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- 2 – HRD/AOML/NOAA, Miami, FL
- 3 – EMC/NCEP/NOAA, College Park, MD
- 4 - NPS, Monterey, CA

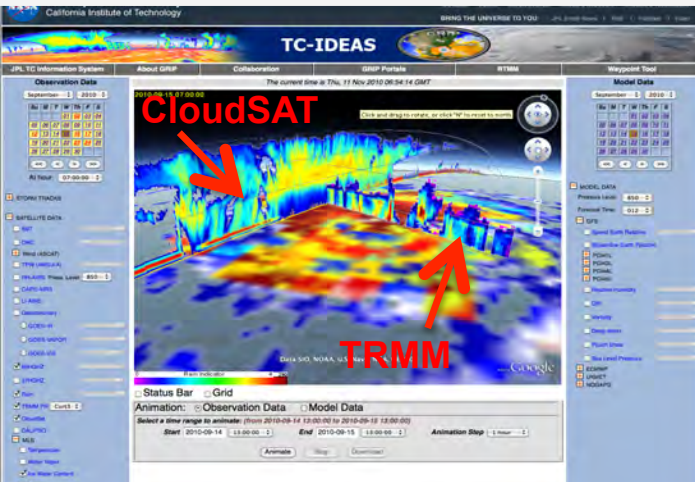
# The JPL Tropical Cyclone Information System

HFIP – August 27<sup>th</sup>, 2014

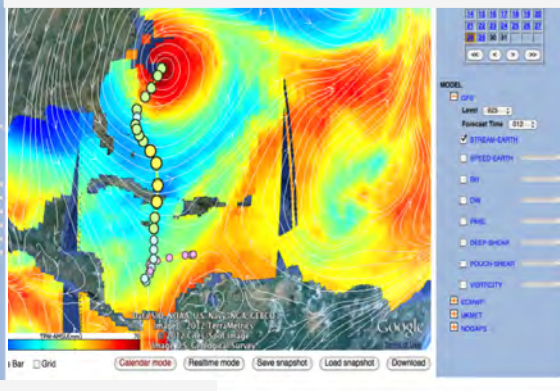


# Motivation for our project - The critical pathways to hurricane forecast improvement

• Is the representation of the precipitation structure correct?



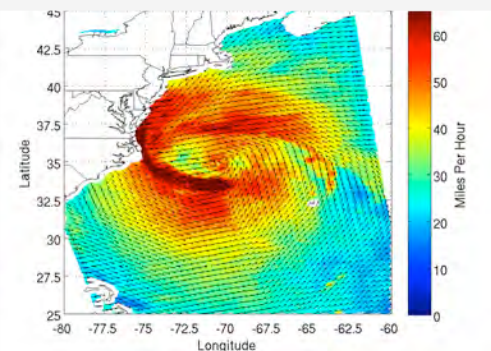
• Is the environment captured correctly?  
• Is the interaction between the storm and its environment realistic?



To improve Hurricane Intensity forecasts, we need to understand how well the models reflect the physical processes and their interactions.

**Satellite observations can help in 3 important ways!**

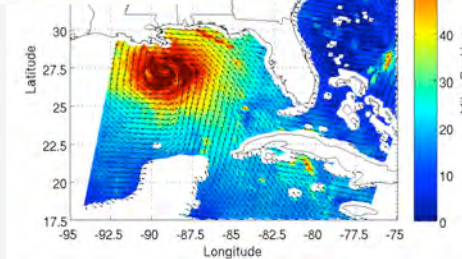
• Is the storm scale and asymmetry reflected properly?



Hurricane Sandy  
As seen by the  
ISRO's OSCAT



Hurricane Katrina  
As seen by the  
NASA's QuikSCAT



1. Understanding the physical processes
2. Validation and improvement of hurricane models through the use of satellite data
3. Development and implementation of advanced techniques for assimilation of satellite observations inside the hurricane core.

• Despite the significant amount of satellite data today, they are still underutilized in hurricane research and operations, due to complexity and volume.



# The JPL TCIS – Tropical Cyclone Information System

<http://tropicalcyclone.jpl.nasa.gov>

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To facilitate hurricane research, we are developing the JPL Tropical Cyclone Information System (JPL TCIS) of multi-instrument observations and some model data pertaining to:

- i) the thermodynamic and microphysical structure of the storms;
- ii) the air-sea interaction processes;
- iii) the larger-scale environment.

This system is being developed under NASA support (ESTO/AIST funding currently, and the Hurricane Science Research Program (HSRP) in the past).

The project is developed in close collaboration with our colleagues from NOAA/EMC and NOAA/AOML/HRD to bring the operational and research versions of HWRF forecasts into the satellite database and to develop a set of on-line analysis tools.



# The JPL TCIS – Tropical Cyclone Information System

<http://tropicalcyclone.jpl.nasa.gov>

## Tropical Cyclone Data Archive

- Satellite depiction of hurricanes over the globe
- 12-year record (1999-2010)
- offers both data and imagery, making it a unique source to support:
  - hurricane research
  - forecast improvement
  - algorithm development
  - instrument design

## HS3 – Interactive NRT Atlantic portal

<http://tropicalcyclone.jpl.nasa.gov/hs3>

- Integrates model forecasts with satellite and airborne observations from a variety of instruments and platforms, allowing for easy model/observations comparisons.
- Allows interrogation of a large number of atmospheric and ocean variables to better understand the large-scale and storm-scale processes associated with hurricane genesis, track and intensity changes.
- Very rich information source during the analysis stages of the field campaigns.

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### TROPICAL CYCLONE INFORMATION SYSTEM

Welcome to the JPL Tropical Cyclone Information System

The JPL Tropical Cyclone Information System (TCIS) was developed to support hurricane research. It has two components: a 12-year global archive of multi-satellite hurricane observations and, what was a near real-time portal, that supported the 2010 NASA Genesis and Rapid Intensification Processes (GRIP) hurricane field campaign. Together, data and visualizations from the near-real time system and data archive can be used to study hurricane process, validate and improve models, and assist in developing new algorithms and data assimilation techniques. Below you will find links to various portals where you can view different types of data.

- Introduction
- Team
- Colaborators
- Funding
- Publications

Super typhoon Pongsona struck the U.S. island of Guam on Sunday, December 8, 2002. The composite image (left) of the super typhoon was made by overlaying data from the infrared, microwave, and visible/near-infrared sensors that make up the AIRS sounding system. This storm can also be seen with the standard AIRS Vis/NIR (right).

**Tropical Cyclone Data Archive**

The TCIS Data Archive is a comprehensive tropical cyclone database of multi-parameter satellite observations pertaining to the thermodynamic and microphysical structure of the storms, the air-sea interaction processes and the larger-scale environment. Currently, it contains satellite depictions of hurricanes over the globe from 1999-2010. Users are able to browse through hurricane seasons and ocean basins to find specific storms of interest. The portal is designed to facilitate the finding of coincident observations from multiple instruments, and it provides fast access to pre-subsetted data and plots, making this a unique tool for hurricane research. Additionally, data files can be directly accessed through our [FTP site](#).

**HS3 Data Portal**

This near real-time interactive portal was developed to support the multi-year Hurricane and Severe Storm Sentinel (HS3) aircraft campaign. HS3 is a five year mission with a three year airborne component (2012-2014). The campaign's main goal is to investigate the processes that underlie hurricane formation and intensity change in the Atlantic Ocean basin. This portal allows users to analyze and compare observation data and model forecasts in the North Atlantic basin from July to November of each year of the campaign.

Site Manager: Svetlita M Hristova-Veleva      PRIVACY      Webmaster: Quoc Vu (JPL Clearance: CL#08-348)



# Part 1: The Interactive NRT Atlantic portal

1. Bringing observations and models into a common analysis system and developing interactive visualization tools
2. Analysis tools



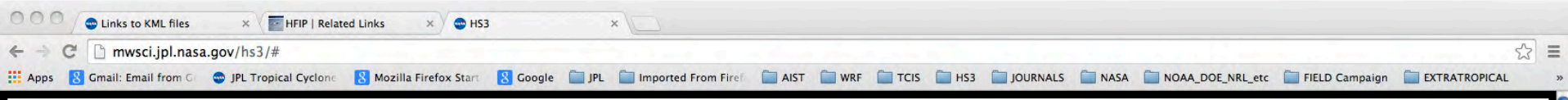
# 1. Bringing observations and models into a common analysis system and developing interactive visualization tools

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- **Satellite Observations**
  - Geostationary (IR, VIS, IRcolor, vapor) – hourly; 2-day IR animations
  - Thermodynamics
    - TPW from AMSU – 6h composite, 2-day animations
    - AISR – soundings, RH and temperature at pressure levels
  - Aerosol Optical Thickness (MODIS) - daily
  - Storm structure – 6h composites
    - Passive Microwave Observations(8 channels, the Rain Index) – multi-satellite
    - 3D from TRMM-PR curtains, coming up are the GPM-DPR obs.
  - SST – multi-instrument product; daily
  - Ocean Surface winds from scatterometer observations – 6h composites
- **Models – ECMWF, GFS, NAVGEM, UKMET**
  - Model fields and pouch analysis **provided by the Montgomery Research Group**
- **HWRF synthetic data**
  - **provided by EMC (Vijay Tallapragada and Sam Trahan)**
- **Hurricane tracks – from observations and models (pouch tracks)**
- **Limited set of airborne observations (HAMSR, dropsondes, APR2)**



# HS3 Portal – NRT in 2012-14, Atlantic (<http://tropicalcyclone.jpl.nasa.gov/hs3>) Features (needs Google Earth API; opens on the latest available PMW observations)



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## HURRICANE AND SEVERE STORM SENTINEL [HS3]

Tropical Cyclone Information System > HS3 Portal

2014-08-25 02:00:00

SATellite & AIRCRAFT DATA

**GOES IR**



**"Best Track"**

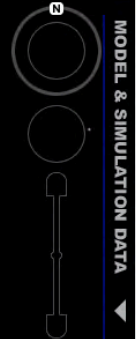
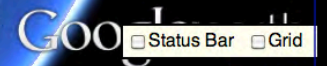


Image Landsat  
Data SIO, NOAA, U.S. Navy, NGA, GEBCO



DATA SELECTION ▲ SNAPSOTS ▲

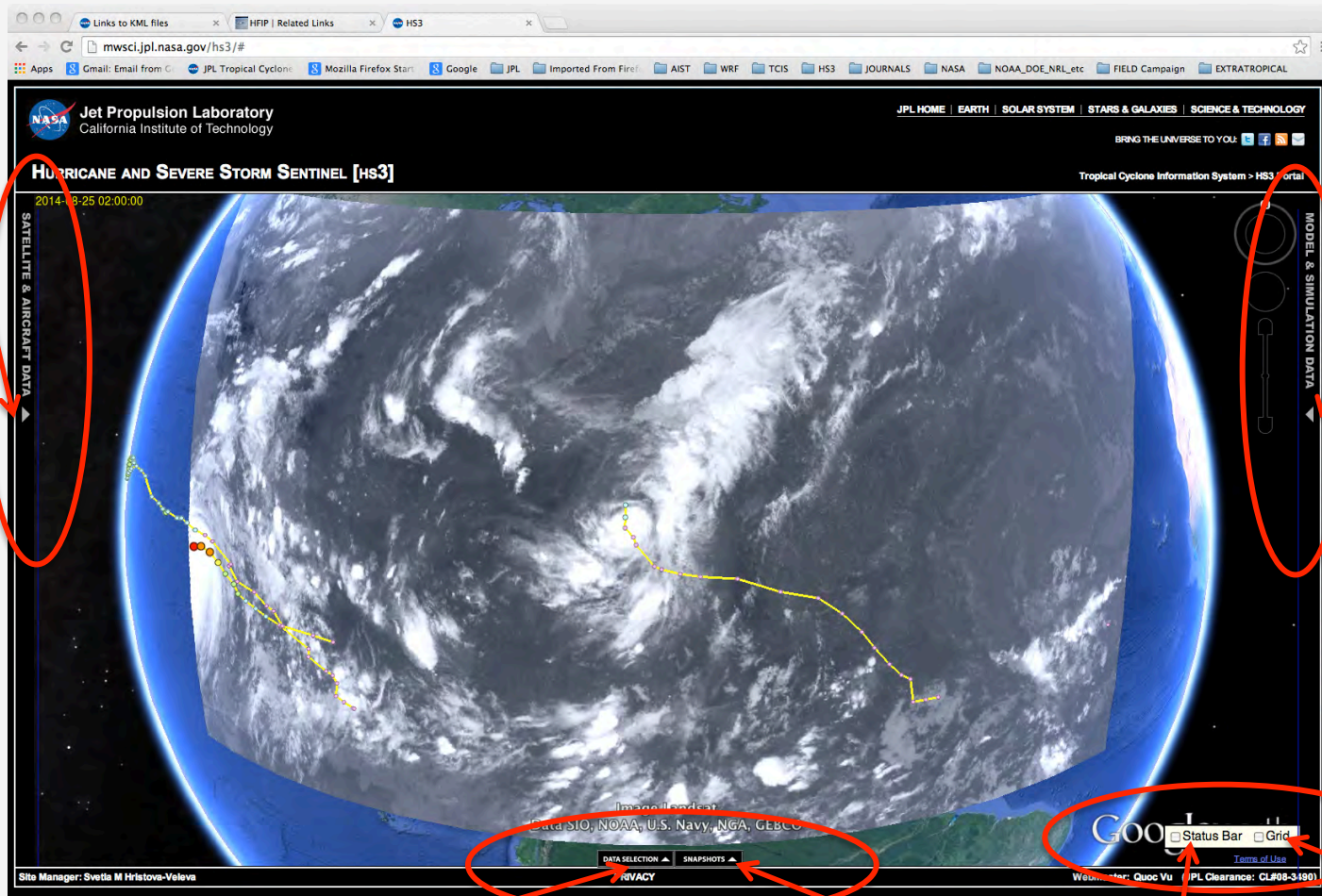


## Features

Two Calendar-driven menus (click on the triangles on the two sides):

- Observations

- Model data



Analysis Tools

Save a view

Overlay Grid  
Find lat/lon of a point



**Bringing models and observations together** (The portal combines satellite, some airborne, and model data and **provides interactive visualization** to allow the users to relate the observed and the forecasted parameters)

# “Best Track” and Pouch tracks

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## HURRICANE AND SEVERE STORM SENTINEL [HS3]

Tropical Cyclone Information System > HS3 Portal

2014-08-21 00:00

Hurricanes: Invest (08/24-08/25, TD)

August 2014

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
						31

Ending at hour: 18:00:00

**STORM TRACK**

- BEST TRACK
- POUCH TRACK
- P17L
- P21L
- P22L
- P23L

**SATELLITE DATA**

- AIRS
- AOT (MODIS)
- Geostationary
  - IR
  - IR 2 Day Animation
  - IRCOLOR
  - VAPOR
  - VIS
- Microwave Rain Signature
- TPW
- TRMM
- WIND
- CloudSat
- SST

**GOES IR**

**MODEL & SIMULATION DATA**

August 2014

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
						31

**MODEL**

- ECMWF
  - Press: 850
  - Forecast Time: 012
  - SPEED-COMOVING
  - STREAM-COMOVING
  - P17L
  - P21L
  - P22L
  - P23L
  - DEEP-SHEAR
  - OW
  - PMSL
  - POUCH-SHEAR
  - RH
  - SPEED-EARTH
  - STREAM-EARTH
  - TEMP
  - TPW
  - VORTICITY
- GFS
  - NAVGEM
  - UKMET

Name: P17L  
Model: GFS  
Time: 2014-08-21 00:00:00  
Location: 13.49N, -53.43W

Image Landsat  
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

DATA SELECTION | SNAPSHOTS

Site Manager: Svetla M Hristova-Veleva | PRIVACY | Webmaster: Quoc Vu (JPL Clearance: CL#08-3490)

**Bringing models and observations together** (The portal combines satellite, some airborne, and model data and **provides interactive visualization** to allow the users to relate the observed and the forecasted parameters)

# “Best Track” and Pouch tracks

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## HURRICANE AND SEVERE STORM SENTINEL [HS3]

Tropical Cyclone Information System > HS3 Portal

2014-08-25 17:00:00

Hurricane: Invest (08/24-08/25, TD)

August 2014

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
						31

Ending at hour: 18:00:00

**STORM TRACK**

- BEST TRACK
- POUCH TRACK
- P17L
- P21L
- P22L
- P23L

**SATELLITE DATA**

- AIRS
- AOT (MODIS)
- Geostationary
  - IR
  - IR 2 Day Animation
  - IRCOLOR
  - VAPOR
  - VIS
- Microwave Rain Signature
- TPW
- TRMM
- WIND
- CloudSat
- SST

**GOES VIS**

Name: P17L  
Model: GFS  
Time: 2014-08-21 00:00:00  
Location: 13.49N, -53.43W

Image Landsat  
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Google Earth

DATA SELECTION | SNAPSHOTS

Site Manager: Svetla M Hristova-Veleva

PRIVACY

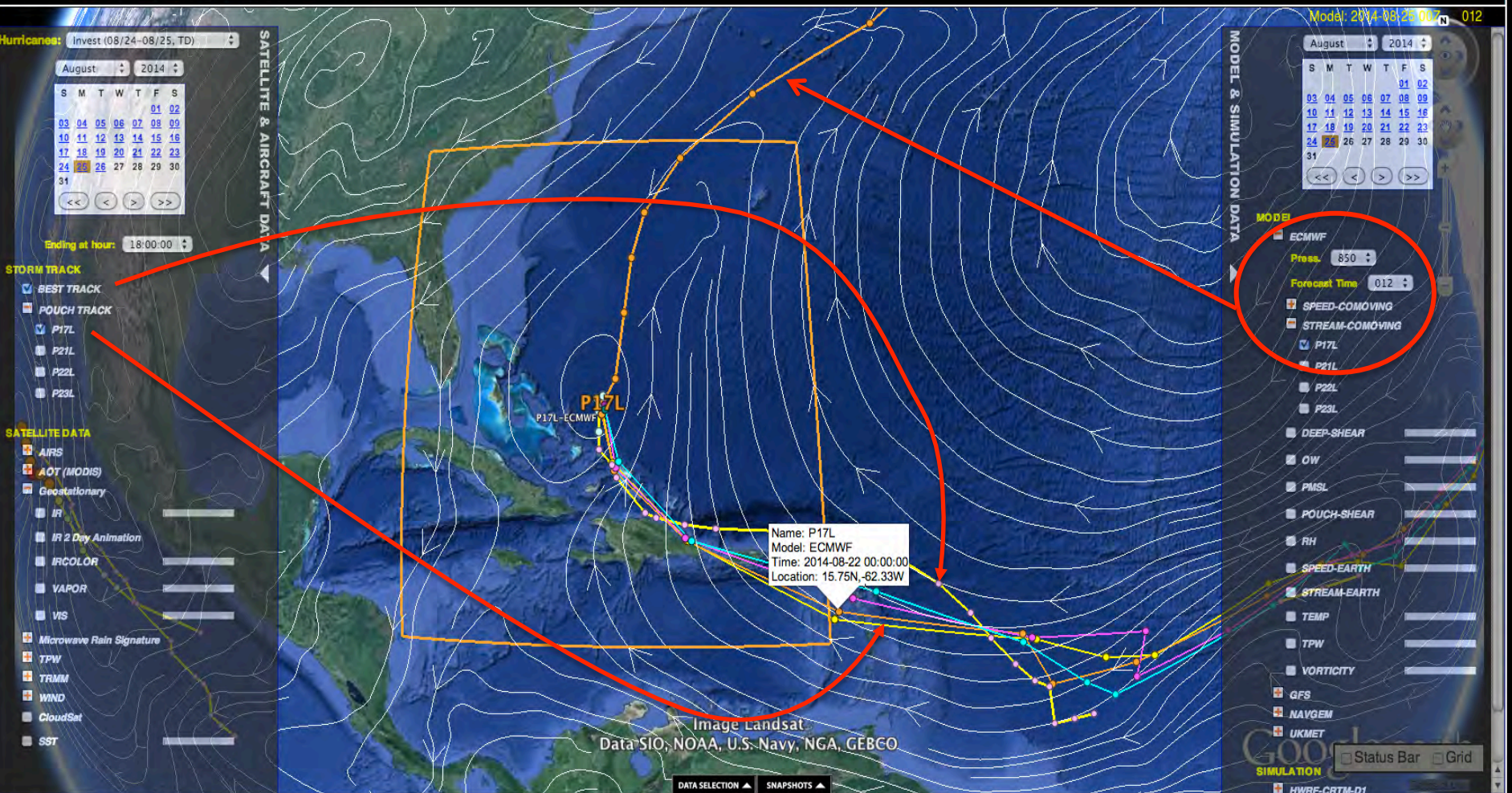
Webmaster: Quoc Vu (JPL Clearance: CL#08-3-190)

# Bringing models and observations together (The portal combines satellite, some airborne, and model data and provides interactive visualization to allow the users to relate the observed and the forecasted parameters)

## “Best Track”, Pouch tracks and Pouch forecasts, Pouch-relative model flow

### HURRICANE AND SEVERE STORM SENTINEL [HS3]

Tropical Cyclone Information System > HS3 Portal





# HS3 Portal – NRT in 2012-14, Atlantic (<http://tropicalcyclone.jpl.nasa.gov/hs3>) Forecast Uncertainty 5 days out - Hurricane Sandy (2012)

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## HURRICANE AND SEVERE STORM SENTINEL

2012-10-29 15:00:00

**Hurricanes:**

Select a hurricane:

October 2012

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	31			

Ending at hour: 15:00:00

**STORM TRACK**

BEST TRACK

POUCH TRACK

**SATELLITE DATA**

AIRS

AOT (MODIS)

Geostationary

IR

IR 2 Day Animation

IRCOLOR

VAPOR

VIS

Microwave Rain Signature

37COLOR

37H GHz

85H GHz

Rain Indicator

TPW

TRMM

WIND

SST

Name: Sandy-18L  
 Time: 2012-10-24 06:00:00  
 Location: 15.7N,-77.1W  
 Wind Speed:55 knots  
 Central Pressure:988 mb

Early Forecast  
 Late Forecast  
 Ensemble Forecast

Site Manager: Svetia M Hristova-Veleva

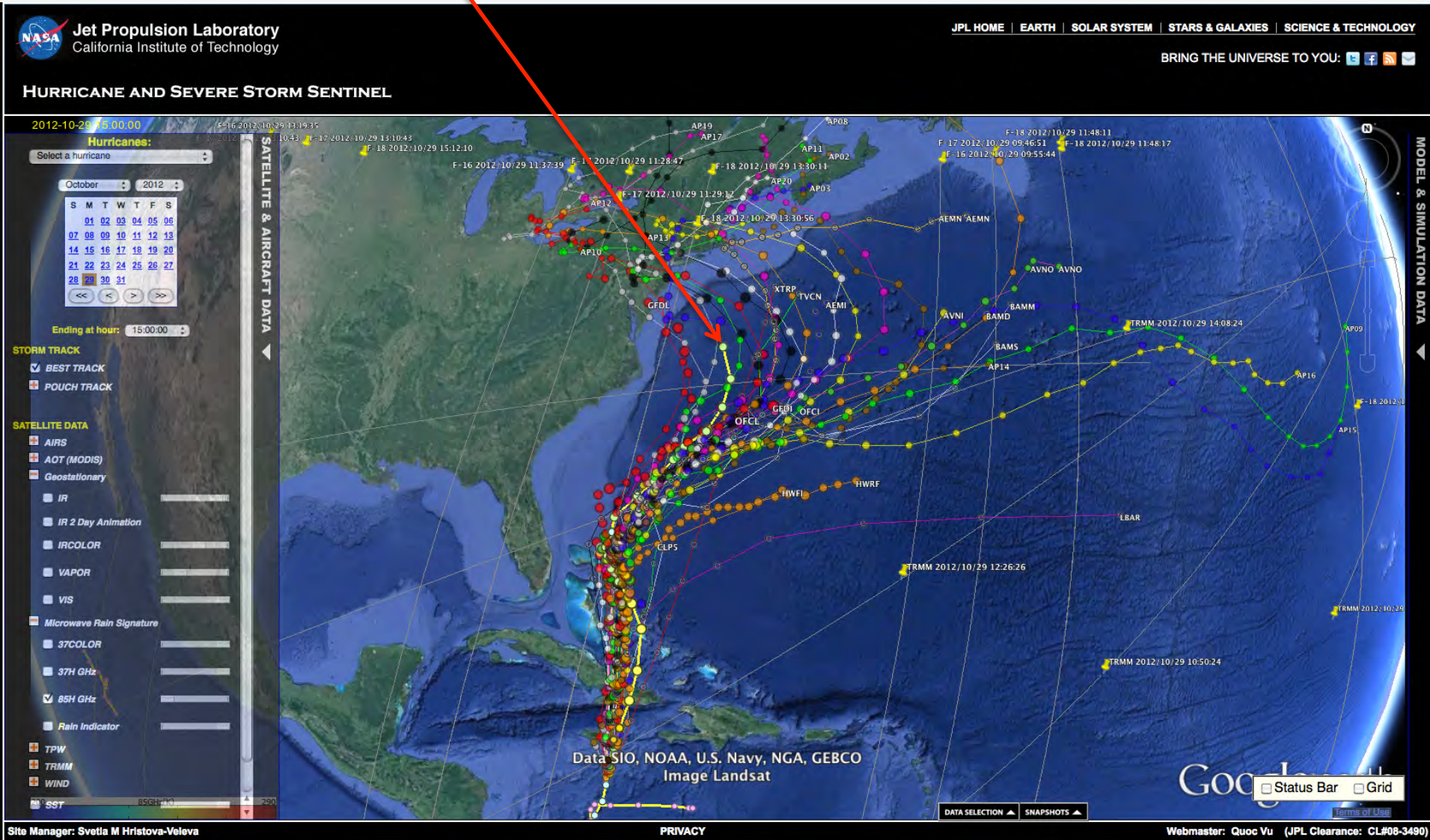
PRIVACY

Webmaster: Quoc Vu (JPL Clearance: CL#08-3490)



# HS3 Portal – NRT in 2012-14, Atlantic (<http://tropicalcyclone.jpl.nasa.gov/hs3>) Forecast Uncertainty 5 days out - Hurricane Sandy (2012)

## Best Track





# HS3 Portal – NRT in 2012-14, Atlantic (<http://tropicalcyclone.jpl.nasa.gov/hs3>)

## The Power of the Satellite Observations – Hurricane Sandy (2012)

Note the multitude of Polar Orbiting Satellites that supplement GEOS observations

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### HURRICANE AND SEVERE STORM SENTINEL

2012-10-29 15:00:00

Hurricanes:

October 2012

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	31			

Ending at hour: 15:00:00

STORM TRACK

BEST TRACK

POUCH TRACK

SATELLITE DATA

- AIRS
- AOT (MODIS)
- Geostationary
- IR
- IR 2 Day Animation
- IRCOLOR
- VAPOR
- VIS
- Microwave Rain Signature
- 37COLOR
- 37H GHz
- 85H GHz
- Rain Indicator
- TPW
- TRMM
- WIND
- SST

SATELLITE & AIRCRAFT DATA

MODEL & SIMULATION DATA

2012-10-29 11:04:31  
2012-10-29 13:10:43  
F-16 2012/10/29 15:12:10  
F-16 2012/10/29 11:37:39  
F-17 2012/10/29 11:28:47  
F-18 2012/10/29 13:30:11  
F-18 2012/10/29 11:28:47  
F-18 2012/10/29 13:30:11  
F-18 2012/10/29 13:30:56  
F-16 2012/10/29 09:55:44  
F-16 2012/10/29 11:48:11  
F-16 2012/10/29 09:46:51  
F-16 2012/10/29 09:55:44  
TRMM 2012/10/29 08:24  
TRMM 2012/10/29 12:26:26  
TRMM 2012/10/29 10:50:24  
TRMM 2012/10/29 10:50:24

Data SIO, NOAA, U.S. Navy, NGA, GEBCO  
Image Landsat

GOOGLE Earth

Status Bar Grid

DATA SELECTION | SNAPSHOTS

Site Manager: Svetla M Hristova-Voleva

PRIVACY

Webmaster: Quoc Vu (JPL Clearance: CL#08-3490)



# HS3 Portal – NRT in 2012-14, Atlantic (<http://tropicalcyclone.jpl.nasa.gov/hs3>)

## The Power of the Satellite Observations – 6h composites of 85-91GHz obs

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### HURRICANE AND SEVERE STORM SENTINEL

2012-10-29 11:30:00

Hurricanes:

Select a hurricane

October 2012

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	31			

Ending at hour: 15:00:00

STORM TRACK

- BEST TRACK
- POUCH TRACK

SATELLITE DATA

- AIRS
- AOT (MODIS)
- Geostationary
  - IR
  - IR 2 Day Animation
  - IRCOLOR
  - VAPOR
- VIS
- Microwave Rain Signature
  - 37COLOR
  - 37H GHz
  - 85H GHz
- Rain Indicator
- TPW
- TRMM
- WIND
- SST

SATELLITE & AIRCRAFT DATA

MODEL & SIMULATION DATA

2012-10-29 11:30:43  
2012-10-29 13:10:43  
F-18 2012/10/29 15:12:10  
F-16 2012/10/29 11:37:39  
F-17 2012/10/29 11:28:47  
F-18 2012/10/29 13:30:11  
F-17 2012/10/29 11:29:12  
F-18 2012/10/29 13:30:56  
F-18 2012/10/29 11:48:11  
F-17 2012/10/29 09:46:51  
F-18 2012/10/29 11:49:33  
F-16 2012/10/29 09:55:44  
TRMM 2012/10/29 08:58:58  
F-18 2012/10/29 11:30:00  
TRMM 2012/10/29 12:56:55  
TRMM 2012/10/29 10:50:24  
TRMM 2012/10/29 11:05:24

Data SIO, NOAA, U.S. Navy, NGA, GEBCO  
Image Landsat

GOO

Status Bar Grid

DATA SELECTION | SNAPSHOTS

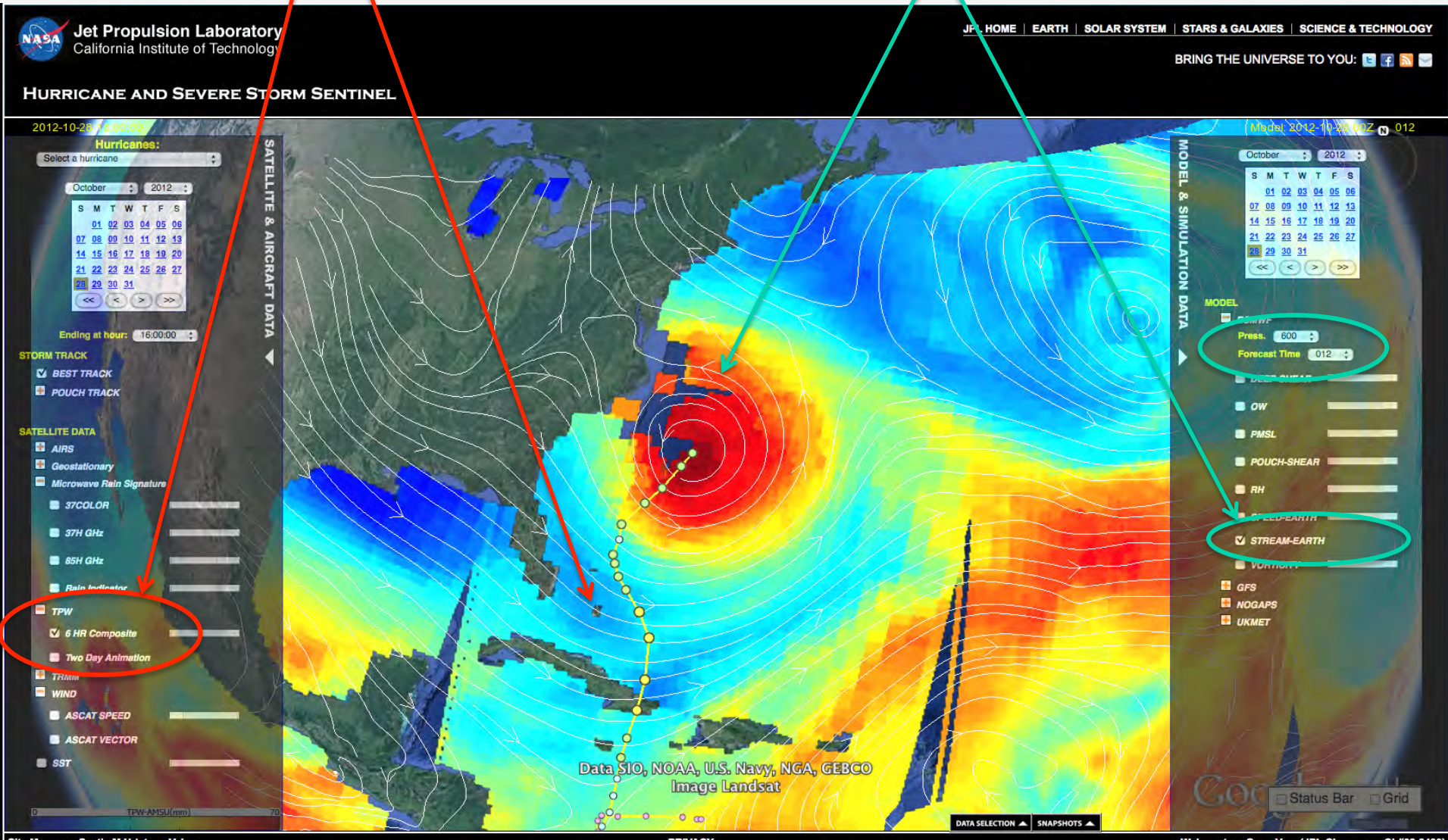
Site Manager: Svetla M Hristova-Veleva

PRIVACY

Webmaster: Quoc Vu (JPL Clearance: CL#08-3490)

# Bringing model and observations together:

- Is the dry air in the environment (low TPW, from satellite observations) entering the storm ???
- It does not appear so looking at the midlevel flow from the model.



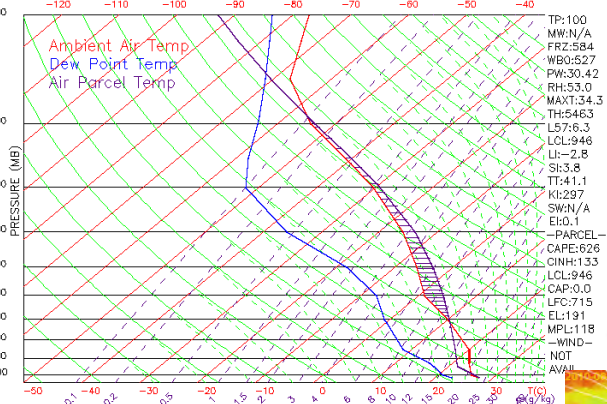




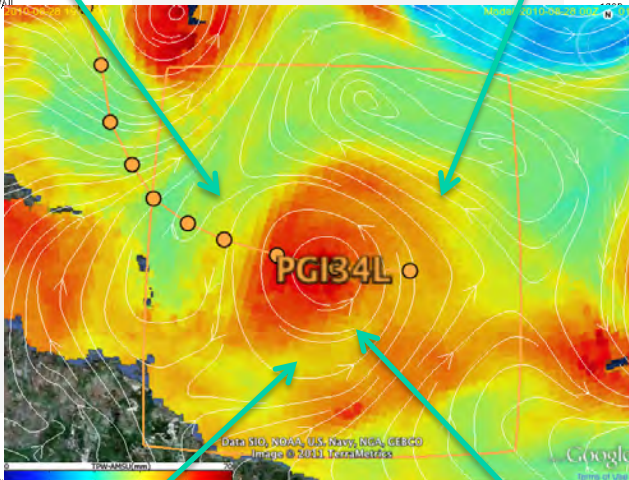
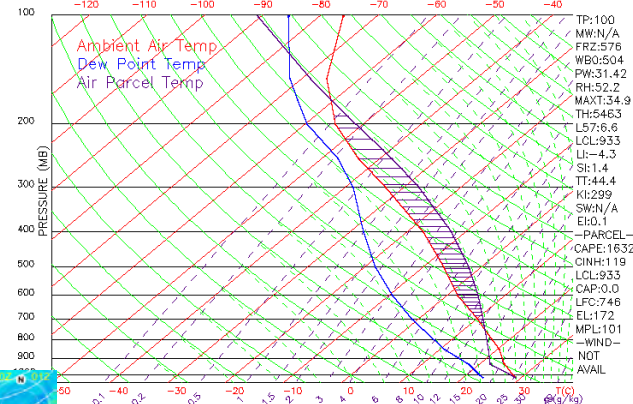
# The thermodynamics from AIRS

## Hurricane Earl; Aug. 28, 2010 19Z

AIRS SkewT Diagram 2010-08-28/16:42:56.73 (Lat/Lon 19.34/-57.76 deg)

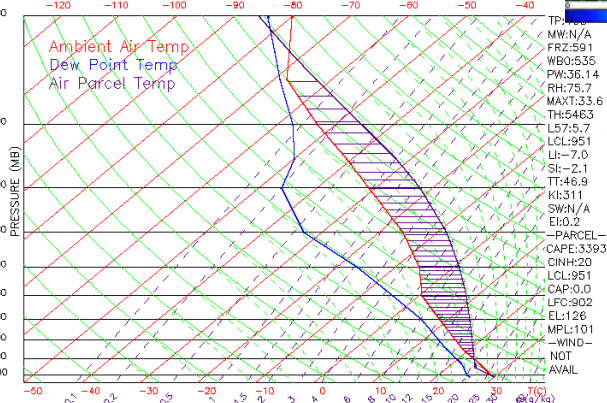


AIRS SkewT Diagram 2010-08-28/16:42:38.87 (Lat/Lon 19.81/-45.90 deg)

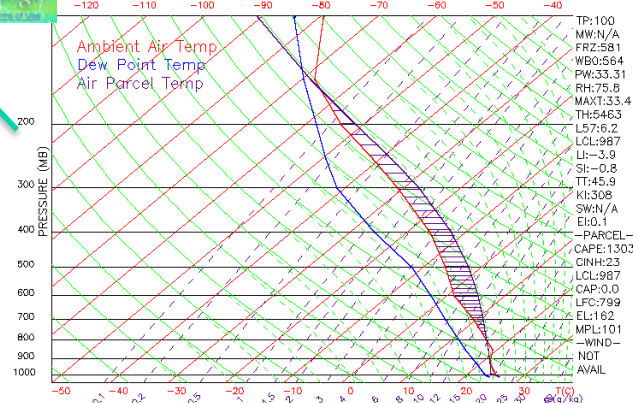


1. TPW from AMSU
2. Soundings from AIRS
3. Pouch-relative flow from ECMWF

AIRS SkewT Diagram 2010-08-28/16:40:25.80 (Lat/Lon 10.82/-52.30 deg)



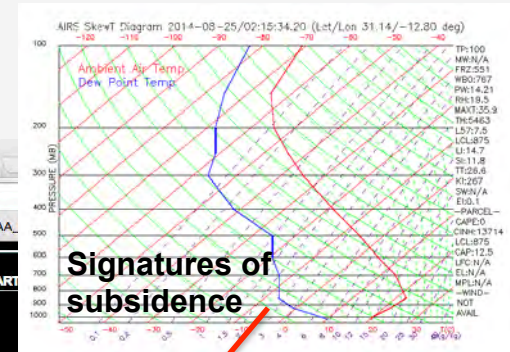
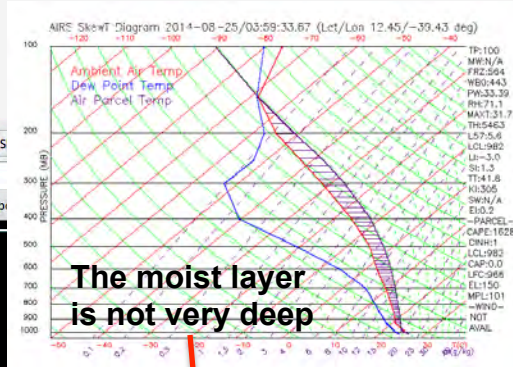
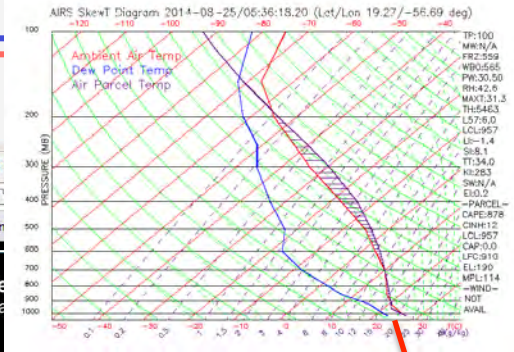
AIRS SkewT Diagram 2010-08-28/16:40:35.67 (Lat/Lon 11.84/-49.18 deg)





# HS3 Portal – NRT in 2012-14, Atlantic (<http://tropicalcyclone.jpl.nasa.gov/hs3>)

## The thermodynamics from AIRS



### HURRICANE AND SEVERE STORM SENTINEL [HS-3]

2014-08-25 08:00:00

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
31	

Ending at hour: 08:00:00

**STORM TRACK**

- BEST TRACK
- POUCH TRACK
- P17L
- P21L
- P22L
- P23L

**SATELLITE DATA**

- AIRS
- CAPE
- RH Pres. 200
- TEMP Pres. 200
- AOT (MODIS)
- Geostationary
- IR
- IR 2 Day Animation
- IRCOLOR
- VAPOR
- VIS
- Microwave Rain Signature
- TPW
- 6 HR Composite
- Two Day Animation
- TRMM

Site Manager: Svetla M Hristova-Velva

The current time:

2014-08-25/05:36:18.20  
(-56.69, 19.270)  
CAPE:878  
SkewT/lot

Image Landsat  
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

MODEL & SIMULATION DATA

Model: 2014-08-25 00Z N 012

August 2014

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
31						

MODEL:

- ECMWF
- Press. 850
- Forecast Time 01Z
- SPEED-COMMOVING
- STREAM-COMMOVING
- P21L
- P22L
- P23L
- DEEP-SHEAR
- OW
- PMSL
- POUCH-SHEAR

Deep moist layer

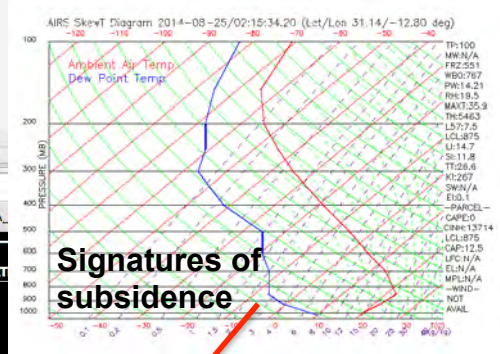
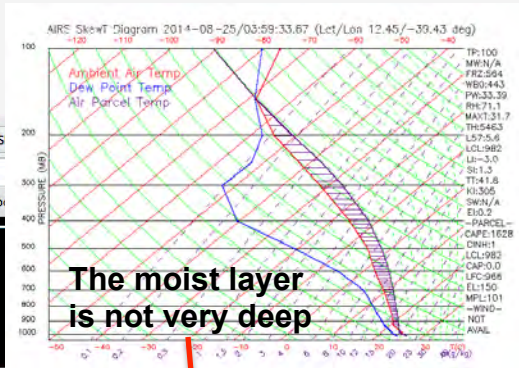
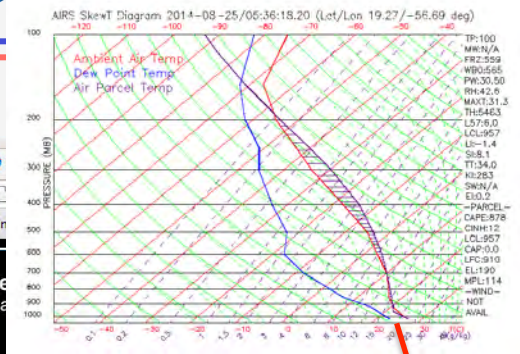
Bar Grid

Distance: CL#08-3490



# HS3 Portal – NRT in 2012-14, Atlantic (<http://tropicalcyclone.jpl.nasa.gov/hs3>)

## The thermodynamics from AIRS and the AOT from MODIS



The moist layer is not very deep

Signatures of subsidence

### HURRICANE AND SEVERE STORM SENTINEL [HS3]

2014-08-25 00:00:00

Ending at hour: 08:00:00

STORM TRACK  
 BEST TRACK  
 POUCH TRACK

SATELLITE DATA  
 AIRS  
 CAPE  
 LI  
 RH Press: 200  
 PMP Press: 200  
 AOT (MODIS)  
 AOT-AQUA  
 AOT-FINE-AQUA  
 AOT-FINE-TERRA  
 AOT-TERRA  
 Geostationary  
 IR  
 IR 2 Day Animation  
 IRCOLOR  
 VAPOR  
 VIS  
 Microwave Rain Signature  
 TPW  
 6 HR Composite  
 Two Day Animation

Model: 2014-08-25 00Z 012

August 2014

MODEL & SIMULATION DATA  
 ECMWF  
 Press: 850  
 Forecast Time 012  
 SPEED-COMOVING  
 STREAM-COMOVING  
 P17L  
 P21L  
 P23L  
 DEEP-SHEAR  
 OW  
 PMSL  
 POUCH-SHEAR

The current time:

Image Landsat  
 Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Deep moist layer

Site Manager: Svetla M Hristova-Velova

PRIVACY

Distance: CL#08-3490



# Understanding what is this structure in the model – Tim Dunkerton called it "leopard's fur" pattern in ecmwf RH in the boundary layer

mwsci.jpl.nasa.gov/hs3/#

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## HURRICANE AND SEVERE STORM SENTINEL [hs3]

Tropical Cyclone Information System > HS3 Portal

Model: 2014-08-11 00Z 012

Hurricanes: July (08/01-08/13; 2)

August 2014

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
31						

Ending at hour: 12:00:00

**STORM TRACK**

- BEST TRACK
- POUCH TRACK

**SATELLITE DATA**

- AIRS
- AOT (MODIS)
- Geostationary
  - IR
  - IR 2 Day Animation
  - IRCOLOR
  - VAPOR
  - VIS
- Microwave Rain Signatures
  - TPW
  - TRMM
  - WIND
  - CALIPSO
  - CloudSet
  - SST

**MODEL & SIMULATION DATA**

MODEL

- ECMWF
  - Press: 925
  - Forecast Time: 012
  - SPEED-COMOVING
  - STREAM-COMOVING
    - P13L
    - P17L
    - P17L
    - DEEP-SHEAR
    - OW
    - PMSL
    - POUCH-SHEAR
    - RH
    - SPEED-EARTH
    - STREAM-EARTH
    - TEMP
    - TPW
    - VORTICITY
  - GFS
  - NAVGEM
  - UKMET

**SIMULATION**

- HWRF-CRTM-D1atus Bar
- Grid
- HWRF-CRTM-D3

Data SIO, NOAA, U.S. Navy, NGA, GEBCO  
Image Landsat

DATA SELECTION | SNAPSHOTS

Site Manager: Svetla M Hristova-Velleva | PRIVACY | Webmaster: Quoc Vu (JPL Clearance: CL#08-3490)



# Understanding what is this structure in the model – Tim Dunkerton called it "leopard's fur" pattern in ecmwf RH in the boundary layer

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## HURRICANE AND SEVERE STORM SENTINEL [hs3]

Tropical Cyclone Information System > HS3 Portal

2014-08-11 12:00:00

Hurricanes: Julio (08/01-08/13, 2)

August 2014

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
31						

Ending at hour: 12:00:00

**STORM TRACK**

- BEST TRACK
- POUCH TRACK

**SATELLITE DATA**

- AIRS
- AOT (MODIS)
- Geostationary
- IR
- IR 2 Day Animation
- IRCOLOR
- VIS**
- Microwave Rain Signature
- TPW
- TRMM
- WIND
- CALIPSO
- CloudSet
- SST

**MODEL & SIMULATION DATA**

MODEL

- ECMWF
- Press: 925
- Forecast Time: 012
- SPEED-COMOVING**
- STREAM-COMOVING**
- P13L
- P12L
- P17L
- DEEP-SHEAR
- OW
- PMSL
- POUCH-SHEAR
- RH
- SPEED-EARTH
- STREAM-EARTH
- TEMP
- TPW
- VORTICITY
- GFS
- NAVGEM
- UKMET

Simulation: HWRF-CRTM-D1atus Bar Grid, HWRF-CRTM-D3

Data SIO, NOAA, U.S. Navy, NGA, GEBCO  
Image Landsat

DATA SELECTION | SNAPSHOTS

Site Manager: Svetla M Hristova-Veleva | PRIVACY | Webmaster: Quoc Vu (JPL Clearance: CL#08-3490)

# Understanding what is this structure in the model?

Tim Dunkerton called it "leopard's fur" pattern in ECMWF boundary layer RH

The model/obs overlay collaborates his suggestion that "shallow overturning circulations are responsible for vorticity and RH anomalies alike in these regions". The Sc in the visible imagery are well correlated with the model's RH and vorticity fields (not shown).

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### HURRICANE AND SEVERE STORM SENTINEL [HS3]

Tropical Cyclone Information System > HS3 Portal

2014-08-11 12:00:00

Hurricanes: July (08/01-08/13; 2)

August 2014

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
31						

Ending at hour: 12:00:00

**STORM TRACK**

- BEST TRACK
- POUCH TRACK

**SATELLITE DATA**

- AIRS
- AOT (MODIS)
- Geostationary
- IR
- IR 2 Day Animation
- IRCOLOR
- VAPOR
- VIS
- Microwave Rain Signature
- TPW
- TRMM
- WIND
- CALIPSO
- CloudSet
- SST

**MODEL & SIMULATION DATA**

MODEL

- ECMWF
- Press: 925
- Forecast Time: 012
- SPEED-COMOVING
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- P13L
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- DEEP-SHEAR
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- PMSL
- POWER-SHEAR
- RH
- SPEED-EARTH
- STREAM-EARTH
- TEMP
- TPW
- VORTICITY
- GFS
- NAVGEM
- UKMET

Model: 2014-08-11 00Z 012

August 2014

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
31						

Data SIO, NOAA, U.S. Navy, NGA, GEBCO  
Image Landsat

Site Manager: Svetla M Hristova-Veleva

PRIVACY

Webmaster: Quoc Vu (JPL Clearance: CL#08-3490)



# How best to Evaluate the Models (*with an eye on the microphysics*)

---

- In situ microphysical observations to distinguish between different modeling approaches and improve on the most promising ones.
- These point measurements cannot adequately reflect the space and time correlations characteristic of the convective processes.
- An alternative approach to evaluating microphysical assumptions is to use multi-parameter remote sensing observations.
- In doing so, we could compare modeled to retrieved geophysical parameters. The satellite retrievals, however, carry their own uncertainty.
- To increase the fidelity of the evaluation results, we should
  - bring model and observations into a common analysis system
  - use instrument simulators to produce satellite observables from the model fields and compare to the observed.
  - Improve model forecast through data assimilation that also uses the instrument simulators



# Goals of our current project

- To develop the technology to provide the fusion of observations (satellite, airborne and surface) and operational model simulations to help improve the understanding and forecasting of the hurricane processes.

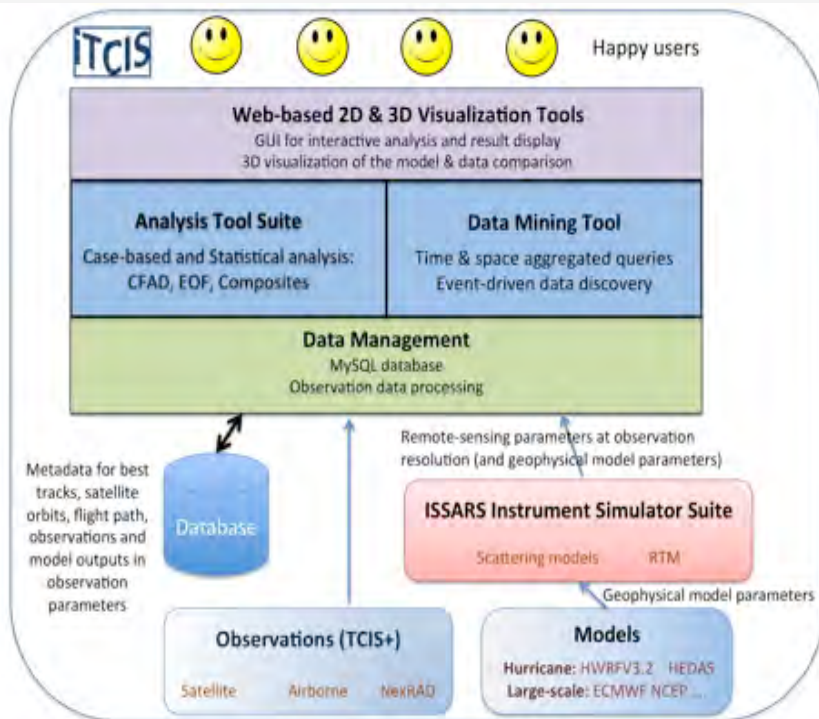
We are developing three critical components to allow the merger of observations with model forecasts:

**1) Couple instrument simulator (NEOS<sup>3</sup>) with operational hurricane forecast models** and

incorporate simulated satellite observables into the existing database of satellite and air-borne observations.

**2) Develop set of analysis tools** that will enable users to calculate joint statistics, produce composites, compare modeled and observed quantities to facilitate the evaluation of different hurricane models

**3) Develop visualization to enable analysis** (e.g., data immersion approaches to enable real-time interaction with the models, and visualization of highly complex systems)





# FUSION OF MODELS AND OBSERVATIONS

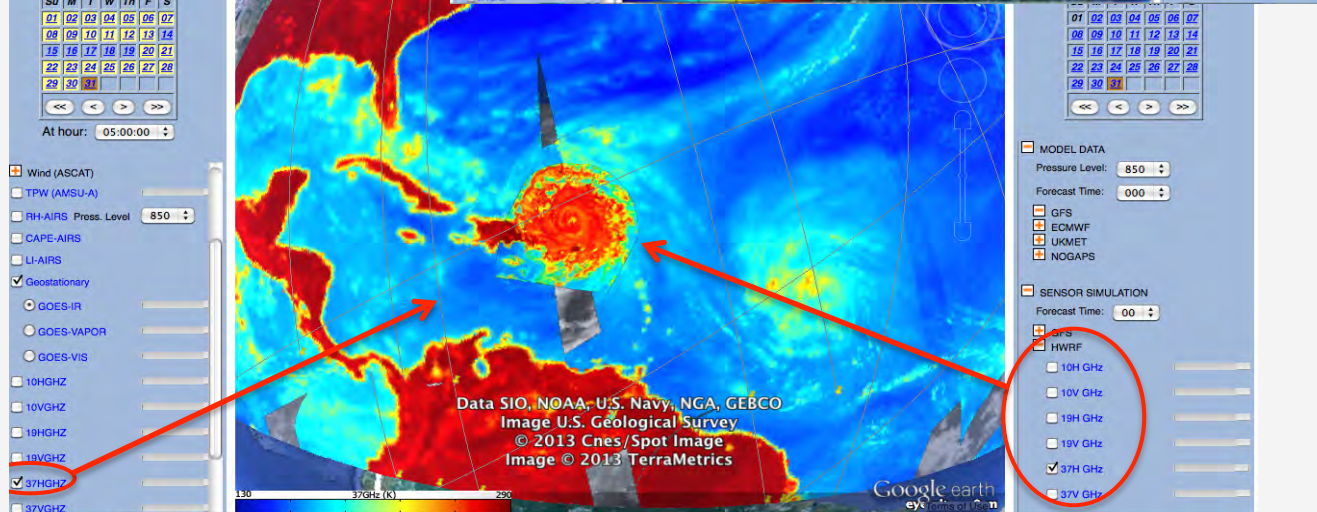
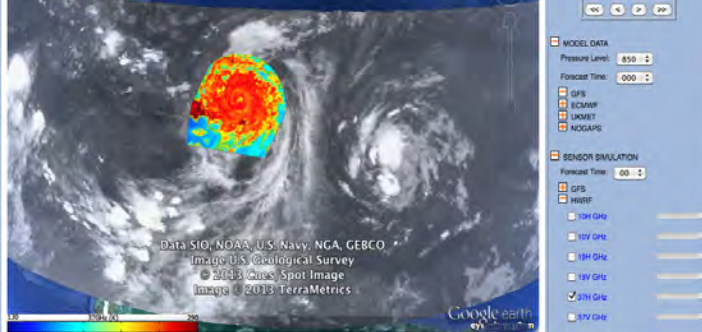
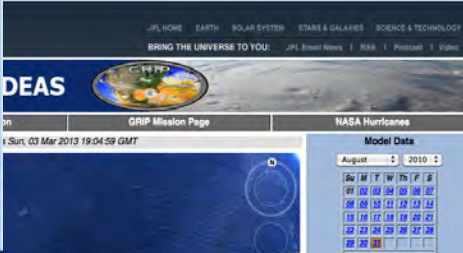
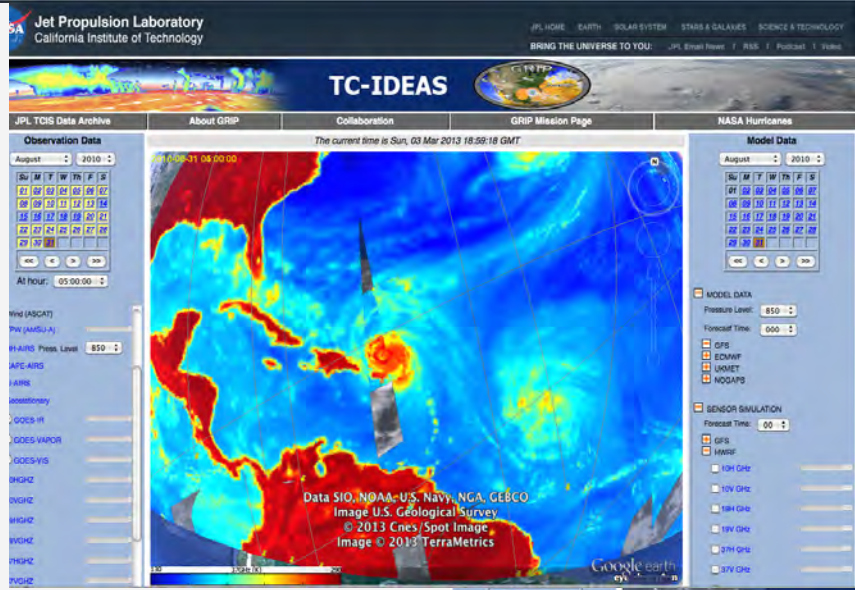
Integrating hurricane model forecasts with satellite & airborne observations from a variety of instruments and platforms

- Research HWRF model forecasts were used as input to NEOS<sup>3</sup>
- Considered are the model microphysical assumptions; the instrument characteristics and sampling
- The synthetic “satellite observations” were:
  - Incorporated in the database of satellite obs.
  - Visualized in the portal
- Limited # of cases!
- Not in NRT!

Satellite Observations



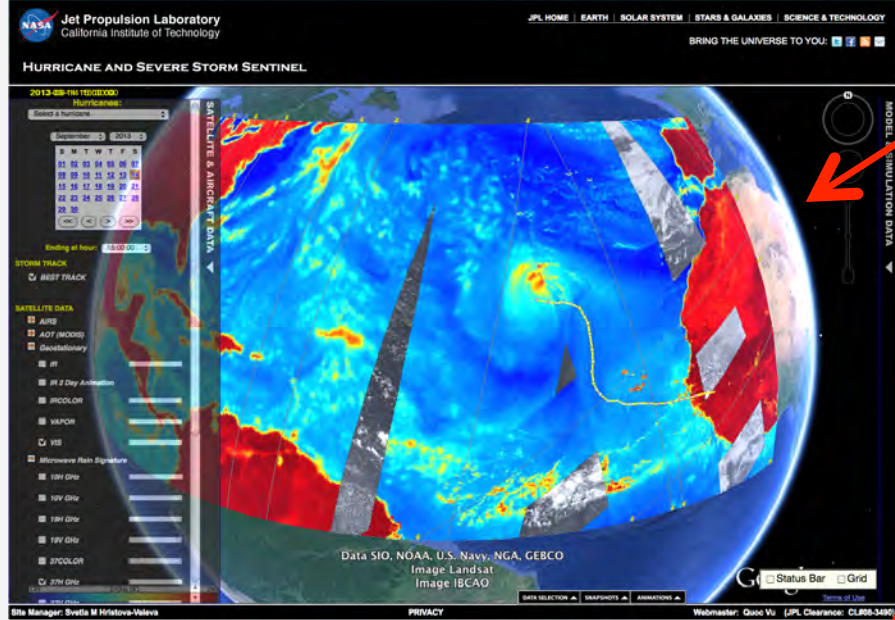
Synthetic Observations from Model



# FUSION OF MODELS AND OBSERVATIONS

Integrating hurricane model forecasts with satellite & airborne observations from a variety of instruments and platforms

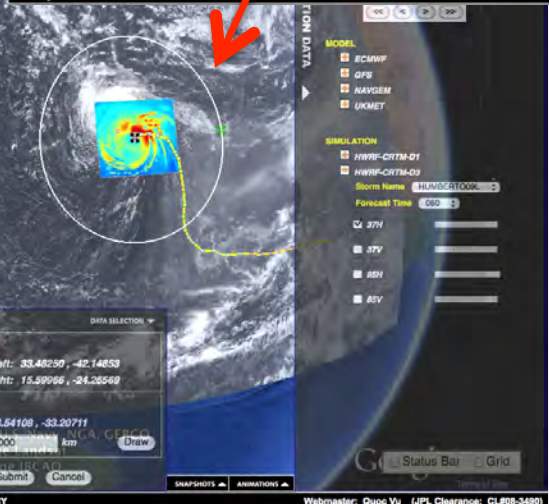
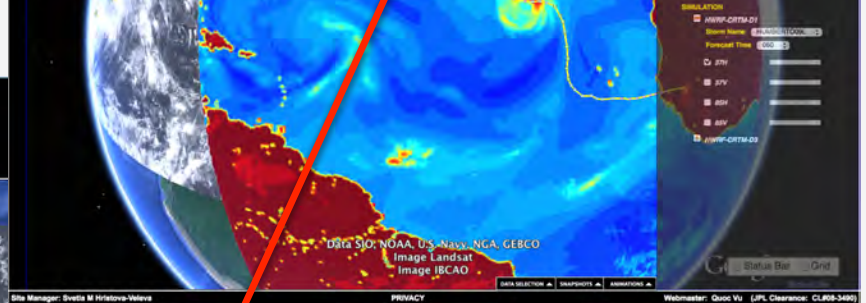
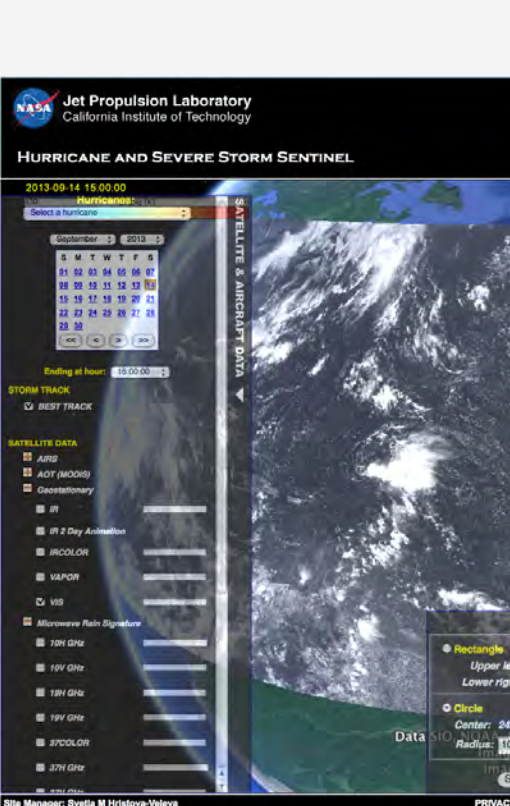
- Operational HWRF model forecasts are used as input to CRTM, provided courtesy of EMC
- Including synthetic satellite observations from the same model (HWRF) but produced by different forward simulators (NEOS<sup>3</sup> and CRTM) will be of high interest in revealing the uncertainty that comes from the instrument simulators themselves.



Satellite Observations



Synthetic Observations from Model

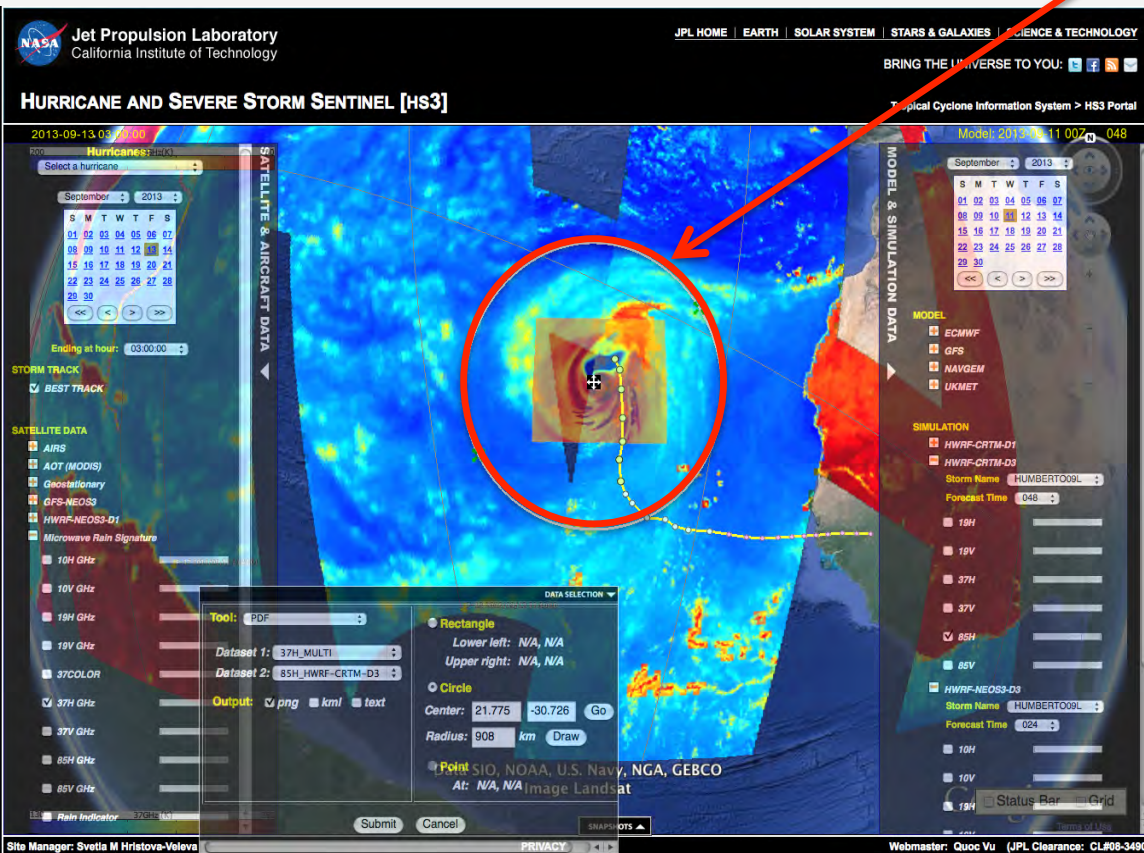




## 2. Analysis Tools

Analysis tools that can be applied to both observed and synthetic data for on-line statistical and structural analysis

- Interactively select region
- Gather data from observed and synthetic sources
  - brightness temperatures
- Statistical comparisons
  - Storm-relative coordinates
  - Joint PDFs
  - Azimuthal averages
- Storm Structure
  - ARCHER
  - Wave Number Analysis
  - Object classification
  - Metrics for model/obs objects
- Visualization of analysis





## 2. Analysis tools

**general requirement – the data need to be displayed**

---

- **Statistical tool to evaluate the storm vertical structure**
  - Emphasis on microphysics – ***the Joint Probability Density Functions (Joint PDF)***
    - *Any pair of passive microwave brightness temperatures*
    - *Either from observations or from model*
    - *Describes the manifolds occupied by the observations and the models*
    - *Could be used to provide information on the correlations between the warm rain (lower frequencies) and frozen precipitation above (higher frequencies), hence, information on the vertical structure*
- **Storm structure Tools**
  - Degree of organization - ***The Automated Rotational Center Hurricane Eye Retrieval (ARCHER)***
    - *Works with 85 GHz brightness temperatures (observations or model)*
  - Storm Size and Asymmetry - ***The Wave Number Analysis Tool***
    - *Works with either*
      - *the Rain Index (computed from multi-channel passive microwave observations and soon with model data)*
      - *or with the surface winds (from observations)*



# The Selection Tool

1. Select the region of interest
  - Circle, Square, Point
2. Select the tool (e.g. PDF)
3. Select two frequencies
4. Submit the job ...

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**HURRICANE AND SEVERE STORM SENTINEL**

**Hurricanes:**  
Select a hurricane

September 2013

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: 10:00:00

**STORM TRACK**

BEST TRACK  
 POUCH TRACK

**SATELLITE DATA**

AIRS  
 AOT (MODIS)  
 Geostationary  
 GFS-NEOS3  
 Microwave Rain Signature

10H GHz  
 10V GHz  
 19H GHz  
 19V GHz  
 37COLOR  
 37H GHz  
 37V GHz  
 85H GHz  
 85V GHz

**DATA SELECTION**

Tool: PDF  
Dataset 1: 85H  
Dataset 2: 37H

Parameters:  
Param 1: Testing  
Param 2: myscripts.pl

Output:  png  kml  text

Rectangle  
Upper left: 18.876, -32.870  
Lower right: 9.3385, -22.155

Circle  
Center: N/A, N/A  
Radius: N/A km

Point  
At: N/A, N/A

Submit Cancel

Site Manager: Svetla M Hristova-Veleva

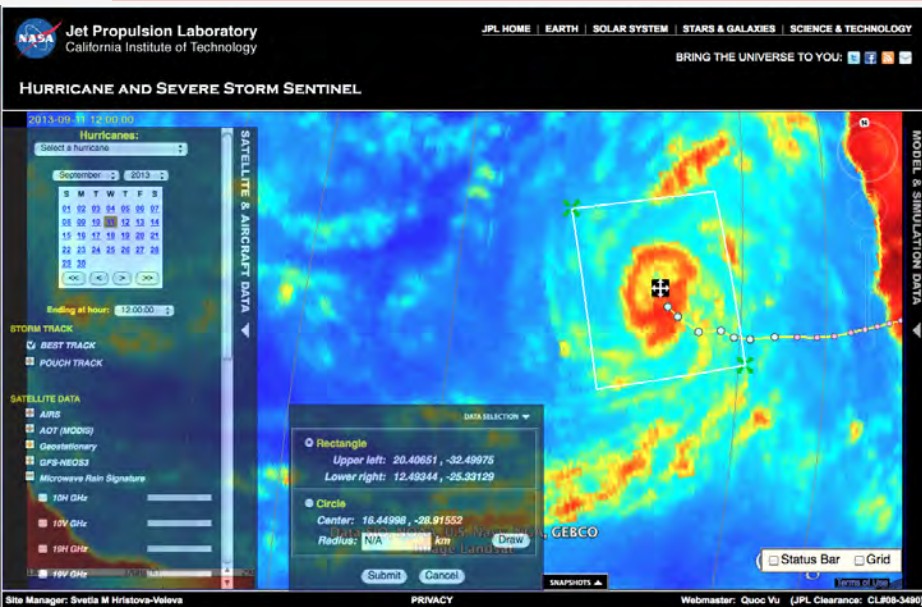
PRIVACY

Webmaster: Quoc Vu (JPL Clearance: CL#08-3490)

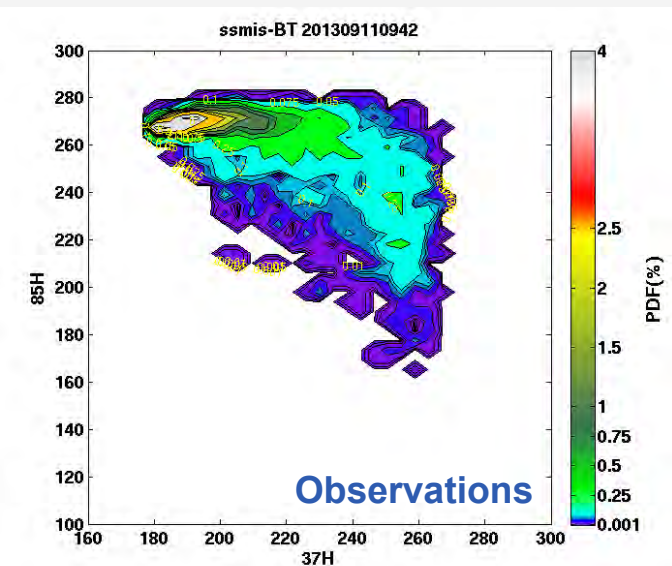


# Statistical Tool: Joint Distribution of Brightness Temperatures

## Example: The Joint PDF of 37GHz and 85GHz TBs; Humberto



- The statistical relationship between the 37 GHz TBs and the 85 GHz TB presents information on the vertical structure of the storm

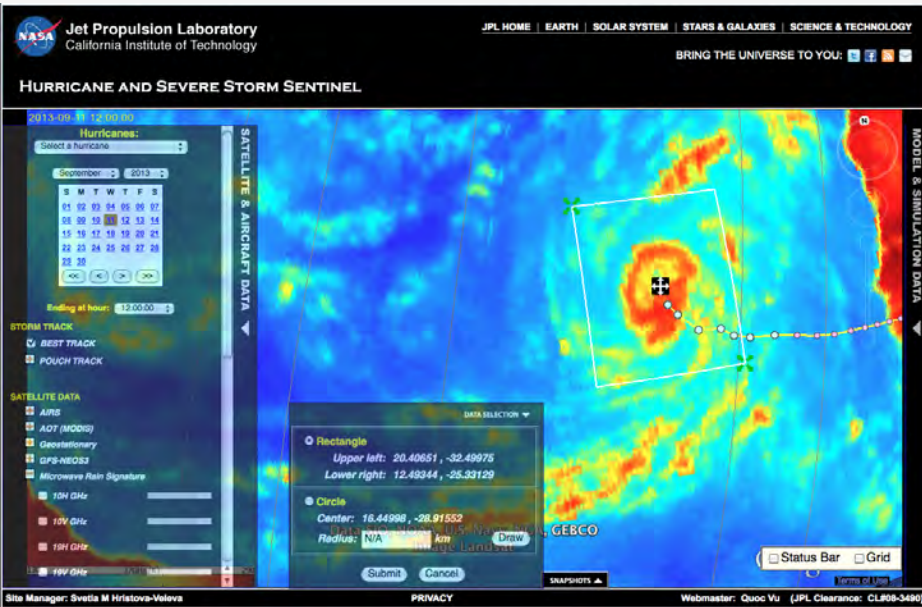


- The Joint PDF illustrates this relationship

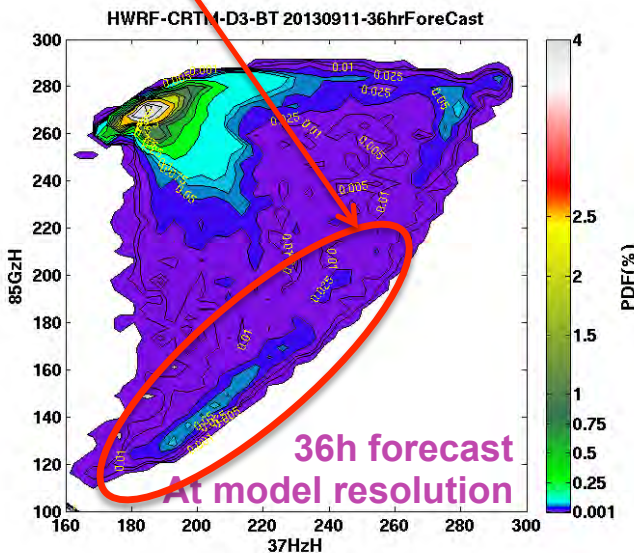
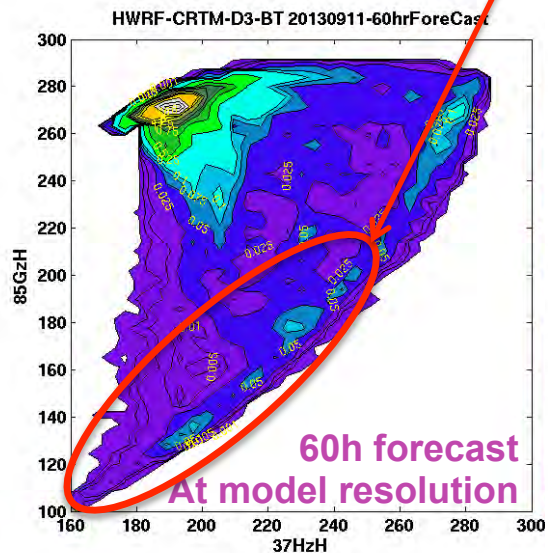
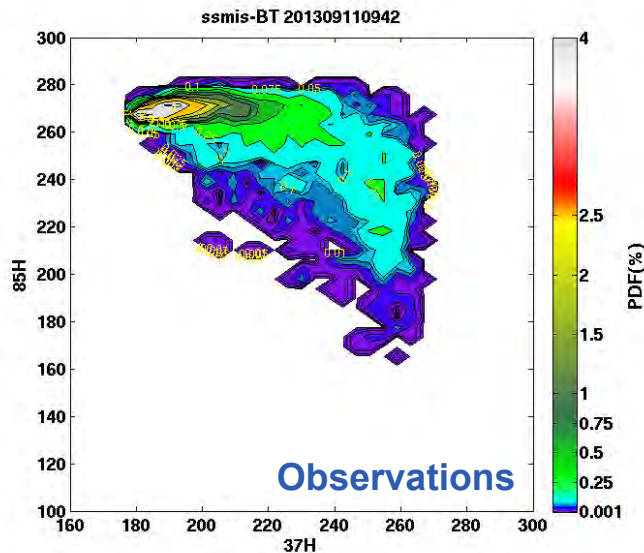


# Statistical Tool: Joint Distribution of Brightness Temperatures

## Example: The Joint PDF of 37GHz and 85GHz TBs; Humberto



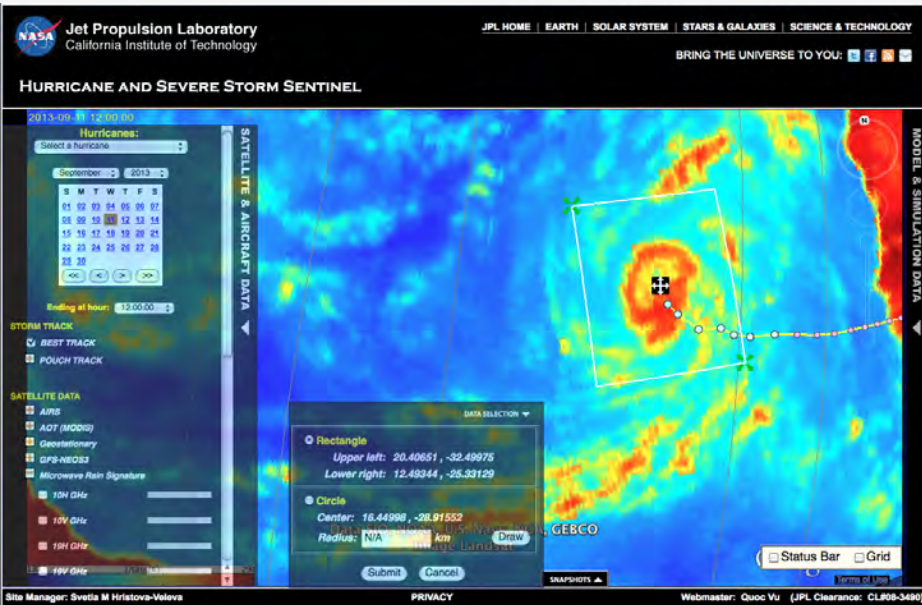
- The statistical relationship between the 37 GHz TBs and the 85 GHz TB presents information on the vertical structure of the storm
- The vertical branch indicates too much scattering of radiation by the frozen precipitation



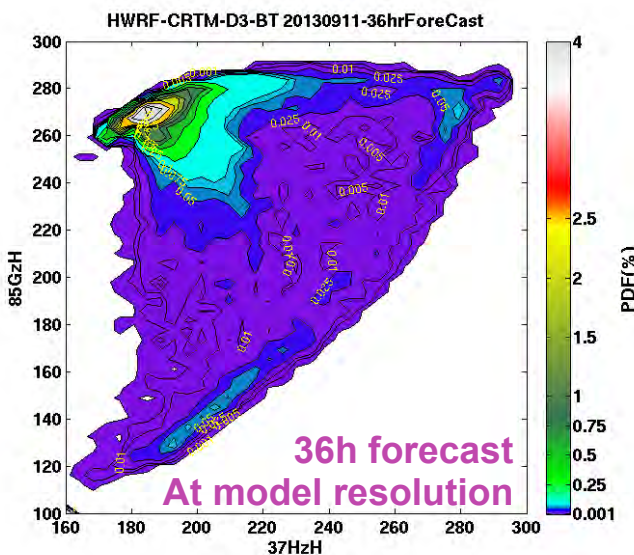
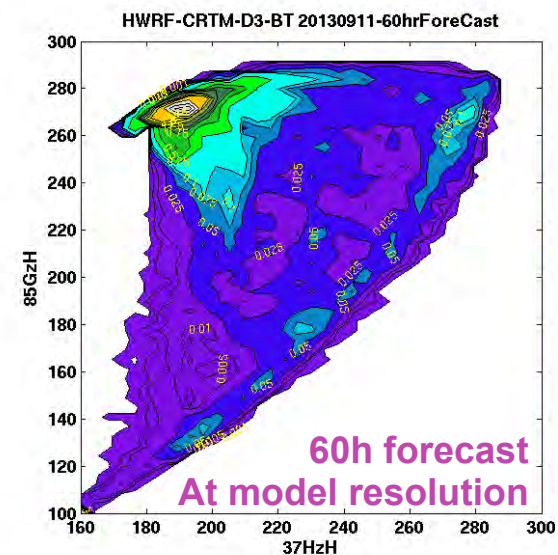
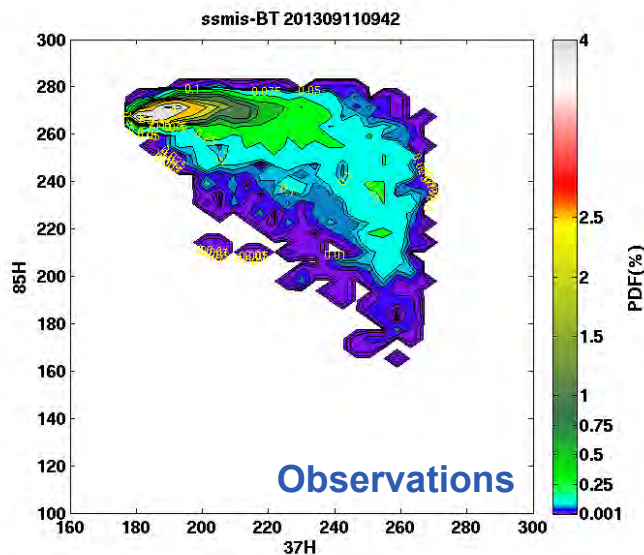


# Statistical Tool: Joint Distribution of Brightness Temperatures

## Example: The Joint PDF of 37GHz and 85GHz TBs; Humberto



- The statistical relationship between the 37 GHz TBs and the 85 GHz TB presents information on the vertical structure of the storm
- The vertical branch indicates too much scattering of radiation by the frozen precipitation
- Question: Is the ice too much or is its forward modeling inaccurate?
  - Need to consider the resolution!





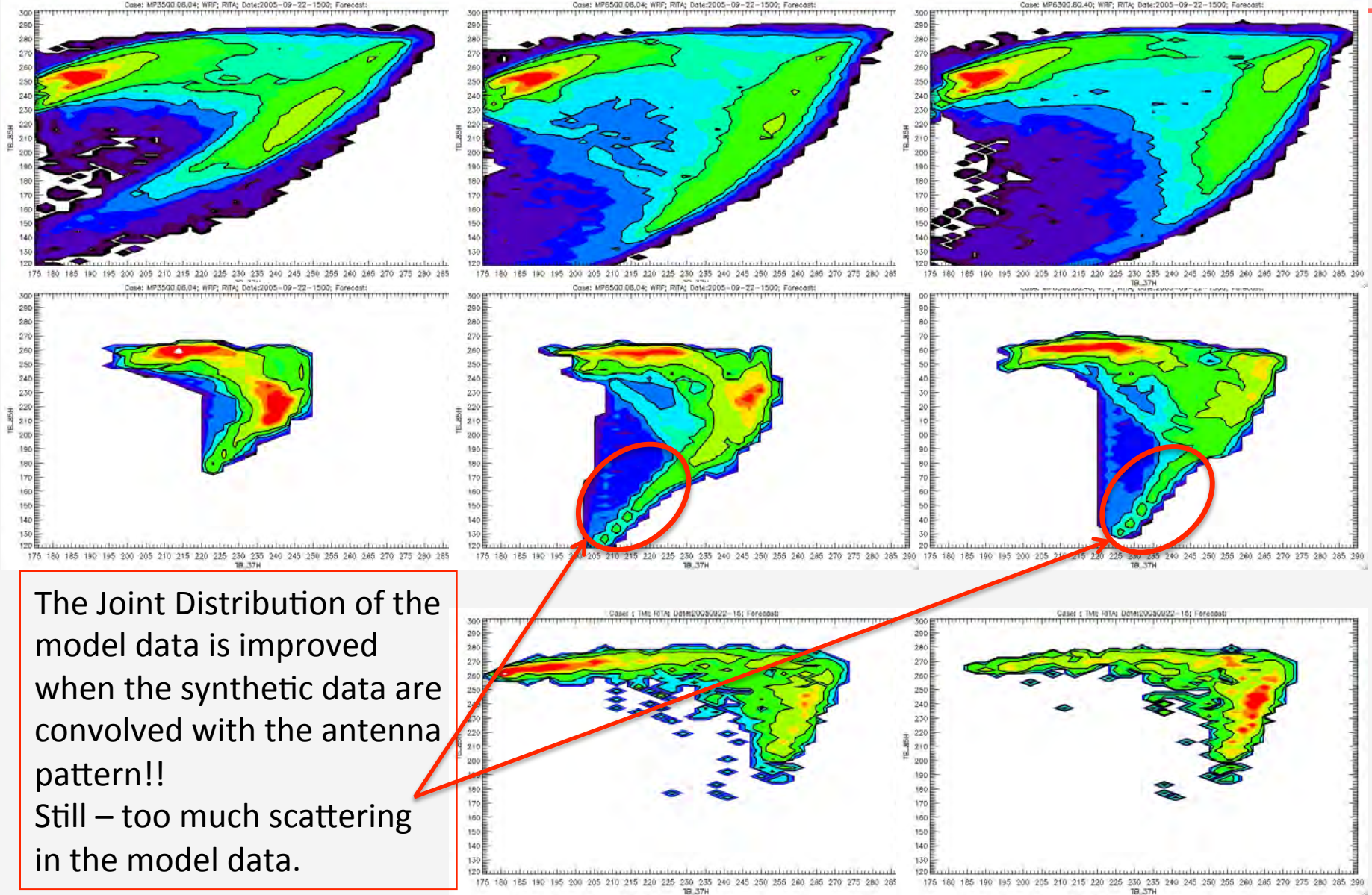


# Joint Distribution (37H vs 85H) – Impact of Resolution

M3-500.08.04

M6-500.08.04

M6-300.80.40



WRF res.

TMI res

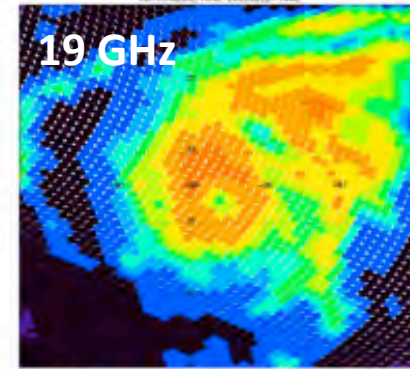
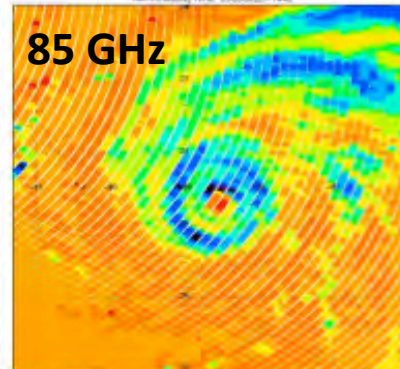
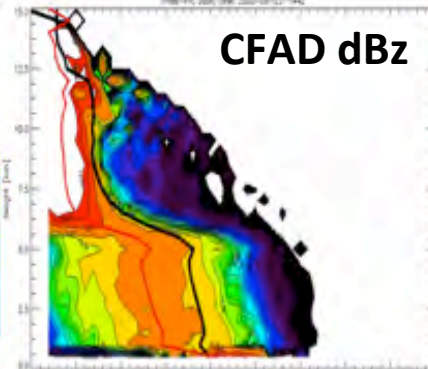
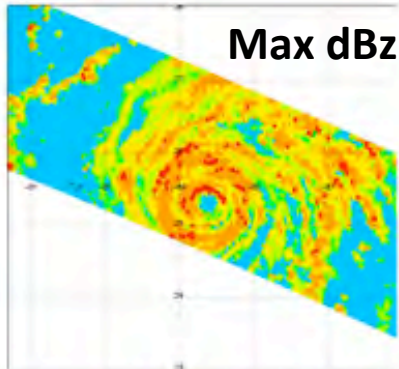
TMI obs.

The Joint Distribution of the model data is improved when the synthetic data are convolved with the antenna pattern!!  
Still – too much scattering in the model data.

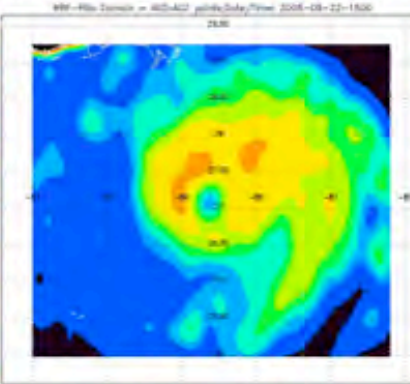
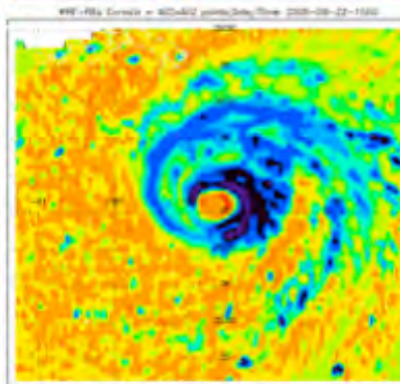
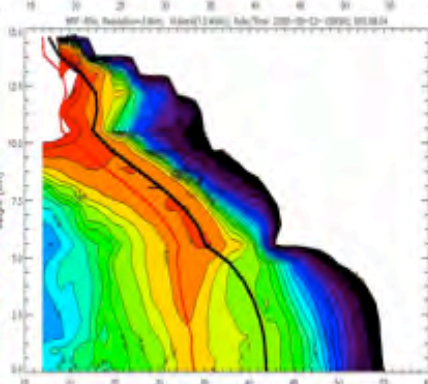
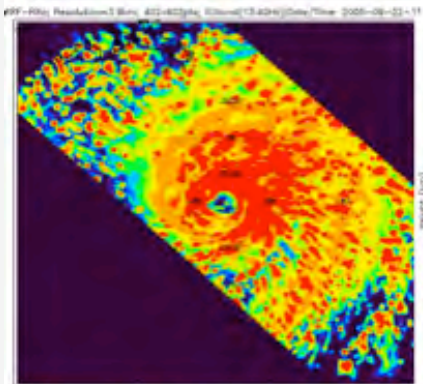


# Example of MODEL EVALUATION – the Impact of Microphysics

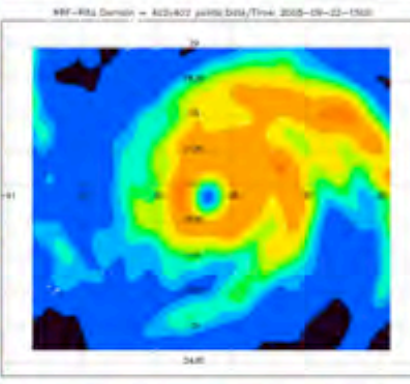
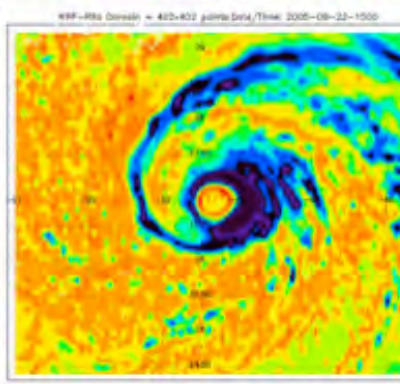
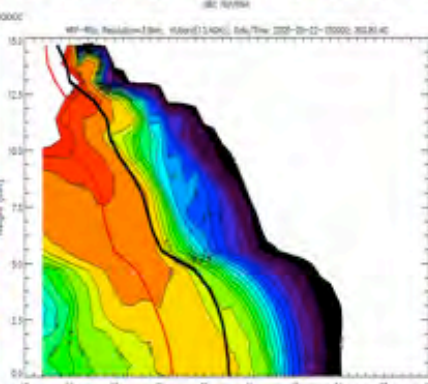
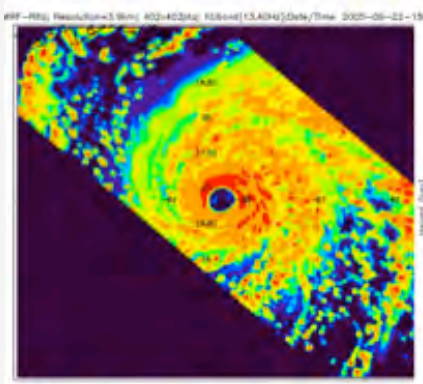
TRMM



WRF  
WSM3



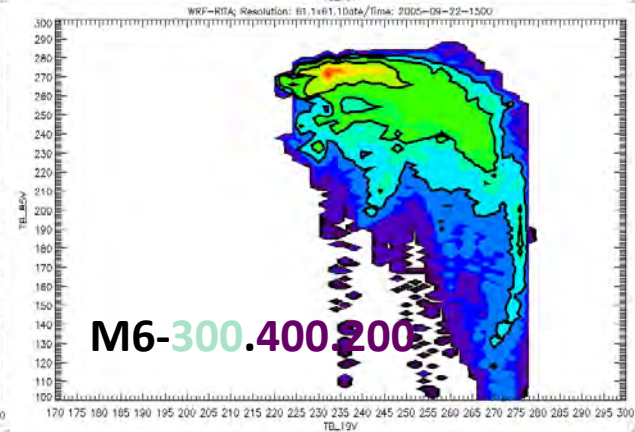
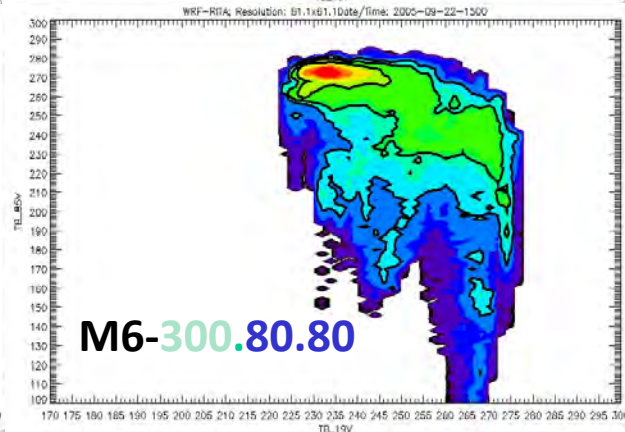
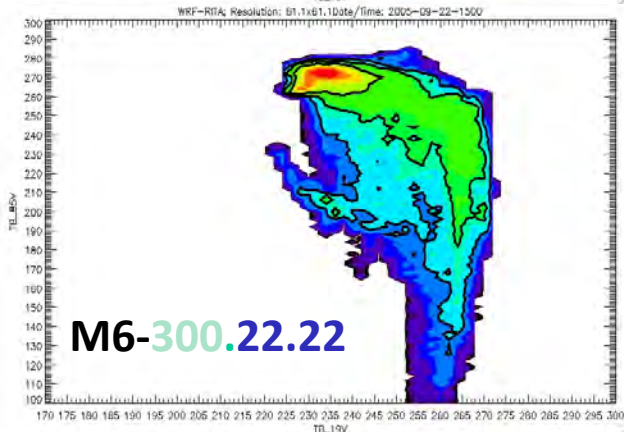
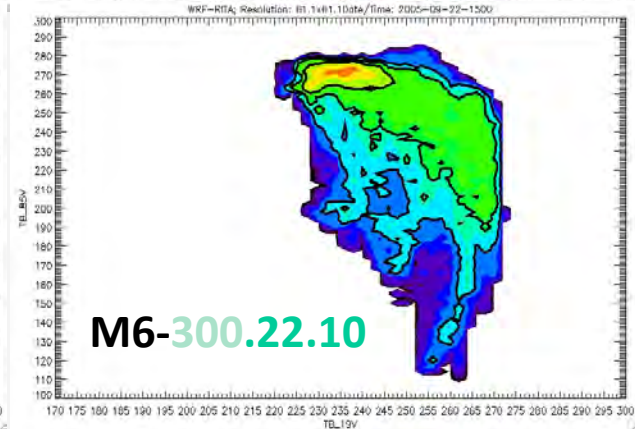
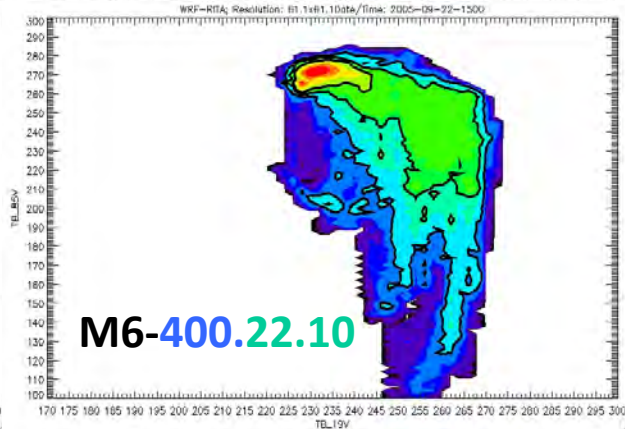
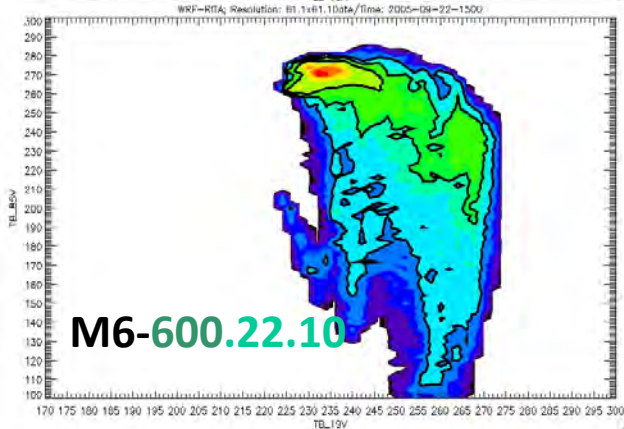
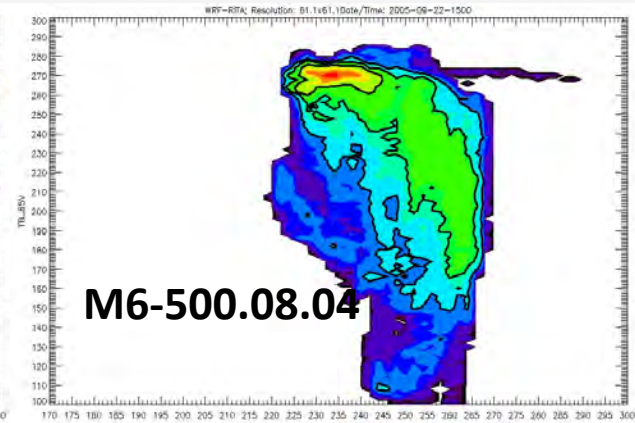
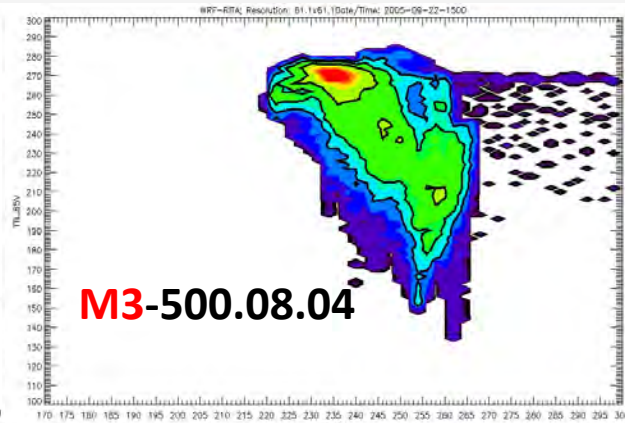
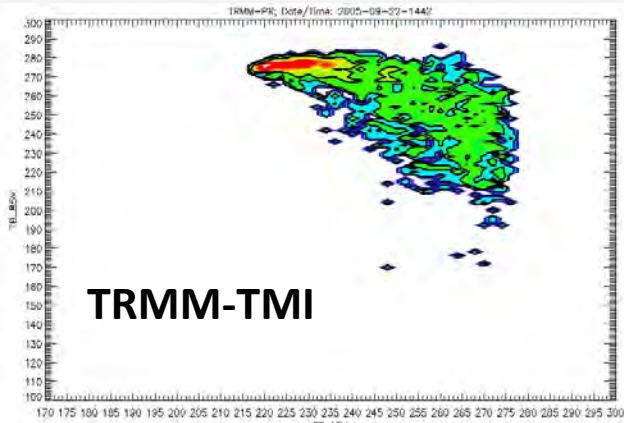
WRF  
WSM6  
New PSD





# Joint Distribution (19H vs 85H) – Impact of Microphysics

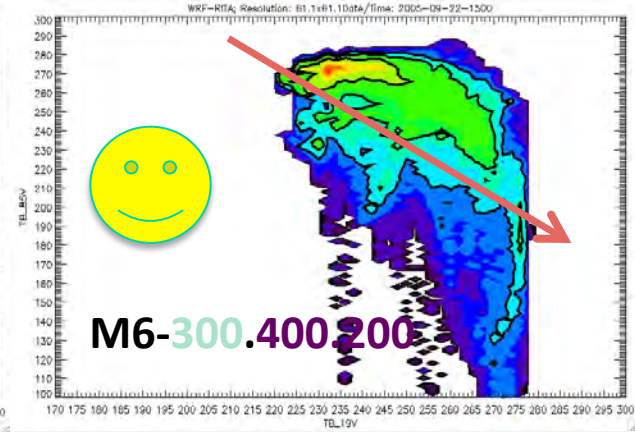
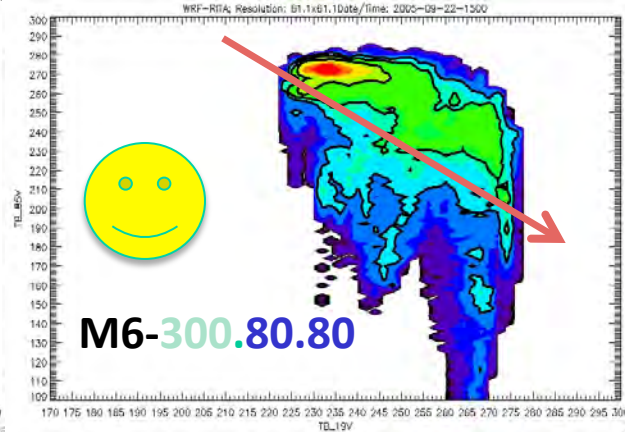
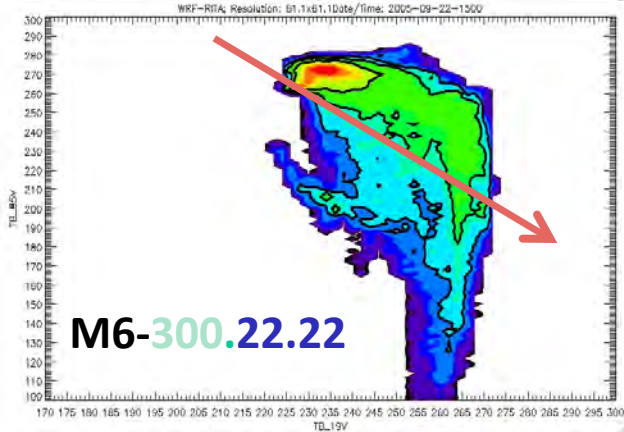
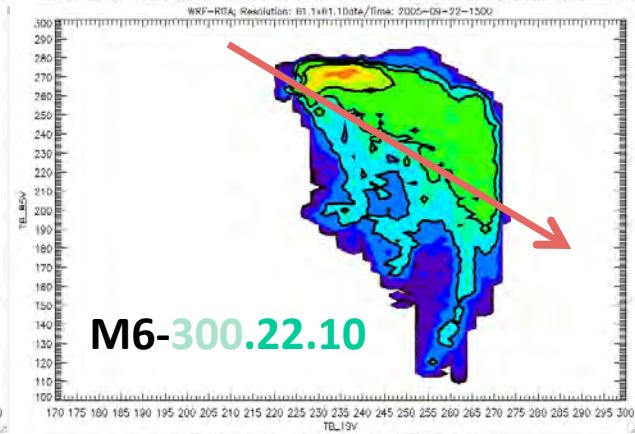
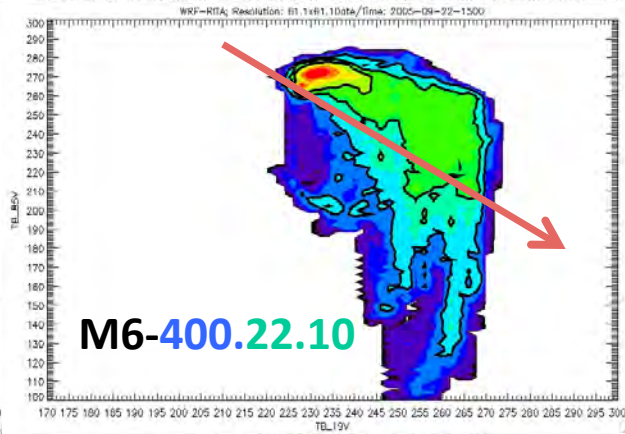
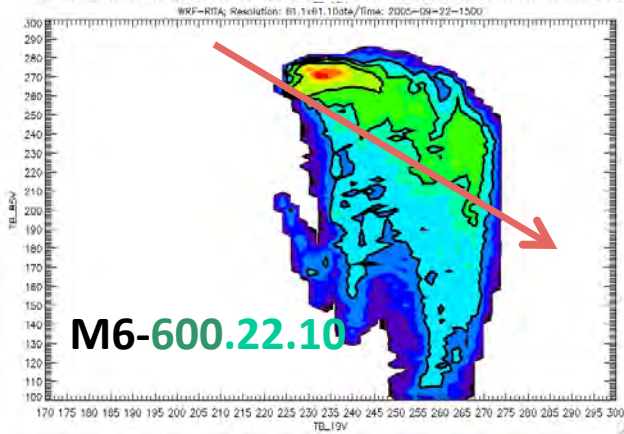
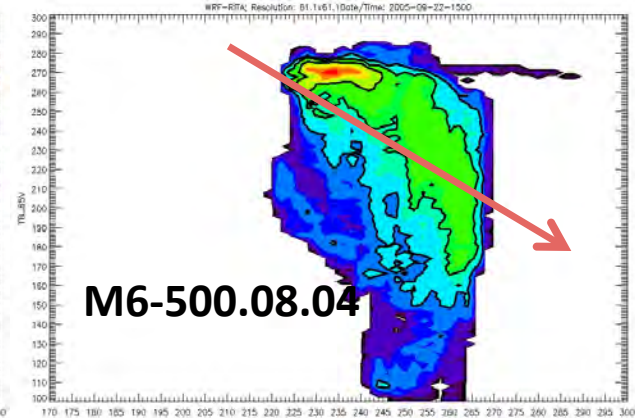
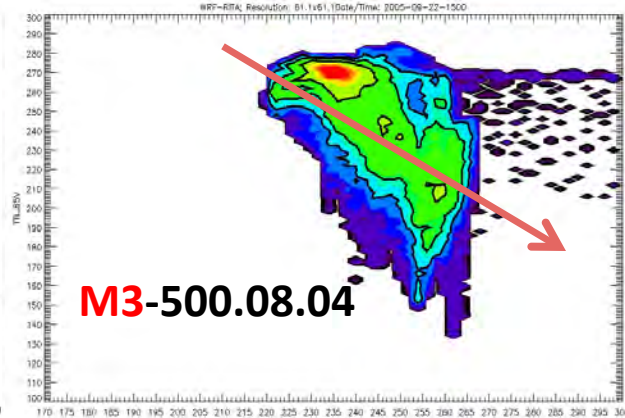
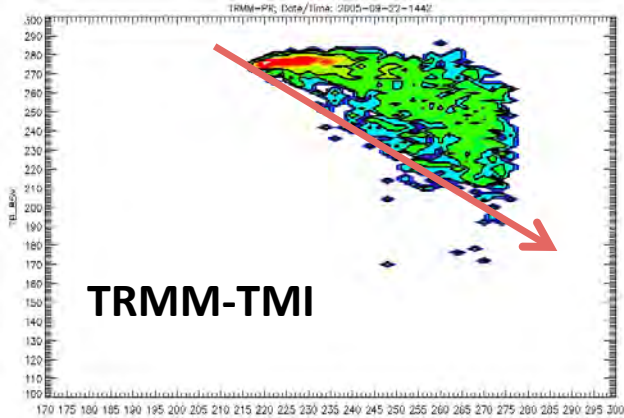
## PDF of the relation 85V-19V





# Joint Distribution (19H vs 85H) – Impact of Microphysics

## PDF of the relation 85V-19V





# Storm structure Tool: Degree of Organization

## The Automated Rotational Center Hurricane Eye Retrieval (ARCHER)

- Developed by CIMSS/NRL (Wimmers & Velden, 2010)
- We have license to run it and have done some off-line analysis, using the original version
- Provides:
  - Objective fix guidance for forecasters
  - Quantifies the degree of storm organization

First Guess

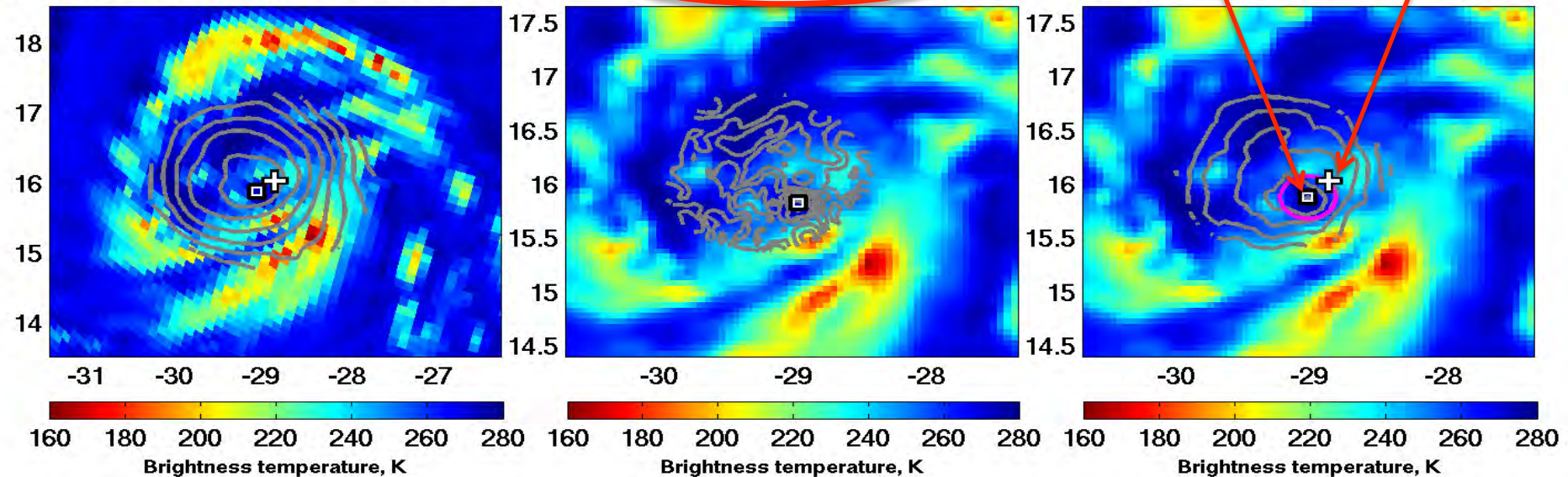
Target

ssmis-F18 85GHzH 20130911T094830 Vmax=63.0, Vx= kts

Weighted Guided Fine Spiral Score = 287

Ring Score = 15

Combined score=300, Threshold=268



Additional information can be found in Wimmers, A. and C. Velden, 2010: Objectively Determining the Rotational Center of Tropical Cyclones in Passive Microwave Satellite Imagery, *J. Appl. Meteor.*, 49, 2010.

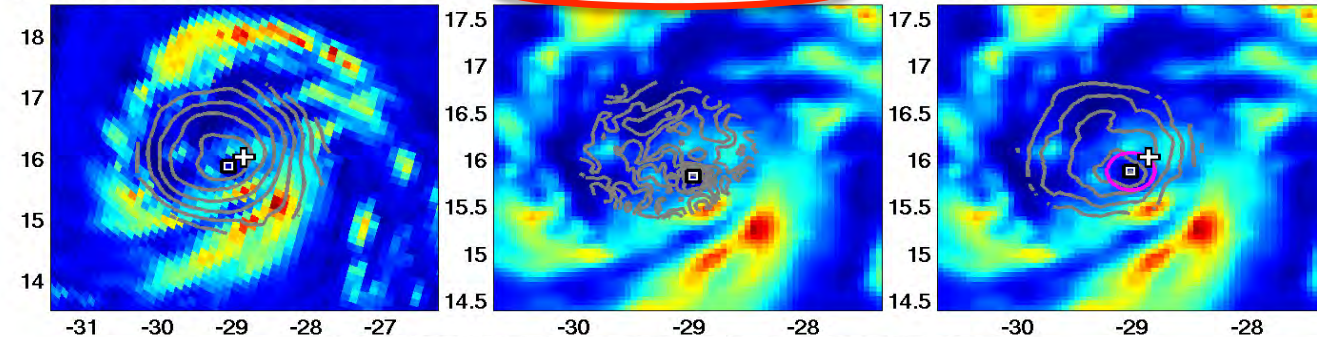


# Storm structure Tool: Degree of Organization

## The Automated Rotational Center Hurricane Eye Retrieval (ARCHER)

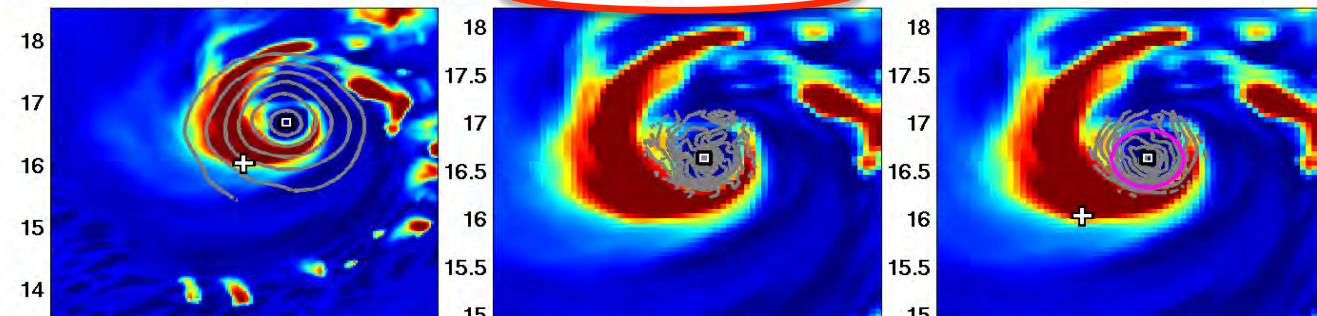
OBSERVED

ssmis-F18 85GHzH 20130911T094830 Vmax=63.0, Vx= kts  
Weighted Guided Fine Spiral Score = 287 **Ring Score = 15** Combined score=300, Threshold=268



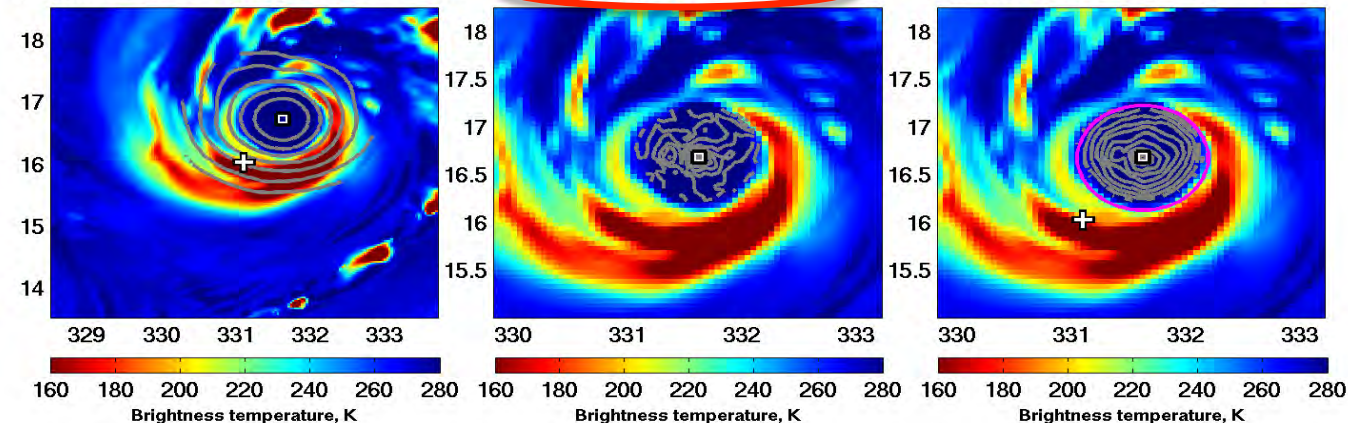
36h forecast

HWRf-CRTM-D3 85GzH 20130910T000000 Vmax=63.0, Vx= kts  
Weighted Guided Fine Spiral Score = 329 **Ring Score = 57** Combined score=386, Threshold=268



60h forecast

HWRf-CRTM-D3 85GzH 20130909T000000 Vmax=63.0, Vx= kts  
Weighted Guided Fine Spiral Score = 402 **Ring Score = 53** Combined score=455, Threshold=268

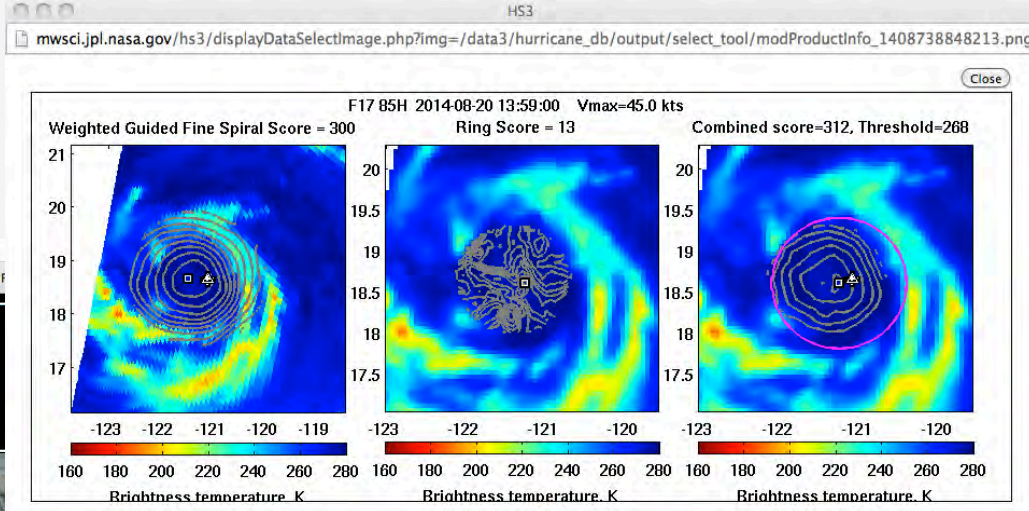


• ARCHER scores suggest the model forecasts over-predicted the structure in this case.

• This conclusion is in agreement with the model-predicted intensity parameters:

- Observed:
  - Vmax = 65kts
  - MSLP = 989 mb
- 36h forecast
  - Vmax = 72 kts
  - MSLP = 977mb
- 60h forecast
  - Vmax = 83 kts
  - MSLP = 971mb

# Storm structure Tool: Degree of organization ARCHER (EP hurricane Lowell)



mwsci.jpl.nasa.gov/hs3/#

NASA Jet Propulsion Laboratory  
California Institute of Technology

## HURRICANE AND SEVERE STORM SENTINEL [HS3]

2014-08-20 15:00:00

Hurricanes: Karina (08/10-08/22, 1)

August 2014

Ending at hour: 15:00:00

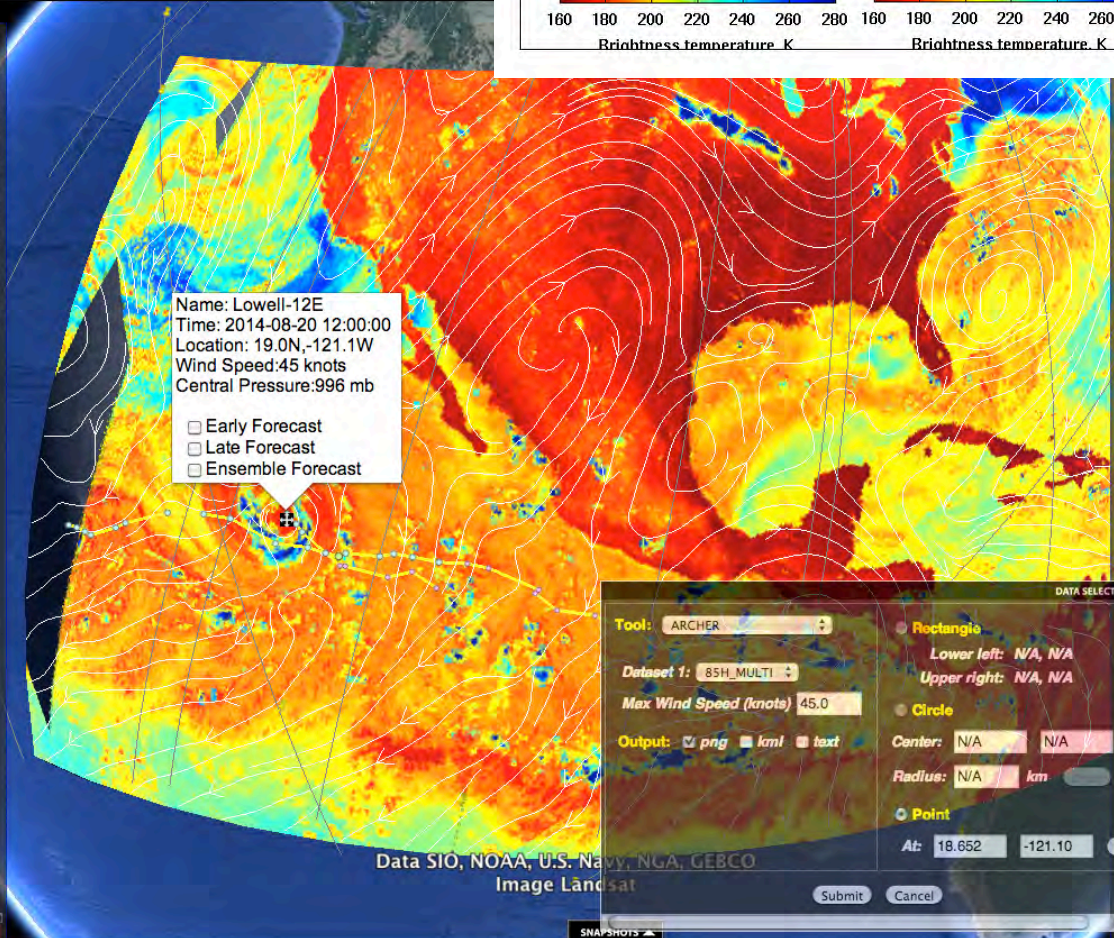
**STORM TRACK**

- BEST TRACK
- POUCH TRACK

**SATELLITE DATA**

- AIRS
- AOT (MODIS)
- Geostationary
- Microwave Rain Signature
- 10H GHz
- 10V GHz
- 19H GHz
- 19V GHz
- 37COLOR
- 37H GHz
- 37V GHz
- 85H GHz
- 85V GHz
- Rain Indicator
- TPW
- 6 HR Composite
- Two Day Animation
- TRMM

SATELLITE & AIRCRAFT DATA



DATA SELECTION

Tool: ARCHER

Dataset 1: 85H\_MULTI

Max Wind Speed (knots) 45.0

Output:  png  kml  text

Rectangle  
Lower left: N/A, N/A  
Upper right: N/A, N/A

Circle  
Center: N/A, N/A  
Radius: N/A km

Point  
At: 18.652, -121.10

Submit Cancel

L & SIMULATION DATA

MODEL

- ECMWF
- GFS
- Pres: 200
- Forecast Time 012
- SPEED-COMOVING
- STREAM-COMOVING
- DEEP-SHEAR
- OW
- PMSL
- POUCH-SHEAR
- RH
- SPEED-EARTH
- STREAM-EARTH
- TEMP
- TPW
- VORTICITY
- NAVGEM
- UKMET

SIMULATION

- HWRF-CRTM-D1
- HWRF-CRTM-D3

Google Status Bar Grid



# Storm structure Tool: Storm Size and Asymmetry

## The Wave Number Analysis Tool

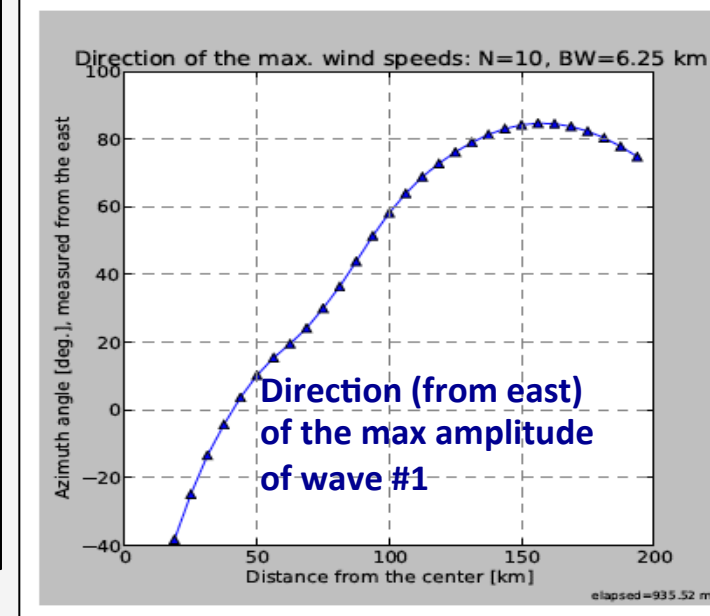
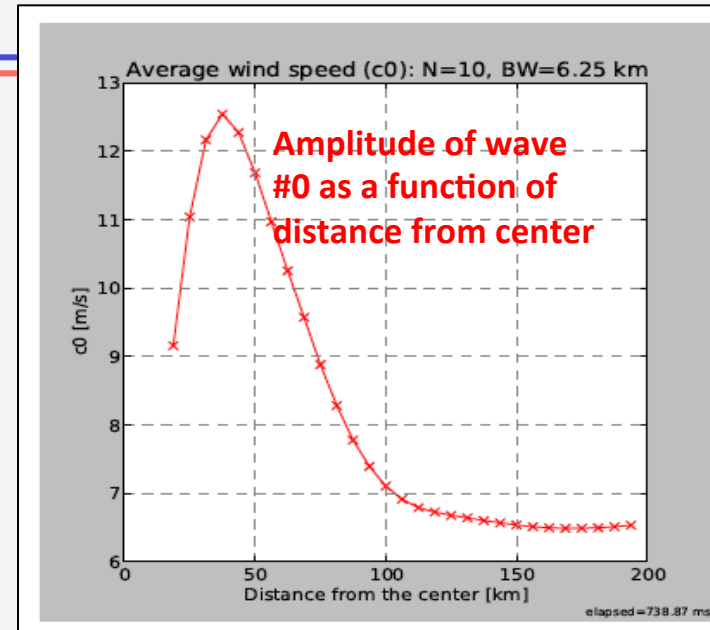
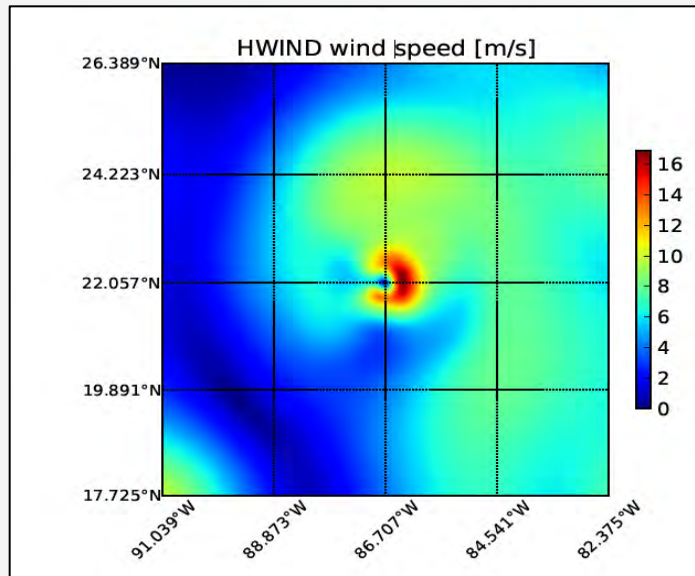
### First adopted and used by NOAA/AOML/HRD

- Lonfat, M., F.D. Marks, and S.S.Chen, 2004: "Precipitation Distribution in Tropical Cyclones using the Tropical Rainfall Measuring Mission (TRMM) microwave imager : A Global Perspective" MWR 132(7)
- Vukicevic, T., E. Uhlhorn, P. Reasor and B. Klotz, 2013: "A novel multi-scale intensity metric for evaluation of tropical cyclone intensity forecasts", Journal of the Atmospheric Sciences 2013 ;doi: <http://dx.doi.org/10.1175/JAS-D-13-0153.1>

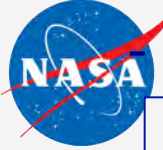
### Tool Developed for the JPL TCIS by

- Z. Haddad, N. Niamsuwan, T.-S. Shen
- Available now
- **Works with:**

- **Surface winds**
- **Rain Index**







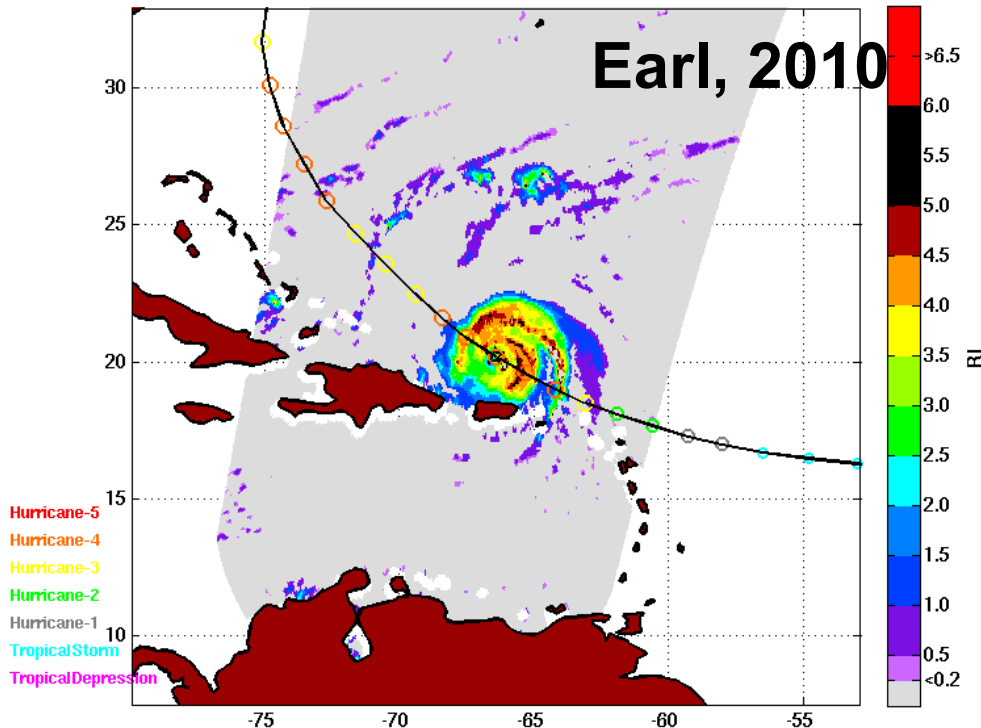
# The Rain Indicator – a multi-channel depiction of the storm structure

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

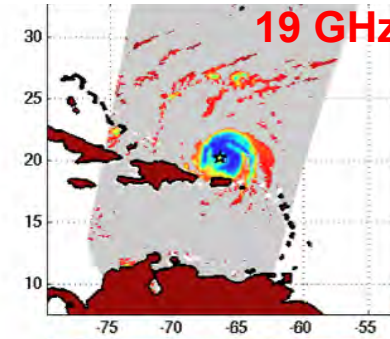
Microwave signals at the top of the atmosphere can be classified into two categories:

- **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.

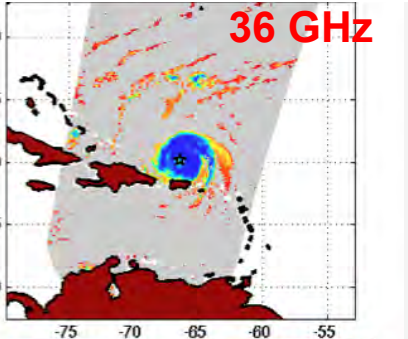
AMSRE AQUA-1 Rain Index(RI) Earl 2010/08/31 06:19:38



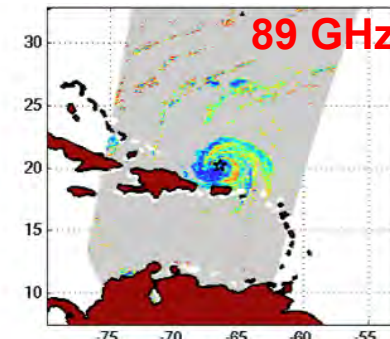
Polarization Difference



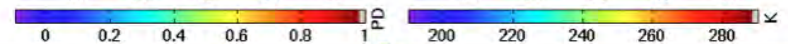
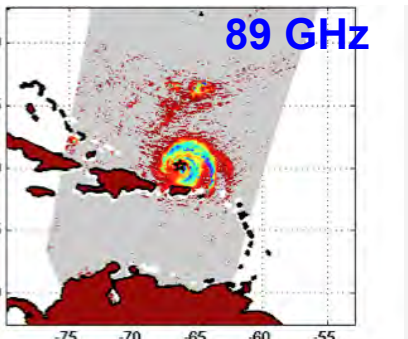
Polarization Difference



Polarization Diff



Polarization Corrected Temp.

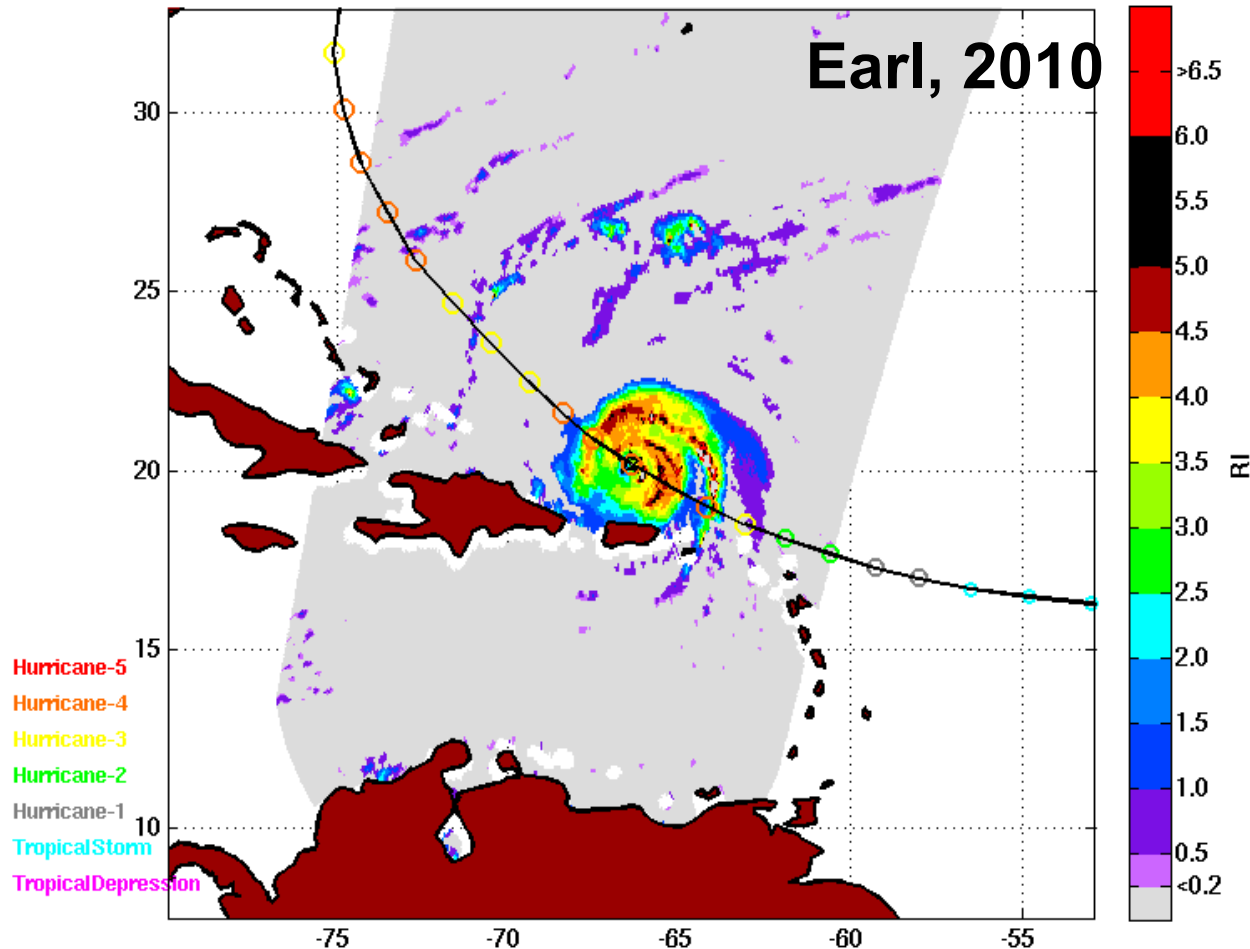




# The Rain Indicator – a multi-channel depiction of the storm structure

*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*

AMSRE AQUA-1 Rain Index(RI) Earl 2010/08/31 06:19:38



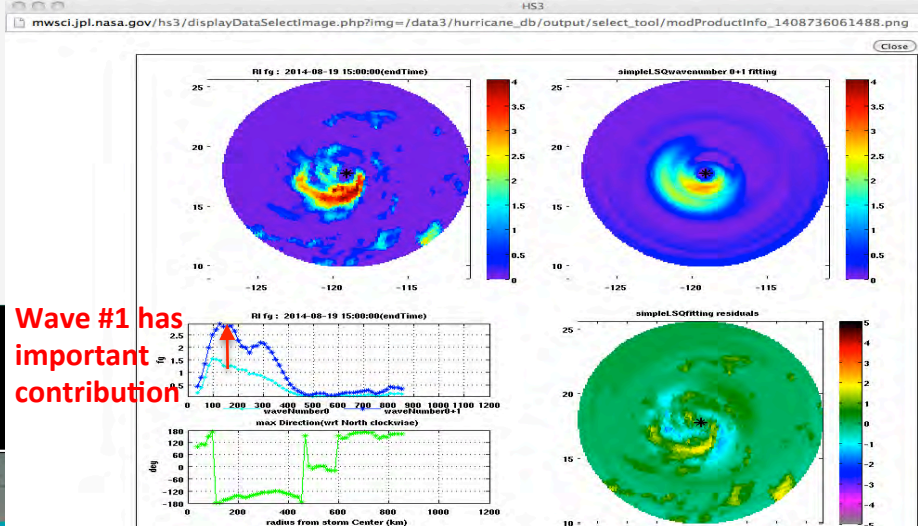
## Advantages of Using the Rain Indicator over single passive microwave channels

- combines the emission and scattering signals from the **multi-channel information** to present a **cohesive depiction of the rain and the graupel above**, covering the precipitation spectrum
- Uses polarization difference. Hence, it is **less affected by calibration accuracy.**

# Storm structure Tool:

## Storm Size and Asymmetry

### The Wave Number Analysis Tool using the Rain Index (EP hurricane Lowell)



NASA Jet Propulsion Laboratory  
California Institute of Technology

#### HURRICANE AND SEVERE STORM SENTINEL [HS3]

2014-08-19 15:00:00

**SATELLITE & AIRCRAFT DATA**

15 Hurricanes (km)

Karina (08/10-08/19, 1)

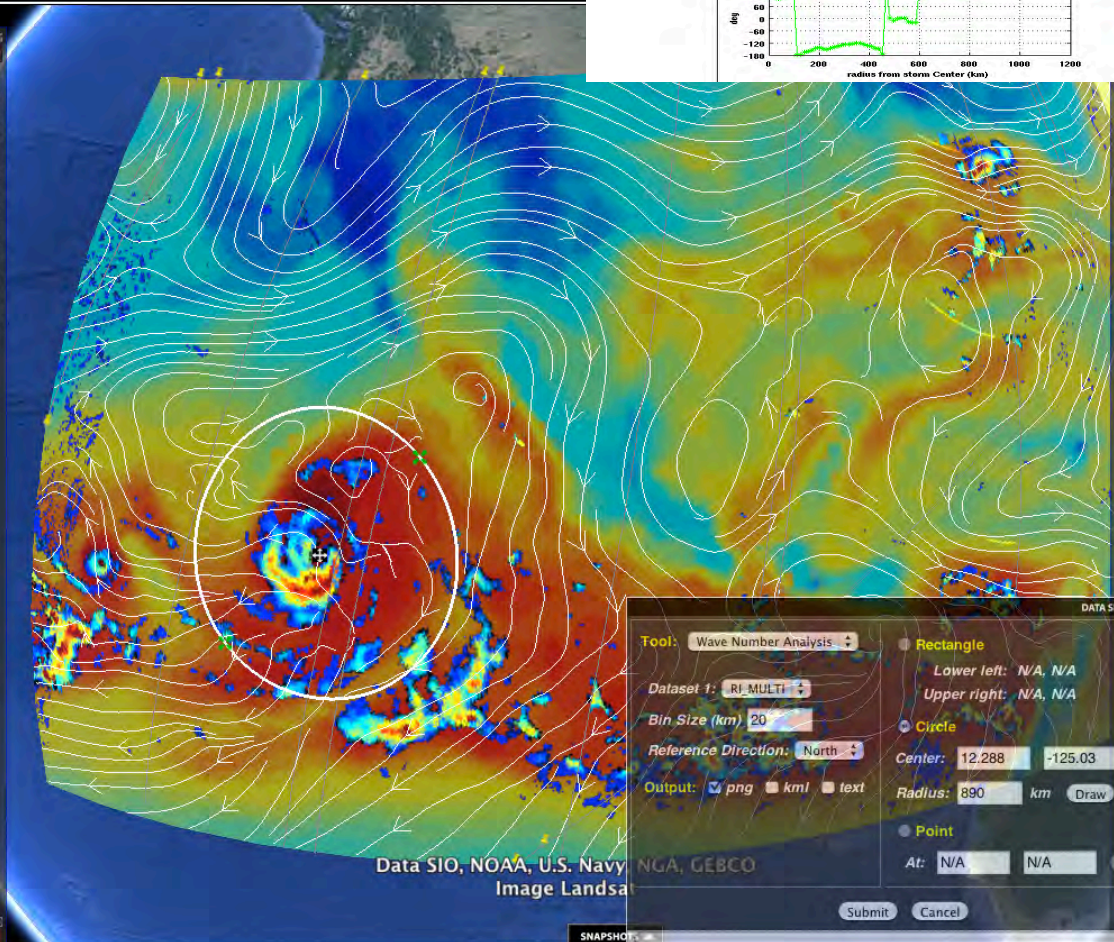
August 2014

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
						31

Ending at hour: 15:00:00

**SATELLITE DATA**

- AIRS
- Geostationary
  - IR
  - IR 2 Day Animation
  - IRCOLOR
  - VAPOR
  - VIS
- Microwave Rain Signature
  - 10H GHz
  - 10V GHz
  - 19H GHz
  - 19V GHz
  - 37COLOR
  - 37H GHz
  - 37V GHz
  - 85H GHz
  - 85V GHz
  - Rain Indicator
  - TPW
  - Rain Indicator



**MODEL**

- ECMWF
- GFS
- Phase: 200
- Forecast Time: 012
- SPEED-COMOVING
- STREAM-COMOVING
- DEEP-SHEAR
- OW
- PMSL
- POUCH-SHEAR
- RH
- SPEED-EARTH
- STREAM-EARTH
- TEMP
- TPW
- VORTICITY
- NAVGEM
- UKMET

**SIMULATION**

- HWRF-CRTM-D1
- HWRF-CRTM-D3

**DATA SELECTION**

Tool: Wave Number Analysis

Dataset 1: RI-MULTI

Bin Size (km): 20

Reference Direction: North

Output:  png  kml  text

Rectangle

Lower left: N/A, N/A

Upper right: N/A, N/A

Circle

Center: 12.288, -125.03

Radius: 890 km

Point

At: N/A, N/A

Submit Cancel

# Storm structure Tool:

## Storm Size and Asymmetry

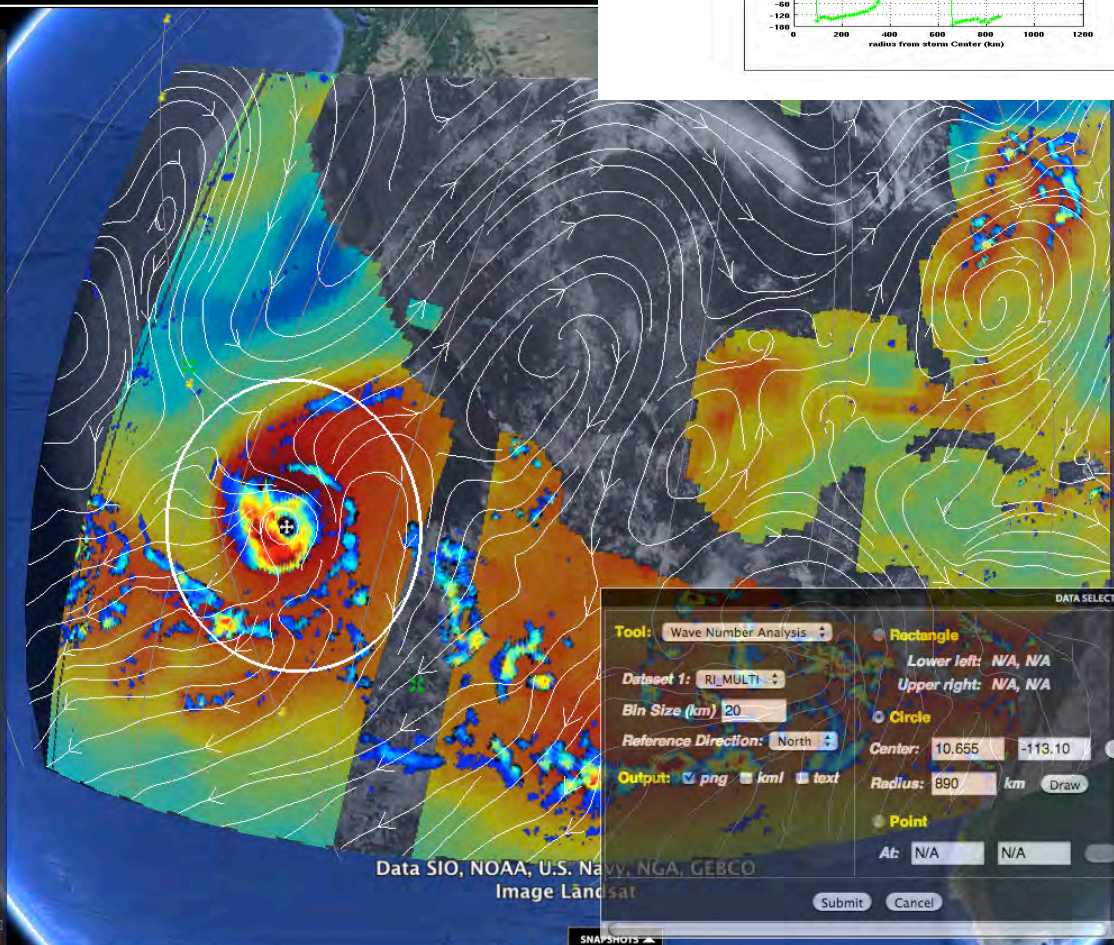
### The Wave Number Analysis Tool using the Rain Index (EP hurricane Lowell)



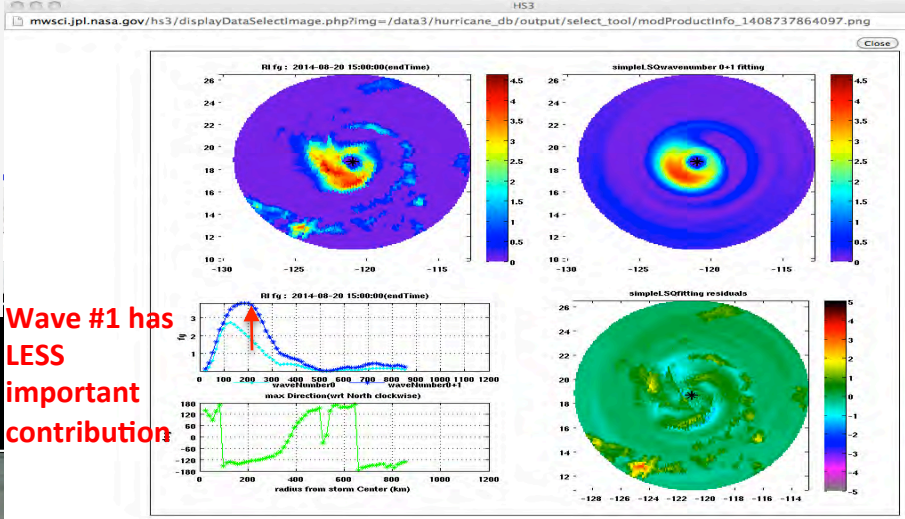
#### HURRICANE AND SEVERE STORM SENTINEL [HS3]

2014-08-20 15:00:00

- SATELLITE & AIRCRAFT DATA
- Ending at hour: 15:00:00
- STORM TRACK
  - BEST TRACK
  - POUCH TRACK
- SATELLITE DATA
  - AIRS
  - AOT (MODIS)
  - Geostationary
    - IR
    - IR 2 Day Animation
    - IRCOLOR
    - VAPOR
    - VIS
  - Microwave Rain Signature
    - 10H GHz
    - 10V GHz
    - 19H GHz
    - 19V GHz
    - 37COLOR
    - 37H GHz
    - 37V GHz
    - 85H GHz
    - 85V GHz
    - Rain Indicator
    - TPW
    - IR Composite
    - Two Day Animation
  - TRMM
  - Rain Indicator



Wave #1 has LESS important contribution



# Storm structure Tool:

## Storm Size and Asymmetry

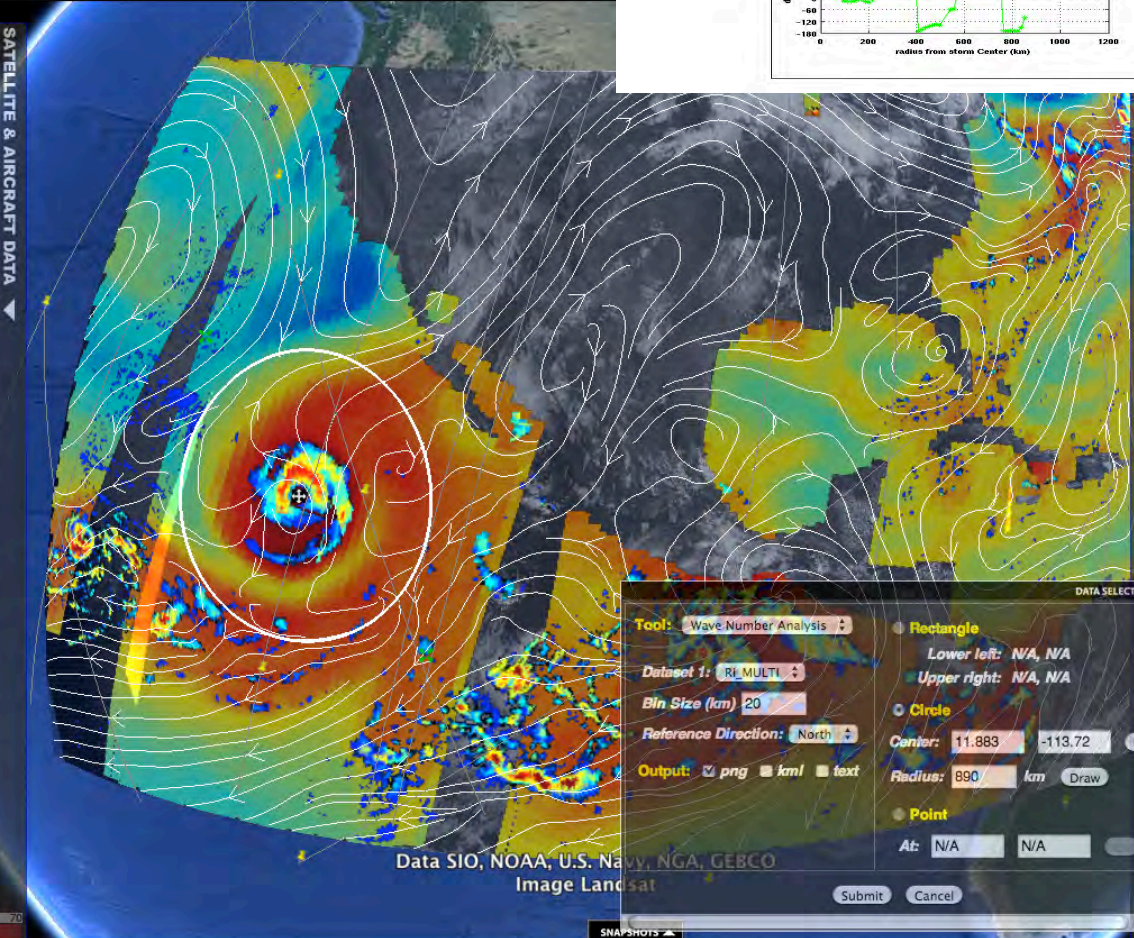
### The Wave Number Analysis Tool using the Rain Index (EP hurricane Lowell)

NASA Jet Propulsion Laboratory  
California Institute of Technology

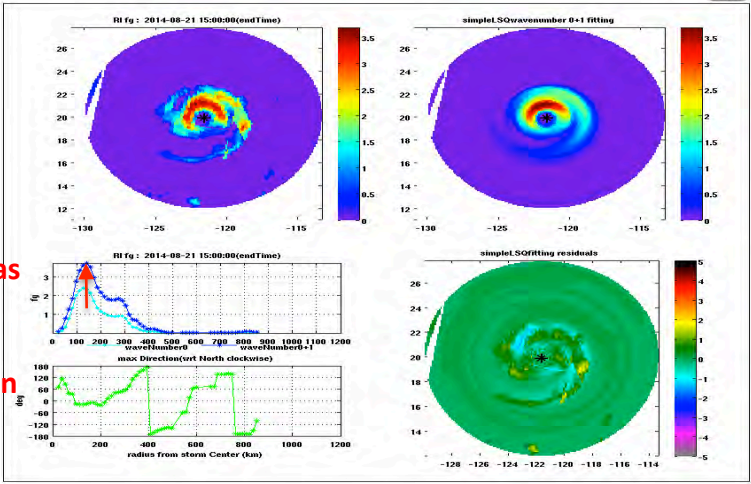
#### HURRICANE AND SEVERE STORM SENTINEL [HS3]

2014-08-21 15:00:00

- STORM TRACK**
  - BEST TRACK
  - POUCH TRACK
- SATELLITE DATA**
  - AIRS
  - AOT (MODIS)
  - Geostationary
    - IR
    - IR 2 Day Animation
    - IRCOLOR
    - VAPOR
    - VIS
    - Microwave Rain Signature
      - 10H GHz
      - 10V GHz
      - 19H GHz
      - 19V GHz
      - 37COLOR
      - 37H GHz
      - 37V GHz
      - 85H GHz
      - 85V GHz
  - Rain Indicator
  - TPW
  - 6 HR Composite
  - Two Day Animation
  - TRMM
  - WIND
  - CloudSet
  - SST



Wave #1 has LEAST important contribution



- MODEL**
  - ECMWF
  - GFS
    - Pres: 200
    - Forecast Time: 012
    - SPEED-COMOVING
    - STREAM-COMOVING
    - DEEP-SHEAR
    - OW
    - PMSL
    - POUCH-SHEAR
    - RH
    - SPEED-EARTH
    - STREAM-EARTH
    - TEMP
    - TPW
    - VORTICITY
  - NAVGEM
  - UKMET

DATA SELECTION

Tool: Wave Number Analysis

Dataset 1: RI MULTI

Bin Size (km): 20

Reference Direction: North

Output:  png  kml  text

Rectangle: Lower left: N/A, N/A; Upper right: N/A, N/A

Circle: Center: 11.883, -113.72; Radius: 890 km

Point: At: N/A, N/A

Submit Cancel

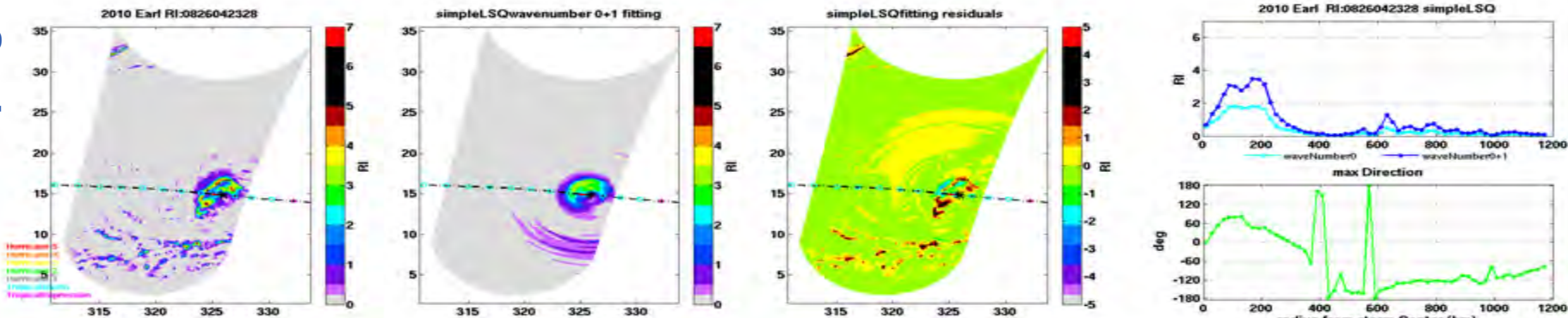


# Storm structure Tool: Storm Size and Asymmetry

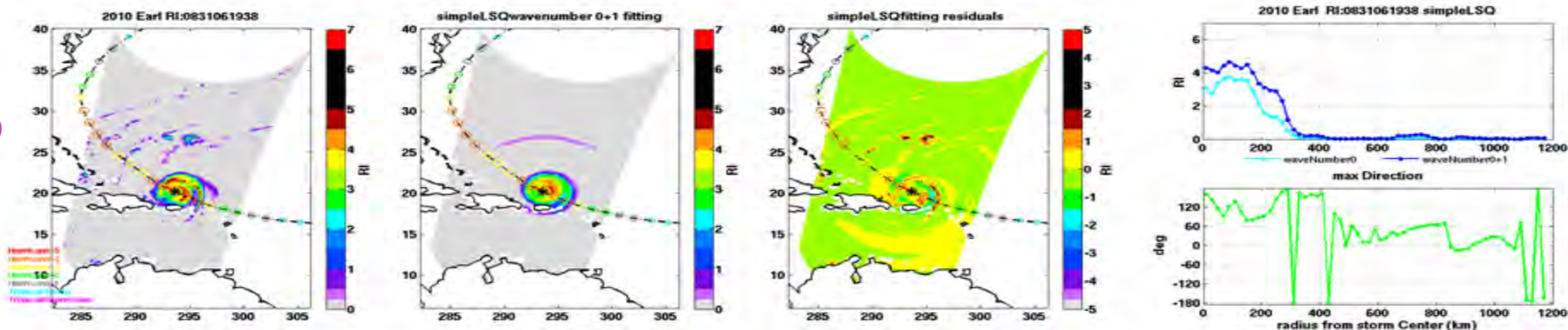
## The Wave Number Analysis Tool using the Rain Index (multi-channel PMW index)

More details on the Rain Index can be found in Hristova-Veleva et al. 2013, JAMC 52, 2828–2848

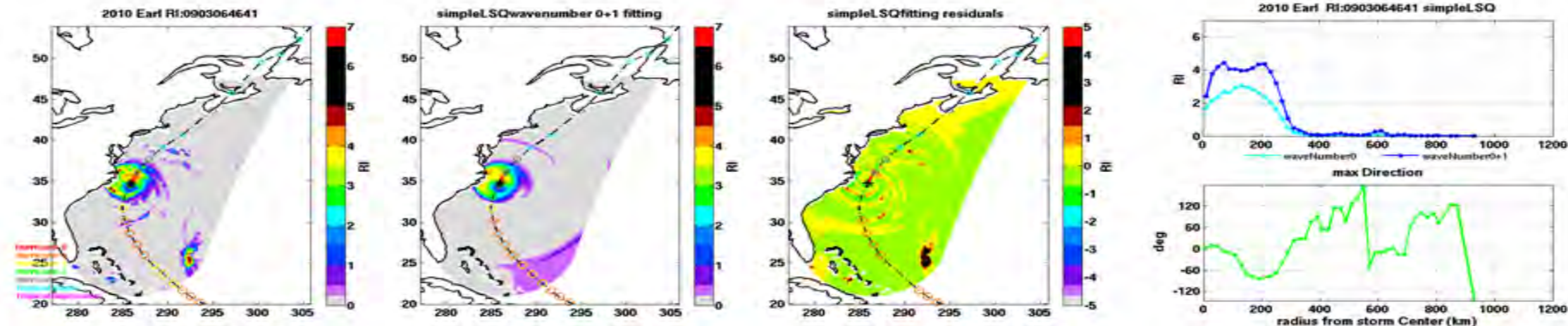
Developing



During RI



Mature



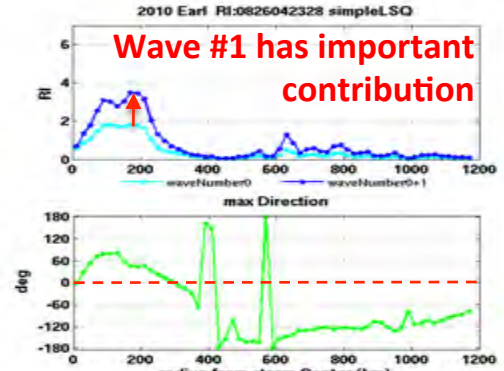
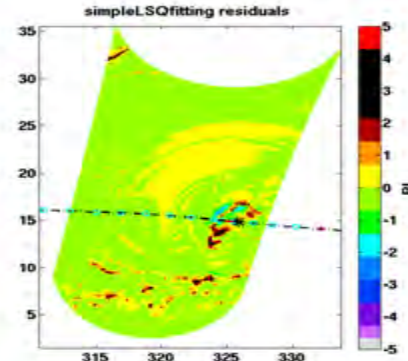
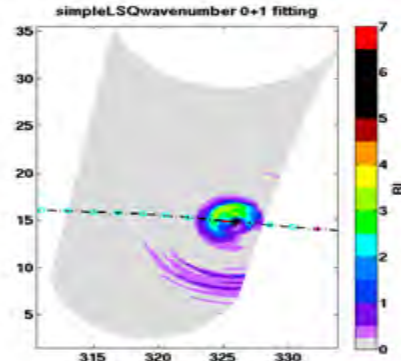
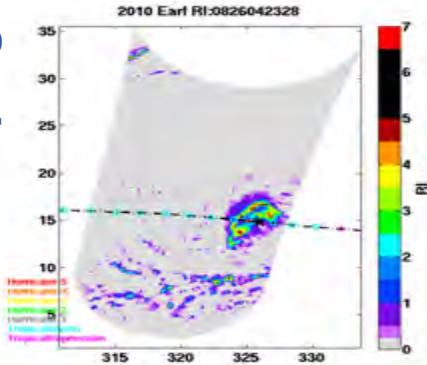


# Storm structure Tool: Storm Size and Asymmetry

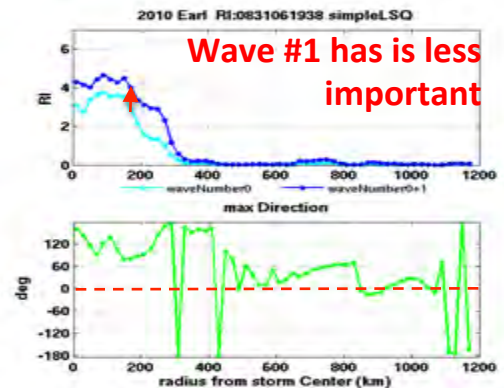
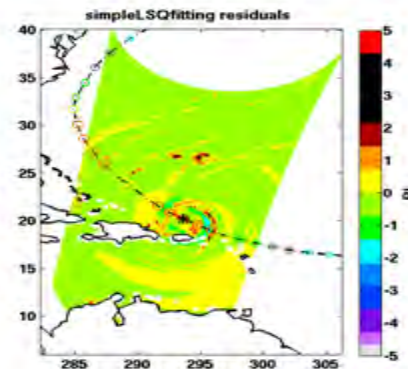
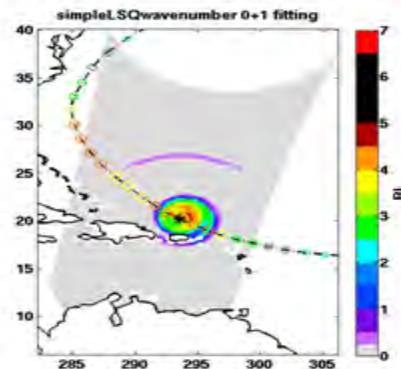
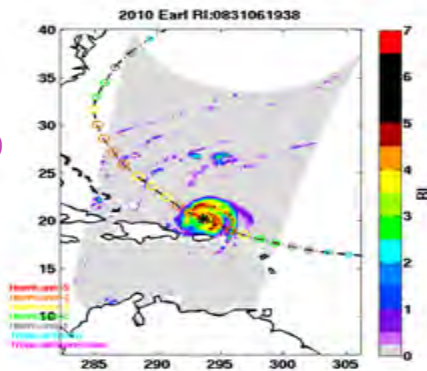
## The Wave Number Analysis Tool using the Rain Index (multi-channel PMW index)

More details in the Rain Index can be found in Hristova-Veleva et al., JAMC, 2013

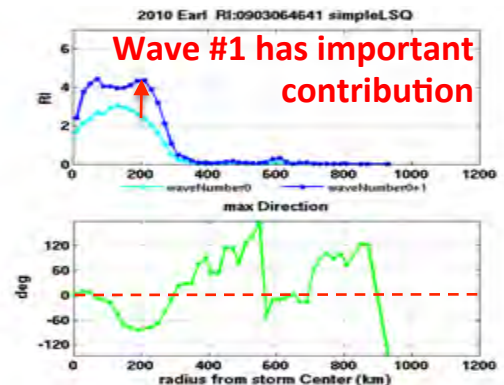
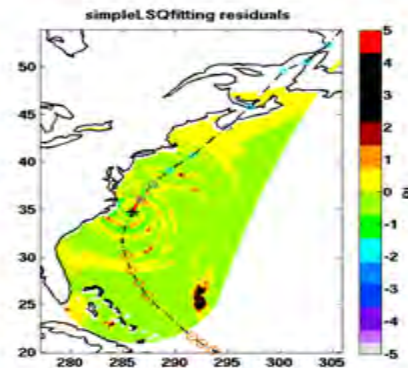
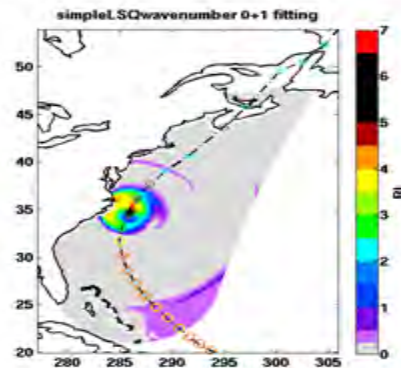
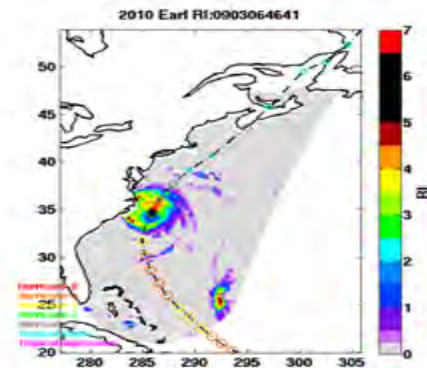
Developing



During RI



Mature





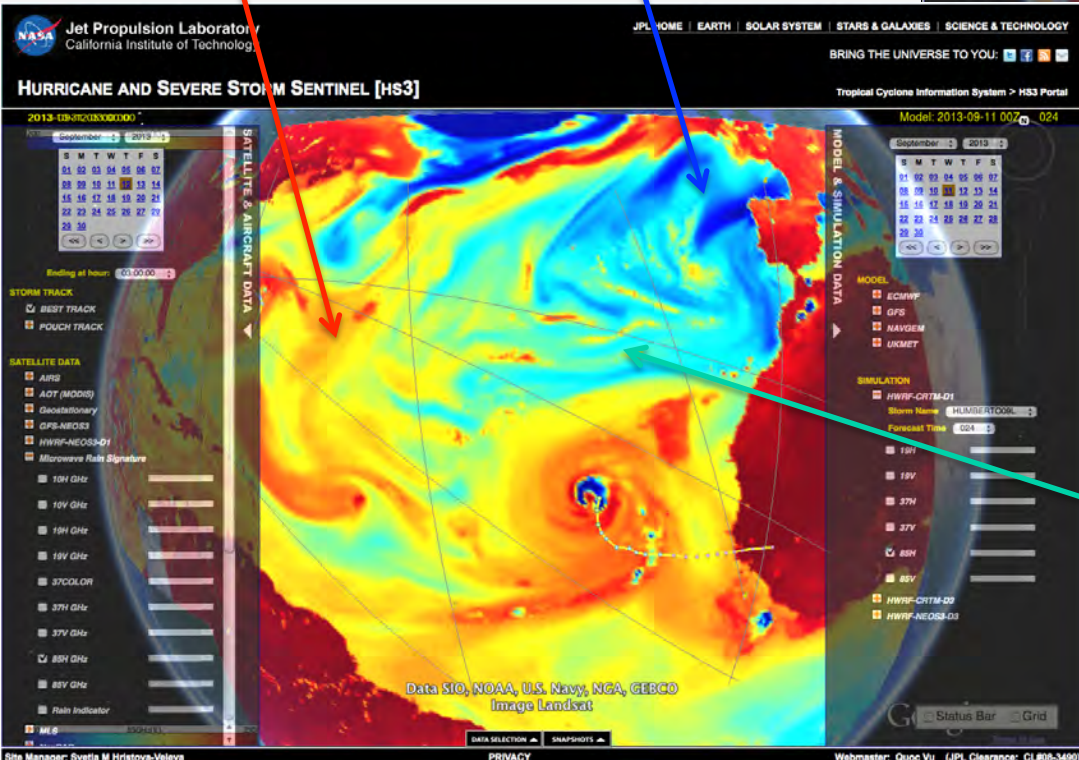
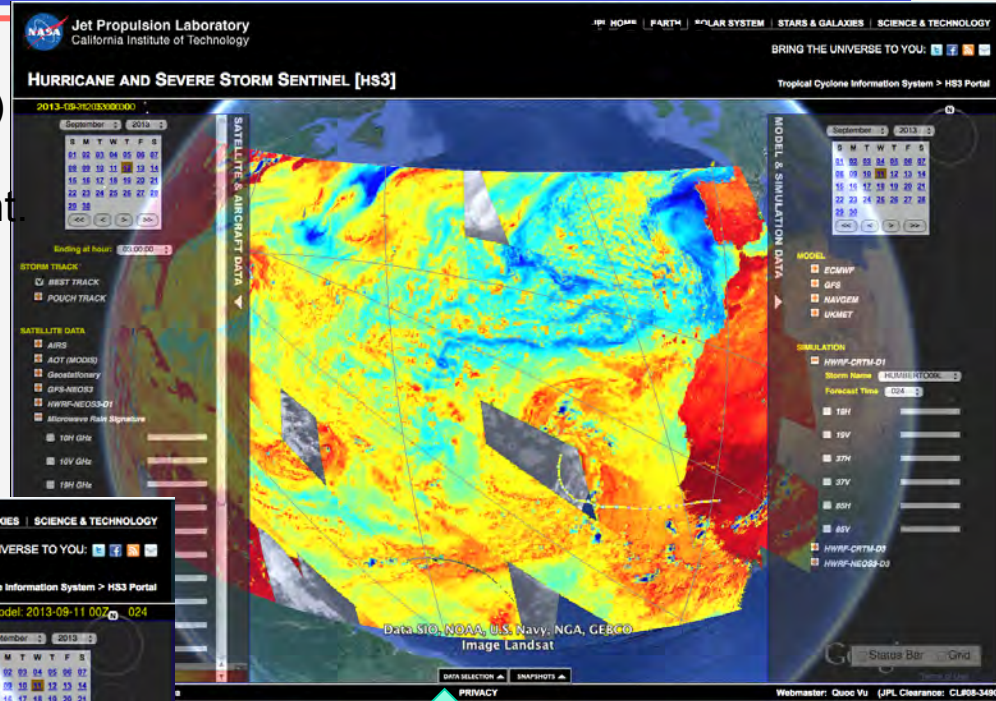
# Task Summary – Major Accomplishments

## How to evaluate whether the model represents the environment well

An example of how observed and synthetic brightness temperatures (85 GHz in this case) can be used to evaluate whether the model properly represents the large-scale environment.

HWRF model based on (NEOS<sup>3</sup>) and the operational CRTM instrument simulators

**MOIST AIR**  
**DRY AIR**



- Overall – a very good comparison of brightness temperatures
- Area north of the hurricane is a bit too moist in the model





# Summary

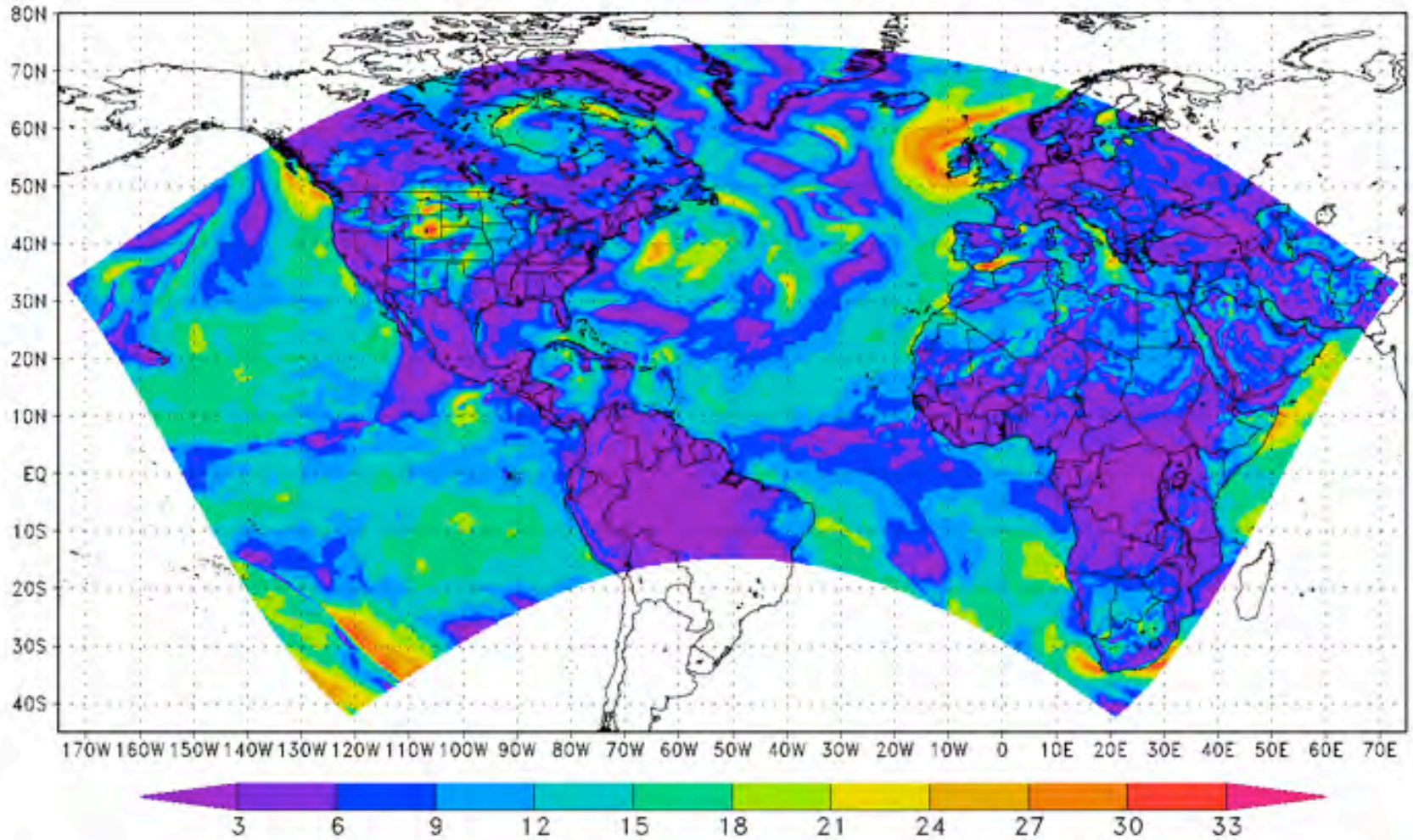
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- To achieve the HFIP goals of improving the forecast accuracy of hurricane intensity, track and impact at landfall we first **need to understand whether the models properly reflect the physical processes and their interactions.**
- To address the need for improving the model physics, the 2013 annual HFIP meeting suggested that **all available observations (satellite, airborne, in-situ) should be used systematically and extensively to evaluate the model performance.**
- Furthermore, the participants highlighted **the need for developing new metrics and tools for evaluating the storm structure, the interaction between different physical processes** (multiparameter observations) **and the evaluation of the multi-scale interactions** (feedback between the storm and its environment).
- **Such studies require the use of large amounts of satellite data, coming from diverse instruments in order to create robust statistics.** Due to the complexity of the remote sensing data and the volume of the respective model forecast this in-depth evaluation is usually limited to a number of case studies.
- **With the goal to facilitate model evaluation that goes beyond the comparison of "Best Track" metrics, we are working on providing fusion of models and observations by bringing them together into a common system and developing online analysis and visualization tools.**
- Our system is ***under development. Expected that many components will be operational during the coming season.*** Stay tuned ... 😊



# Basin-scale HWRF – coming up!

AL/EP Cyclogenesis Domain (dx=27km) / 10m Wind [kt]



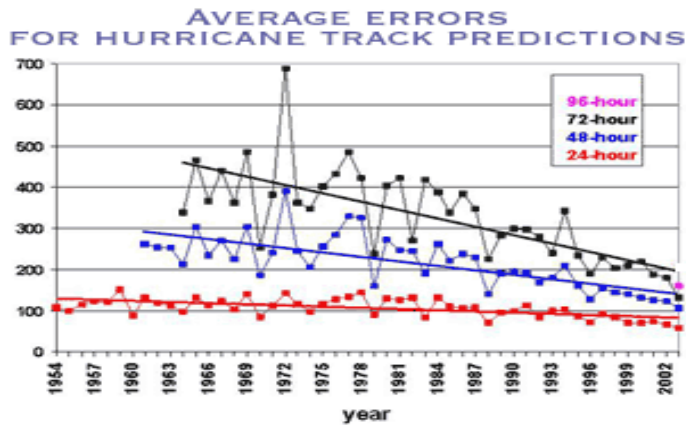


*Thank you !*

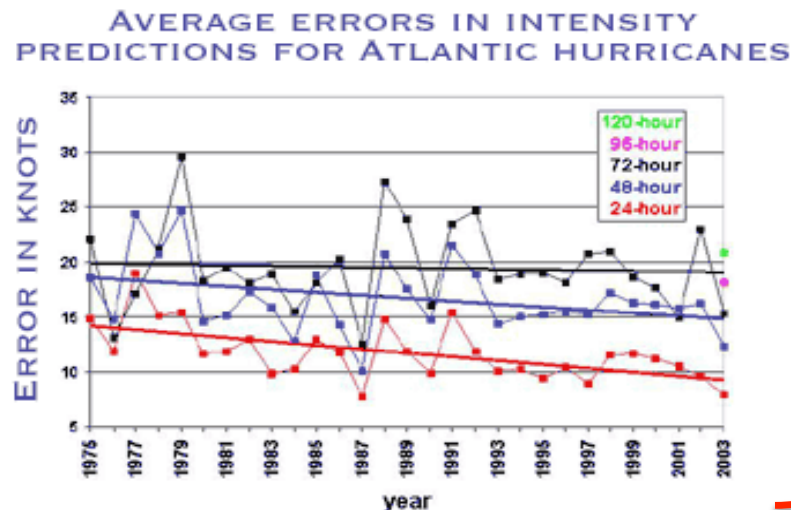


# Current state-of-the-art hurricane prediction

- **25% reduction in 48 hour track error over the past 6 years**



- **Intensity forecasts have not improved as fast.**



## But WHY ???

- What are the sources of the intensity errors?
- **Do the models properly reflect the physical processes and their interactions?**
  - Is the representation of the precipitation structure correct?
  - Is the storm scale and asymmetry reflected properly
  - Is the environment captured correctly
  - Is the interaction between the storm and its environment represented accurately
- **Recognizing an urgent need for more accurate hurricane forecasts, NOAA recently established the multi-agency 10-year Hurricane Forecast Improvement Project (HFIP).**