Analysis and modeling of tropical convection observed by CYGNSS

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Abstract

The Cyclone Global Navigation Satellite System (CYGNSS) is a multi-satellite constellation that utilizes Global Positioning System (GPS) reflectometry to retrieve near-surface wind speeds over the ocean. While CYGNSS is primarily aimed at measuring wind speeds in tropical cyclones, our research has established that the mission may also provide valuable insight into the relationships between wind-driven surface fluxes and general tropical oceanic convection. Currently, we are examining organized tropical convection using a mixture of CYGNSS level 1 through level 3 data, IMERG (Integrated Multi-satellite Retrievals for Global Precipitation Measurement), and other ancillary datasets (including buoys, GPM level 1 and 2 data, as well as ground-based radar). In addition, observing system experiments (OSEs) are being performed using hybrid three-dimensional variational assimilation to ingest CYGNSS observations into a limited-domain, convection-resolving model. Our focus for now is on case studies of convective evolution, but we will also report on progress toward statistical analysis of convection sampled by CYGNSS. Our working hypothesis is that the typical mature phase of organized tropical convection is marked by the development of a sharp gust-front boundary from an originally spatially broader but weaker wind speed change associated with precipitation. This increase in the wind gradient, which we demonstrate is observable by CYGNSS, likely helps to focus enhanced turbulent fluxes of convection-sustaining heat and moisture near the leading edge of the convective system where they are more easily ingested by the updraft. Progress on the testing and refinement of this hypothesis, using a mixture of observations and modeling, will be reported.

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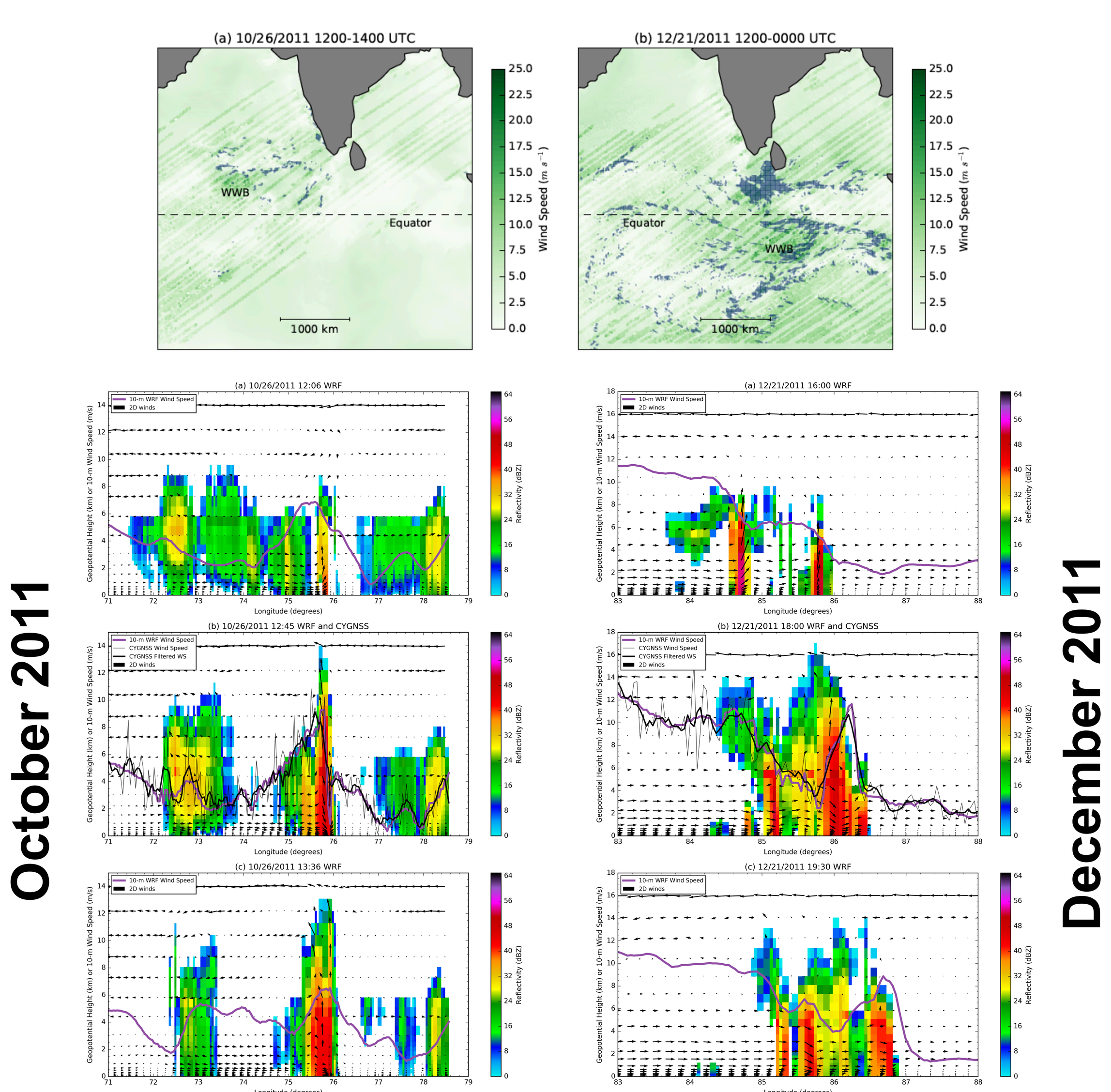
1. Introduction

The Cyclone Global Navigation Satellite System (CYGNSS) is a multi-satellite constellation that launched 15 December 2016. The primary objective of CYGNSS is to use bistatic Global Positioning System (GPS) reflectometry to accurately measure near-surface wind speeds within the heavily raining inner core of tropical cyclones.

CYGNSS also features rapid revisit times over a given region in the tropics - ranging from several minutes to a few hours, depending on the constellation geometry at that time. Despite the focus on tropical cyclones, the ability of CYGNSS to provide rapid updates of winds, unbiased by the presence of precipitation, has many other potential applications related to general tropical convection.

2. Scientific Background

Research with the CYGNSS End-to-End Simulator (E2ES) and Dynamics of the MJO (DYNAMO) modeling cases established that CYGNSS should be able to observe the evolution of gust fronts and westerly wind bursts (WWBs) associated with MJO onset convection. What about real data?



Hoover et al. (2017)

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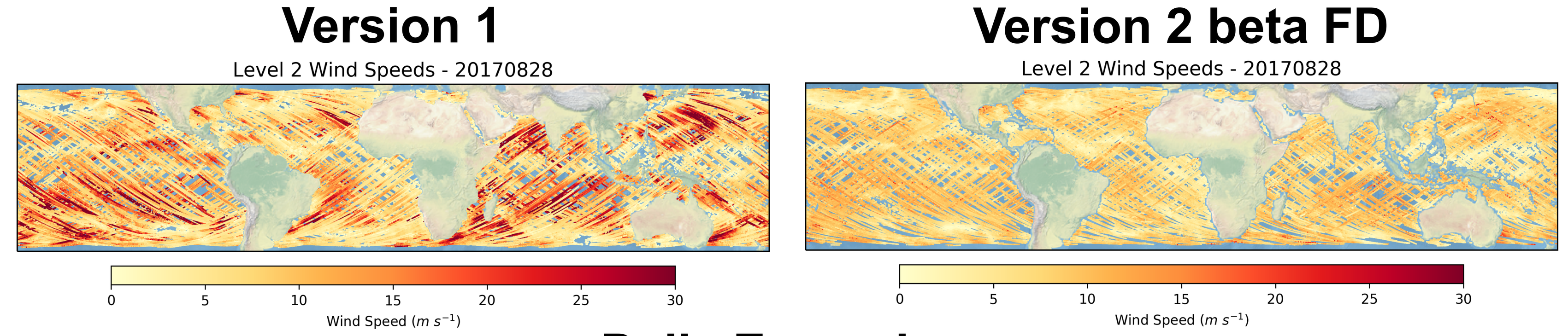
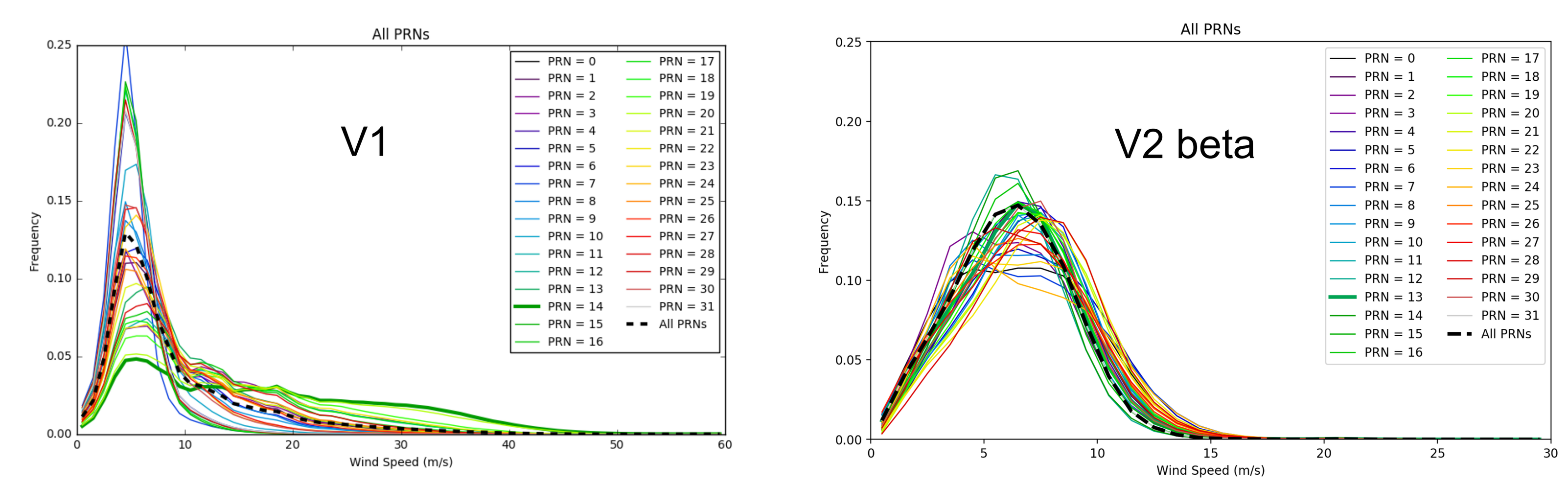
3. Error analysis of V1 and V2 beta winds

First, we must establish that the current CYGNSS dataset is amenable to scientific analysis. CYGNSS Version 1, Level 2 winds featured significant errors due to a variety of reasons, including miscalibration of the Level 1 delay-Doppler maps (DDMs). Recently, many of these errors have been corrected and a V2 beta wind dataset (covering most of August and September 2017) has been made available to the CYGNSS science team. The dataset includes two different GMFs, one suitable for high winds (**LF**) and one suitable for all other situations (**FD**). V2 beta winds show drastic improvement over V1, with RMSE values close to the expected 2 m s^{-1}.

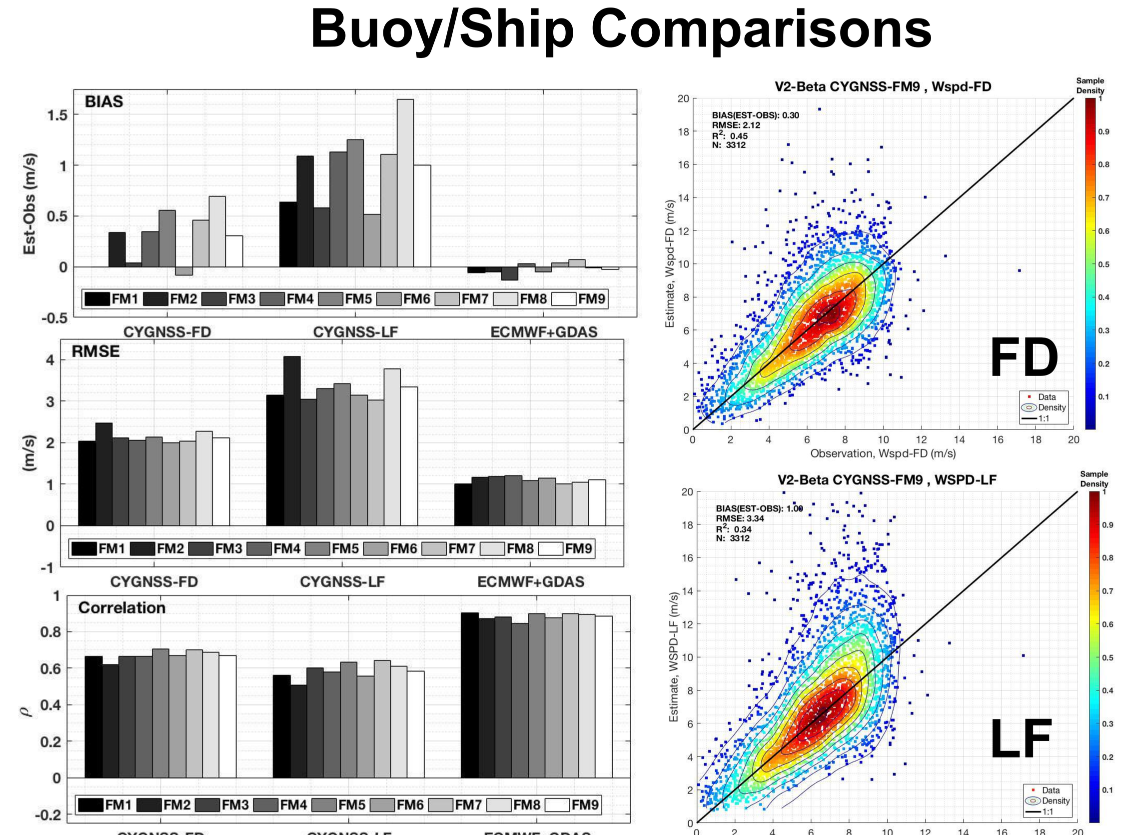


Daily Example



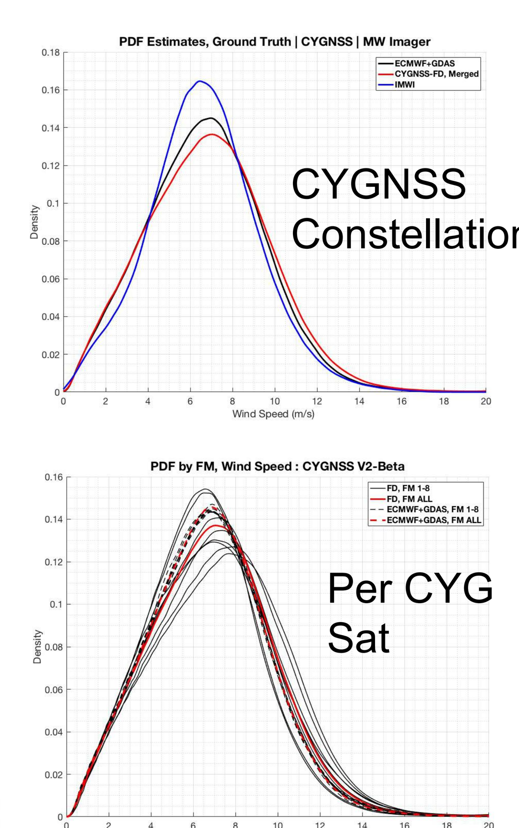
Wind PDFs vs. PRN/GPS code

Buoy/Ship Comparisons

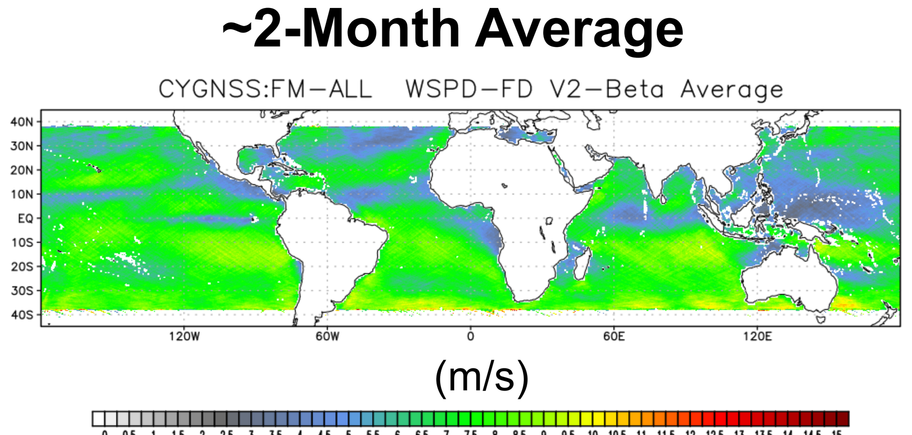


FM1-8 = Individual Sats
FM9 = Constellation

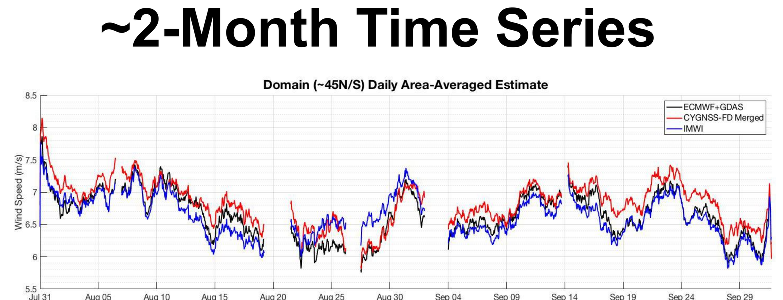
Microwave Imager Comparisons



~2-Month Average



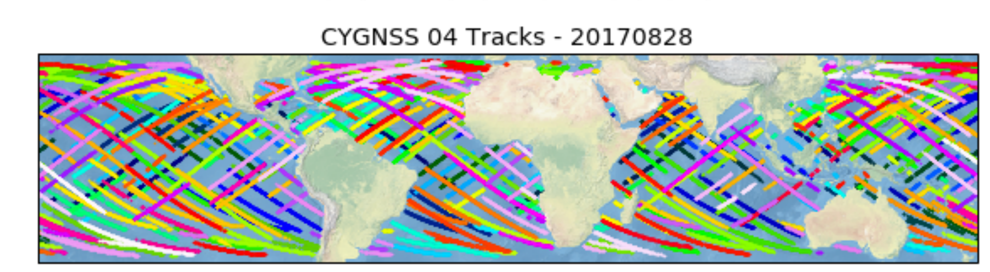
~2-Month Time Series



4. Tracked-based analysis with IMERG

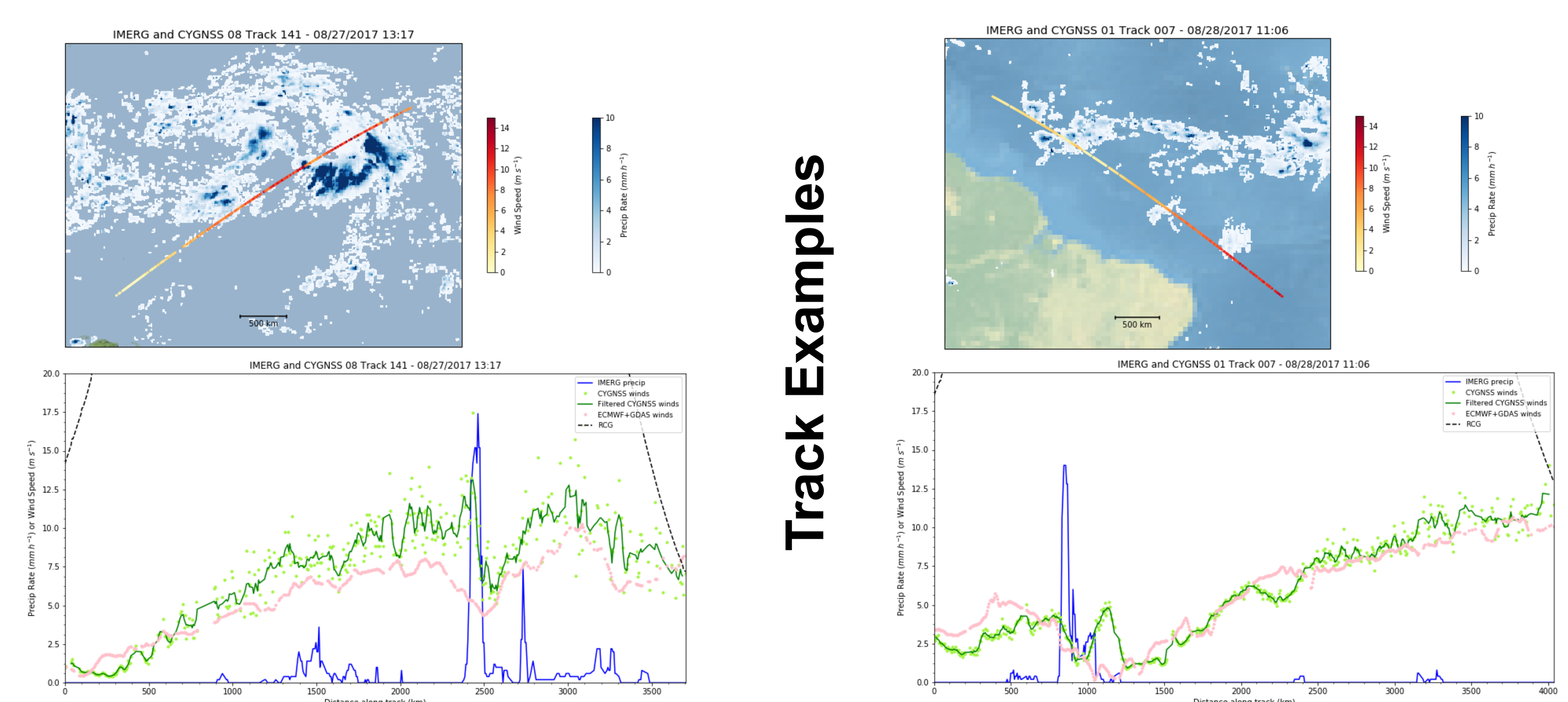
Hoover et al. (2017; JTECH) demonstrated the value of a specular point track-based analysis of CYGNSS Level 2 winds. When combined with precipitation data along the track, as well as simple filtering of the oversampled CYGNSS data, gust fronts and other surface features near precipitation systems are readily apparent in both simulated E2ES and real V2 beta CYGNSS data. Since CYGNSS is L-band and thus mostly transparent to precipitation, we hypothesize that sharper gradients and increased offsets between CYGNSS V2 beta winds and ECMWF+GDAS winds in precipitation could be due to model-unresolved cold pools, gust fronts, and/or altered sea states associated with the convection.

Track Identification



CYGNSS vs. ECMWF+GDAS

8/26/17-8/30/17	RMSE (m s^{-1})	Bias (m s^{-1})
FD_{rain}	2.7	+0.0
FD_{norain}	2.0	-0.1
LF_{rain}	3.6	+0.7
LF_{norain}	2.8	+0.3

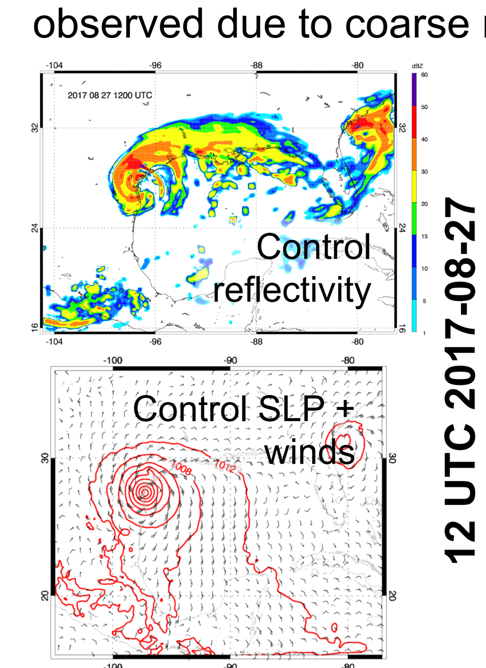


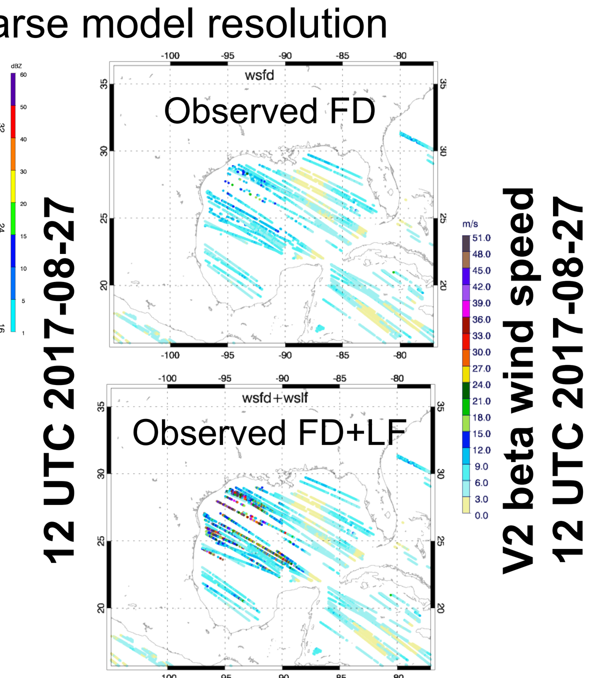
5. Test Observing System Experiment

CYGNSS V2 beta winds were tested in a simple Data Assimilation (DA) experiment focusing on Hurricane Harvey landfall. LF winds had greater impact.

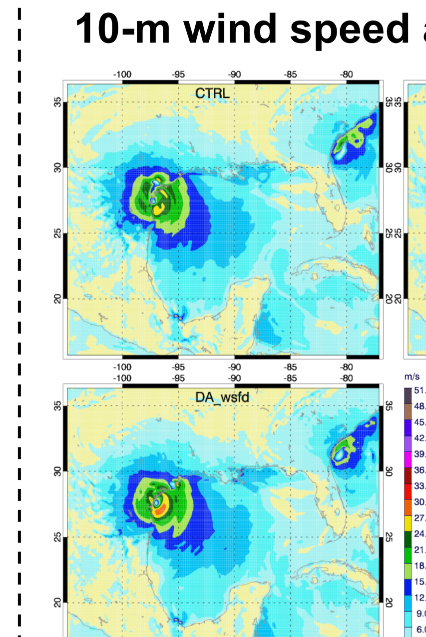
WRF Domain: 9 km resolution (300x250x40)
WRF Control Run: 06 UTC 24 August 2017 – 00 UTC 29 August 2017
DA: 5 cycles – 06 & 12 UTC August 25, 12 UTC August 27, 06 & 12 UTC August 28
DA_wsfd: Assimilate FD wind speed; **DA_hur_wslf**: Assimilate FD + LF around Harvey

Control run: Harvey weaker and slower than observed due to coarse model resolution





10-m wind speed after 3[rd] DA cycle



Stronger storm in DA_hur_wslf

12 UTC 2017-08-27