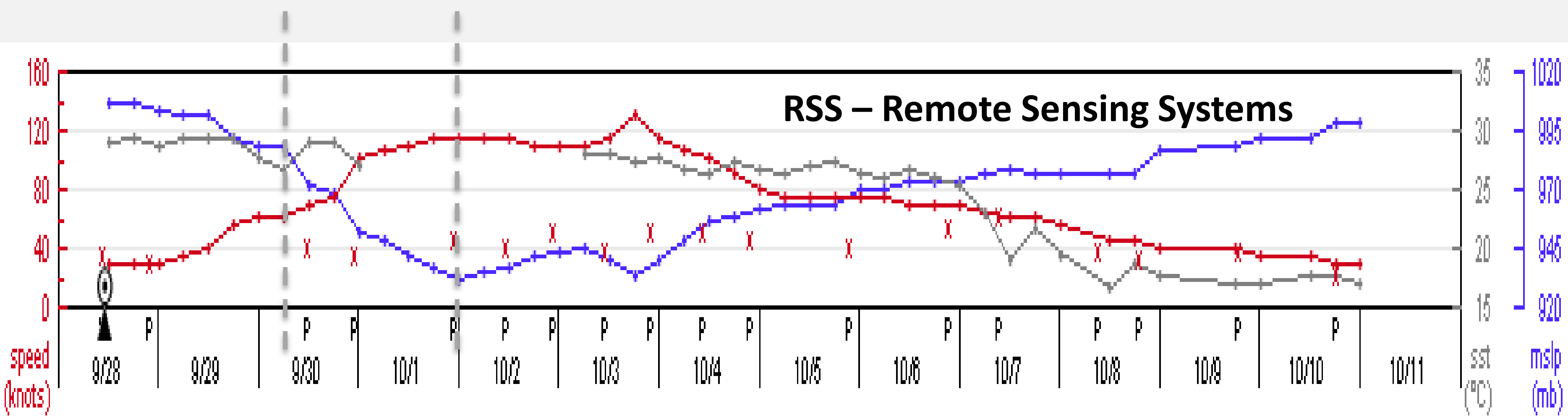
Svetla Hristova-Veleva, Ziad Haddad, Bryan Stiles,

Jet Propulsion Laboratory, California Institute of Technology

Accurate estimation of the ocean surface winds in hurricanes – a critical component for developing predictors for hurricane Rapid Intensification potential

Joaquin

- Hurricane Joaquin, the strongest Atlantic hurricane since Igor in 2010, developed on September 27th 2015. Of particular interest to our study is the evolution of Joaquin's intensity.
- Early in its lifecycle the hurricane underwent a Rapid Intensification (RI) and saw a pressure drop of 57 millibars in about 39 hours, going from a strong tropical storm to a Category 4 hurricane.



Could we predict that?

Current Hypotheses and Questions

- **Inner core processes play crucial role in determining storm's intensity and size.**
- **Need to understand the roles of :**
  - **convective type and organization.**
    - **azimuthally symmetric and weak convection**
    - **isolated, asymmetric deep/intense convection**
  - **spatial distribution of the convection**
    - **radial location with respect to Radius of Maximum Wind**
    - **azimuthal location with respect to the shear vector** (deep convection propagating from Downshear-Right (DSR) to DSL and then to USL)
- **Can we use satellite observations to understand these roles?**

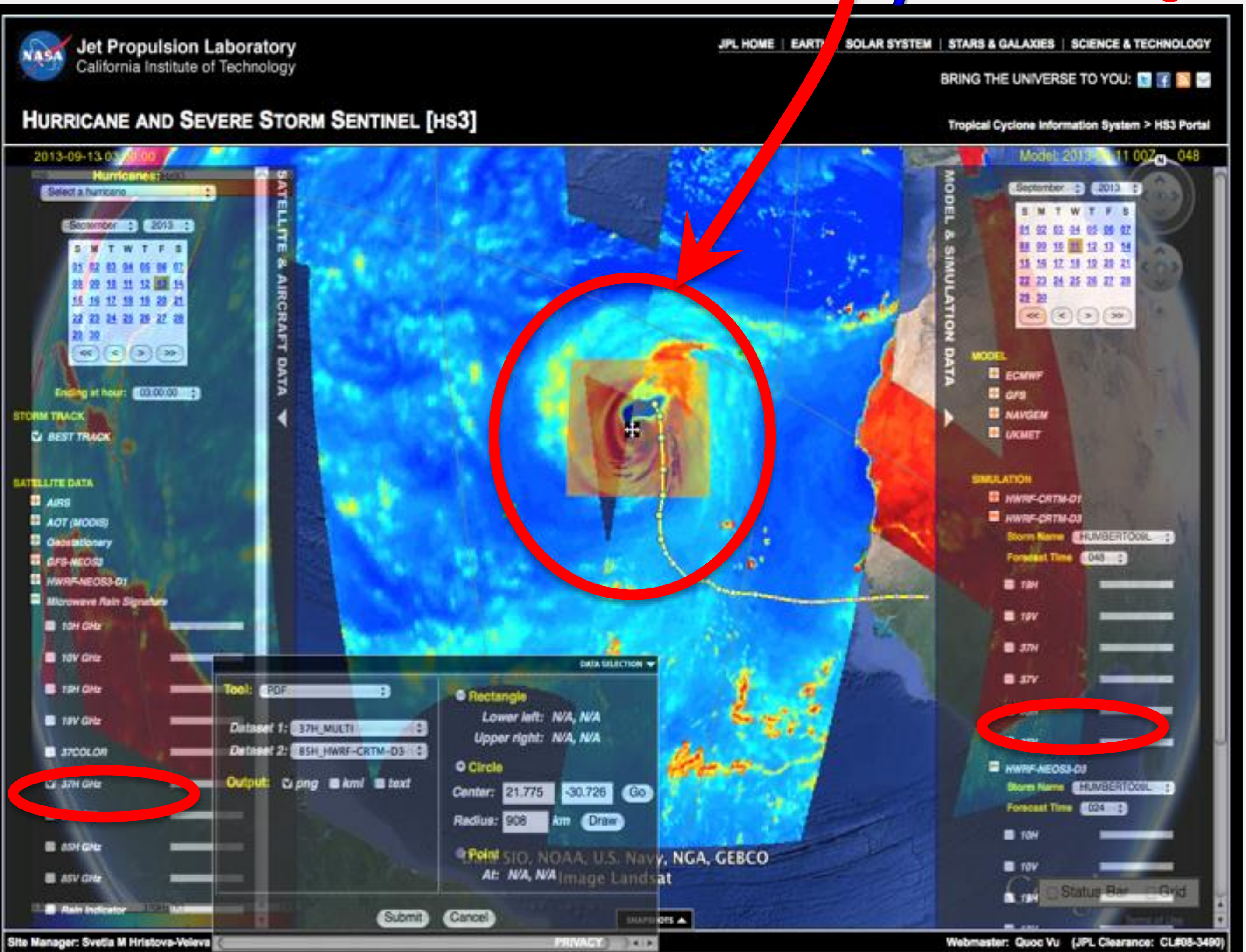
Approach

- Motivated by this, **we examine the relationship between:**
  - **the structure of the 2D precipitation**
    - **GMI, AMSR2, SSMIS**
  - **the structure of the near-surface wind field**
    - **RapidScat, ASCAT and now SMAP**
- **We relate the evolution of these two fields**, as determined from near-simultaneous satellite observations, **to the hurricane intensity changes and we find potential predictive capabilities**.

The North Atlantic Hurricane Watch: On-line Analysis Tools:

http://mwsci.jpl.nasa.gov/nahw

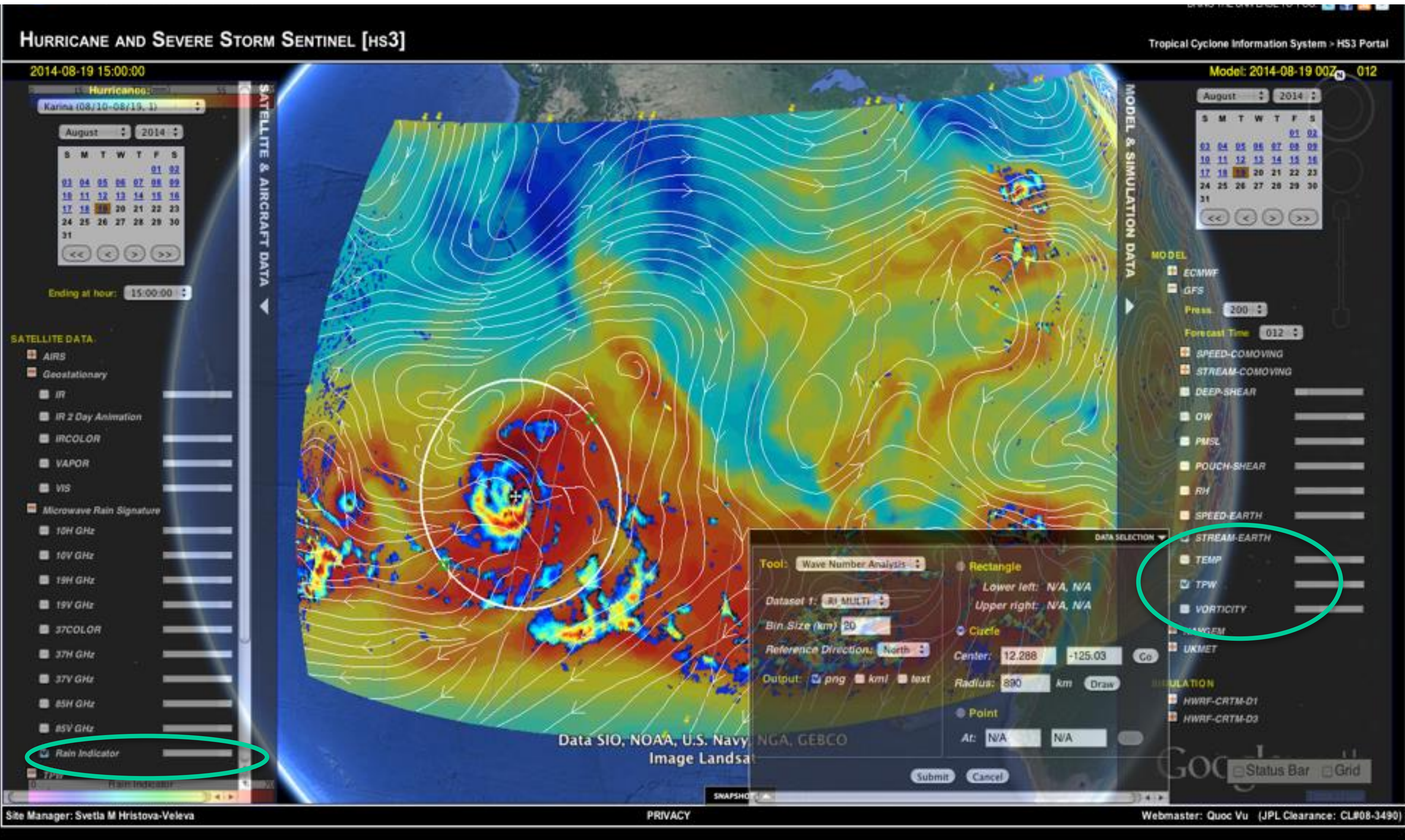
- Interactively select region
- Gather data from **observed** and **synthetic** brightness temperature



- **PERFORM:**

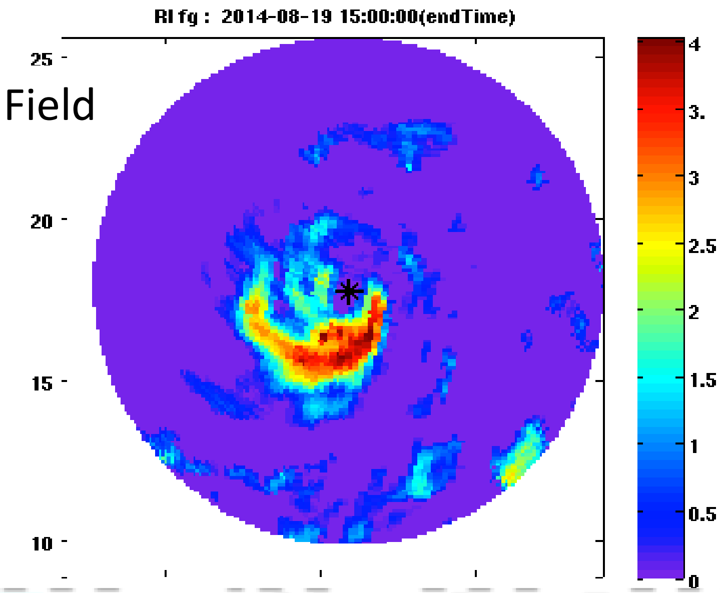
- Statistical evaluation
  - EOFs, Joint PDFs
  - Azimuthal averages
- Storm Structure
  - Storm Size/Asymmetry
  - Storm Center - ARCHER
  - Convective/Stratiform
- Environment
  - Vertical Slices On-demand
- Analysis Visualization

The Observed Rain Index (in contrasting colors); GFS 12h forecast of the TPW (in pastel colors) and the 200 mb flow

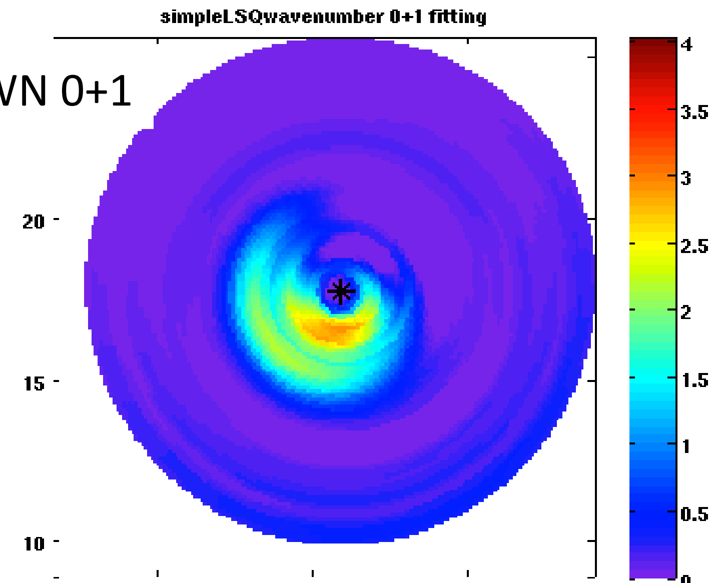


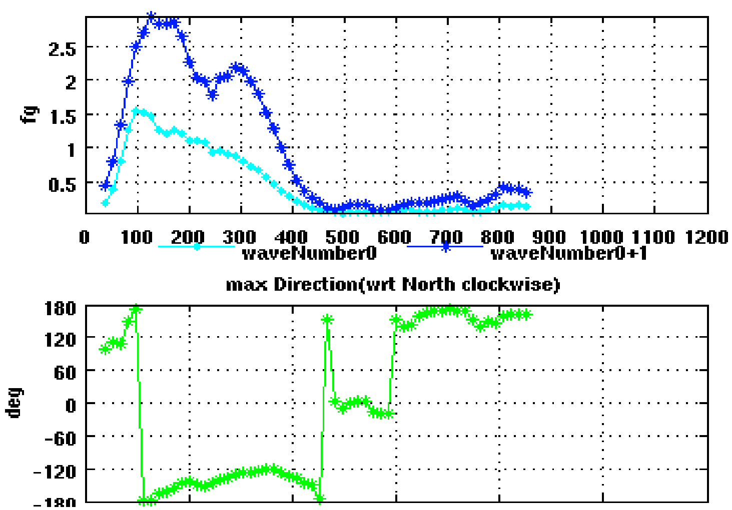
Wave Number Analysis of the Rain Field (as depicted by the Rain Index) from pa microwave observations (following Vukicevic et al. 2013)

Total Field



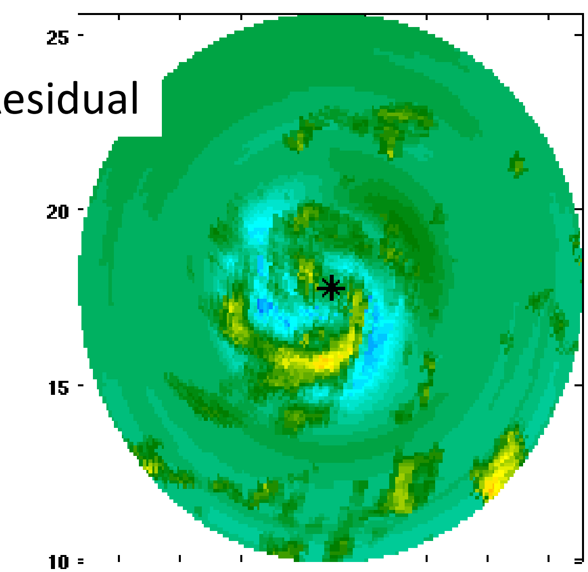
WN 0+1

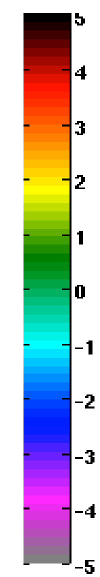




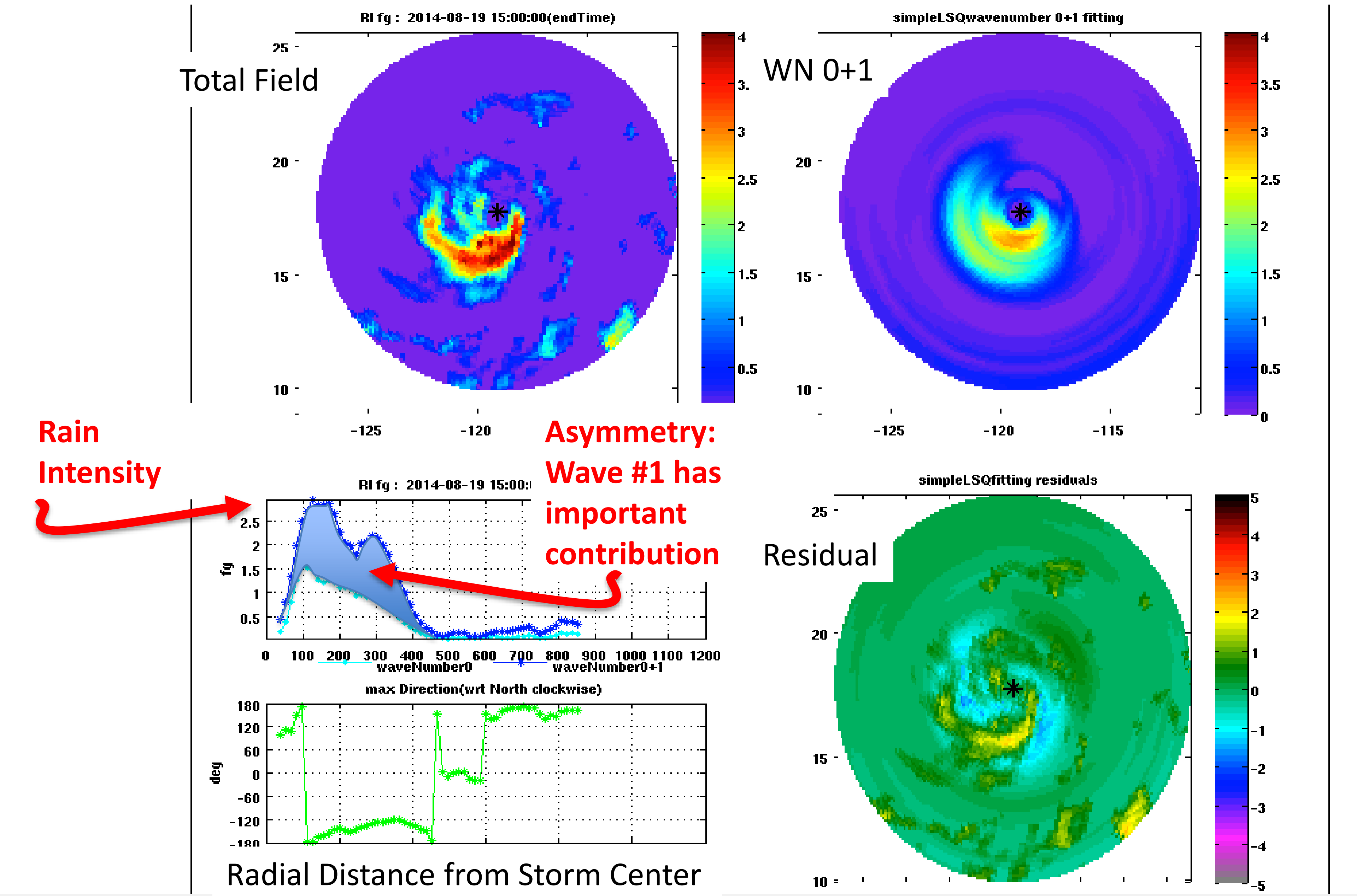
Radial Distance from Storm Center

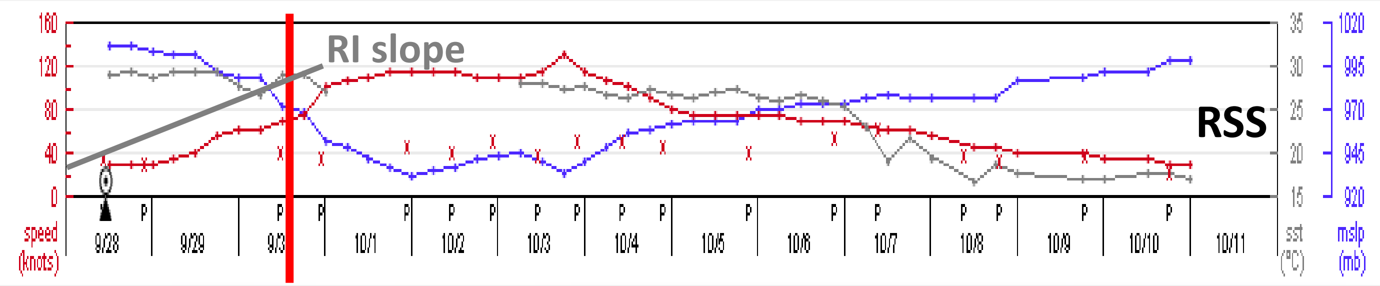
Residual



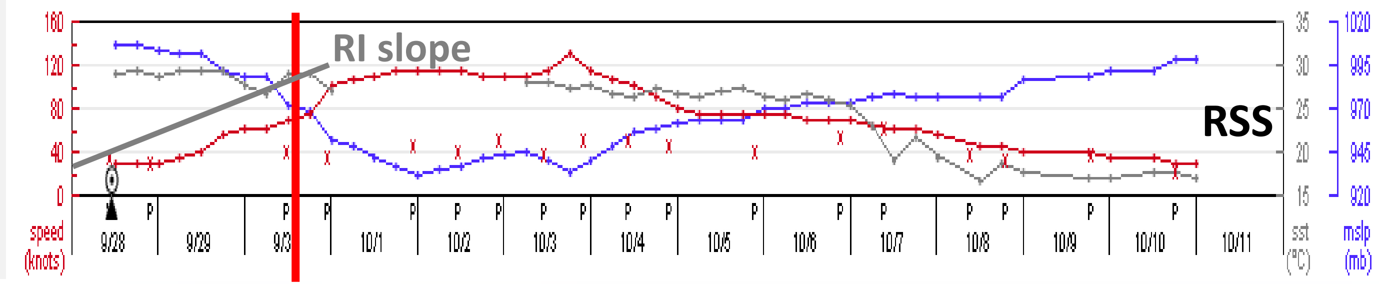


Wave Number Analysis of the Rain Field (as depicted by the Rain Index) from pa
microwave observations: FEATURES of the Rain Field

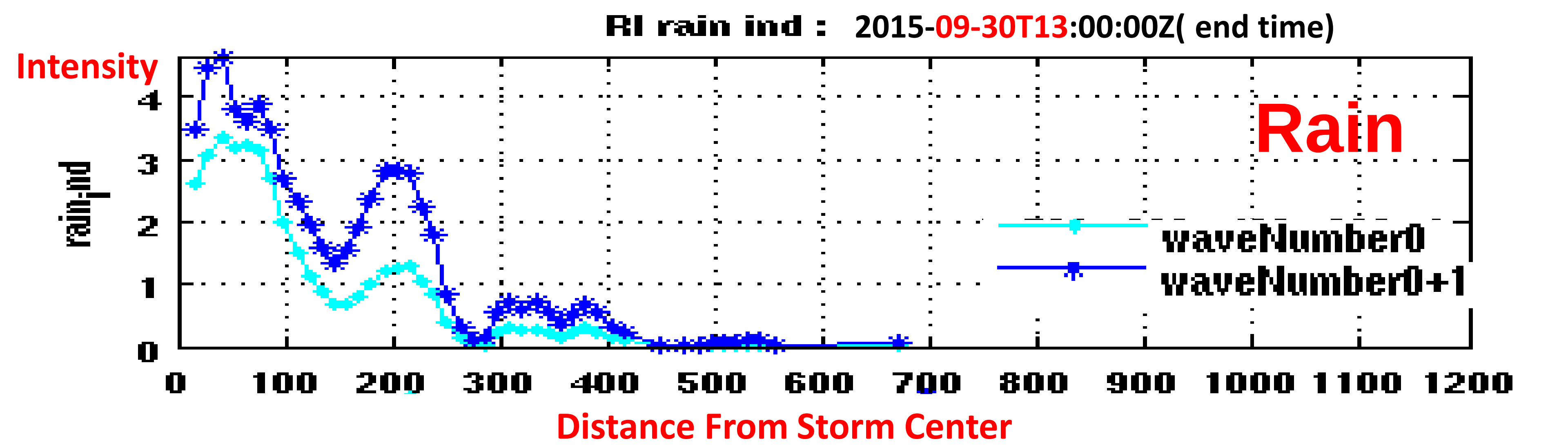




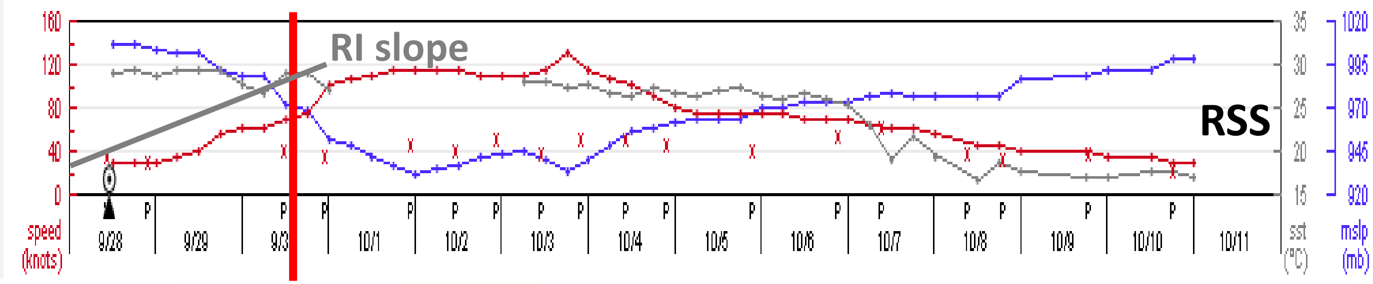
Hurricane Joaquin

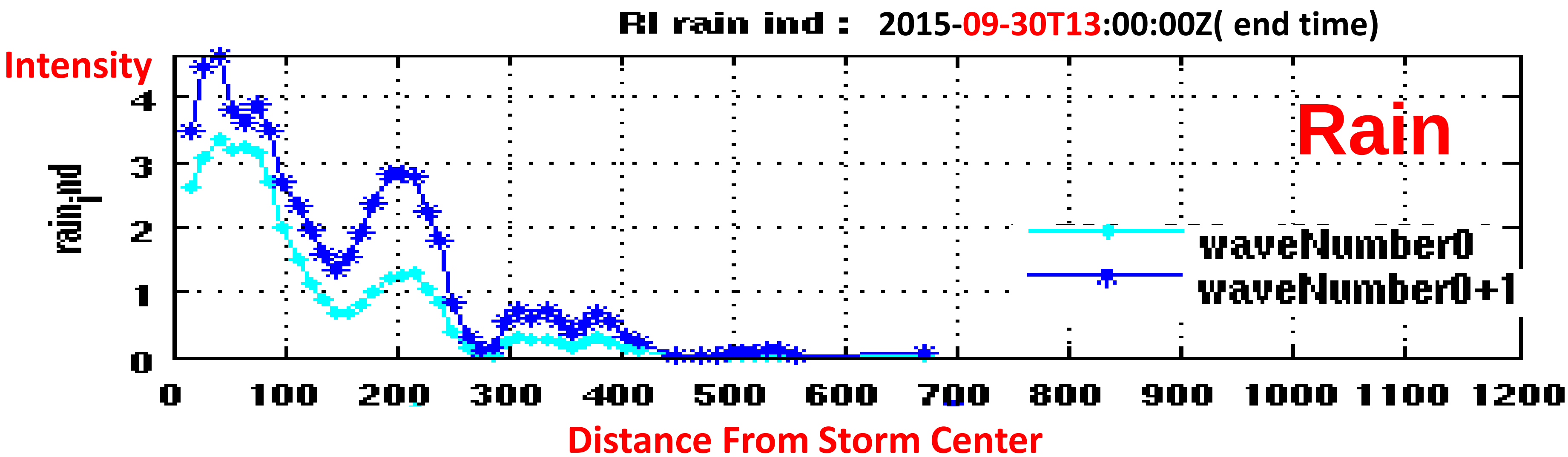


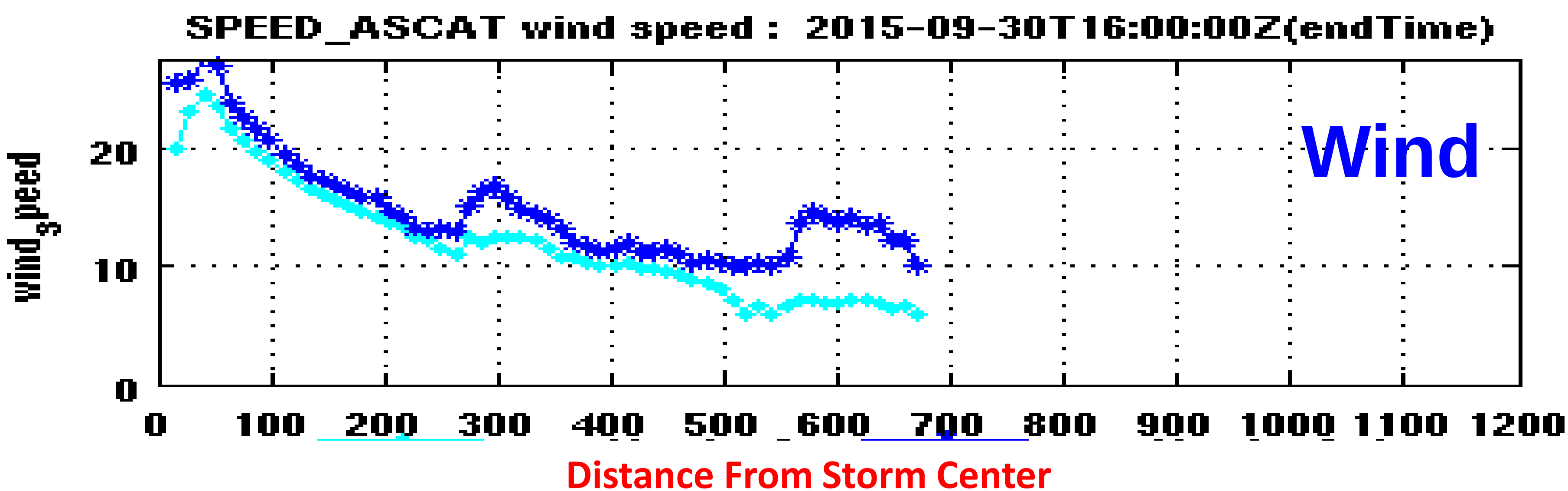
RI slope
RSS
speed (knots)
sst (°C)
mslp (mb)
9/28
9/29
9/30
10/1
10/2
10/3
10/4
10/5
10/6
10/7
10/8
10/9
10/10
10/11

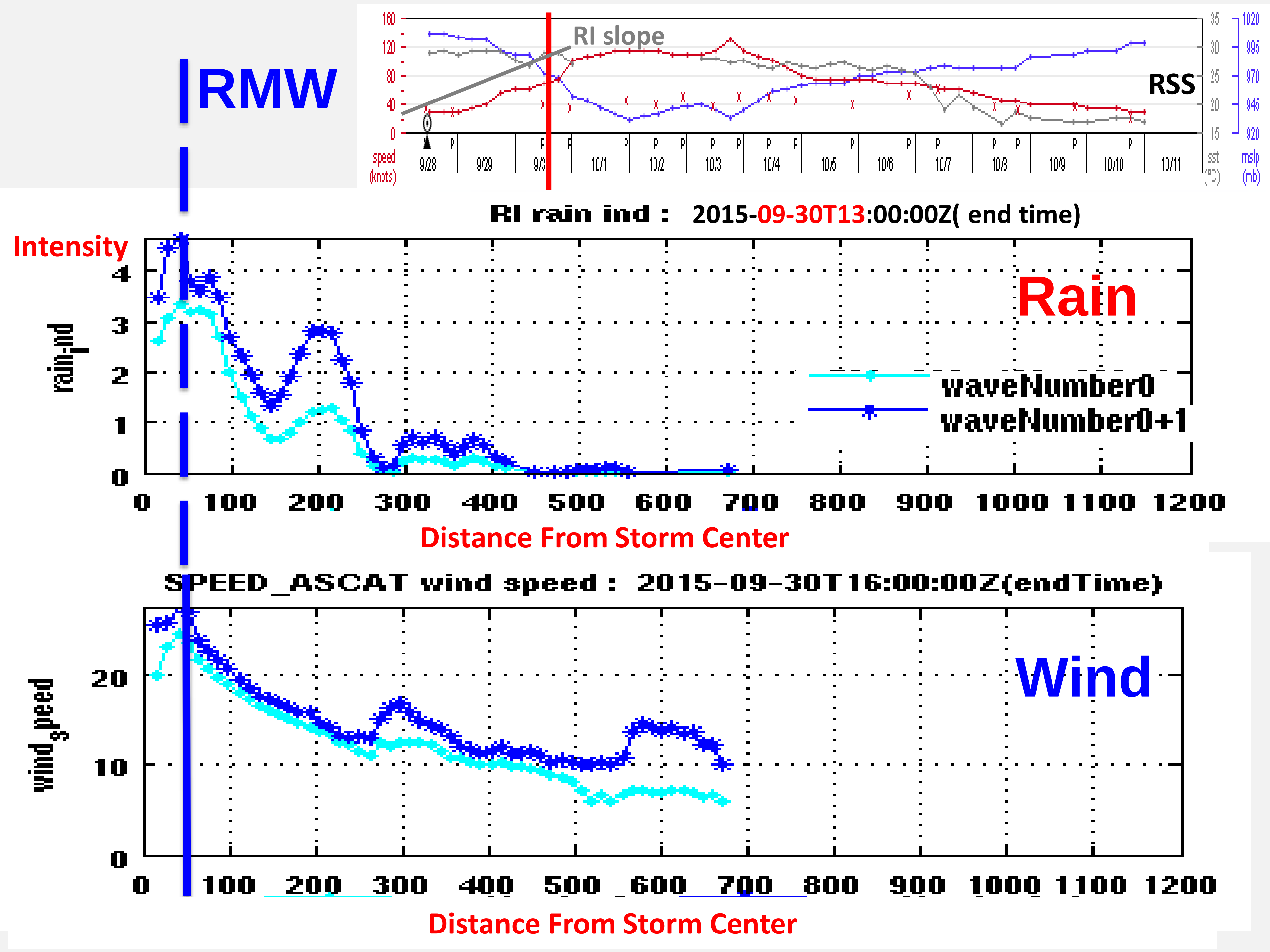


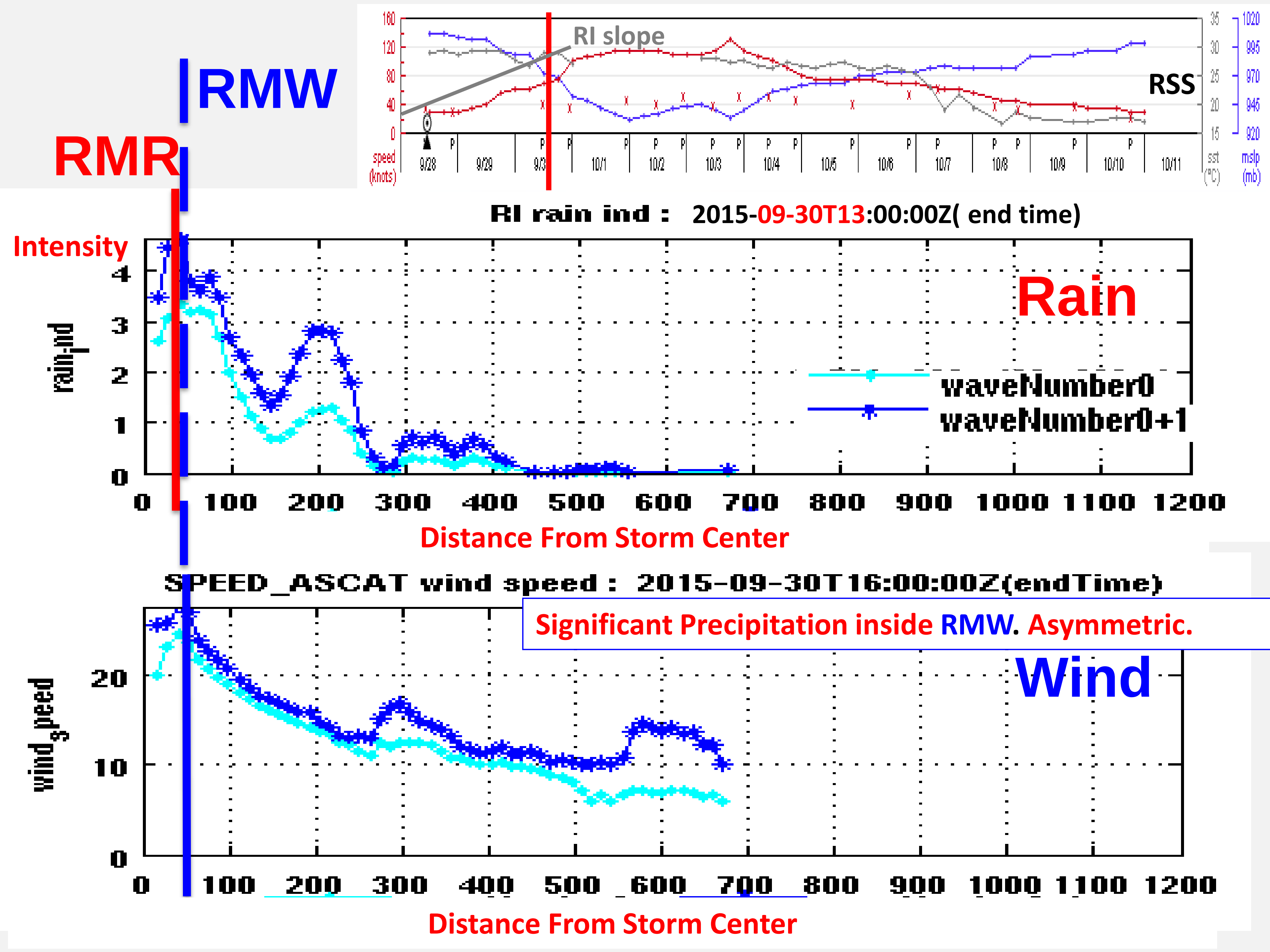
RI rain ind : 2015-09-30T13:00:00Z(end time)
Intensity
rain-ind
Rain
waveNumber0
waveNumber0+1
Distance From Storm Center


RI slope
RSS
speed (knots)
sst (°C)
mslp (mb)

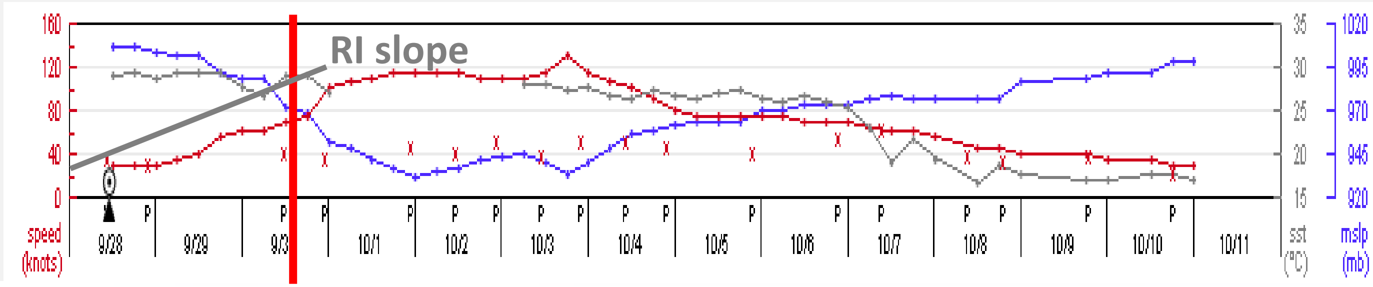

RI rain ind : 2015-09-30T13:00:00Z(end time)
Intensity
rain_ind
Rain
waveNumber0
waveNumber0+1
0 100 200 300 400 500 600 700 800 900 1000 1100 1200
Distance From Storm Center

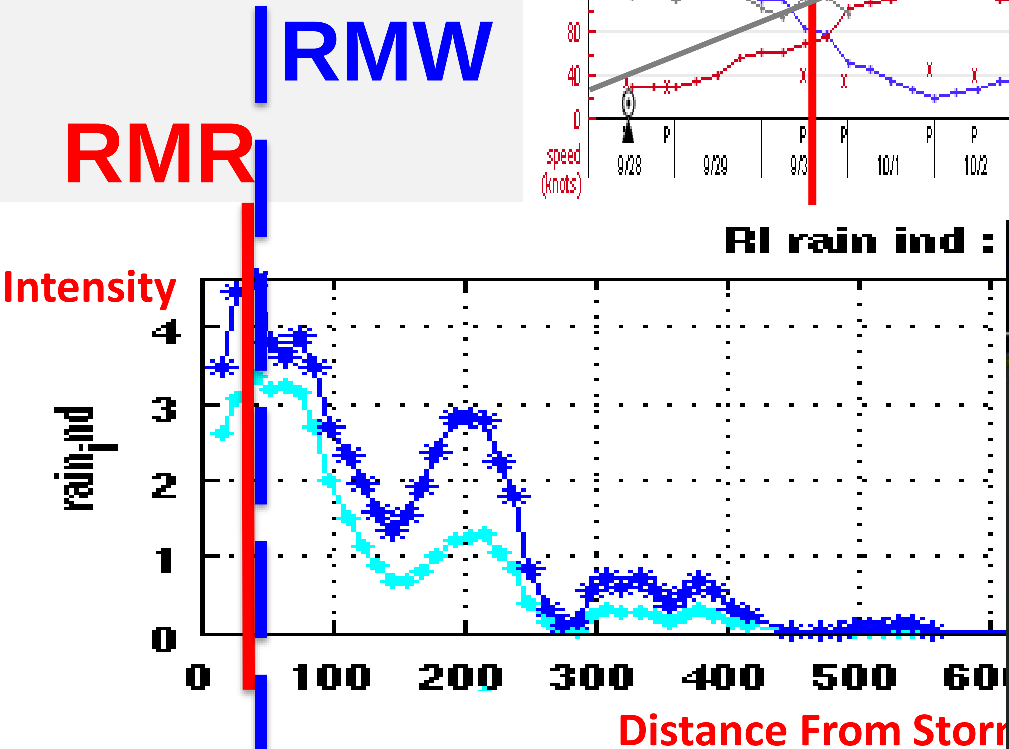

SPEED_ASCAT wind speed : 2015-09-30T16:00:00Z(endTime)
wind_speed
Wind
0 100 200 300 400 500 600 700 800 900 1000 1100 1200
Distance From Storm Center

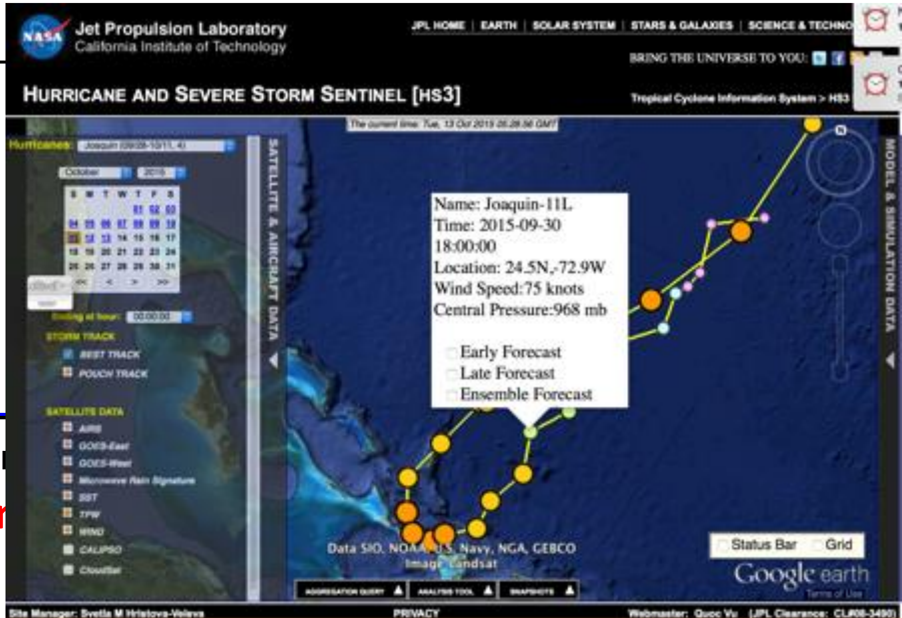

RMW
RI slope
RSS
speed (knots)
sst (°C)
mslp (mb)
9/28
9/29
9/30
10/1
10/2
10/3
10/4
10/5
10/6
10/7
10/8
10/9
10/10
10/11
RI rain ind : 2015-09-30T13:00:00Z(end time)
Intensity
rain_ind
Rain
waveNumber0
waveNumber0+1
Distance From Storm Center
SPEED_ASCAT wind speed : 2015-09-30T16:00:00Z(endTime)
wind_speed
Wind
Distance From Storm Center

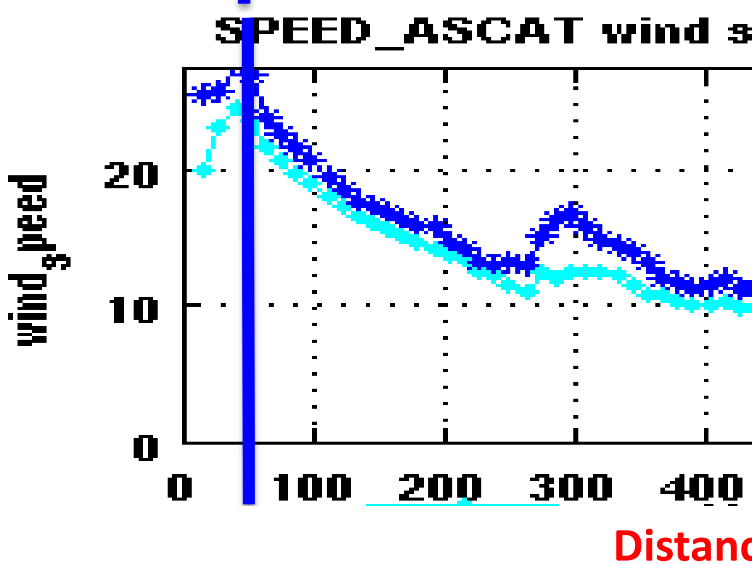


Significant Precipitation inside RMW. Asymmetric.





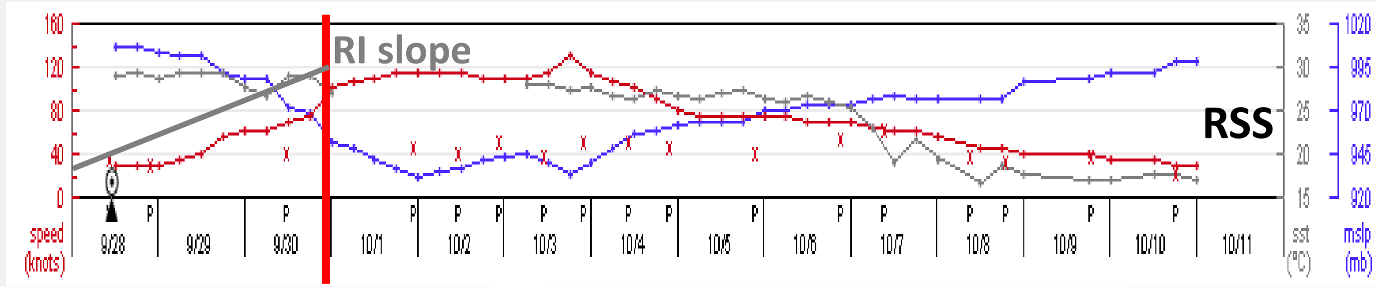


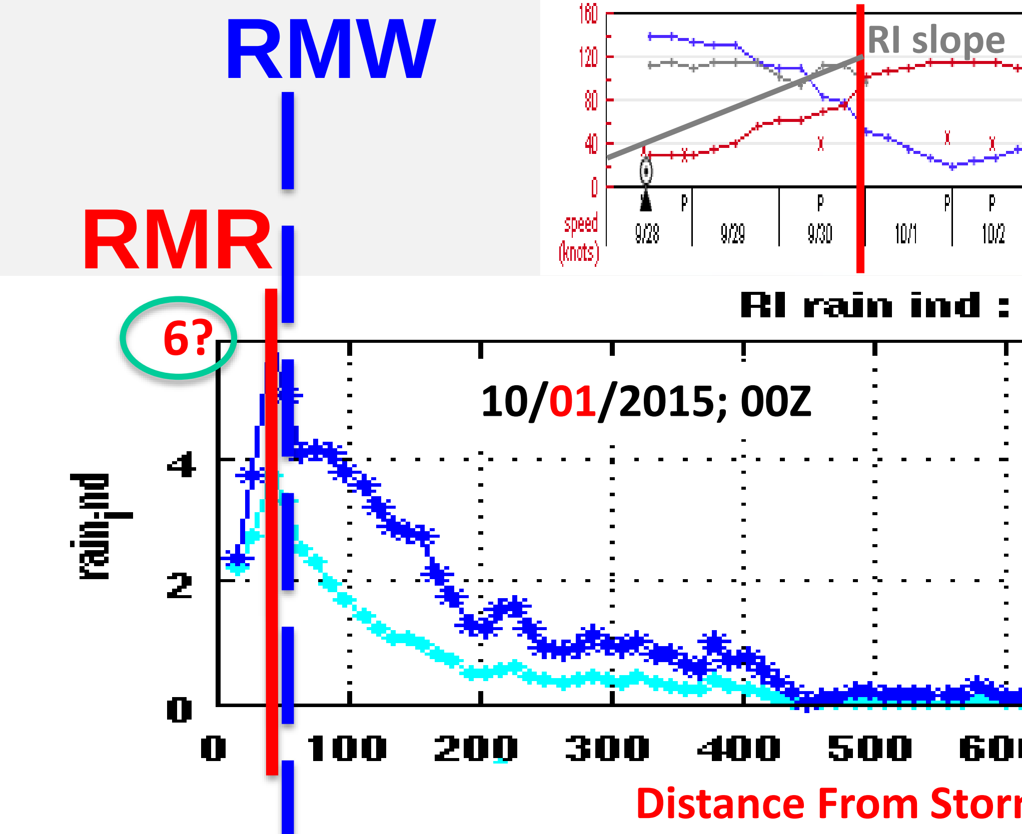


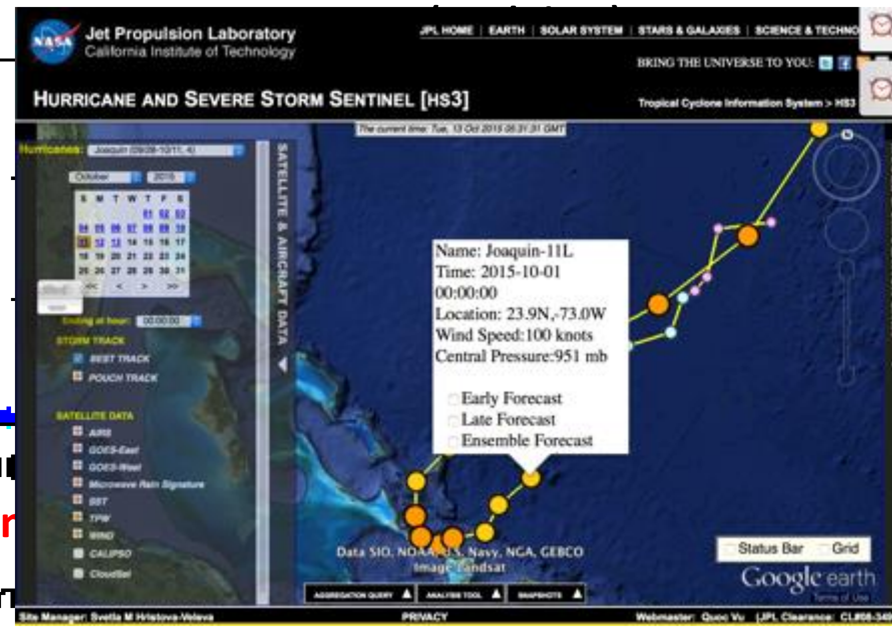
Radius of Max Rain (RMR) is just inside the Radius of Max Wind (RMW).

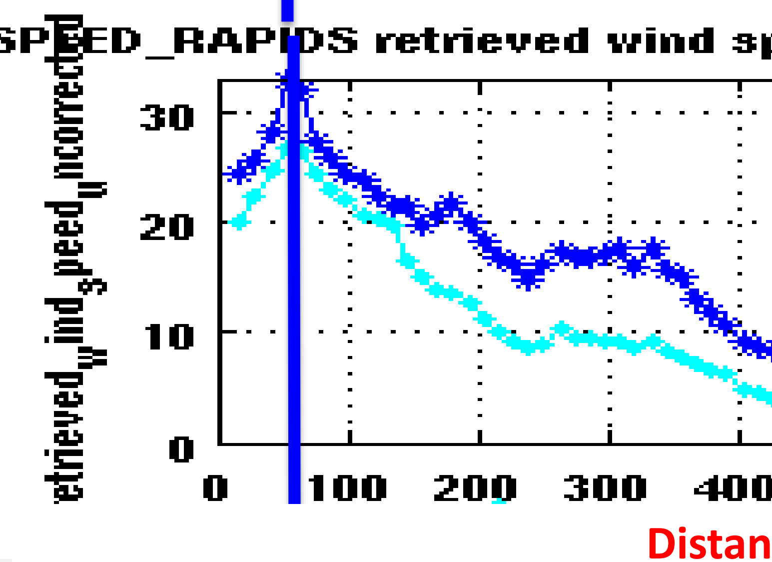
Significant Precipitation inside RMW. Asymmetric.

Conditions are conducive to Intensification? (Rogers et al.) Note: This analysis is before the very RI. The very Rapid Intensification seems to have begun after 18Z.





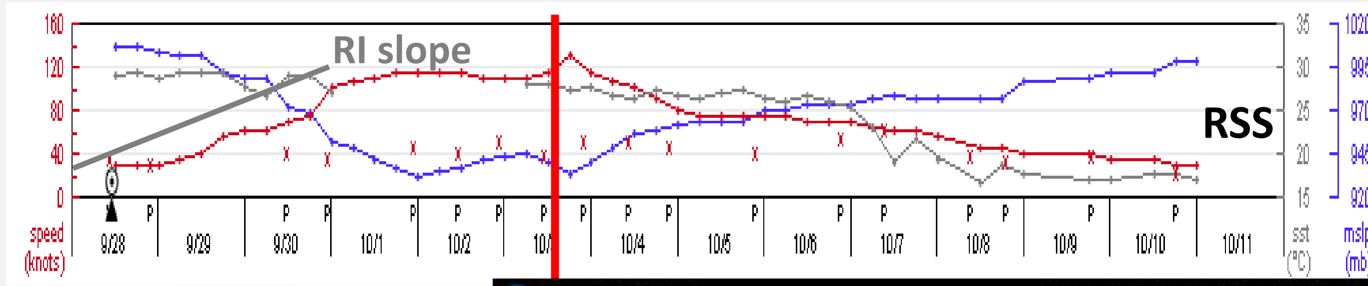


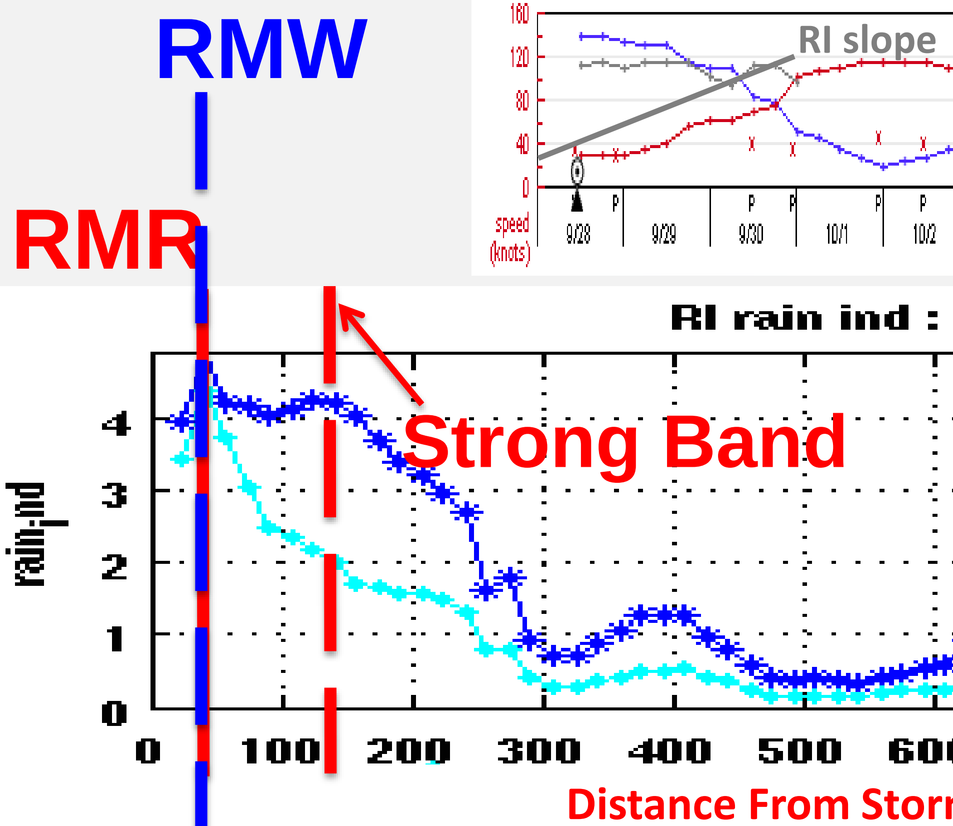


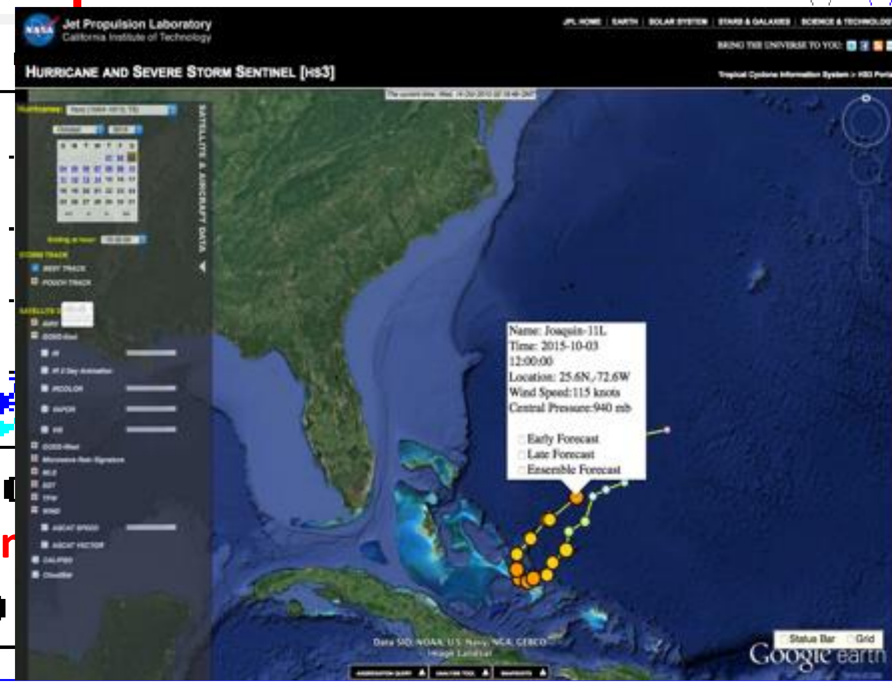
Radius of Max Rain (RMR) is just inside the **Radius of Max Wind (RMW).**

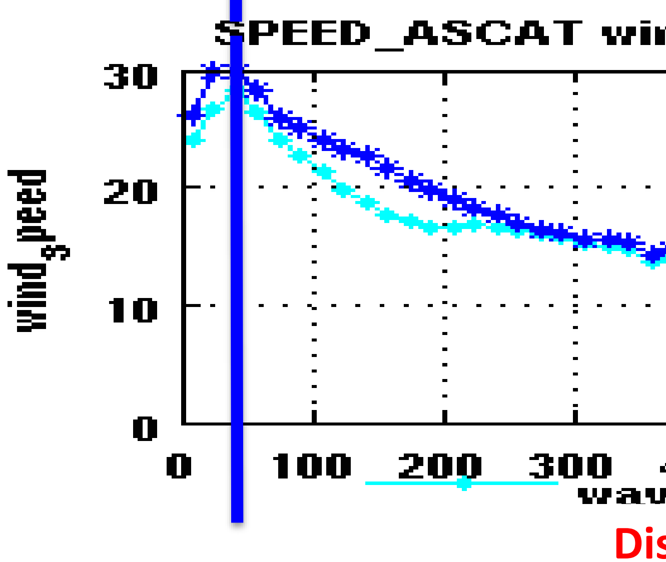
Very intense precipitation inside RMW.
Very symmetric near the center.

Conditions are conducive to Intensification.
This analysis is during the very RI.





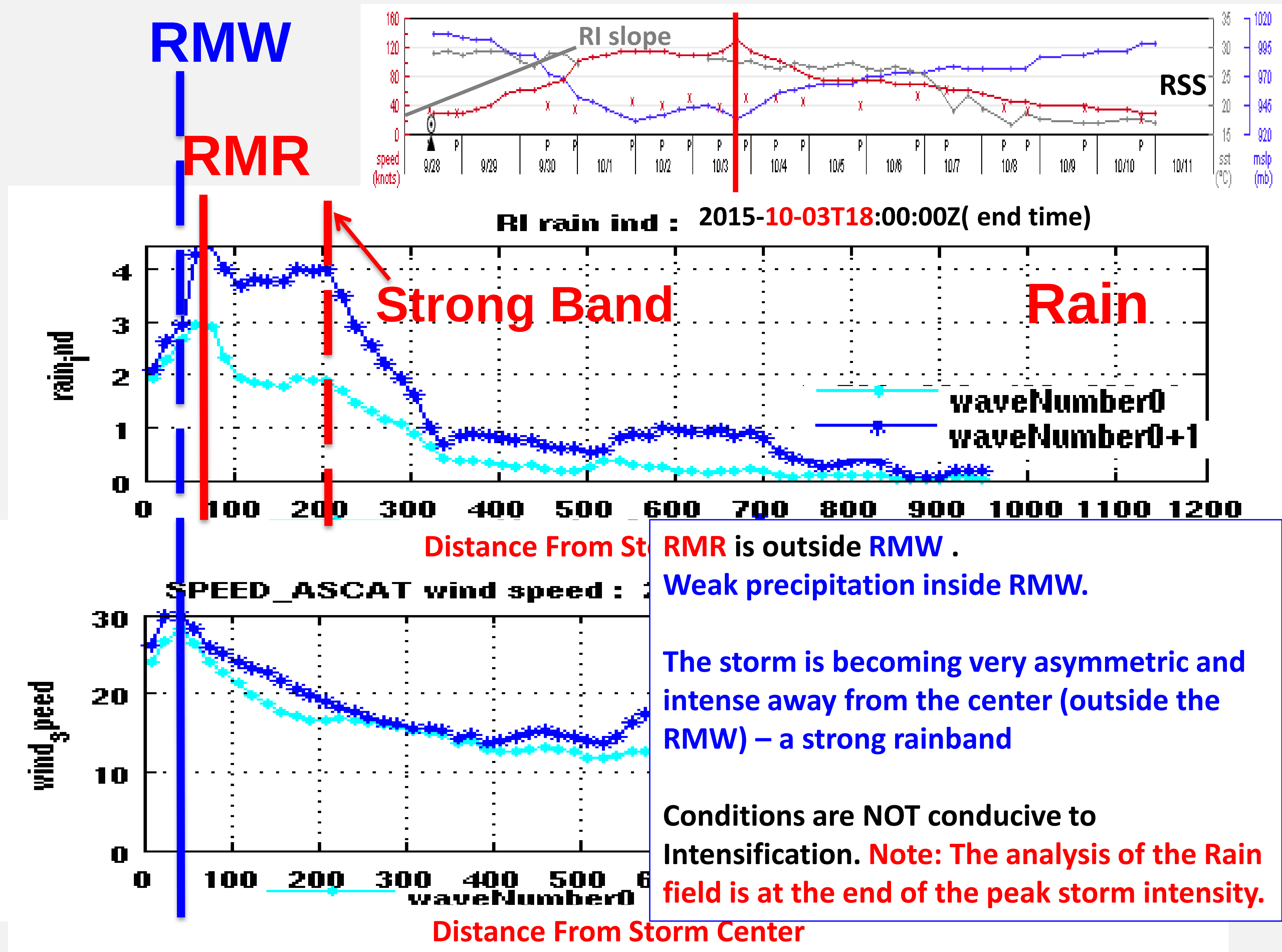




Radius of Max Rain (RMR) is just about the same as the Radius of Max Wind (RMW).

The precip is intense and quite symmetric near the center.
Development of a secondary rainband outside RMW.

Conditions are conducive to Intensification (Rogers et al.)
Note: This analysis is during the very strong intensity.



RMR is outside RMW .
Weak precipitation inside RMW.

The storm is becoming very asymmetric and intense away from the center (outside the RMW) – a strong rainband

Conditions are NOT conducive to Intensification. Note: The analysis of the Rain field is at the end of the peak storm intensity.

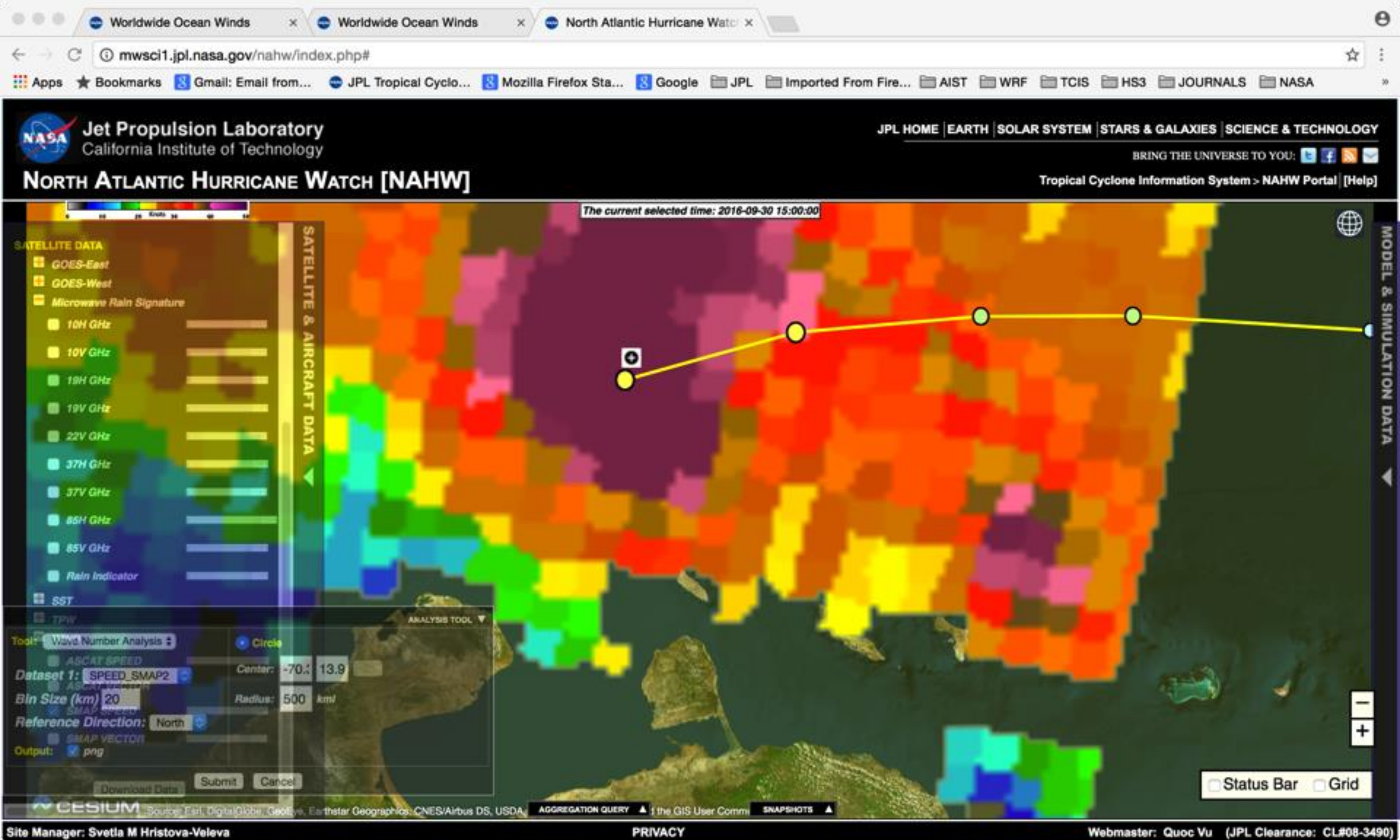
Summary

- Satellite observations, together with our analysis tools, allow quantifying the radial distribution of several important characteristics of the storm:
  - **the degree of storm symmetry**
  - **the radial distribution of the intensity** (wind, rain)
  - **the intensity/symmetry of rain in relation to the RMW**, with dynamical consequences for the RI
- According to theory and recent research, and supported by our studies, these analyses have potential for predicting Rapid Intensification.

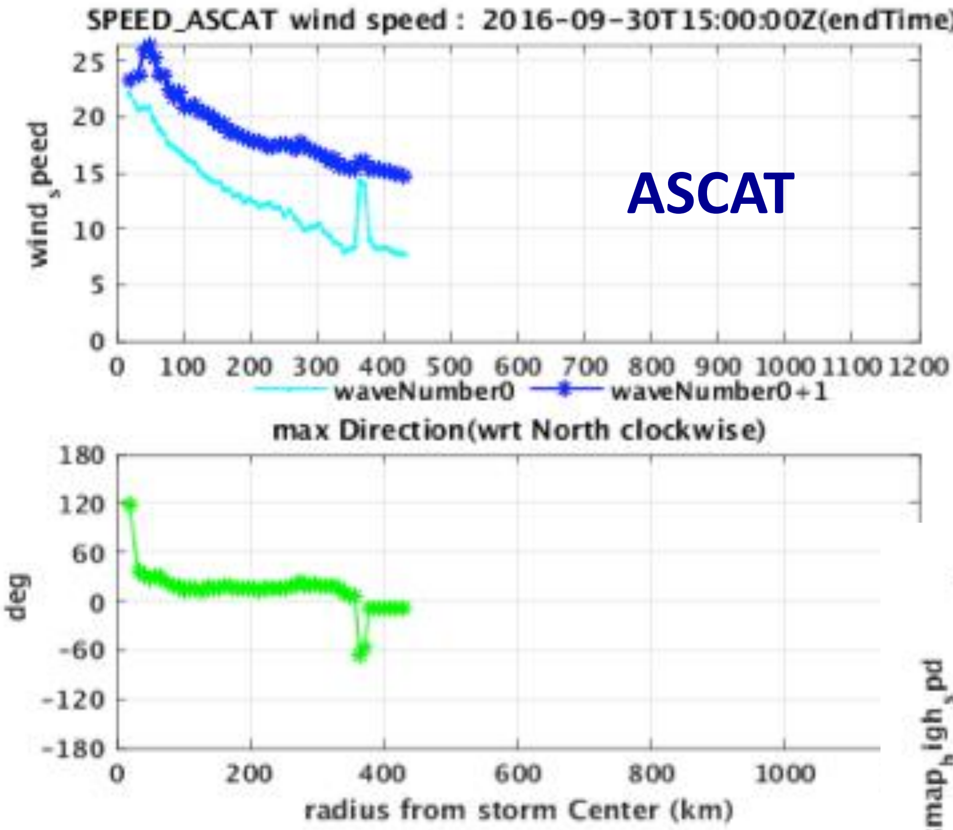
Summary (cont.)

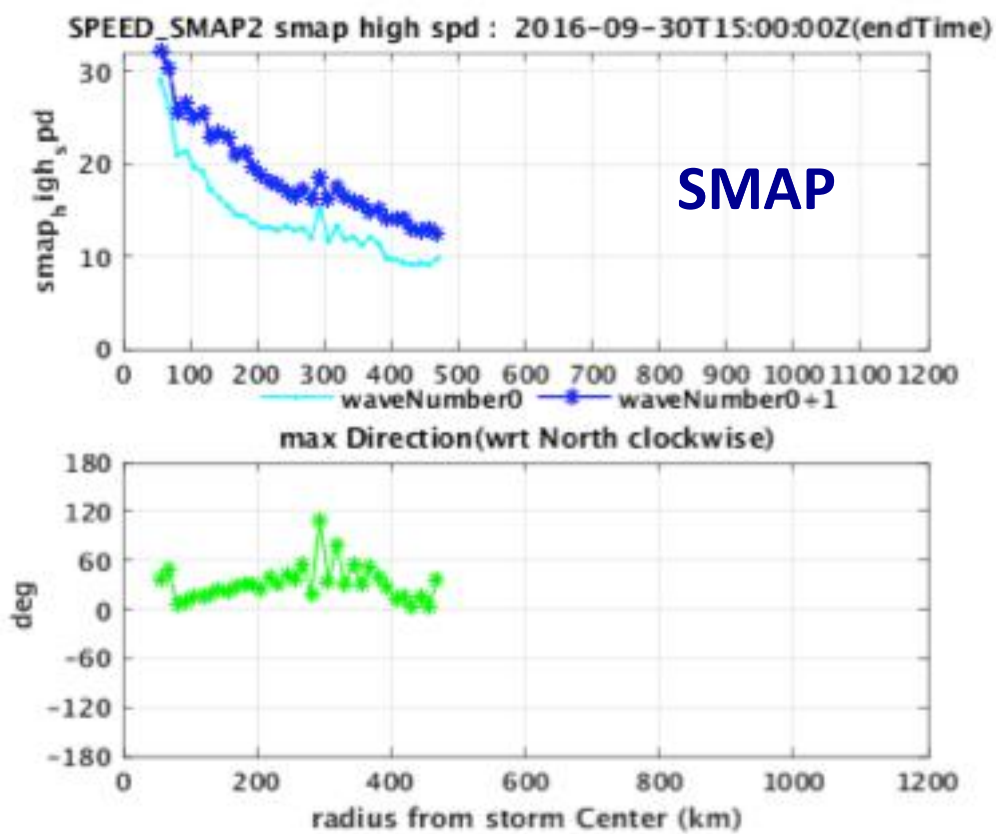
- To make these analyses we need near-coincident (within 3 hours) satellite observations of precipitation and near surface winds.
  - Passive Microwave Observations of precipitation are relatively frequent
  - Satellite observations of near-surface winds are infrequent.
- This brings to the forefront the need of accurate observations of the near-surface ocean winds in hurricane conditions.
  - particular important is the ability to accurately determine the radius of maximum wind.
  - translates into a requirement for accurate determination of high winds, and under the heavy precipitation in the hurricane inner core.
    - Using SMAP observations could help.

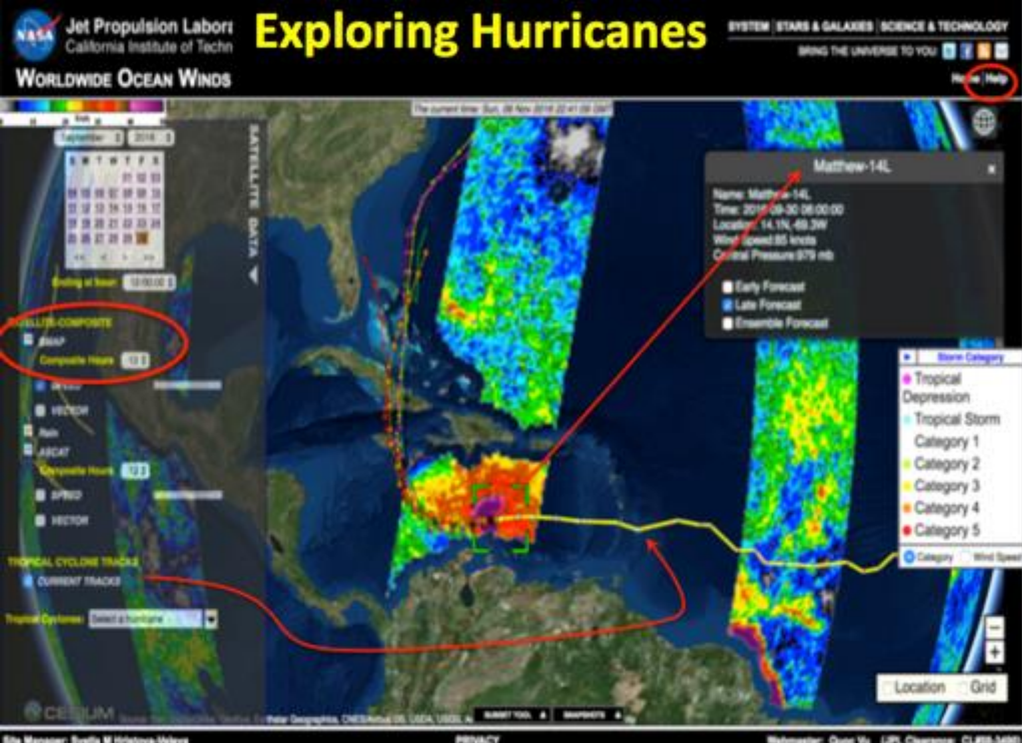
SMAP's view of Hurricane Matthew



The structures from SMAP and ASCAT are very similar







Worldwide Ocean Winds

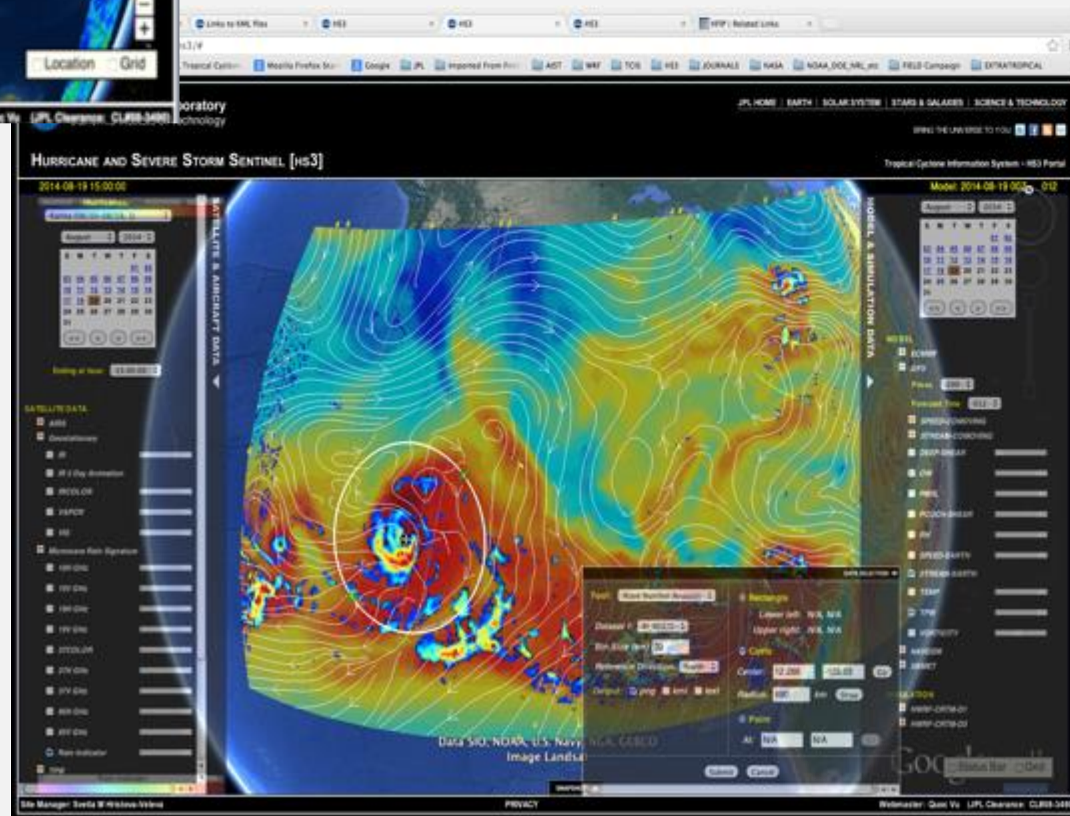
http://wow.jpl.nasa.gov

- Global and 365 days
- ASCAT and SMAP
- Hurricane Tracks
- Hurricane database

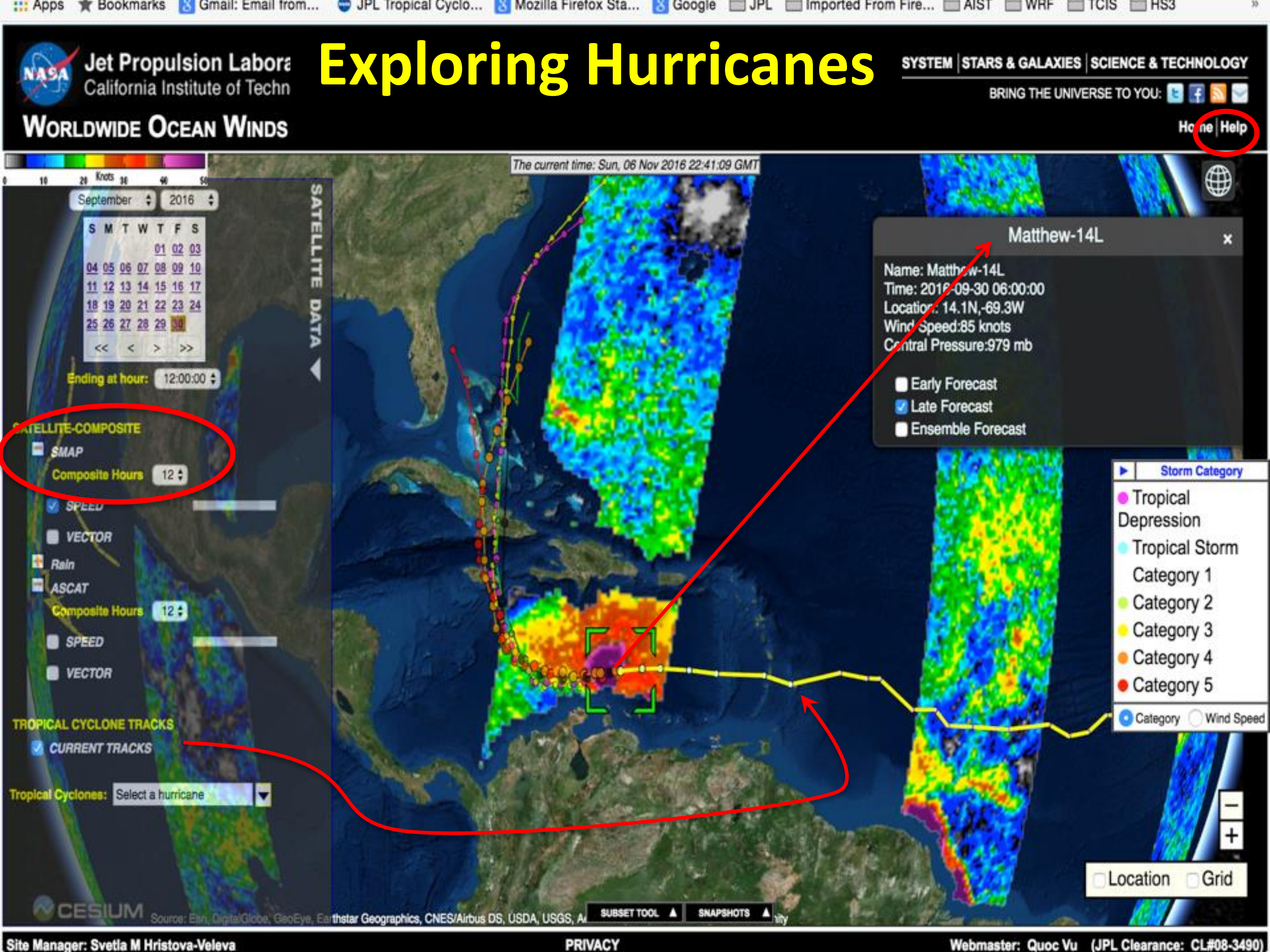
North Atlantic Hurricane Watch

http://mwsci.jpl.nasa.gov/nahw

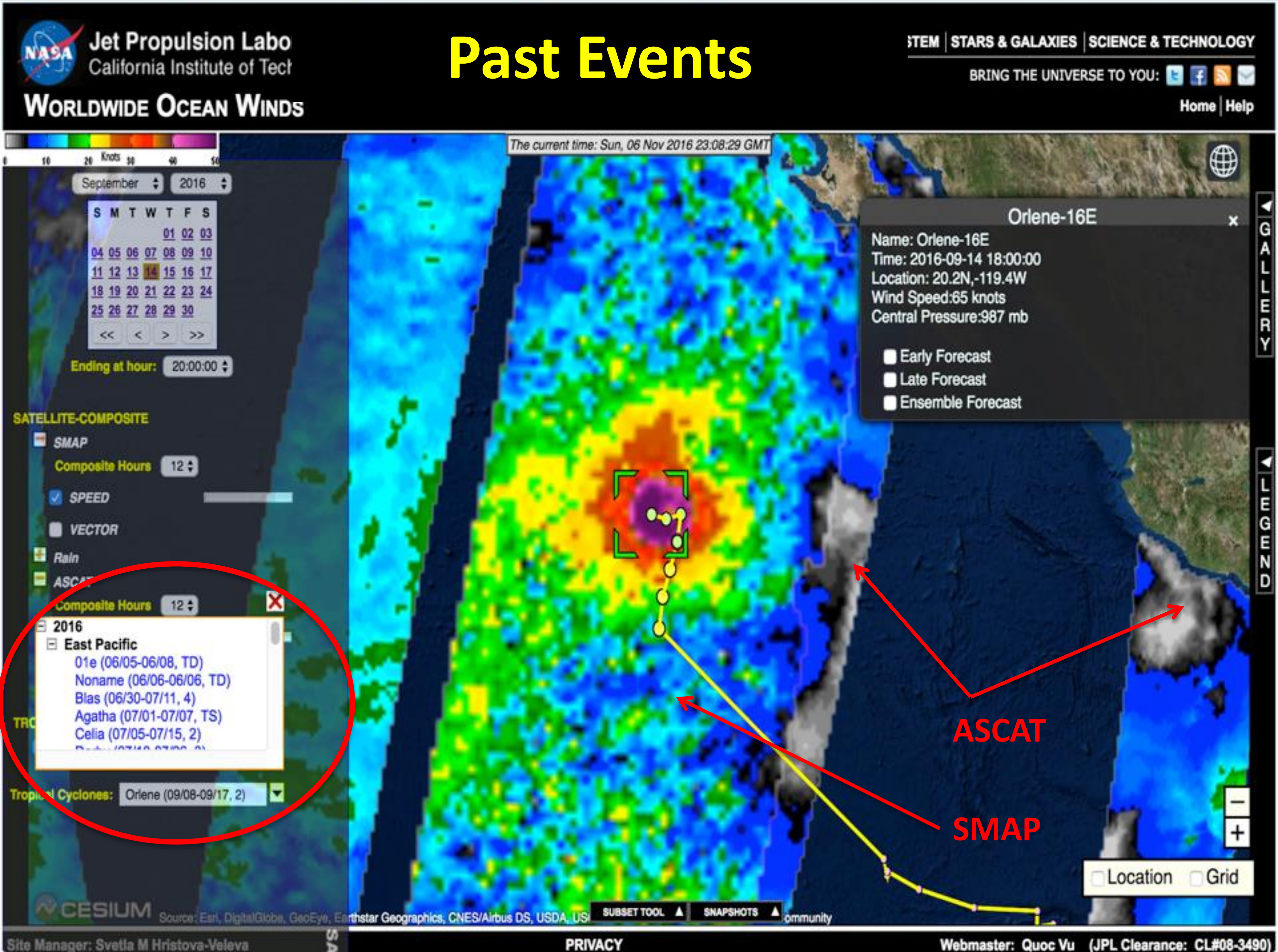
- Atlantic and East Pac. ; seasonal
- ASCAT/SMAP **and Many More Obs.**
  - Rain, SST, IR, AIRS, TPW
- Model data
- Hurricane Tracks
- Hurricane database



Exploring Hurricanes



Past Events



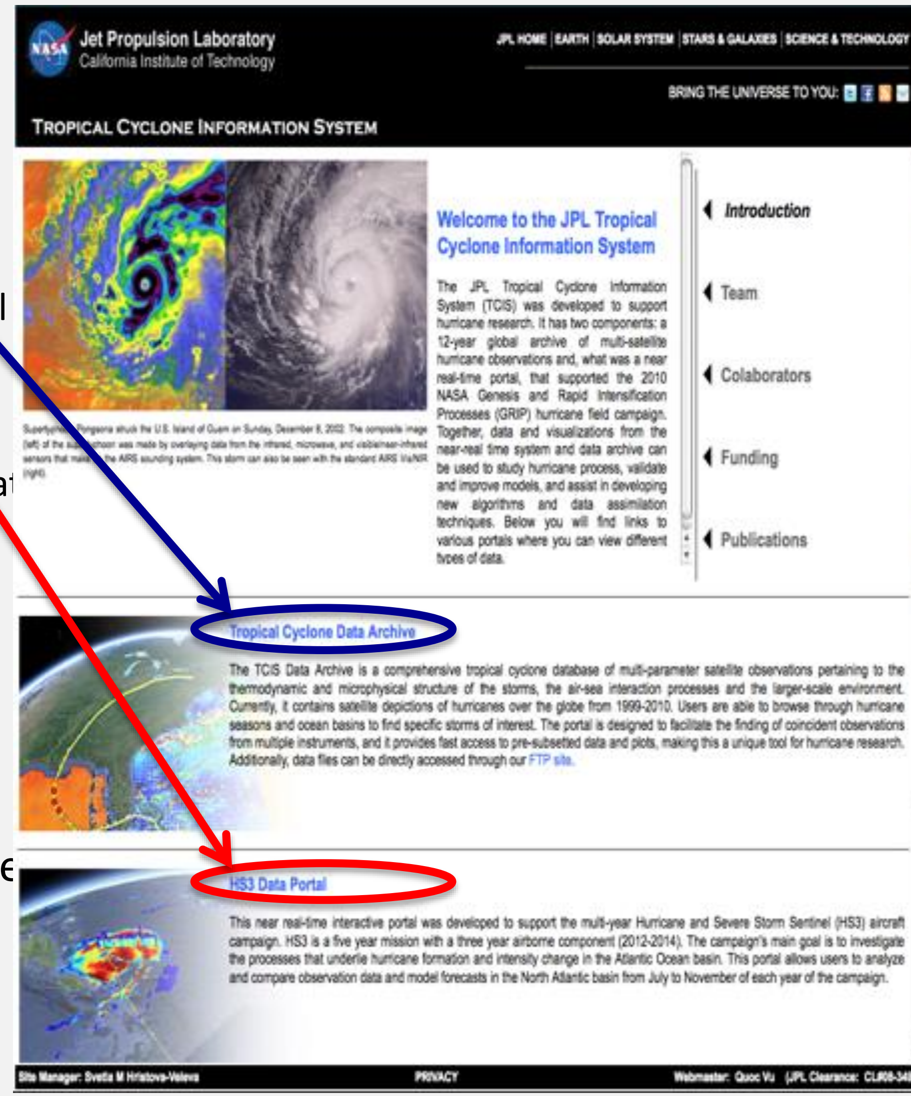
Jet Propulsion Labo
California Institute of Tech
WORLDWIDE OCEAN WINDS
STEM | STARS & GALAXIES | SCIENCE & TECHNOLOGY
BRING THE UNIVERSE TO YOU:
Home | Help
Knots
The current time: Sun, 06 Nov 2016 23:08:29 GMT
September 2016
S M T W T F S
01 02 03
04 05 06 07 08 09 10
11 12 13 14 15 16 17
18 19 20 21 22 23 24
25 26 27 28 29 30
Ending at hour: 20:00:00
SATELLITE-COMPOSITE
SMAP
Composite Hours 12
SPEED
VECTOR
Rain
ASCAT
Composite Hours 12
2016
East Pacific
01e (06/05-06/08, TD)
Noname (06/06-06/06, TD)
Blas (06/30-07/11, 4)
Agatha (07/01-07/07, TS)
Celia (07/05-07/15, 2)
Tropical Cyclones: Orlene (09/08-09/17, 2)
Orlene-16E
Name: Orlene-16E
Time: 2016-09-14 18:00:00
Location: 20.2N,-119.4W
Wind Speed:65 knots
Central Pressure:987 mb
Early Forecast
Late Forecast
Ensemble Forecast
GALLERY
LEGEND
ASCAT
SMAP
Location
Grid
CESIUM
SUBSET TOOL
SNAPSHOTS
Site Manager: Svetla M Hristova-Veleva
PRIVACY
Webmaster: Quoc Vu (JPL Clearance: CL#08-3490)

Backup

Data, tools and sources

- The study utilizes observations and on-line analysis tools provided by the JPL Tropical Cyclone Information System (TCIS), developed to support hurricane research.
- TCIS has two components:
  - The Tropical Cyclone Data Archive - a 12-year global archive of multi–satellite hurricane observations;
  - The North Atlantic Hurricane Watch (NAHW - http://mwsci.jpl.nasa.gov/nahw) - a data portal that monitors hurricanes in the North Atlantic and East Pacific ocean basins. This portal allows users to analyze and compare observation data and model forecasts during each hurricane season (June - November) from 2012 to the present day.
- Data, analysis and visualizations from the TCIS can be used to study hurricane process, validate and improve models, and assist in developing new algorithms and data assimilation techniques.

http://tropicalcyclone.jpl.nasa.gov



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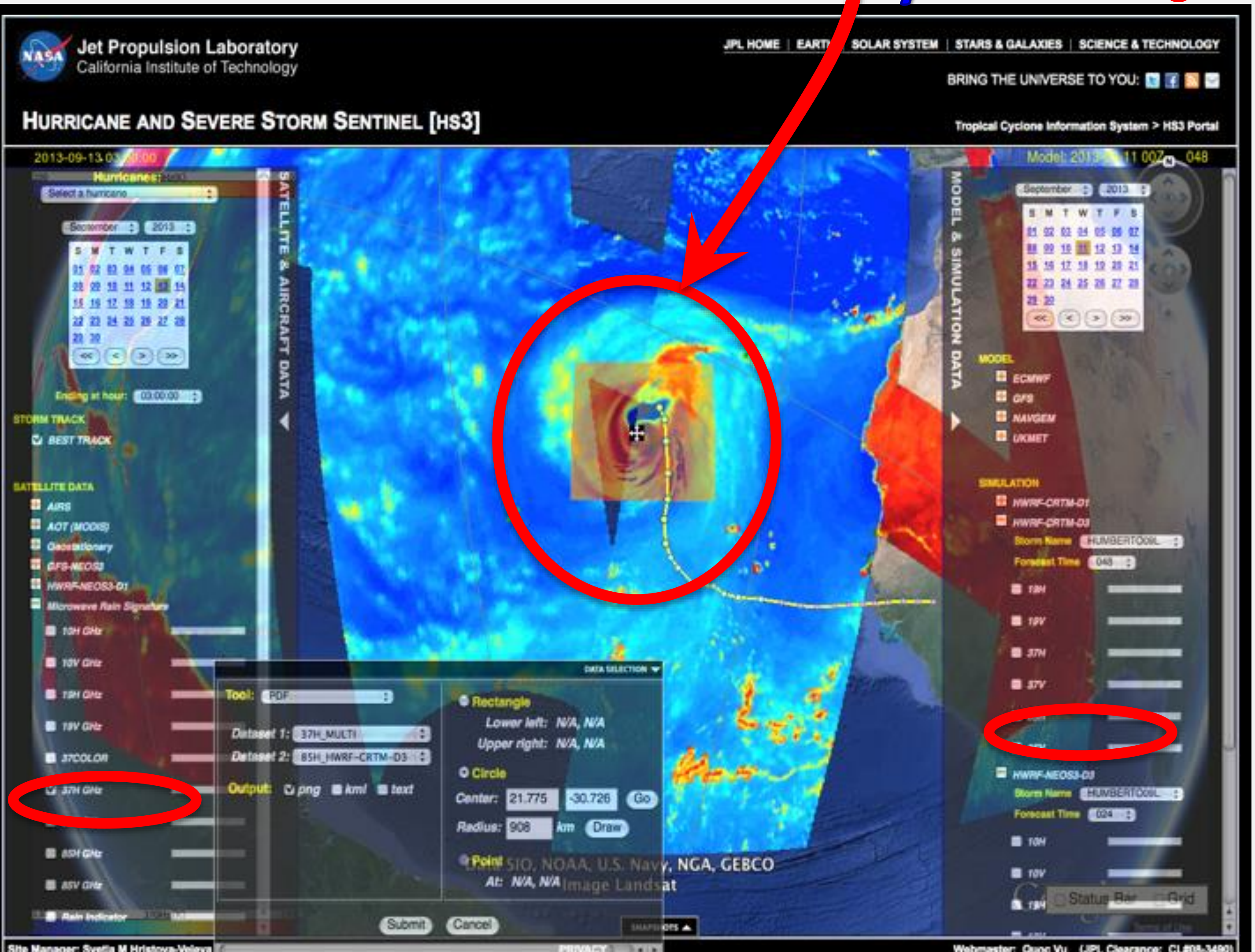

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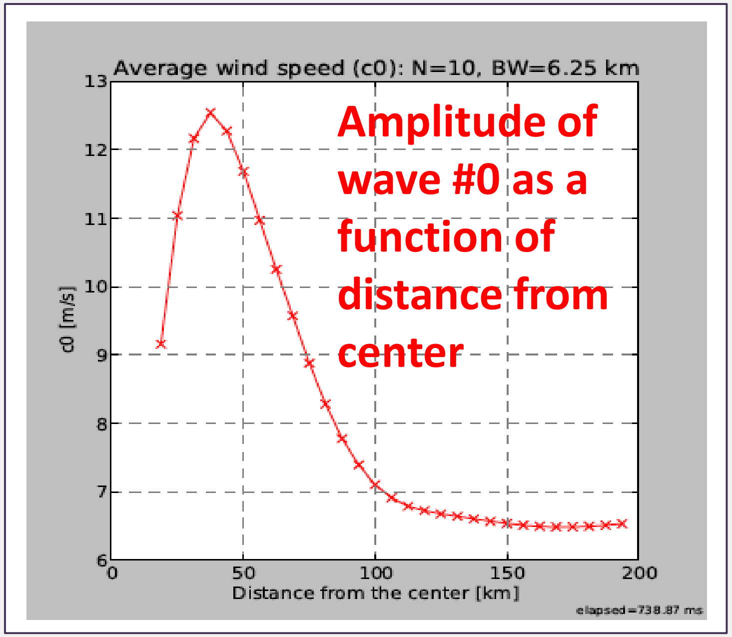
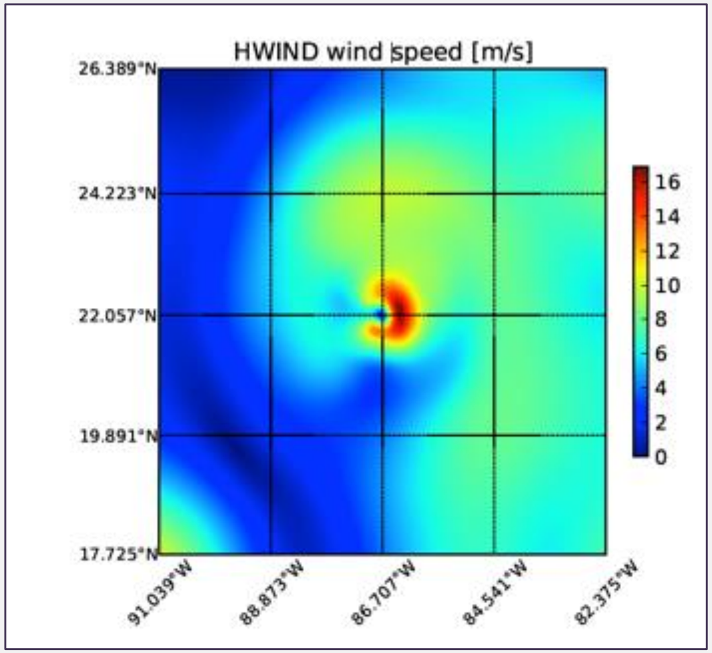
  - Storm Size/Asymmetry
  - Storm Center - ARCHER
  - Convective/Stratiform
- Environment
  - Vertical Slices On-demand
- Analysis Visualization

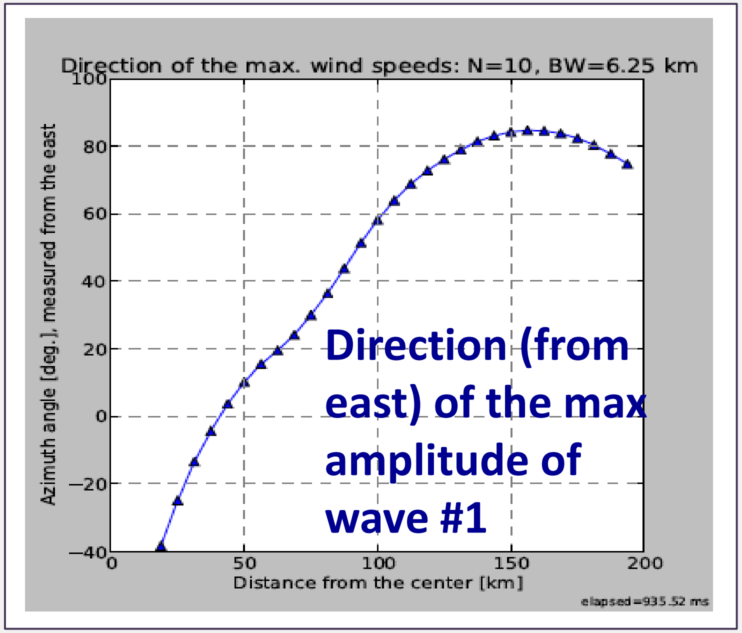
Analysis of the Storm Structure
The Wave Number Analysis Tool
Potential for Intensification

Wavenumber analysis tool

- **First adopted by NOAA/HRD**
- **e.g. Vukicevic et al. (2013)**







Satellite Observations

- To investigate the 2D structure of the precipitation, we use multi-channel passive microwave observations from a number of different instruments (TMI, AMSR-E, SSMI and SSMIS, all available at TCIS).
  - The rain is inferred from **the Rain Index (Hristova-Veleva et al., 2013**) that combines the emission and scattering signals from the multi-channel information (19 GHz –to 89 GHz) to present a cohesive depiction of the rain and the graupel above.
  - **Previous comparisons to NexRad observations show that the Rain Index looks a lot like radar reflectivity and has a resolution on the order of 15-20km.**
- The **wind estimates come from scatterometer observations** made by ASCAT and RapidScat. Both instruments post their retrievals at 12.5km. However, **the actual resolution is closer to 20 km**.

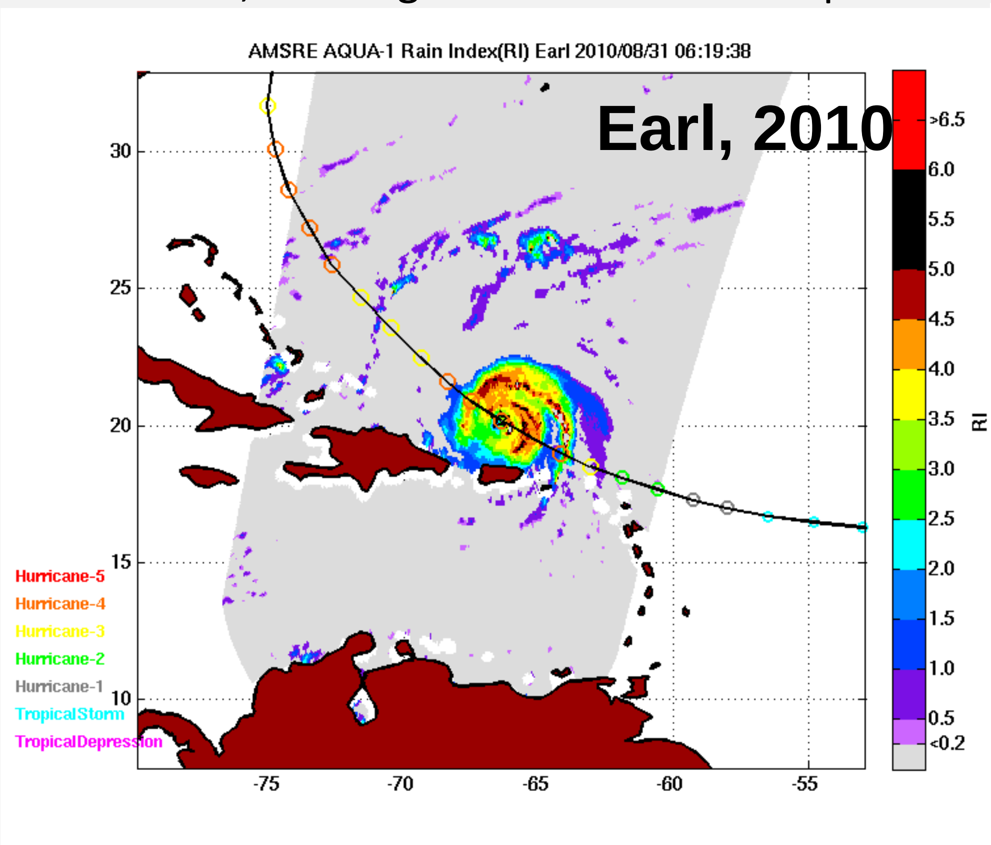
- The Rain Indicator – a multi-channel depiction of the storm structure

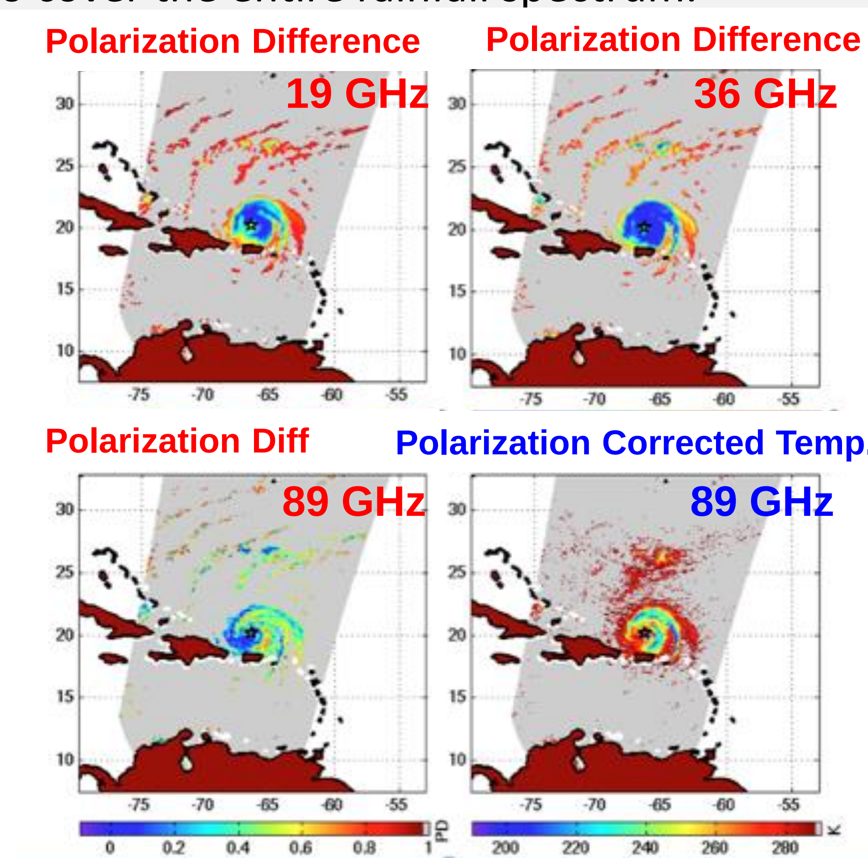
Hristova-Veleva et al., 2013**: "Revealing the Winds Under the Rain. Part I. Passive Microwave Rain Retrievals Using a New, Observations-Based, Parameterization of Sub-Satellite Rain Variability and Intensity: Algorithm Description", **2013, JAMC 52, 2828–2848

Microwave signals at the top of the atmosphere can be classified into two categories:

- **emission signal** - dominant at lower frequencies; **warming**; **better for light rain**. ***Strong emission in the atmosphere reduces the polarization difference (PD) in the ocean surface radiation. Hence, PD is representative of the atmospheric emission.***
- **scattering signal** -dominant at higher frequencies; **cooling; better for heavy rain; PCT**

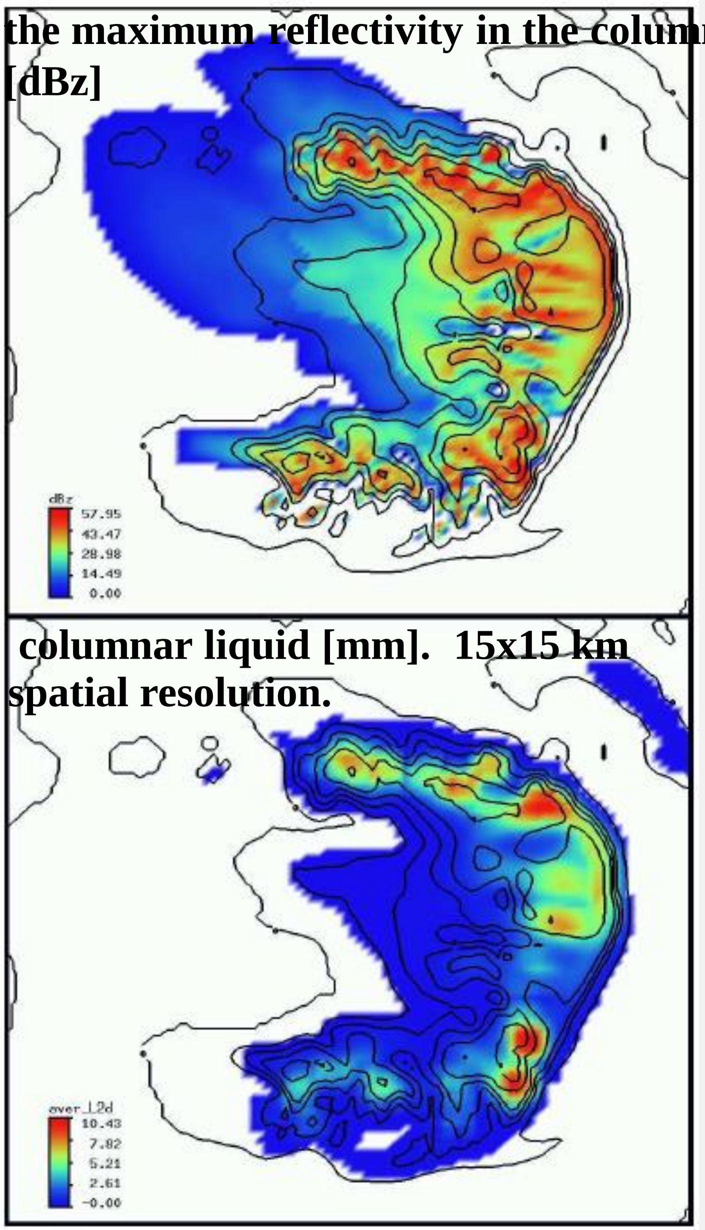
• Hence, both signals have to be incorporated to cover the entire rainfall spectrum.





The Rain Indicator

Rain Indicator (contoured every 1) and the maximum reflectivity in the column [dBz]



columnar liquid [mm]. 15x15 km spatial resolution.

- Microwave signals at the top of the atmosphere can be classified into two categories depending on how the microwave field interacts with the hydrometeors:
  - emission signal - dominant at lower frequencies; warming; better for light rain. ***Strong emission in the atmosphere reduces the polarization difference (PD) in the ocean surface radiation. Hence, PD is representative of the atmospheric emission.*** (1) $RI_{emission} = 1 - \frac{1}{\sum a_i} \sum a_i \; PD_i$
  - scattering signal -dominant at higher frequencies; cooling; better for heavy rain (2) $RI_{scattering} = 1 - \frac{(1+0.818)TB_{V85} - 0.818TB_{H85}}{(1+0.818)TB_{V85BG} - 0.818TB_{H85BG}}$
- Hence, both signals have to be incorporated to cover the entire rainfall spectrum.

$$RainIndicator = aRI_{emission} + bRI_{scattering} + cRI^{2.}_{scattring}$$

Retrieval of Geophysical Parameters

- **Rain Conditions – How good is the Rain Indicator**

Rain Indicator Claudette

NEXRAD RR Claudette

Rain Indicator Isabel

NEXRAD RR Isabel