# Observations of Tropical Cyclones: GPM/CYGNSS Synergies

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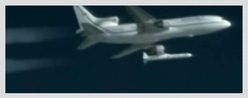
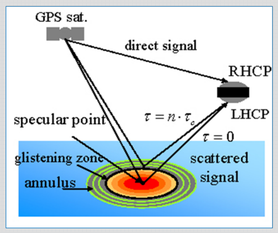
## Abstract

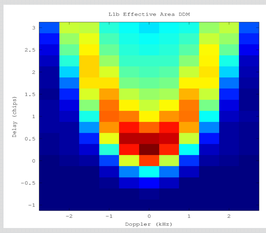
**In this work, we observe recent tropical cyclones captured by the GPM mission and the CYGNSS missions and identify complimentary information of both that will be helpful for the study of tropical cyclones.**

## Introduction



The first of its kind, GNSS-R complete orbital mission, CYGNSS was successfully launched on **Dec 15 2016.** The objective of this mission is to accurately forecast the intensification of tropical cyclones by observing its inner core.



Special features of CYGNSS include :

1. Observations at GPS L1 (~1.5 GHz) permit all weather wind retrievals (even through hurricane eye wall).
2. 2D representation of forward scattered power in the Delay-Doppler space using DDMI.
3. 32 sea-surface measurements per second around the globe.

## Overview of CYGNSS Data Products

**Level 1A :** Raw Level 0 DDMs to DDMs of received power ($P_g$) in units of watts (17 x 11) bins.

**Level 1B :** Delay Doppler Maps (DDMs) of normalized bistatic radar cross section (NBRCS) from unwrapping of forward scattering model using:
1) Un-normalized BRCS values (σ) in units of $m^2$,
2) DDM of effective scattering areas (also in units of $m^2$).

**Level 2 calibration :**
1) Convert L1 observables to sea surface wind speed using empirical Geophysical Model Function (GMF)
2) BRCS to sea surface mean square slope (MSS)

**Level 3 gridded wind product :** Surface wind speed, averaged in space (0.2° lat and lon) and time (1 hour).

Data available at PO.DAAC

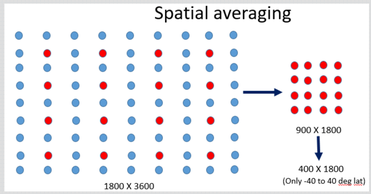
## CYGNSS L3 and GPM IMERG Matchups

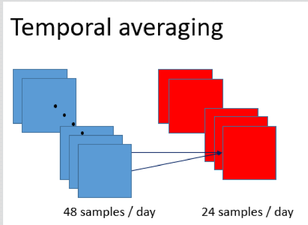
The Integrated Multi-satellitE Retrievals for GPM (IMERG) is the unified U.S. algorithm that provides the multi-satellite precipitation product for the U.S. GPM team.

**GPM IMERG data** : spatial resolution : (0.1 X 0.1) deg
temporal resolution : 30 mins.

**CYGNSS :** spatial resolution : (0.2 X 0.2) deg
temporal resolution : 60 mins.

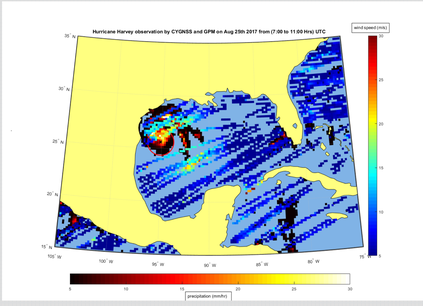
**GPM IMERG variable used** - precipitationCal (mm/hr) [surface precipitation rate based on infrared satellite observations, microwave satellite observations, and calibration datasets]
**CYGNSS L3 variable used** – wind_speed (m/s)



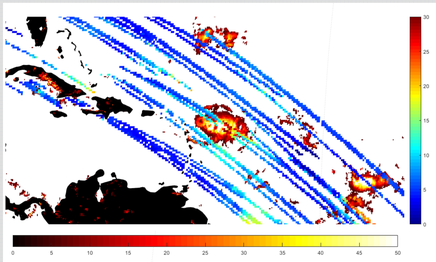

## 2017 Atlantic Hurricane Season Examples

### Hurricane Harvey



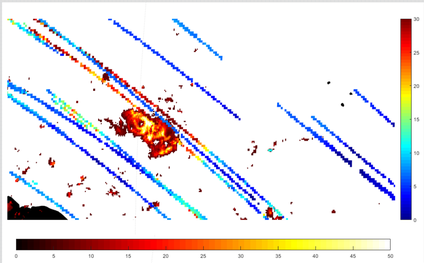
Sample date : **Aug 24 2017**
Time : 09:00 – 10:00 UTC
Maximum sustained wind speed : 25 m/s

### Hurricane Irma



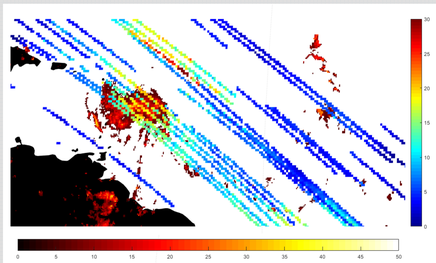
Sample date : **Sep 5th 2017**
Time : 08:00 – 09:00 UTC
Maximum sustained wind speed : 66.6 m/s

### Hurricane Jose



Sample date : **Sep 06 2017**
Time : 07:00 – 08:00 UTC
Maximum sustained wind speed : 26.38 m/s

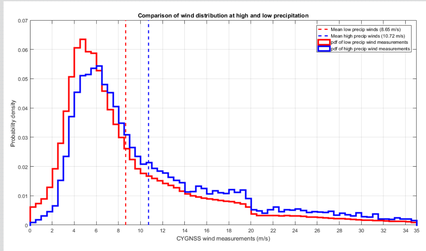
### Hurricane Maria



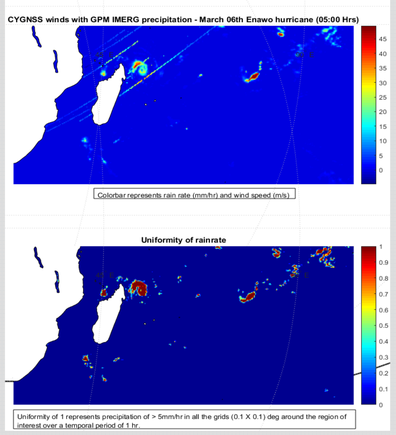
Sample date : **Sep 18 2017**
Time : 02:00 – 03:00 UTC
Maximum sustained wind speed : 38.89 m/s

## Combining GPM precipitation with CYGNSS winds

In the figure below, CYGNSS winds are broken down into 2 regions: winds during high precipitation (>20mm/hr) and during low precipitation (<1 mm/hr). A significant difference between the high and low precipitation winds is seen.

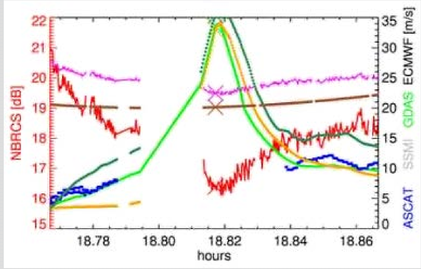



### Case study : Hurricane Enawo




The image on the left shows the GPM IMERG observation of hurricane Enawo made on 6th March 2017. Enawo was one of the strongest hurricane in a decade to hit Madagascar. The image on the top is the overlay of GPM IMERG and CYGNSS L3 winds.

The image below shows CYGNSS observations compared to model, radiometer, and scatterometer wind estimates for Enawo. Note that the radiometer and scatterometer observations can't penetrate the hurricane eye wall, but CYGNSS can.




## Conclusion

The combination of precipitation and surface winds can provide significant insight to tropical cyclone kinetics. Utilising GPM and CYGNSS observations in parallel over tropical cyclones will be studied in depth to explore this topic.