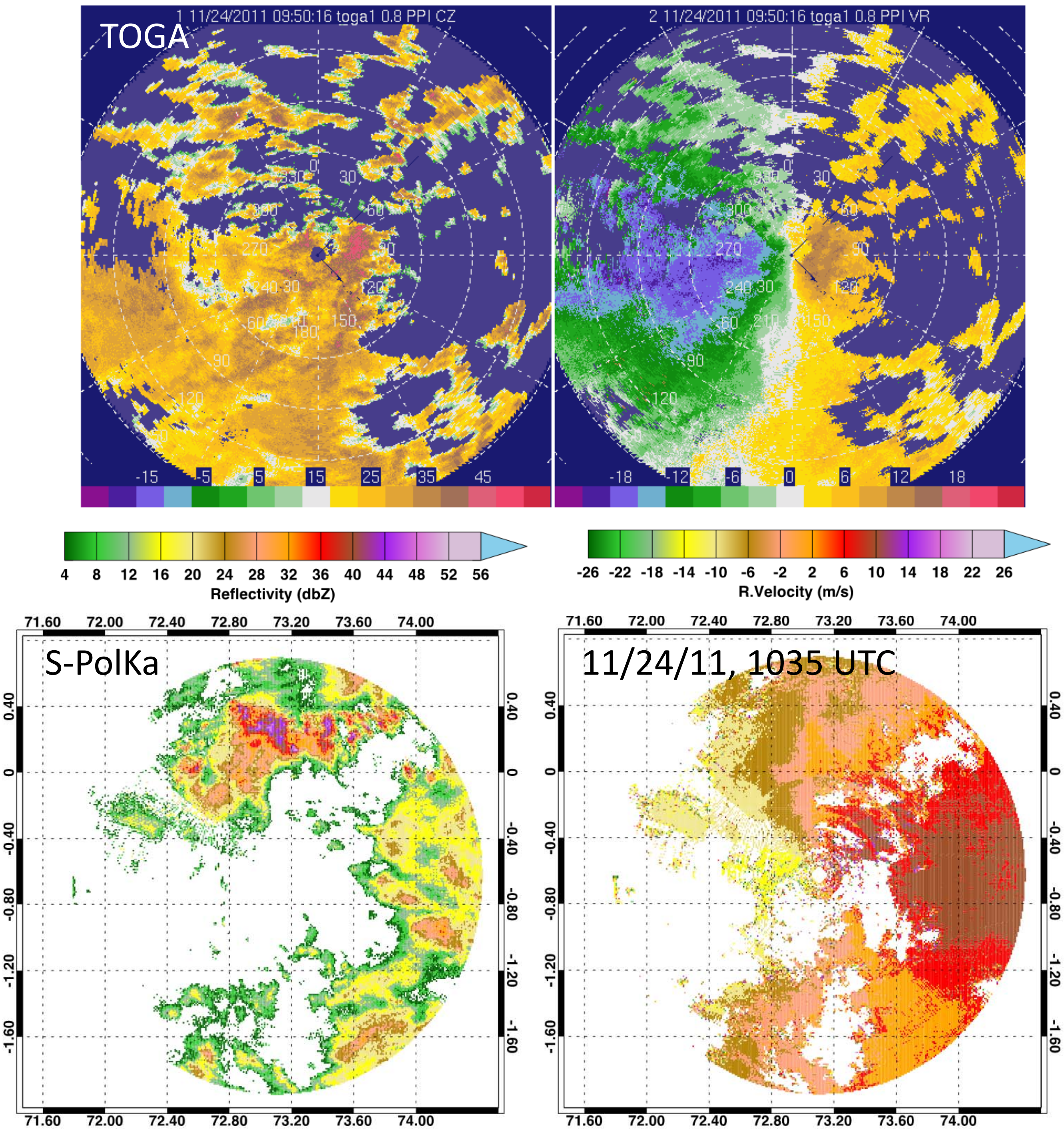


Focusing on roughly last two weeks of each DYNAMO month:

1. November 2011
2. October 2011
3. December 2011

Will produce hi-res wind maps for each of these periods, at least 3-km resolution, 0.5-1 h time steps

Use these maps to study wind variability at time and spatial scales smaller than CYGNSS can provide



DYNAMO Radars

NASA TOGA (Revelle)
Mirai C-band
SMART-R (Gan)
NCAR S-PolKa (Gan)

Assimilate radial velocity into WRF, will also test reflectivity

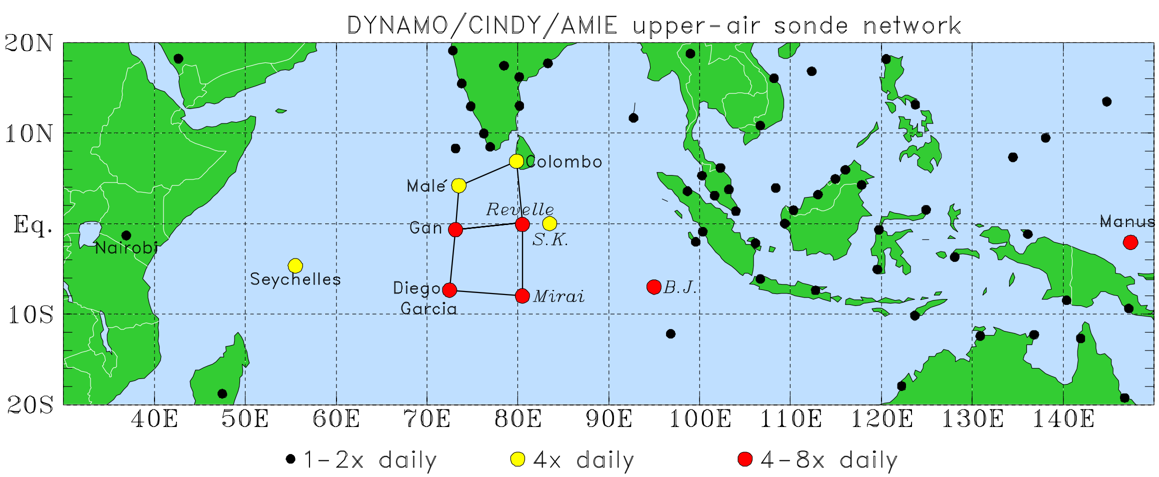
Most QC done, working with CSU and Texas A&M to de-alias the TOGA and SMART-R velocities, and also fix some azimuthal errors with TOGA

Other DYNAMO datasets

- Radiosondes
- Dropsondes (P-3)
- Surface/buoy/ship-based meteorological observations

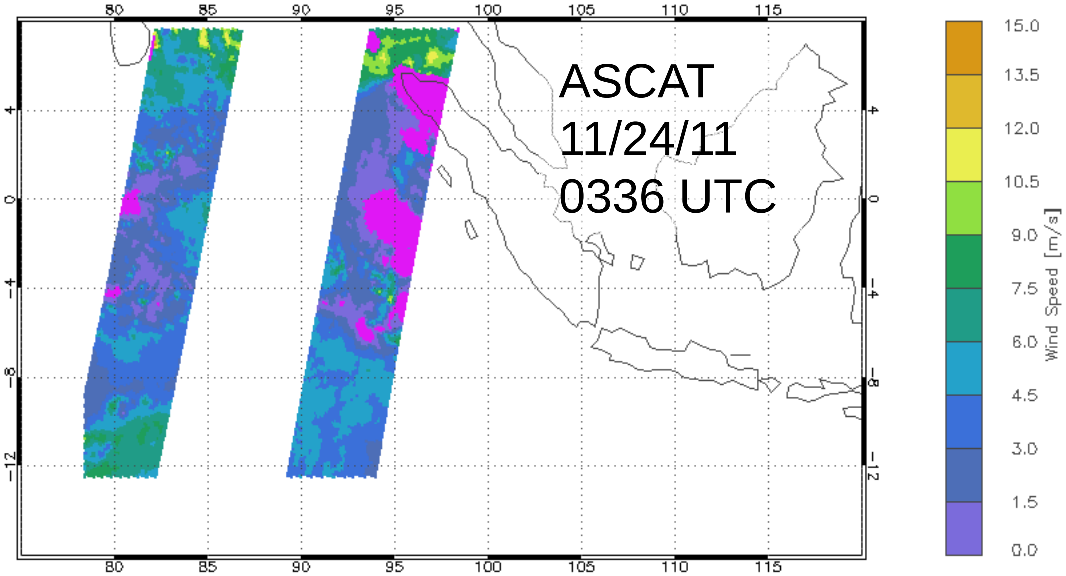
Straightforward assimilation process for WRF 3DVAR

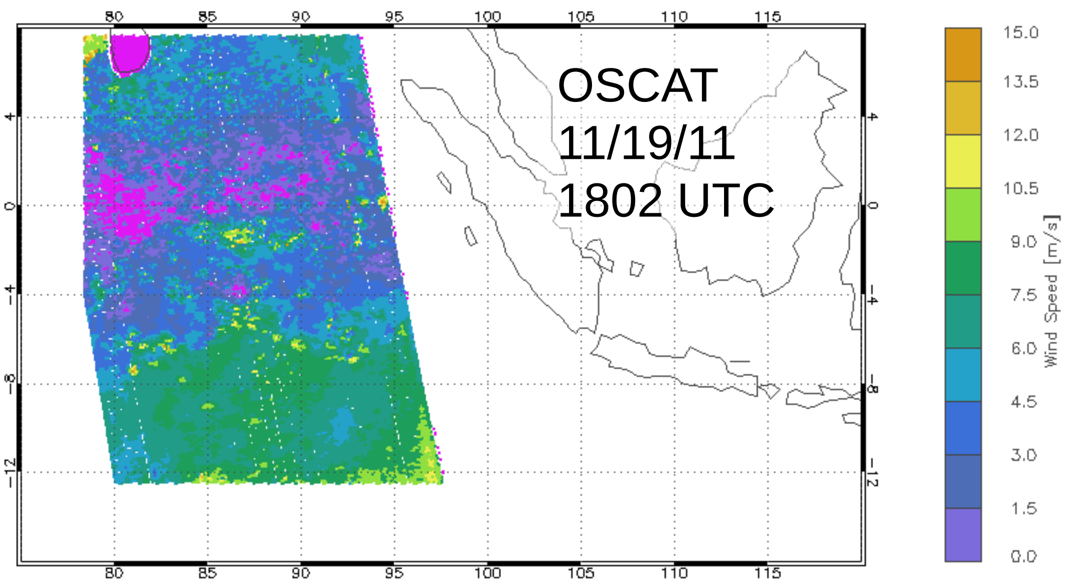
DYNAMO/CINDY/AMIE SOUNDING NETWORK



DYNAMO/CINDY/AMIE sounding network for the period October-December 2011

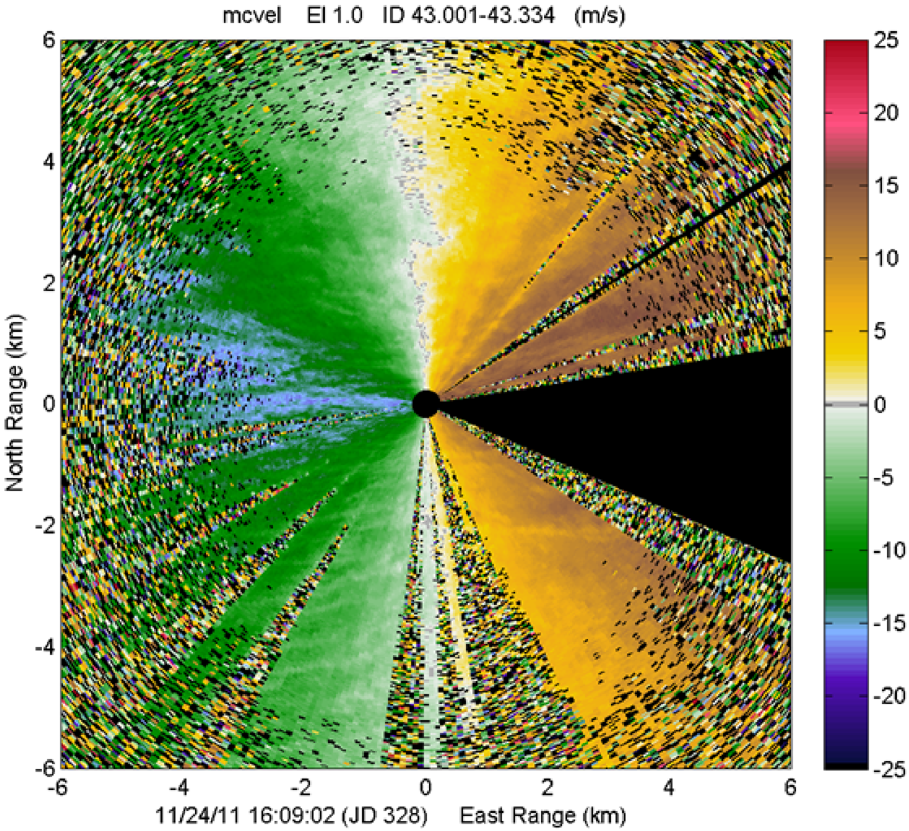
Johnson and Ciesielski (2012)

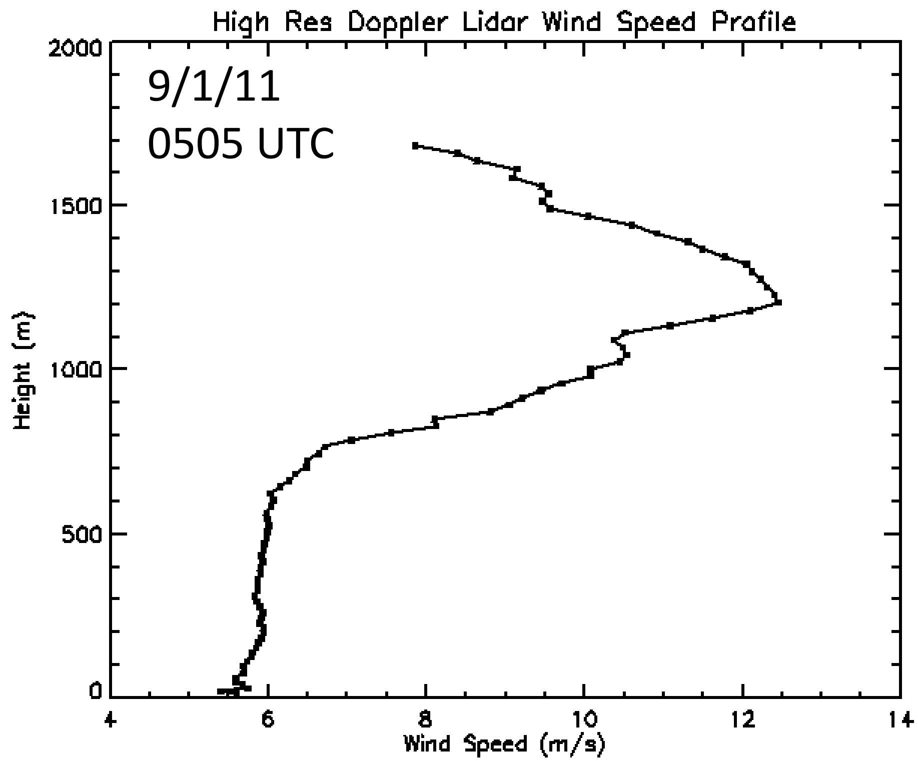




Scatterometer Vector Winds during DYNAMO

Assimilate when available, but also produce test dataset without these inputs but with rest of DYNAMO observations





NOAA High-Resolution Doppler Lidar (HRDL)

- On Revelle for Cruises 1-3 (1 September - 6 December 2011)
- Produced both vertical profiles (incl. ~15 m winds) and horizontally resolved data
- Test assimilation into WRF – try both polar-coordinate data and vertical profiles

NOAA Task - Compare OSCAT, ASCAT, Lidar winds

Create subsets based on wind speed (high or low) and atmospheric stability (stable or unstable), and compare winds within each subset

Though CYGNSS uses Fresnel reflection, and OSCAT/ASCAT use Bragg, comparison valid because both types of wind retrievals depend on sea-surface roughness, parameterized by the mean square slope (MSS).

Use TOGA to confirm HRDL view

Why do this?

MSS/wind speed relationship is not linear, and depends on atmospheric stability!

NEXT STEPS – Immediate future

Transfer funds to NOAA and UAH!

Incorporate CYGNSS science team feedback into analysis approach

De-alias SMART-R/TOGA velocities and correct occasional TOGA azimuthal errors

Prep other DYNAMO data for assimilation

Update WRF 3DVAR framework as needed to handle DYNAMO datastream

Test various assimilation schemes, determine which will be most useful, and execute

NOAA to begin HRDL/scatterometer comparison

Later – Use WRF to perform Observing System Simulation Experiments

Nature run TBD

<u>Goal</u>: Determine how best to assimilate CYGNSS winds into a limited-domain, cloud system resolving forecast model, and provide guidance to CYGNSS leadership on optimal data resolution.

Table 1. Proposed sample OSSE experiments under Objective 3.

Experiment	**Data Assimilation Focus**	**Model Domain**	**Horizontal Resolution**
Background	N/A	2- or 3-level nested domains	12-km, 4-km (also possibly 1.333-km)
CYG	CYGNSS data	2-level nested domains	12-km, 4-km
CYG_NoRain	CYGNSS data in heavy rain areas eliminated	2-level nested domains	12-km, 4-km
CYG_OBS	CYGNSS data, basic multi-platform obs	2-level nested domains	12-km, 4-km
OBS	Basic multi-platform obs	2-level nested domains	12-km, 4-km
OBS_DYN	Enhanced obs from DYNAMO-style instrument array	2- or 3-level nested domains	12-km, 4-km (also possibly 1.333-km)
CYG_HiRes	Higher-resolution, less accurate CYGNSS data	2- or 3-level nested domains	12-km, 4-km (also possibly 1.333-km)
Obs_Err	Sensitivity exp with different observation error setup	2-level nested domains	12-km, 4-km
BG_Err	Sensitivity exp with different background error setup	2-level nested domains	12-km, 4-km