Impact of CYGNSS Data on Tropical Cyclone Analysis and Forecasts Using the Operational HWRF

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Overview

What is CYGNSS?

Review of CYGNSS OSSE results

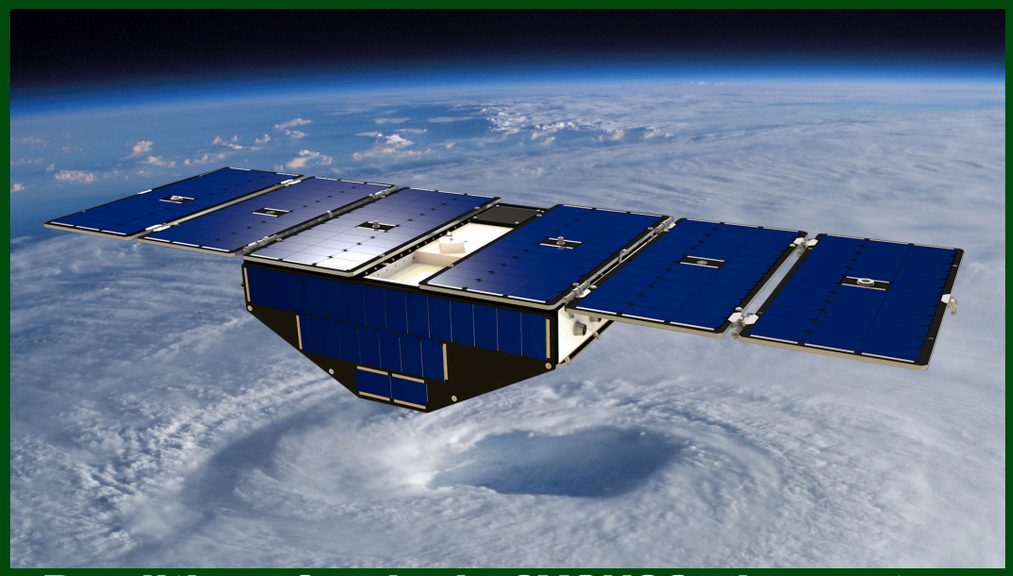
CYGNSS post-launch status

Preliminary OSE results/HWRF

What is CYGNSS?

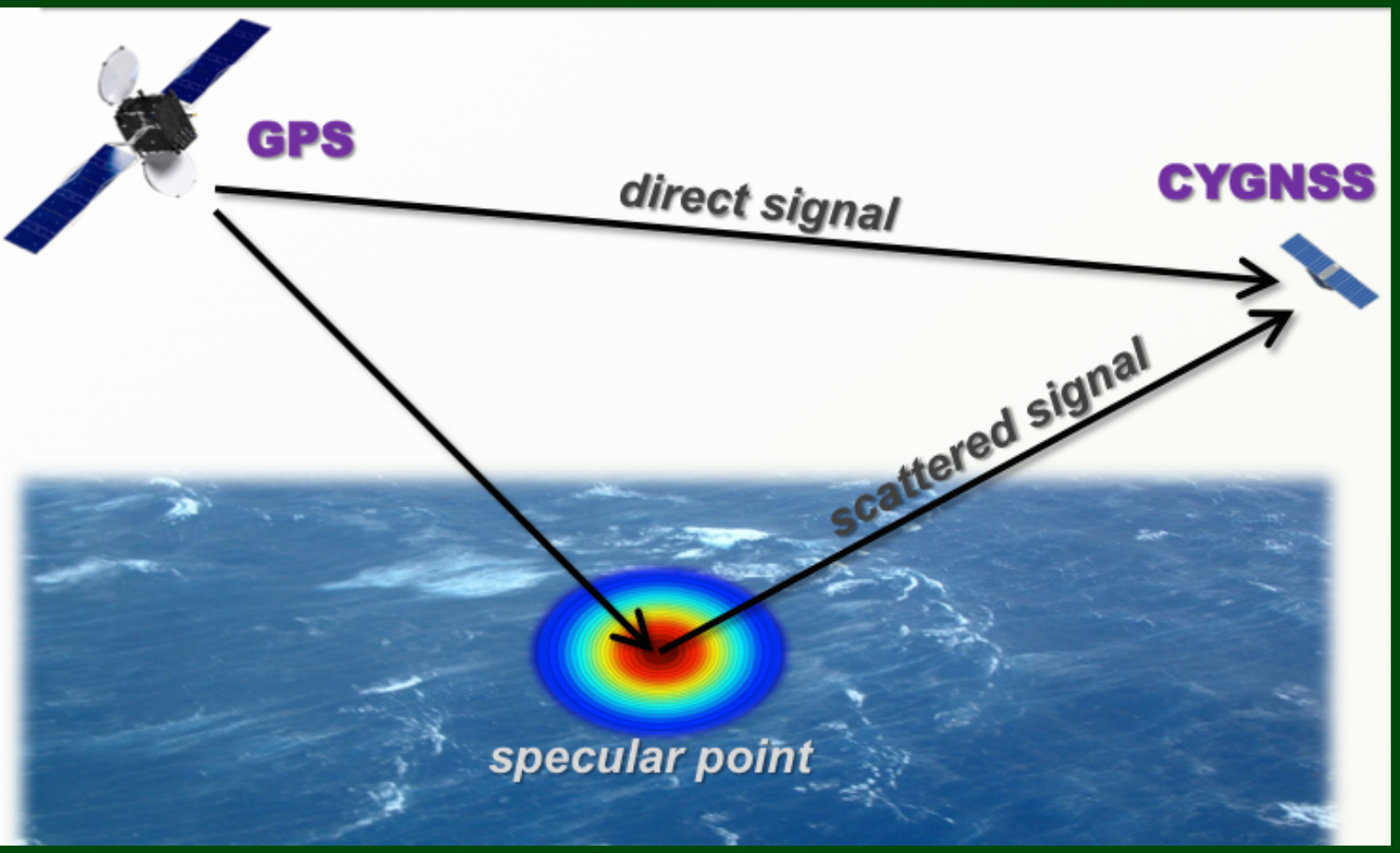
The Cyclone Global Navigation Satellite System (CYGNSS) is a constellation of 8 micro-satellites that launched on December 15, 2016.

- **The body of each satellite measures roughly 51x64x28 centimeters, slightly larger than a standard carry-on suitcase., weigh about 29 kilograms, And each microsatellite has wingspan of 1.67 meters.**



Rendition of a single CYGNSS observatory in orbit over a hurricane. (NASA)

What is CYGNSS?



Basic geometry of bi-static quasi-specular scatterometry

Utilize signals from existing GPS satellites to measure surface wind speeds (surface roughness affects forward-scattered signal)

- **Capable of retrieving usable data over a large range of wind speeds (0-70 m/s) in all precipitating conditions throughout the tropics and subtropics with a frequent revisit times**

OSSE Framework Details

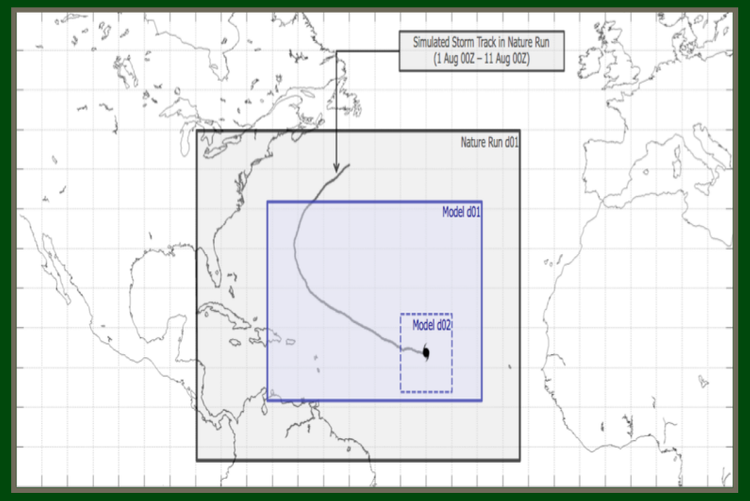
Nature Runs
- **ECMWF: low-resolution T511 (~40km) "Joint OSSE Nature Run"**
- **WRF-ARW: high-resolution 27 km regional domain with 9/3/1 km storm-following nests (v3.2.1)**

Data Assimilation Scheme
- **GSI: Gridpoint Statistical Interpolation. a standard 3D variational assimilation scheme (v3.3).**

Analyses performed at 9km resolution.

Forecast Model
- **HWRF: the 2014 operational Hurricane-WRF model (v3.5).**

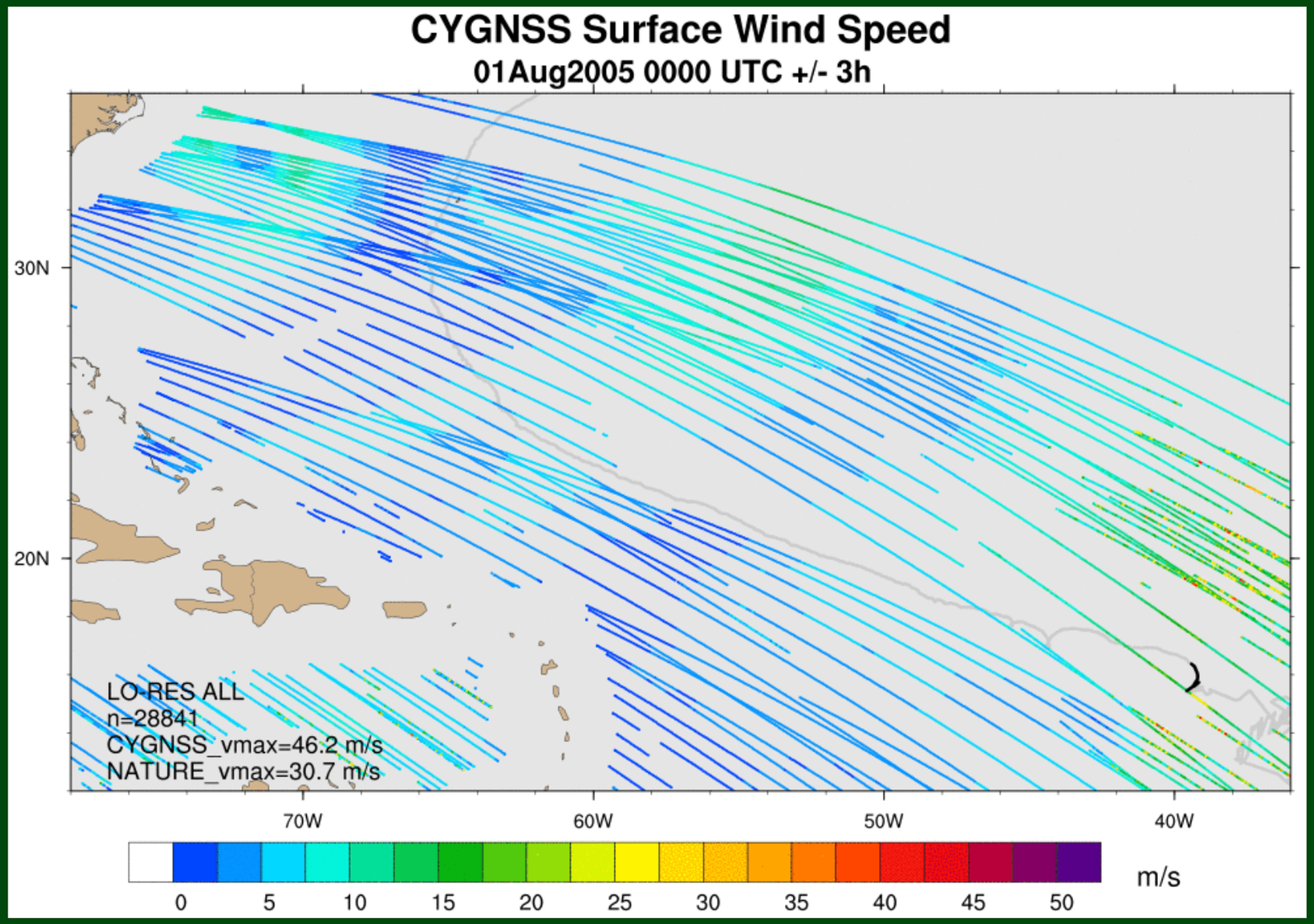
Parent domain has ~9km resolution, single storm-following nest has ~3km resolution.



DA and model cycling performed every 6,3, 1 hours, each run producing a 5-day forecast.

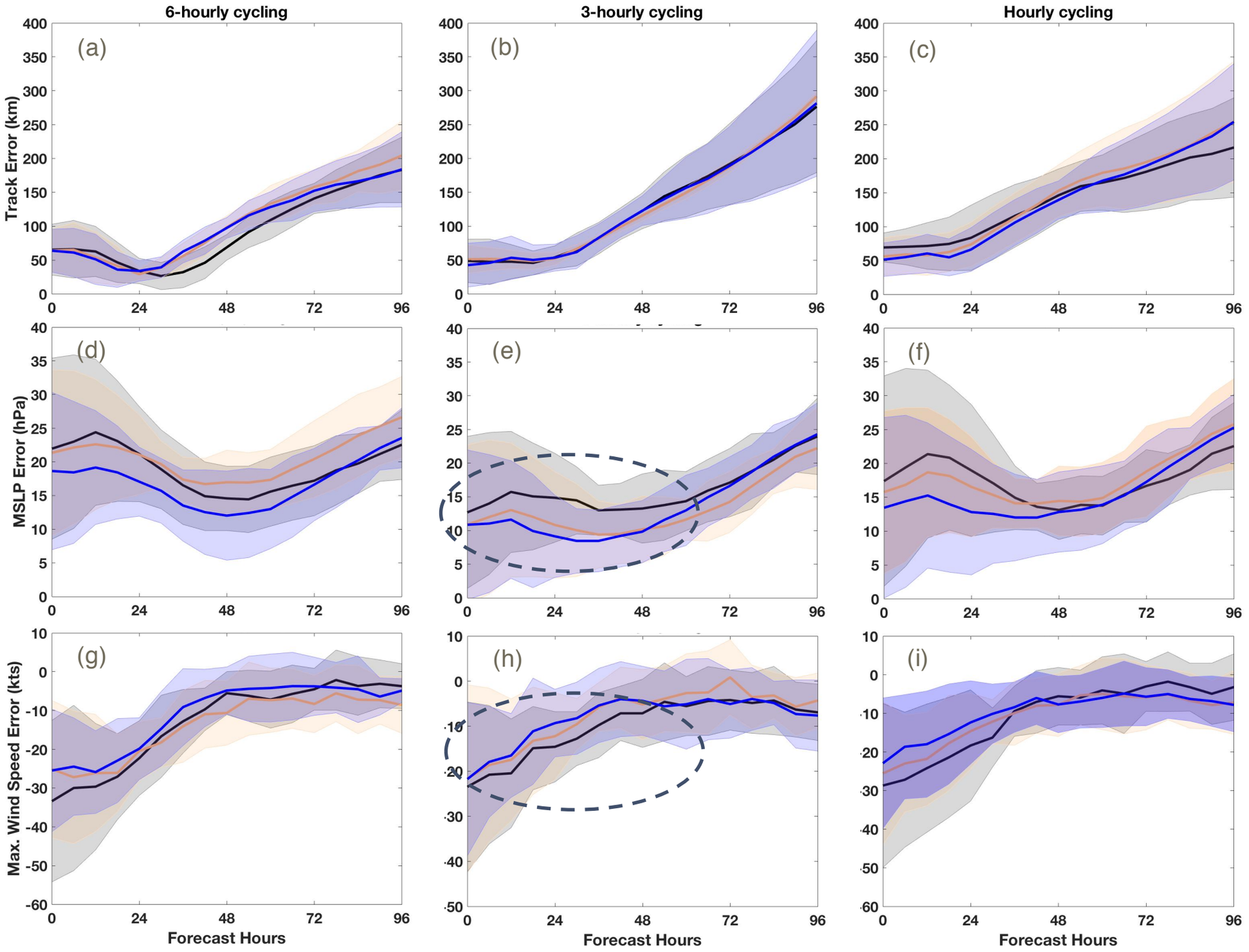
Simulated CYGNSS data

Four-day synthetic CYGNSS dataset generated to span the WRF nature run.



0801 00z - 0805 00z

OSSE IMPACT RESULTS



CYGNSS OSSE

Avg. T.C. Forecast Errors

Track (km)
MSLP (hPa)
Maximum Wind (kts)
(rows)

6-, 3- and hourly cycling *(columns)*

black/grey for **CNTL**,
orange/lgt. orange **CYG**
blue/lgt. blue for **VAM**

OSSE RESULT SUMMARY

Assimilation of CYGNSS data almost always improves hurricane intensity, track analyses, and short range forecasts (0-48 hrs).

DA cycling frequencies affects analyses and forecast errors.

- **3-hrly cycling produced minimum errors in our study**

There are relatively a few samples from one storm, so error statistics are not robust but provide guidance.

CYGNSS Post-launch status

- **Calibration of Level 1 data (delay-Doppler maps) is an on-going mission effort**
- **Low wind speeds (< 13 m/s) are currently more reliable than higher winds (less noisy)**
- **Release of version 2.1 of the Level 1 and Level 2 science data to science team & collaborators is expected end of April**
- **v2.1 will address many of the outstanding cal/val issues**

HWRF CYGNSS Observing System Experiments (OSEs)

- **Components of an OSE**
- **Atmospheric forecast model (HWRF operational, "H217")**
- **Control experiment: NCEP HWRF operations, H217**
- **Data assimilation system**
  - Hybrid 3d-Variational/Ensemble Kalman Filter data assimilation system in the Gridpoint Statistical Interpolation (GSI) framework
- **Experiments using different treatments of CYGNSS data**
  - Wind speed in HWRF operational configuration
  - VAM CYGNSS wind vectors in HWRF operational configuration
- **OSEs will focus on:**
  - Sparsely observed periods of TC lifecycles
  - Operational HWRF forecasts with relatively high intensity error
- **Four candidate hurricanes identified:**
  - Harvey, Irma, Katia, Maria
  - 1-2 day forecasts of hurricane intensity are a focus (OSSE results)

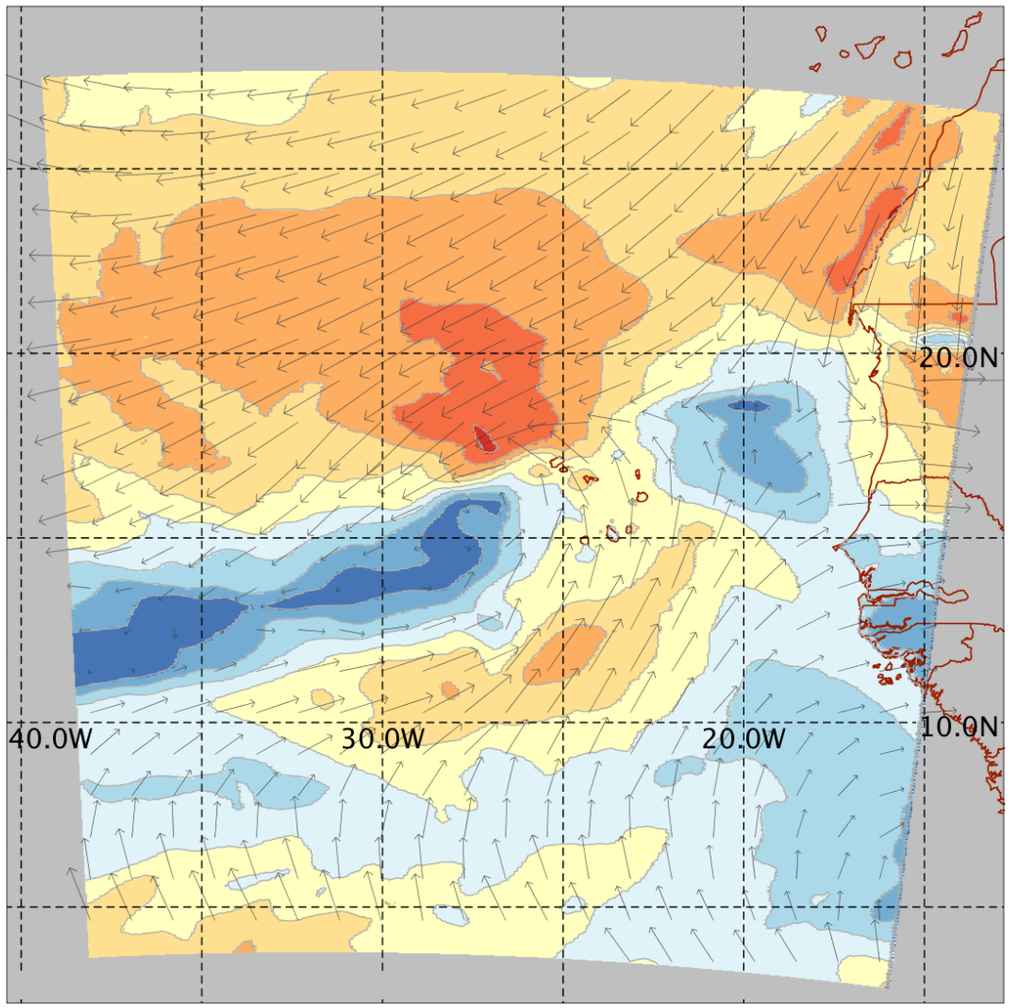
OSE experiments

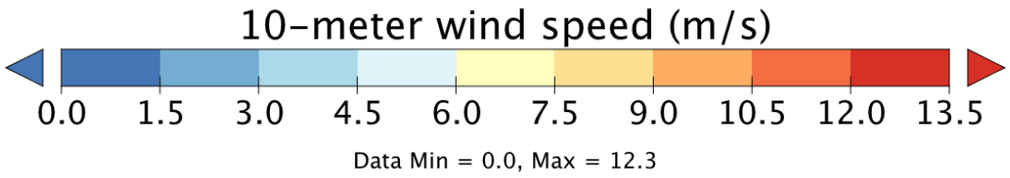
- **Explore impact of low CYGNSS winds speeds (< 13 m/s)**
  - **Smallest retrieval error and least noisy**
- **Irma – impact of QC'd CYGNSS on surface wind analyses**
  - **CYGNSS v2.0 FDS wind speeds**
- **Harvey, Katia – explore forecast impacts on early lifecycles**
  - **CYGNSS v2.0 YSLF wind speeds**

Irma first guess

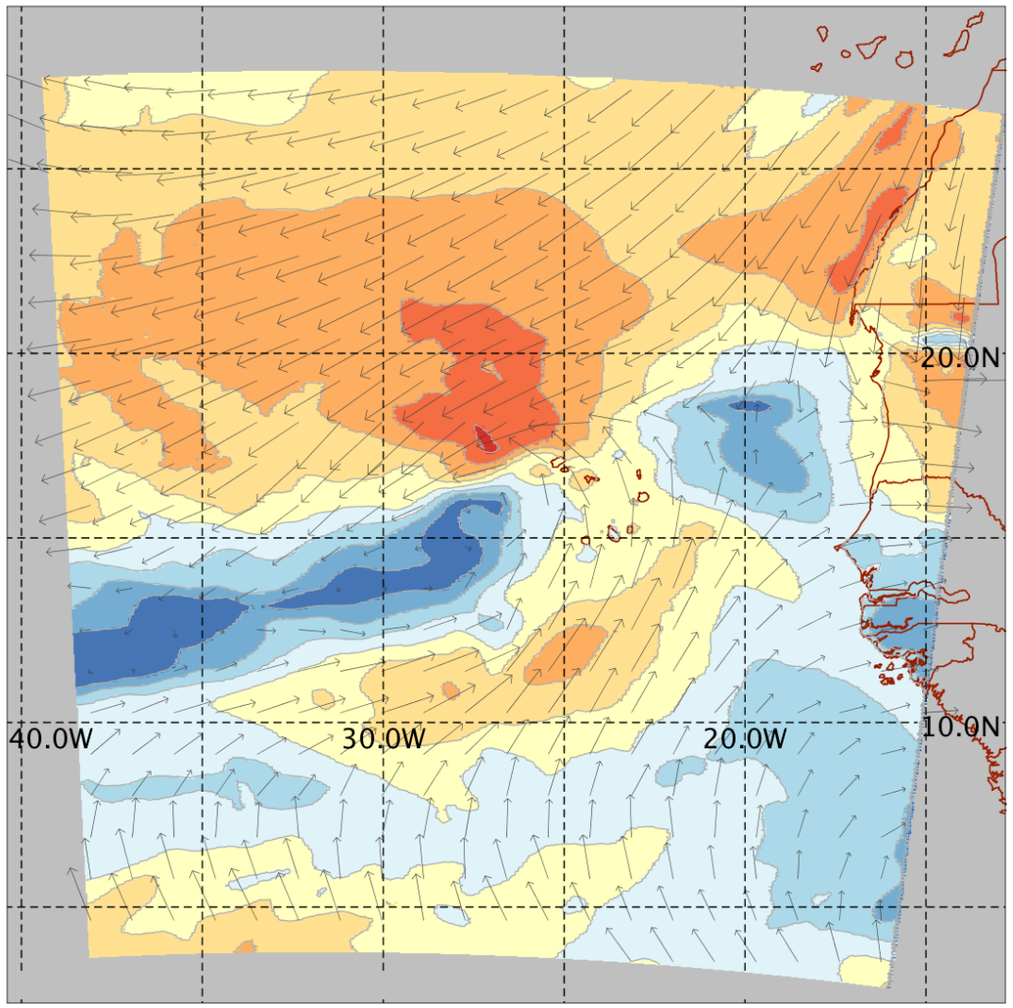
Surface wind speed and vectors, 00 UTC Aug 30, 2017

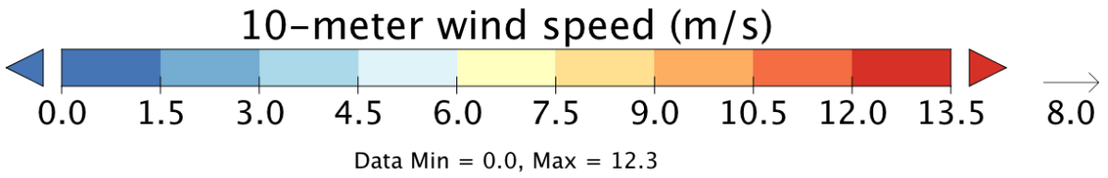
HWRF OPS first guess, 2017083000





HWRF CYGNSS OSE first guess, 2017083000

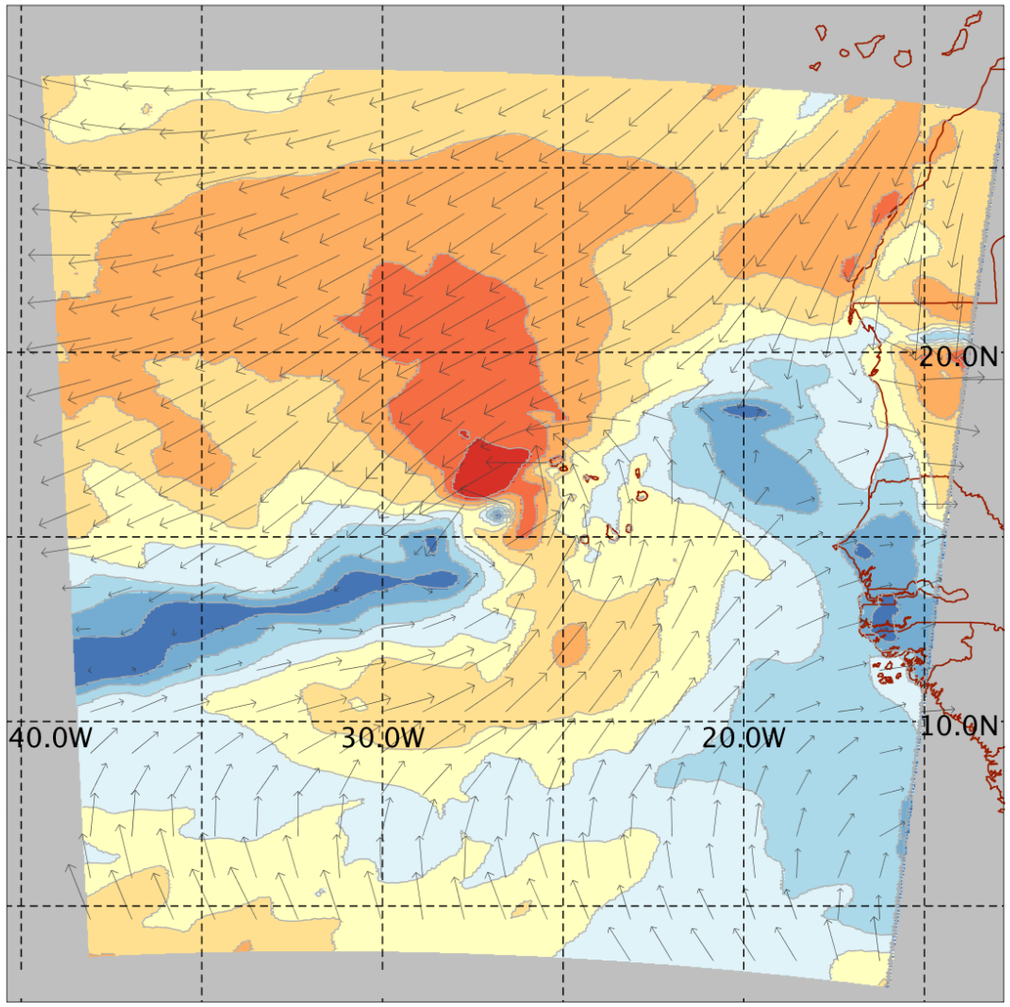


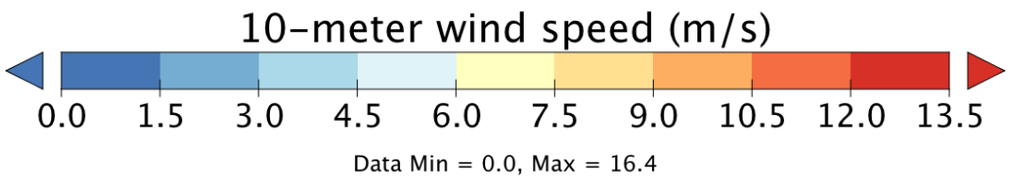


Irma HWRF DA analyses

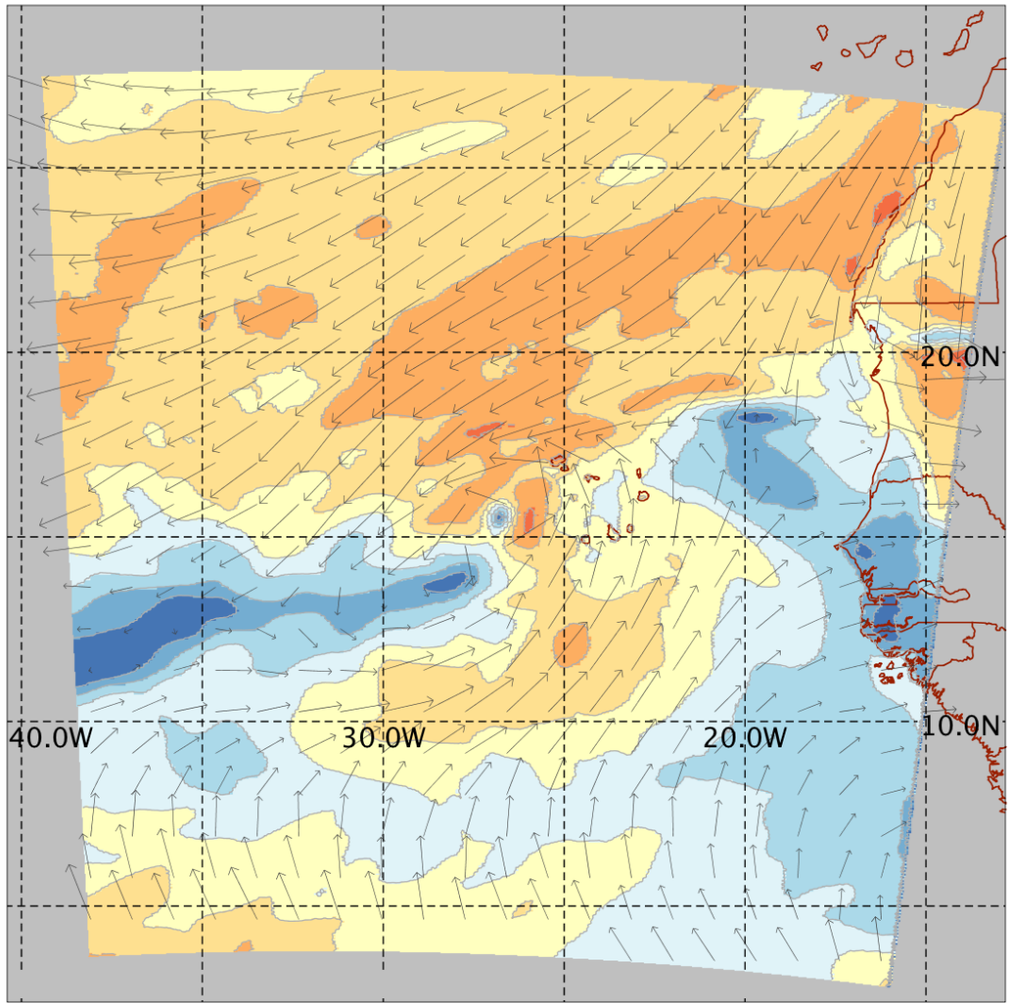
Surface wind speed and vectors, 00 UTC Aug 30, 2017

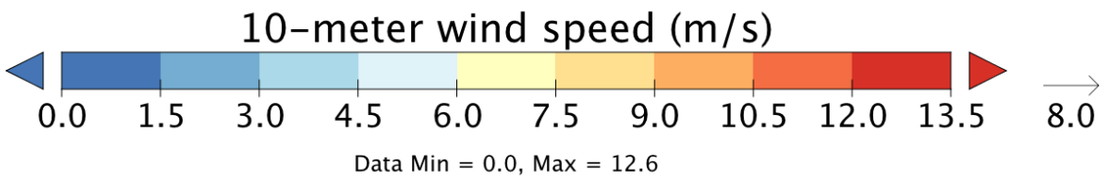
HWRF OPS analysis, 2017083000





HWRF CYGNSS OSE analysis, 2017083000

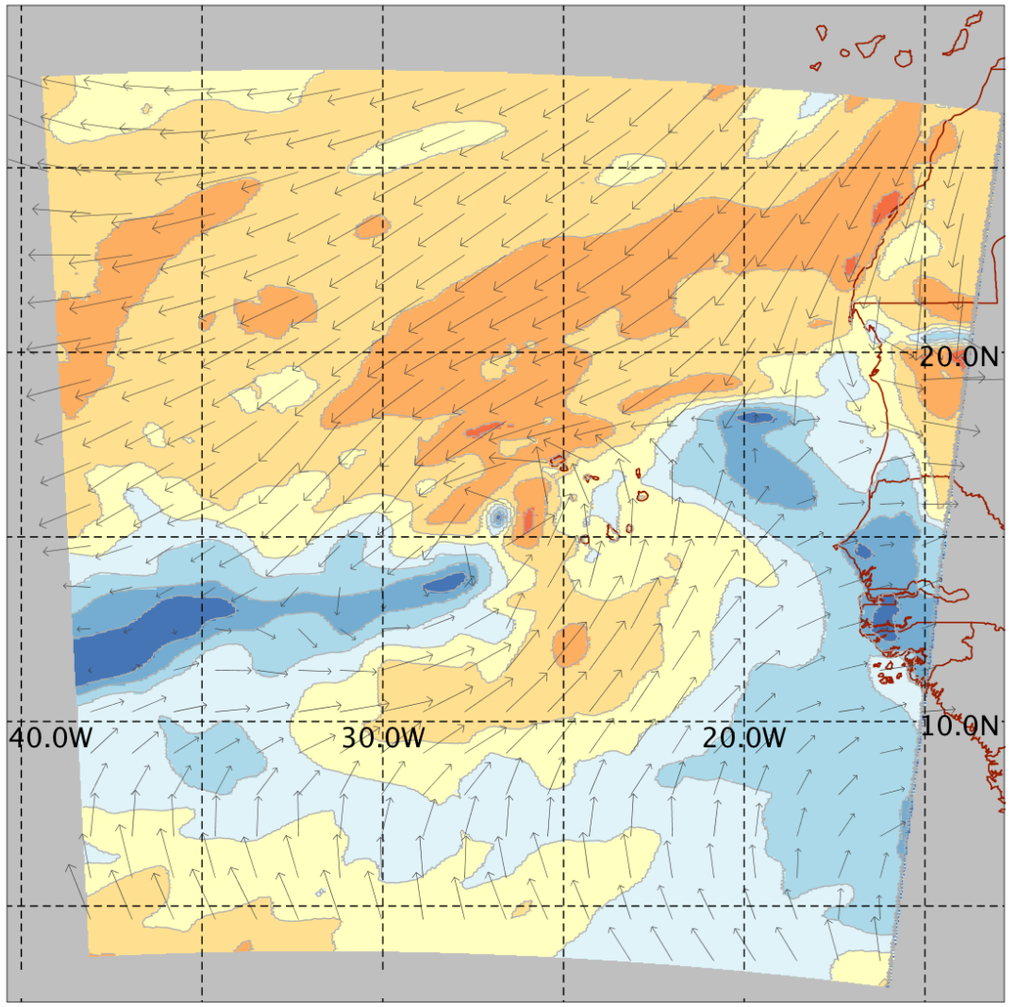




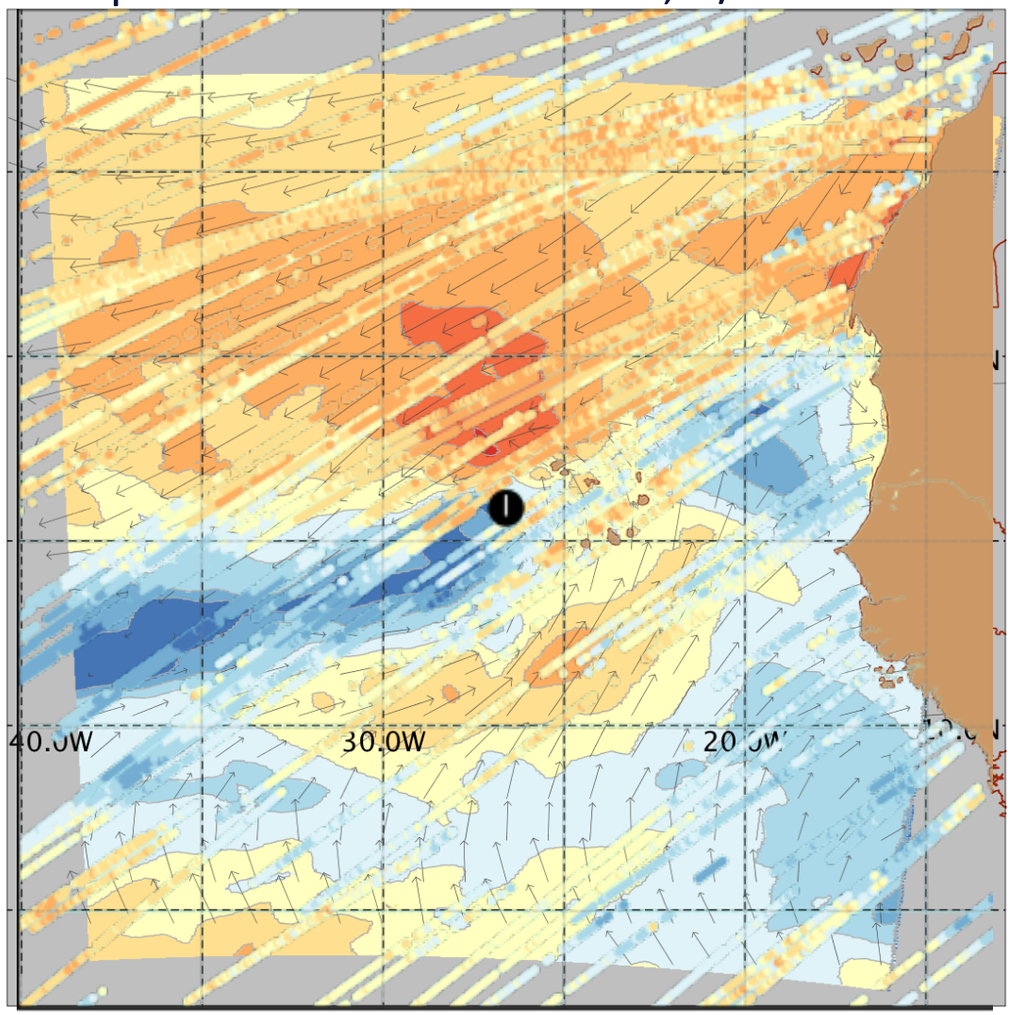
Irma analyses/first guess/observations

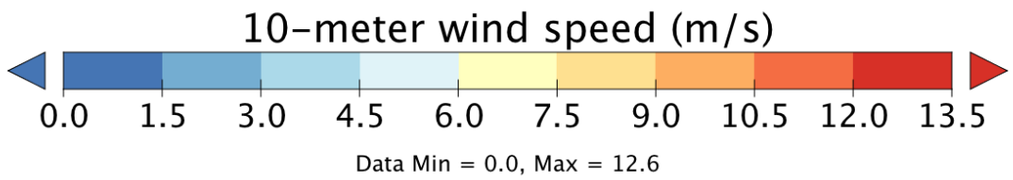
Surface wind speed and vectors, 00 UTC Aug 30, 2017

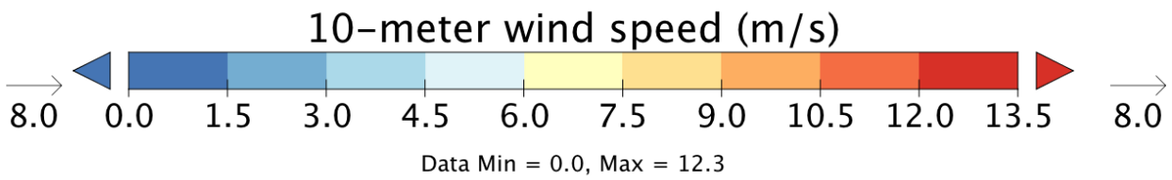
HWRF CYGNSS OSE analysis, 2017083000



HWRF CYGNSS OSE first guess, 2017083000
plus CYGNSS observations, +/- 3 hours

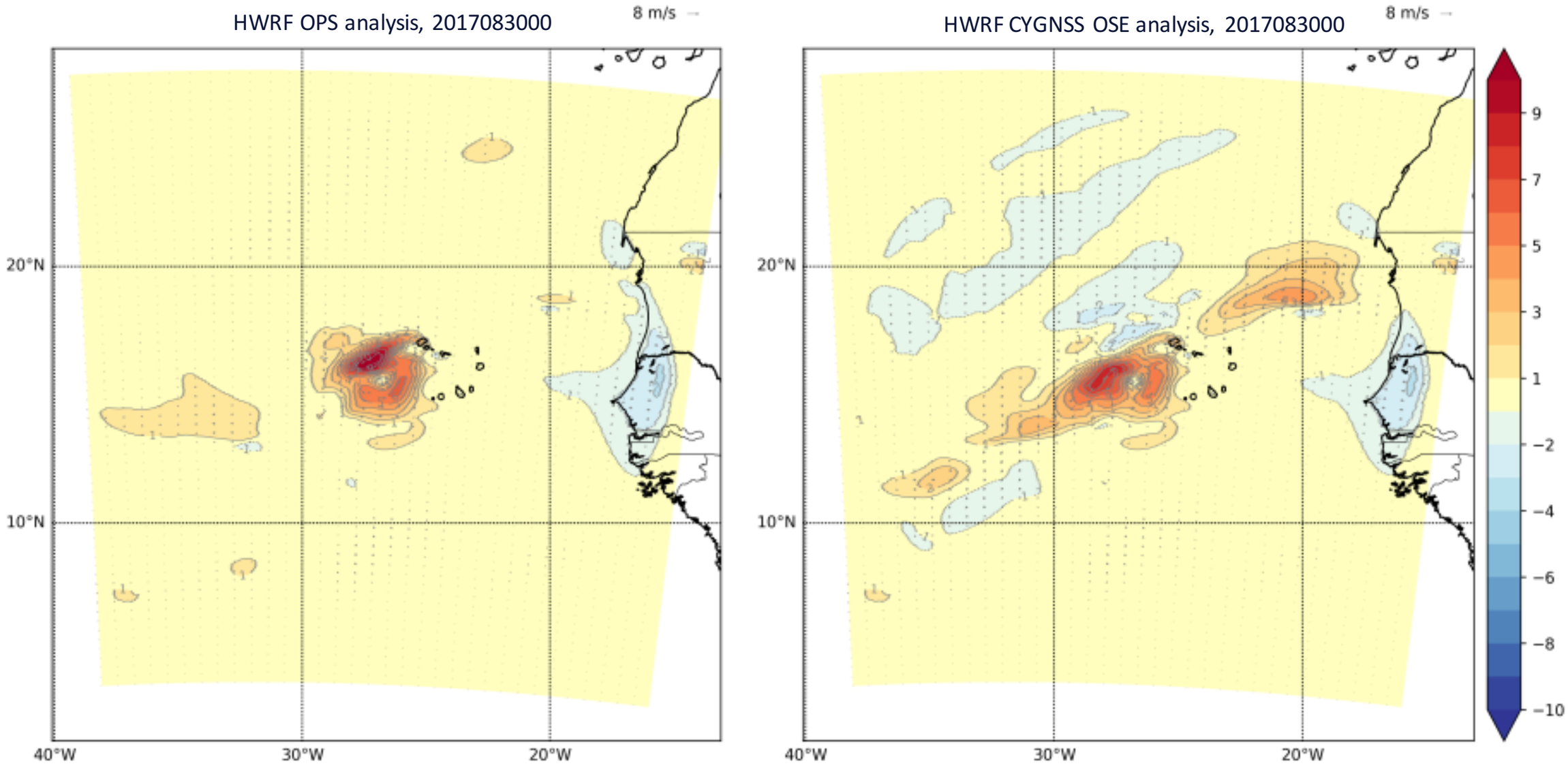






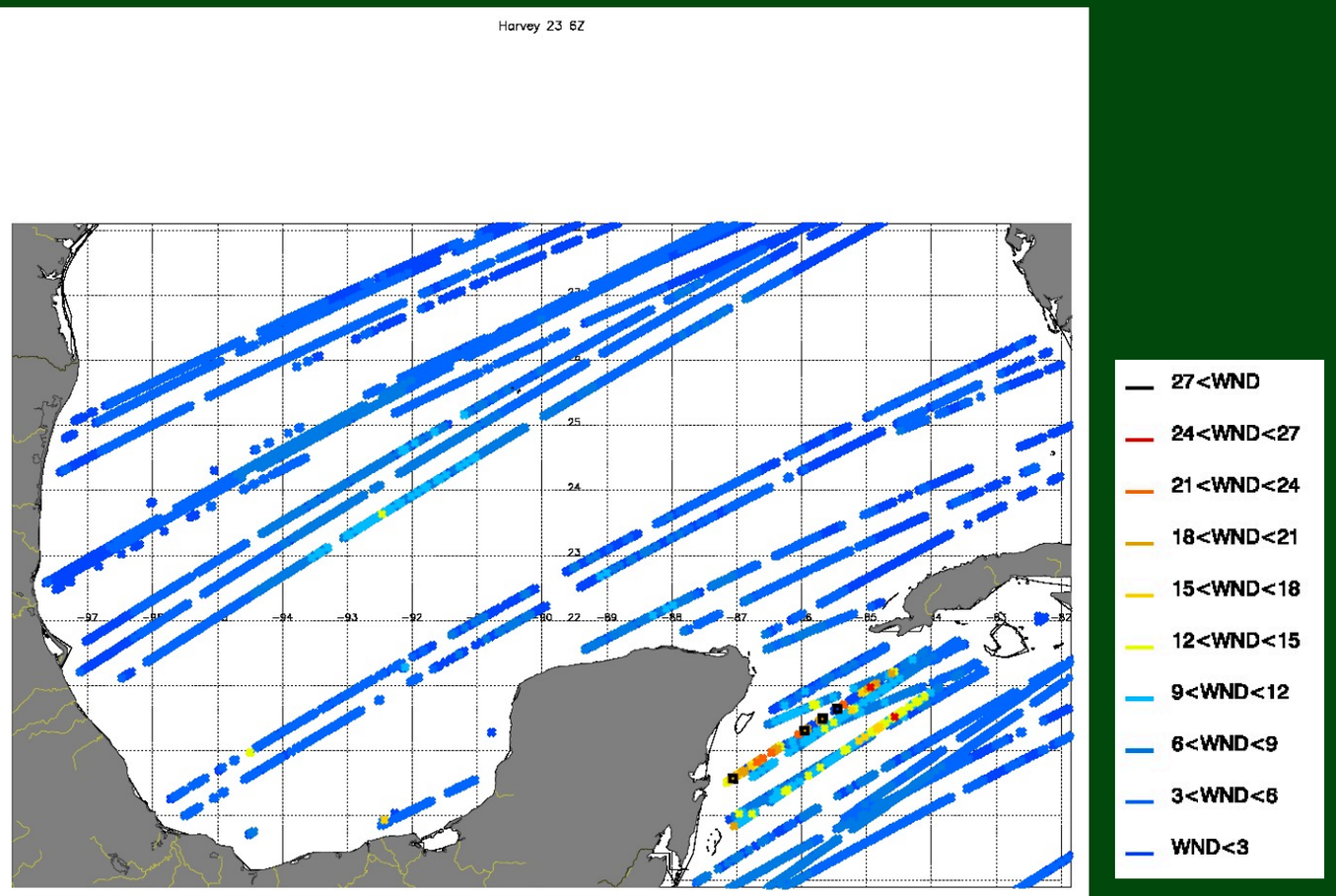
Irma DA analyses increments

Surface wind speed and vector increments, 00 UTC Aug 30, 2017

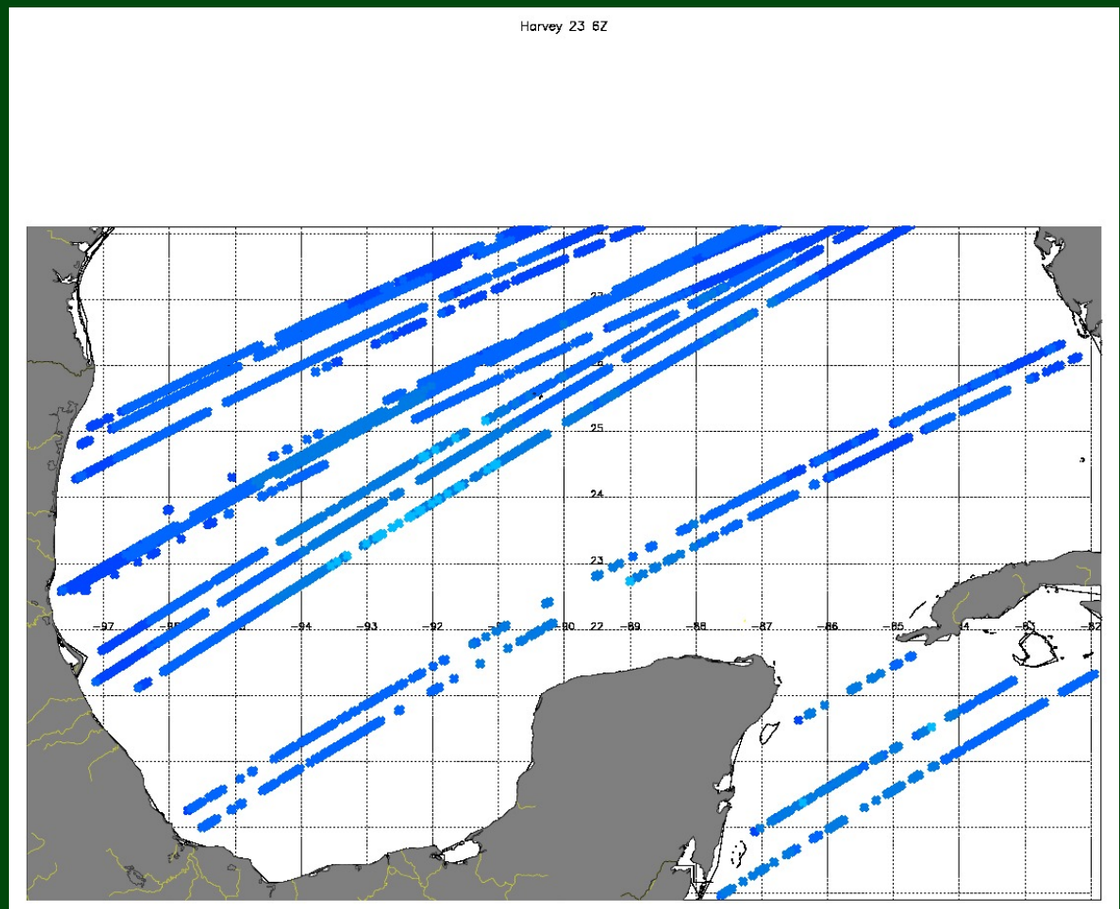


CYGNSS COVERAGE 08/23 06Z, +/- 3 hrs
Harvey

CYGNSS: No QC



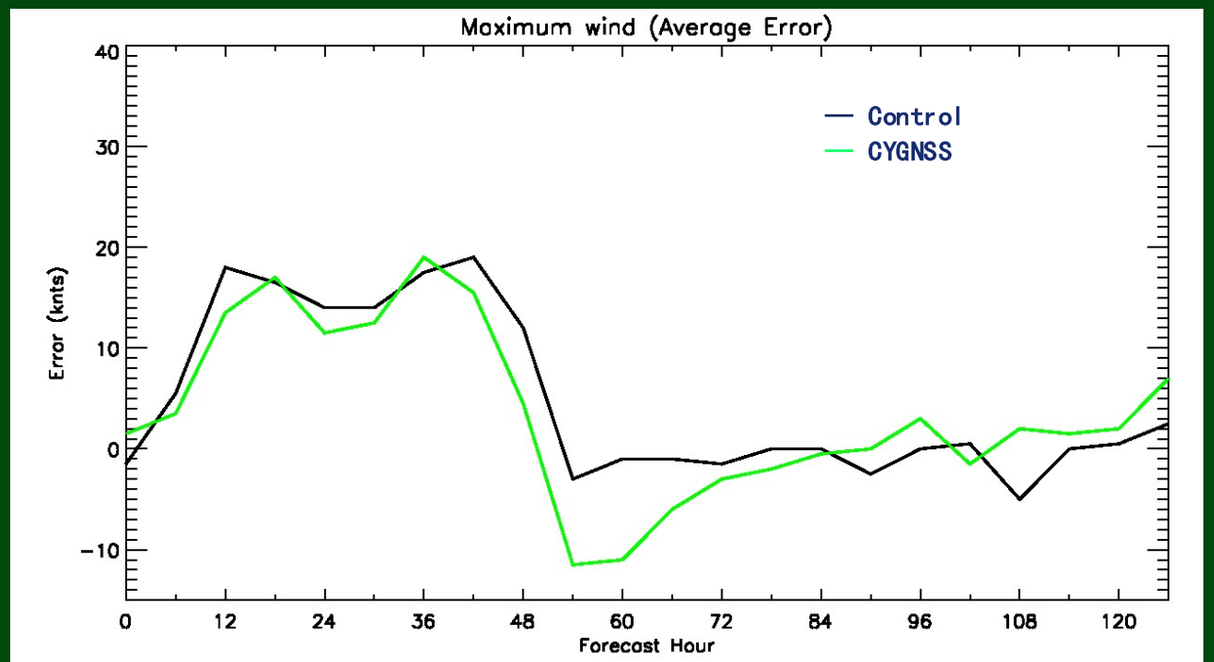
CYGNSS: Strict QC

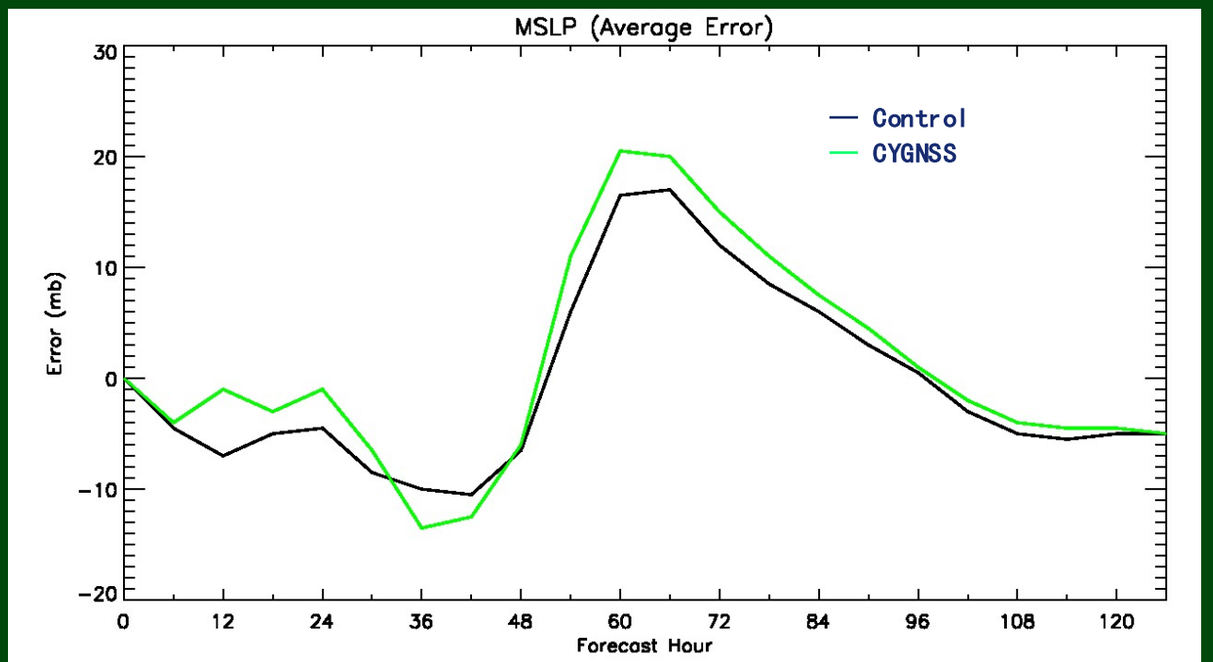


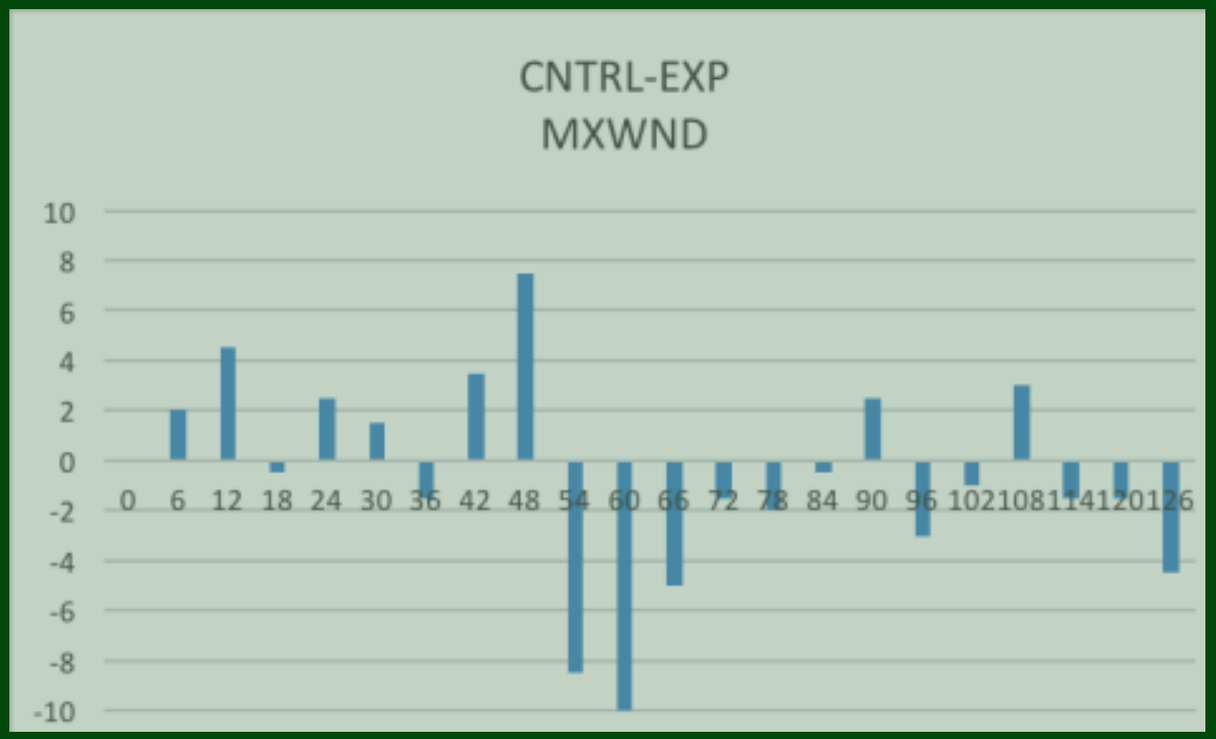
Harvey
CYGNSS *(o-b)* & *(o-a)* statistics table

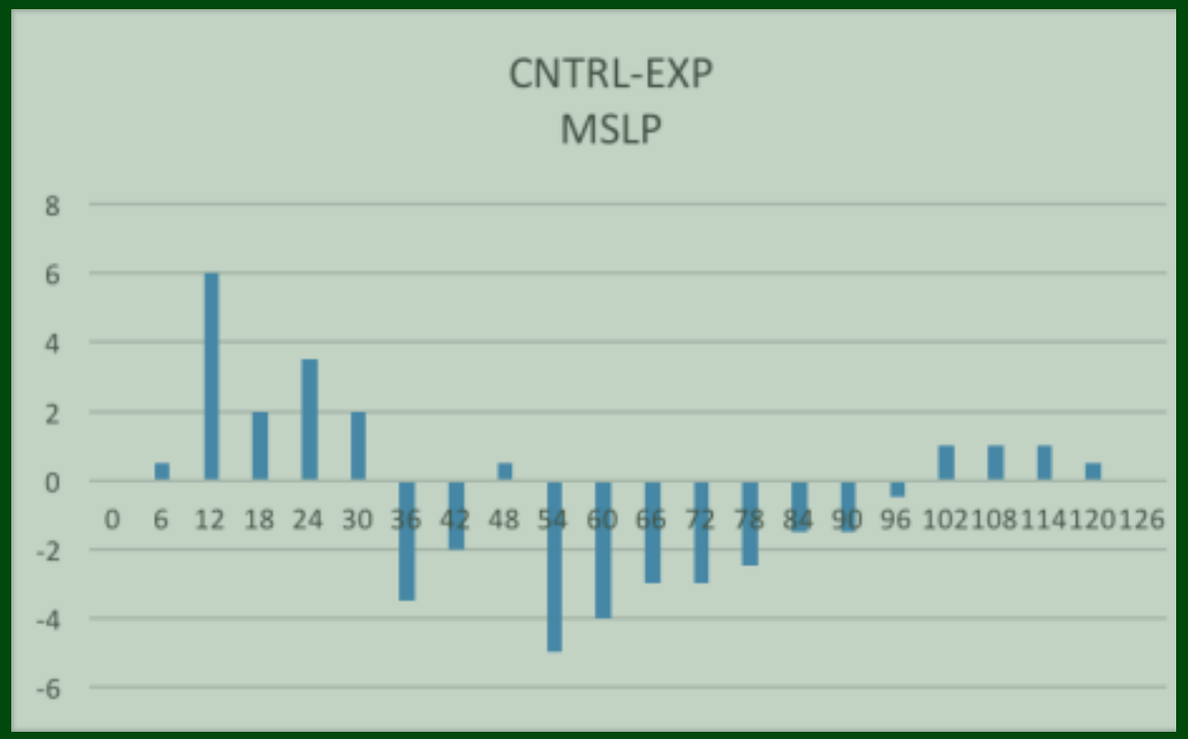
Storm Name	Cycle	Number of points	O-B(mean)	O-B(rms)	O-A(mean)	O-A(rms)
Harvey	8/23/00	0	n/a	n/a	n/a	n/a
	8/23/06	2221	-0.45	1.43	-0.05	0.42
	8/23/12	1725	-0.42	1.17	-0.04	0.48
	8/23/18	4159	-0.61	1.84	-0.03	0.55
	8/24/00	0	n/a	n/a	n/a	n/a
	8/24/06	2619	-0.46	1.13	-0.02	0.37

Harvey
Average Intensity errors 08/24, 00Z & 06Z





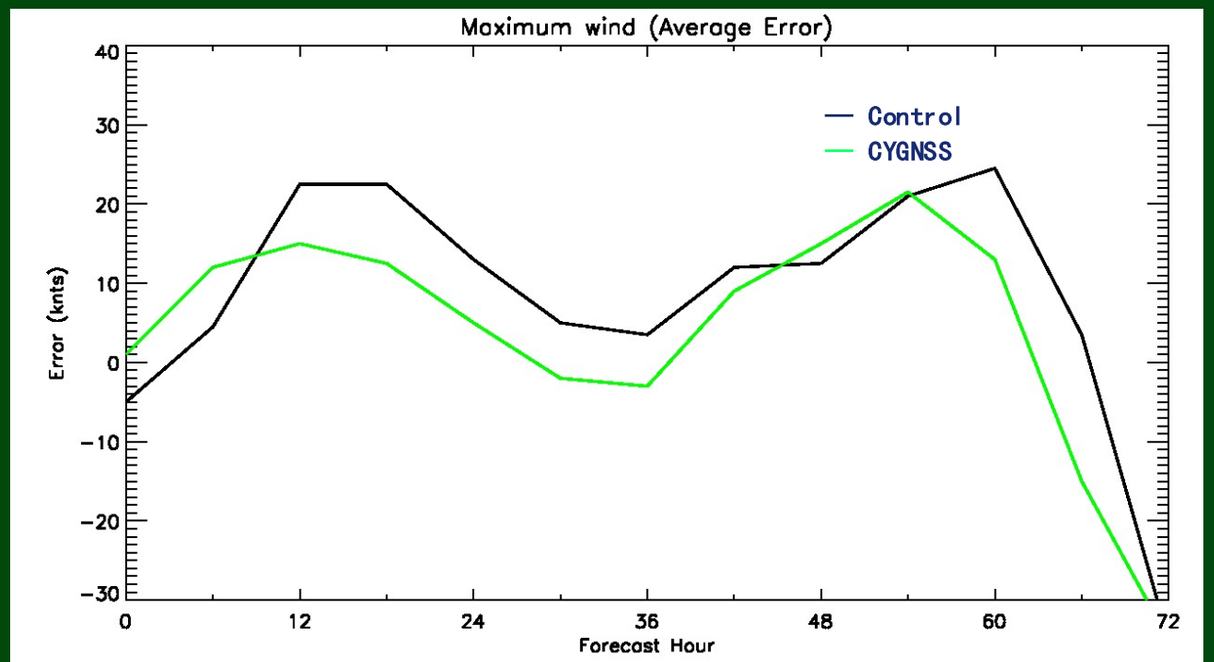


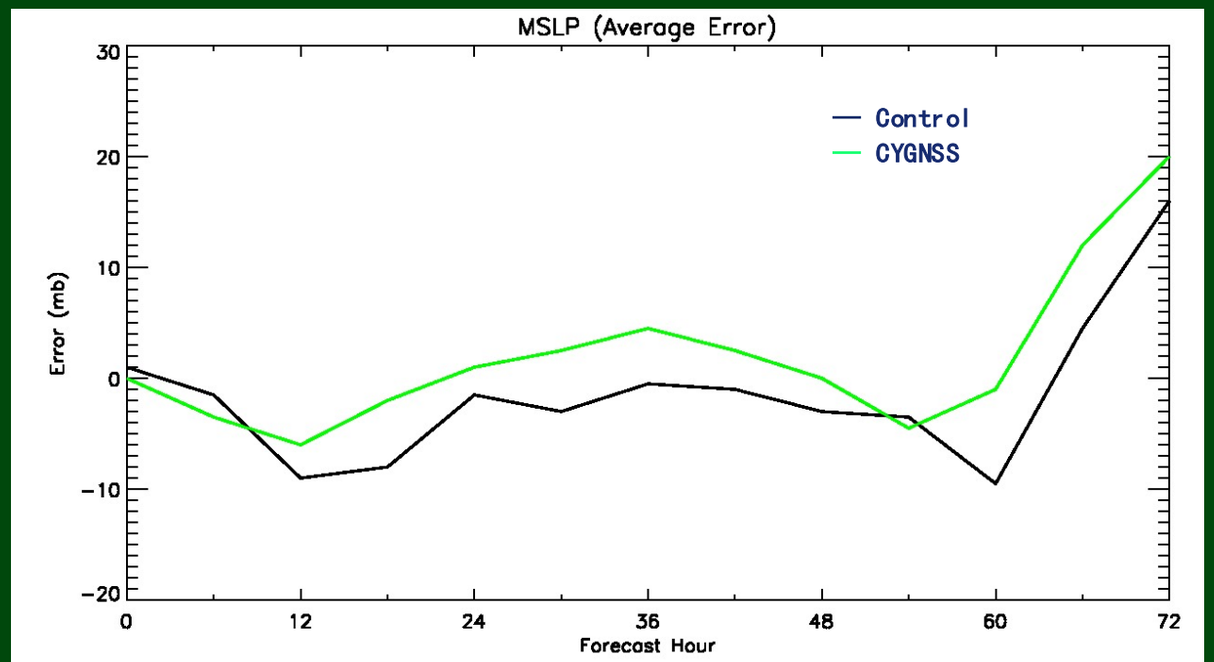


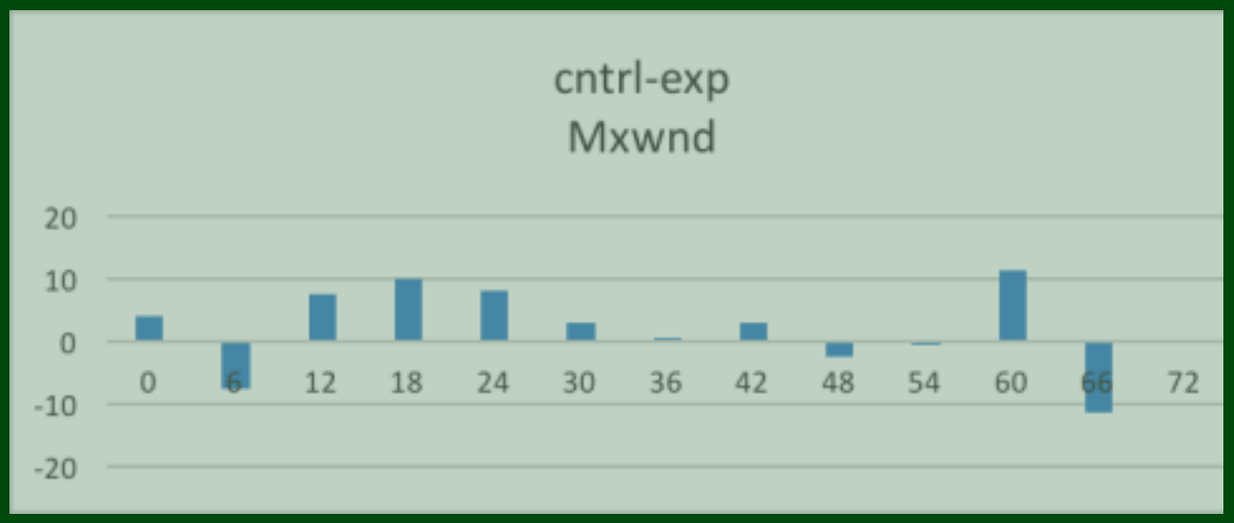
Katia
CYGNSS *(o-b)* & *(o-a)* statistics table

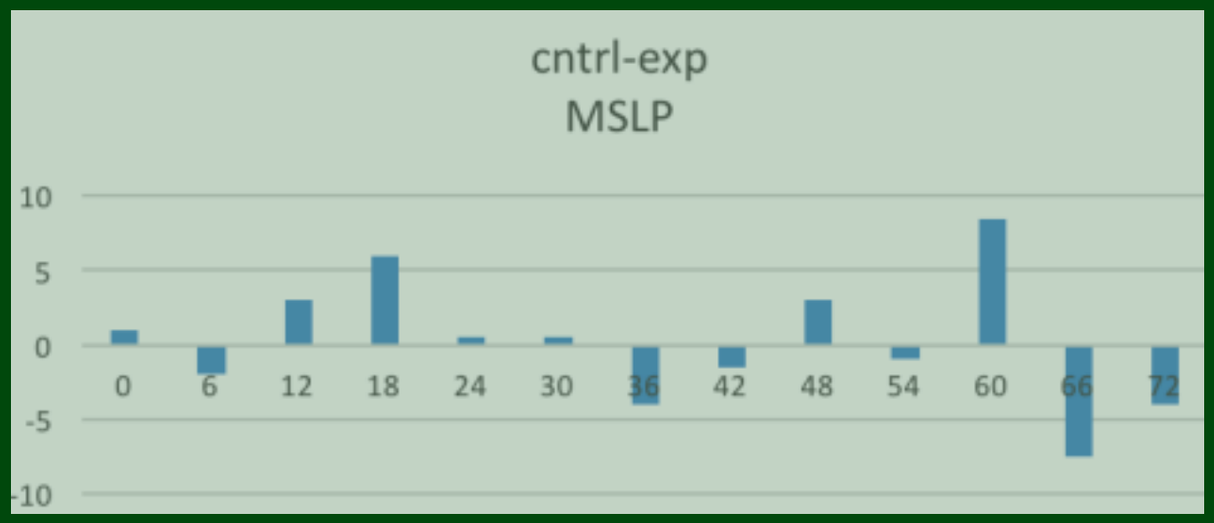
Storm Name	Cycle	Number of points	O-B(mean)	O-B(rms)	O-A(mean)	O-A(rms)
Katia	9/5/00	457	-1.44	1.84	-0.02	0.38
	9/5/06	1358	-0.06	1.06	-0.03	0.46
	9/5/12	1184	-0.04	1.48	0	0.39
	9/5/18	0	n/a	n/a	n/a	n/a
	9/6/00	727	-0.74	1.64	-0.02	0.53
	9/6/06	1788	-0.17	1.05	0.01	0.43
	9/6/12	2116	-0.03	1.50	0.01	0.44

Katia
Average Intensity errors 09/06, 06Z & 12Z

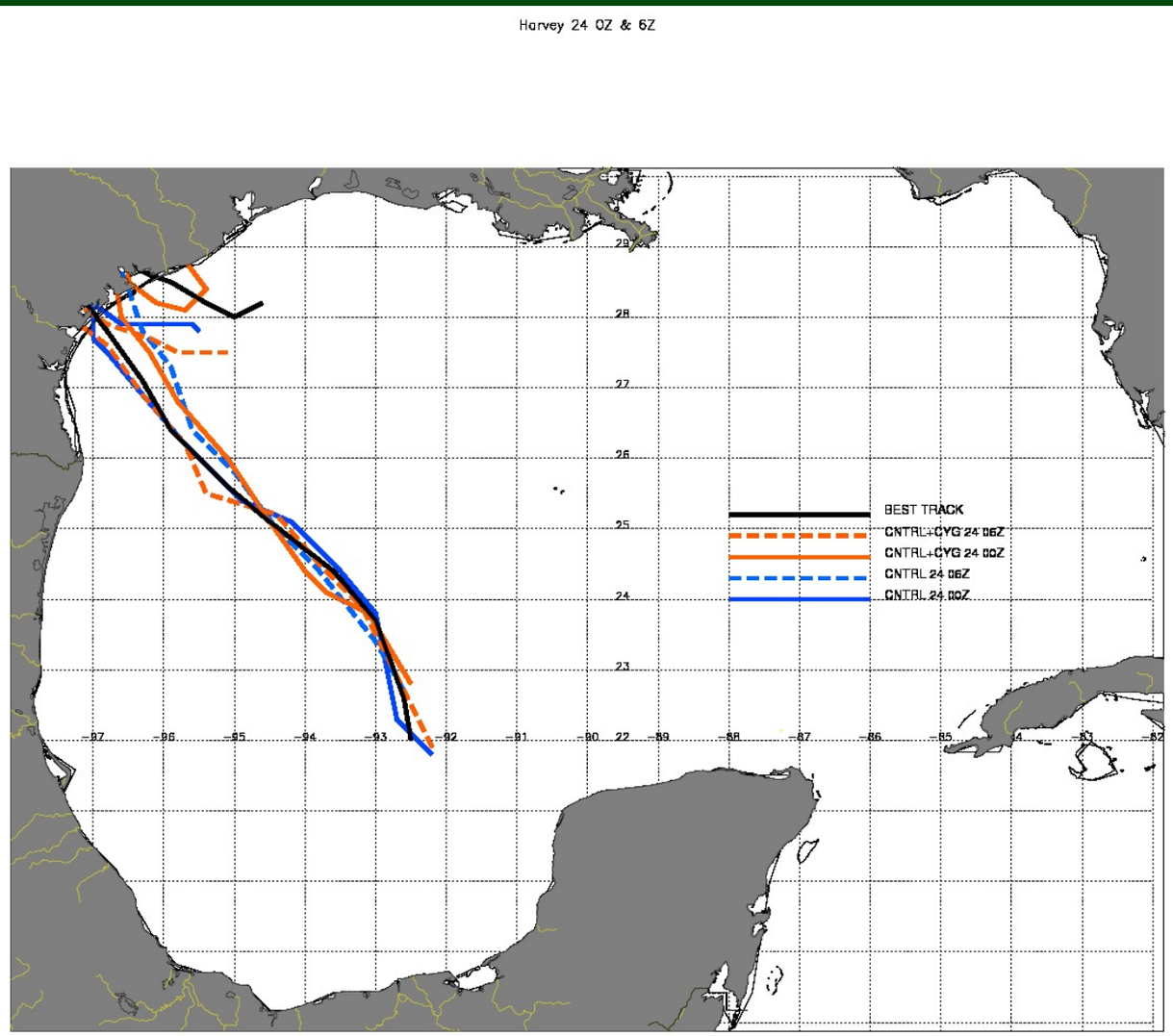


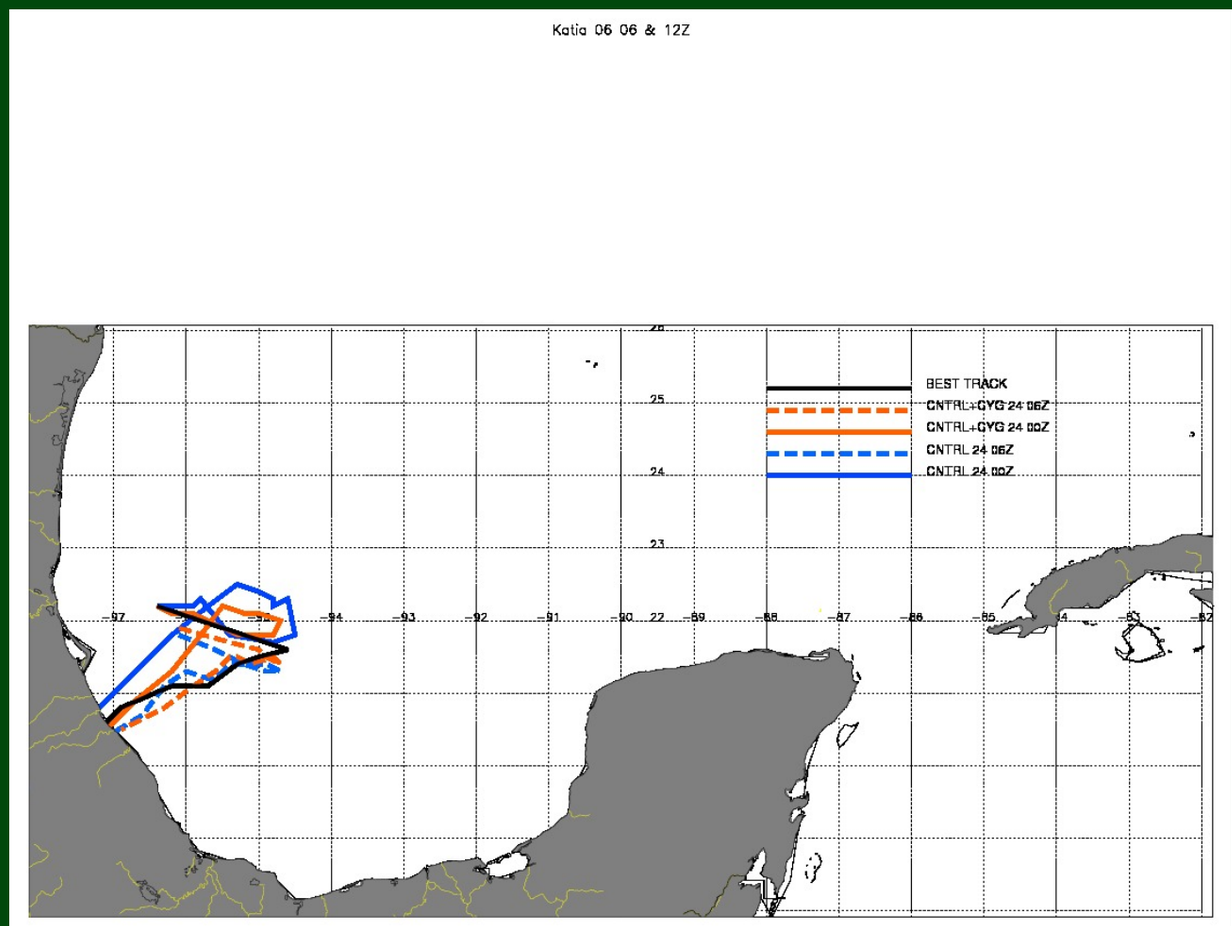






Harvey and Katia
Best track and OSE tracks, 08/24 & 09/06





SUMMARY

Preliminary OSEs results:

- **Using strict CYGNSS observation quality filtering**
- **Using CYGNSS wind speeds 0-13 m/s**
- **Impact on short-term intensity is positive thus far, though not a significant improvement; little impact on track error.**
  - **Consistent with OSSE results.**
- **Testing only a portion of eventual CYGNSS wind speed range.**

Future work

- **Regenerate current results using CYGNSS v2.1 and future releases, and extend to assess full TC lifecycle impacts.**
  - **Reprocessed CYGNSS data (v2.1) will address many of the current noise issues.**
- **Investigate the impact of hybrid 3dVar- ensemble covariances on distributing wind speed information in the vertical and to unobserved variables.**
- **Use a 2D-Var (VAM) to generate CYGNSS wind vectors with adjusted weights, using high resolution HWRF as background, and assimilate.**

QUESTIONS?

Backup Slides

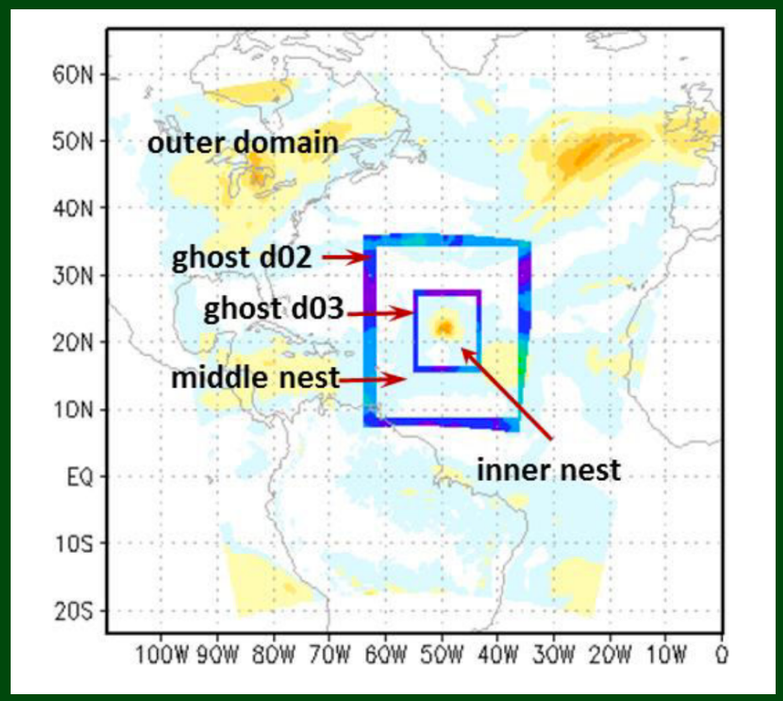
OSE Framework Details

•**Global forecast system initialization and lateral boundary conditions**
  - ***2017 GFS Operational analyses and forecasts***

• **Data Assimilation Scheme**
  - **Hybrid 3d-Variational/Ensemble Kalman Filter data assimilation system in the Gridpoint Statistical Interpolation framework**
  - **Analyses performed at 2 and 6 km resolution.**

•**Forecast Model**
  - ***HWRF*: the 2017 operational Hurricane-WRF model (v3.6). Parent domain has ~18km resolution, two storm-following nests with ~6-km and ~2-km resolution.**

Compare Experiment treatments to Control to assess impact hurricane metrics (minimum sea-level pressure, maximum wind, track error).



•***DA and model cycling performed every 6 hours, each cycle produces a 5-day forecast.***