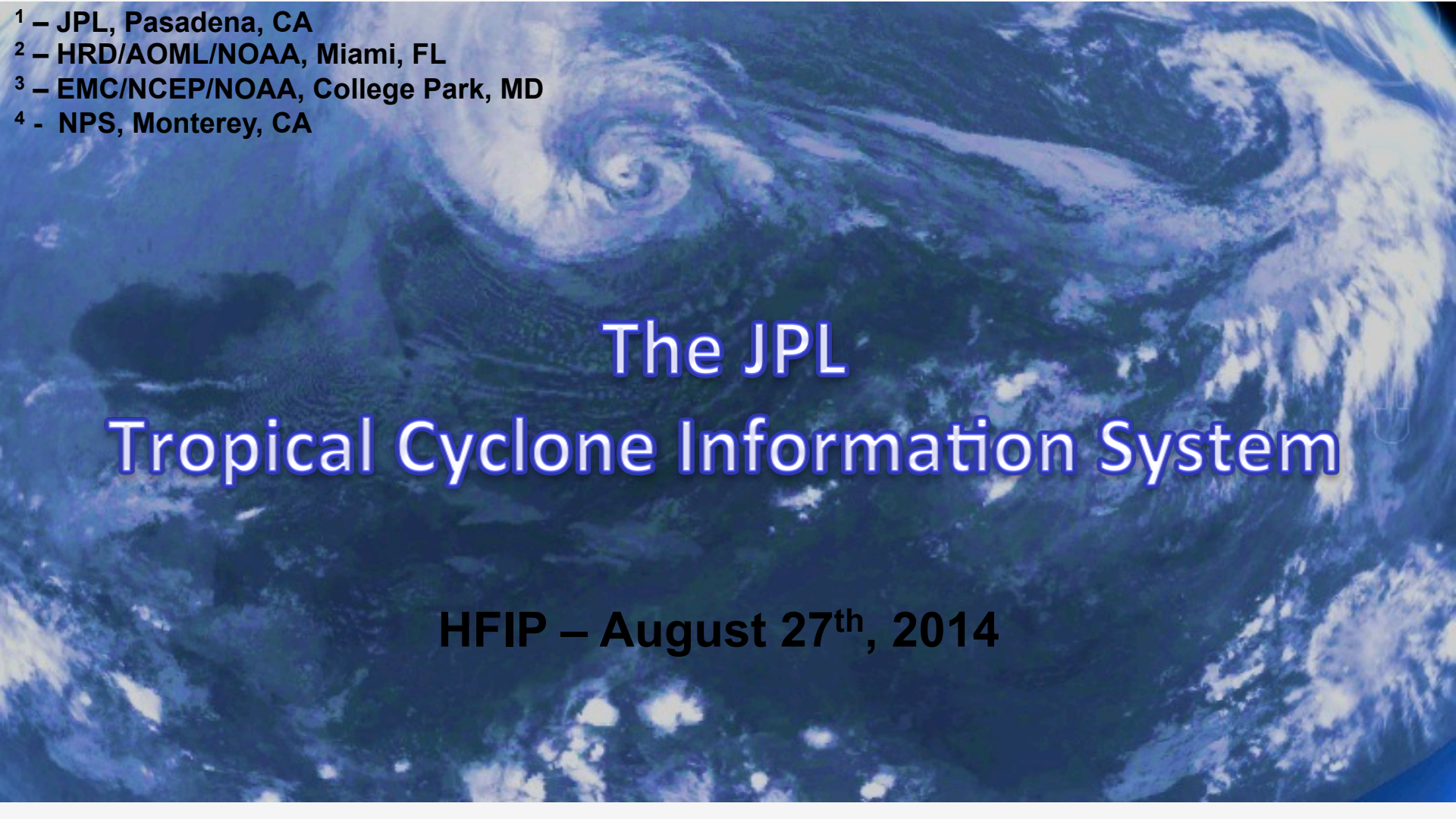


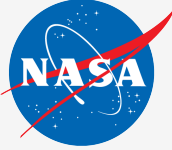
**Svetla Hristova-Veleva<sup>1</sup>, M. Boothe<sup>4</sup>, S. Gopalakrishnan<sup>2</sup>, Z. Haddad<sup>1</sup>,  
M. P. Johnson<sup>1</sup>, B. Knosp<sup>1</sup>, B. Lambrigtsen<sup>1</sup>, F. Marks<sup>2</sup>, P. P. Li<sup>1</sup>,  
M. Montgomery<sup>4</sup>, N. Niamsuwan<sup>1</sup>, W. Poulsen<sup>1</sup>, T.-P. Shen<sup>1</sup>,  
V. Tallapragada<sup>3</sup>, S. Tanelli<sup>1</sup>, S. Trahan<sup>3</sup>, J. Turk<sup>1</sup>, Q. Vu<sup>1</sup>, T. Vukicevic<sup>2</sup>**

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

A satellite image of Earth showing a large tropical cyclone with a clear eye and spiral cloud bands over the ocean. The text is overlaid on this image.

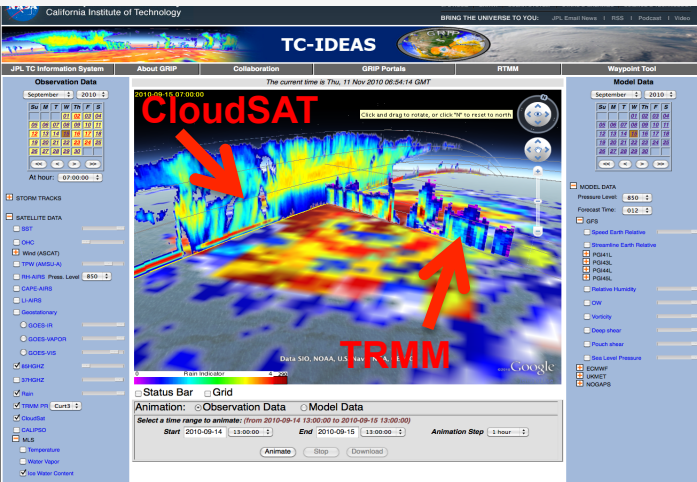
# **The JPL Tropical Cyclone Information System**

**HFIP – August 27<sup>th</sup>, 2014**

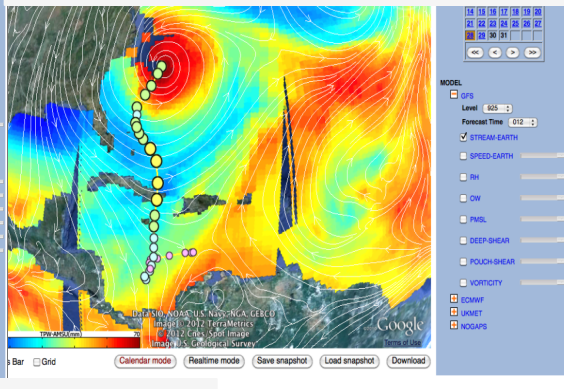


# Motivation for our project - The critical pathways to hurricane forecast improvement

• Is the representation of the precipitation structure correct?



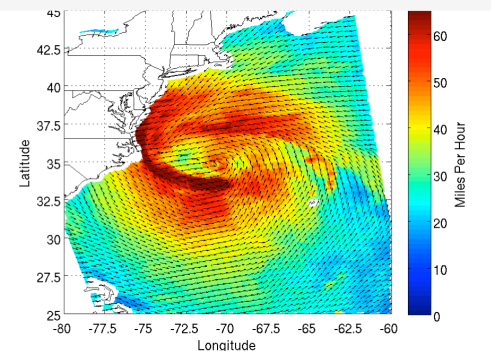
• Is the environment captured correctly?  
• Is the interaction between the storm and its environment realistic?



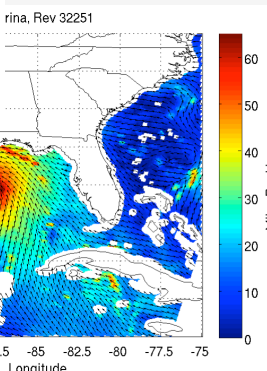
To improve Hurricane Intensity forecasts, we need to understand how well the models reflect the physical processes and their interactions.

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

• Is the storm scale and asymmetry reflected properly?



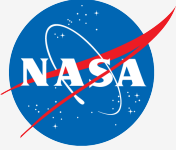
Hurricane Sandy  
As seen by the  
ISRO's OSCAT



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>

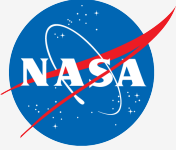
---

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).

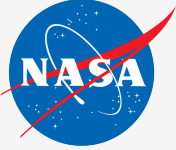
**Tropical Cyclone Data Archive**

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.

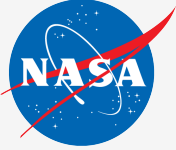
Site Manager: Svetlita M Hristova-Veleva      PRIVACY      Webmaster: Quoc Vu (JPL Clearance: CL#08-346)



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# Part 1: The Interactive NRT Atlantic portal

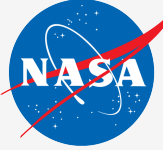
1. Bringing observations and models into a common analysis system and developing interactive visualization tools
2. Analysis tools



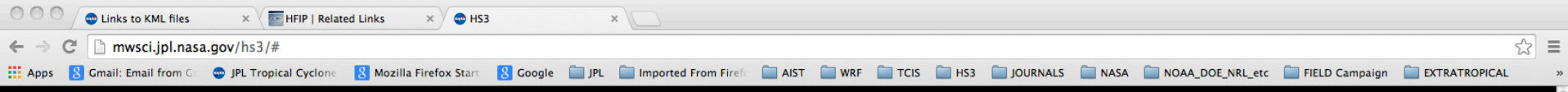
# 1. Bringing observations and models into a common analysis system and developing interactive visualization tools

---

- **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]

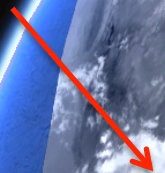
Tropical Cyclone Information System > HS3 Portal

2014-08-25 02:00:00

SATELLITE & AIRCRAFT DATA

MODEL & SIMULATION DATA

**GOES IR**



**"Best Track"**

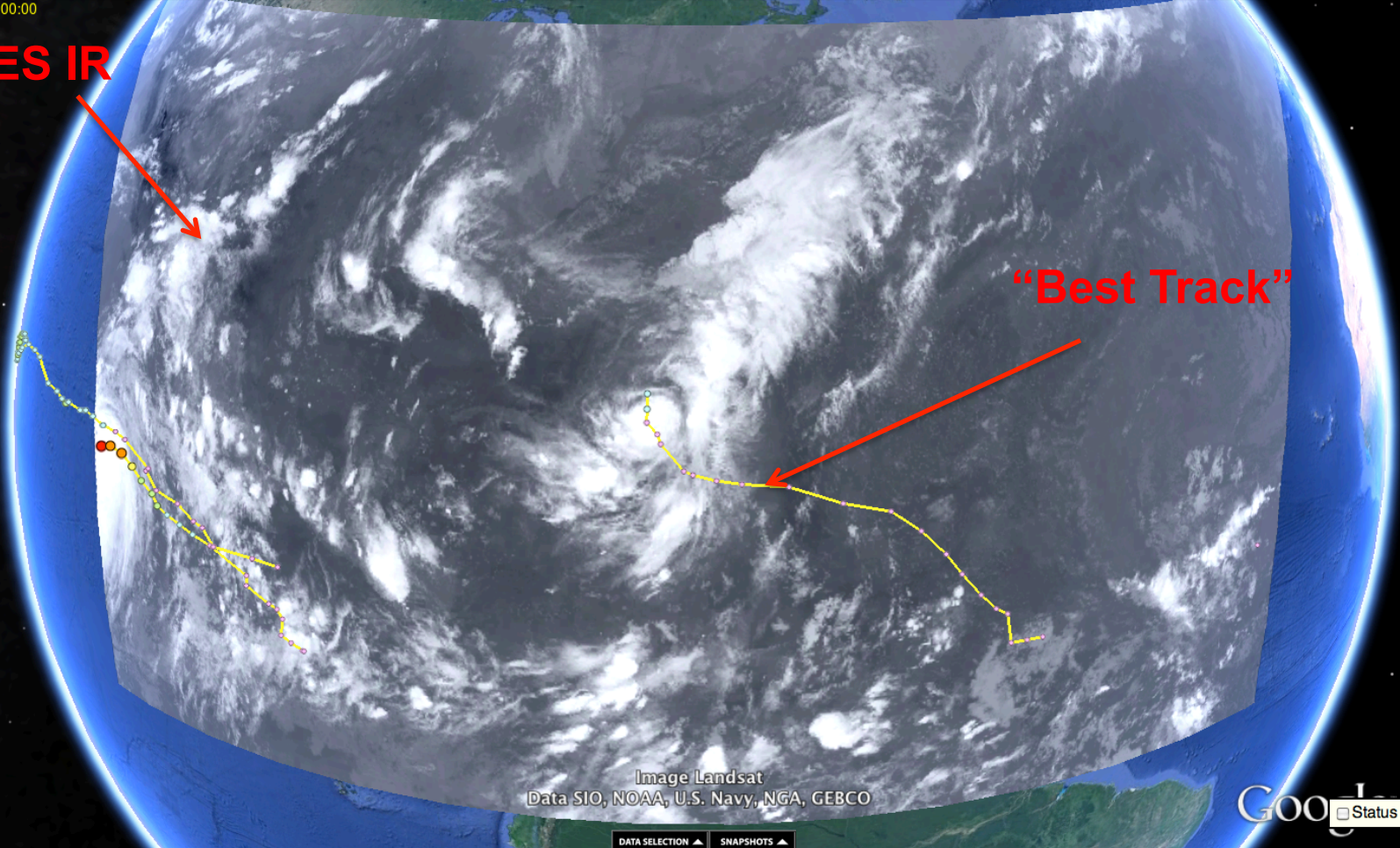
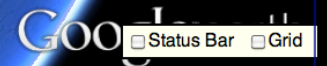
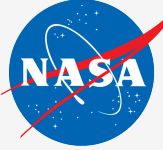


Image Landsat  
Data SIO, NOAA, U.S. Navy, NGA, GEBCO



DATA SELECTION | SNAPSHOTS

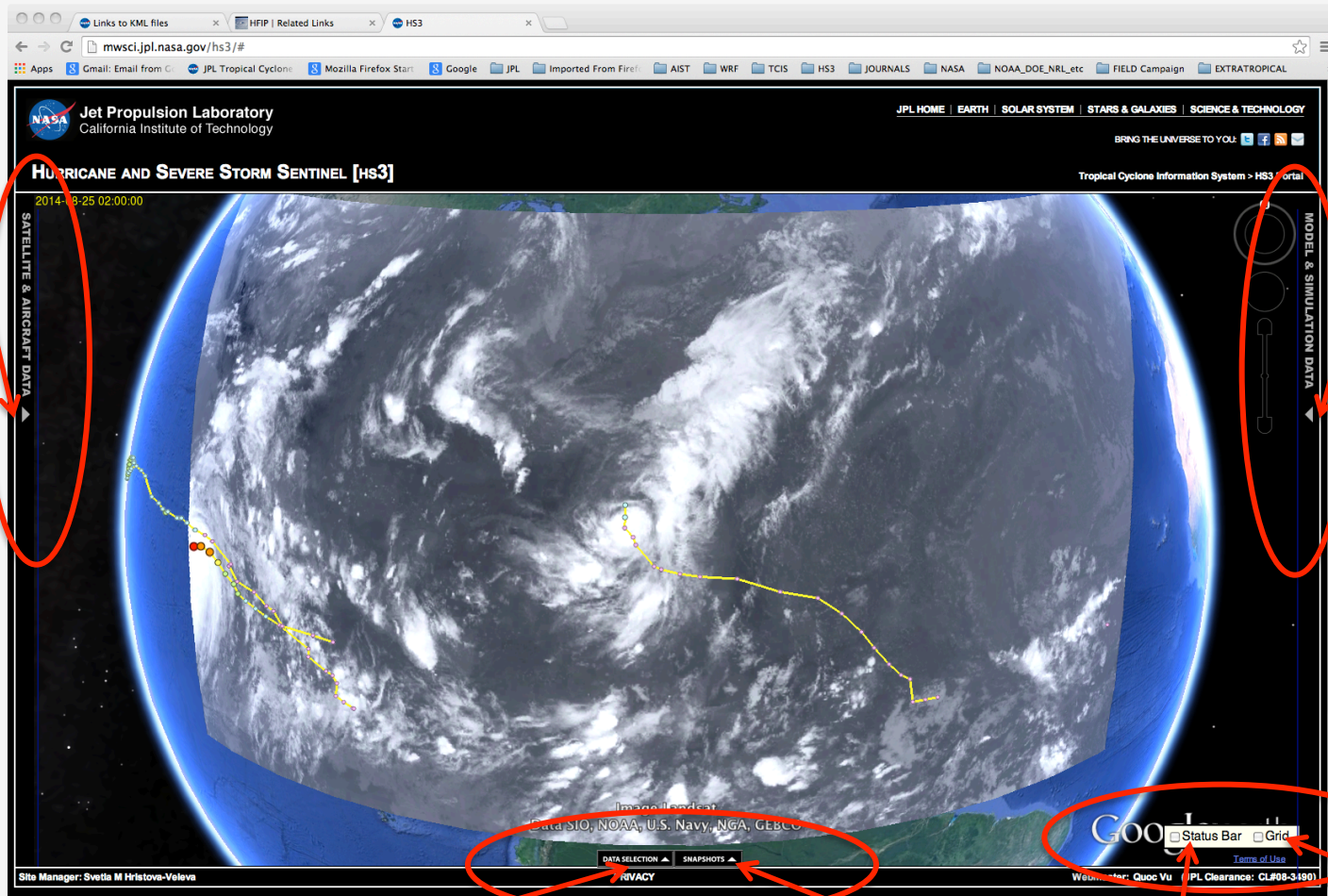


## Features

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

The screenshot displays the Hurricane and Severe Storm Sentinel (HS3) portal interface. At the top, the NASA Jet Propulsion Laboratory logo and navigation links are visible. The main content area features a satellite image of a hurricane with several tracks overlaid: a red 'BEST TRACK' and several multi-colored 'POUCH TRACKS'. A red circle highlights the 'GOES IR' satellite data source. A tooltip for the P17L track provides details: Name: P17L, Model: GFS, Time: 2014-08-21 00:00:00, Location: 13.49N, -53.43W. The interface includes several panels: 'STORM TRACK' with checkboxes for BEST TRACK and POUCH TRACK (P17L, P21L, P22L, P23L); 'SATELLITE DATA' with a 'Transparency Sliders' section for IR, IR 2 Day Animation, IRCOLOR, VAPOR, VIS, Microwave Rain Signature, TPW, TRMM, WIND, CloudSat, and SST; and 'MODEL & SIMULATION DATA' with a calendar and a list of model parameters (ECMWF, SPEED-COMOVING, STREAM-COMOVING, DEEP-SHEAR, OW, PMSL, POUCH-SHEAR, RH, SPEED-EARTH, STREAM-EARTH, TEMP, TPW, VORTICITY, GFS, NAVGEM, UKMET) and simulation options (Status Bar, Grid). The bottom of the page contains site manager, privacy, and webmaster information.

**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

The screenshot displays the Hurricane and Severe Storm Sentinel (HS3) portal interface. At the top, the NASA Jet Propulsion Laboratory logo and navigation links are visible. The main content area features a satellite image of a hurricane system over the ocean. Overlaid on the image are several tracks: a thick red line representing the "Best Track" and multiple thinner, multi-colored lines representing "Pouch Tracks" for various aircraft (P17L, P21L, P22L, P23L). A large red circle highlights a specific area of the storm. On the right side of the image, the text "GOES VIS" is written in large red letters. A tooltip box provides details for the P17L aircraft: Name: P17L, Model: GFS, Time: 2014-08-21 00:00:00, Location: 13.49N, -53.43W. The interface includes a left sidebar with controls for "Hurricanes" (Invest: 08/24-08/25, TD), a calendar for August 2014, and a "STORM TRACK" section with checkboxes for "BEST TRACK" and "POUCH TRACK". Below that is a "SATELLITE DATA" section with checkboxes for various satellite instruments like AIRS, AOT (MODIS), Geostationary (IR, IR 2 Day Animation, IRCOLOR, VAPOR, VIS), Microwave Rain Signature, TPW, TRMM, WIND, CloudSat, and SST. The bottom of the interface shows a "Google Earth" logo, a "Status Bar", and a "Grid" option. Footer information includes "Site Manager: Svetla M Hristova-Veleva", "PRIVACY", and "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

Apps | Gmail: Email from C | JPL Tropical Cyclone | Mozilla Firefox Start | Google | JPL | Imported From Firef | AIST | WRF | TCIS | HS3 | JOURNALS | NASA | NOAA\_DOE\_NRL\_etc | FIELD Campaign | EXTRATROPICAL | CLIMATE

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### HURRICANE AND SEVERE STORM SENTINEL [HS3]

Tropical Cyclone Information System > HS3 Portal

Model: 2014-08-21 00:00 012

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

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

**MODEL & SIMULATION DATA**

MODELS

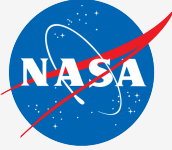
- ECMWF
  - Press: 850
  - Forecast Time: 012
  - SPEED-COMOVING
  - STREAM-COMOVING
  - P17L
  - P21L
  - P22L
  - P23L
  - DEEP-SHEAR
  - OW
  - PMSL
  - POUCH-SHEAR
  - RH
  - SPEED-EARTH
  - STREAM-EARTH
  - TEMP
  - TPW
  - VORTICITY
- GFS
- NAVGEM
- UKMET

Name: P17L  
Model: ECMWF  
Time: 2014-08-22 00:00:00  
Location: 15.75N,-62.33W

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)



# 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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BRING THE UNIVERSE TO YOU:

## HURRICANE AND SEVERE STORM SENTINEL

2012-10-29 05:00:00

**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

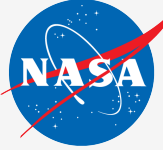
Name: Sandy-18L  
 Time: 2012-10-24  
 06:00:00  
 Location: 15.7N,-77.1W  
 Wind Speed:55 knots  
 Central Pressure:988 mb

Early Forecast  
 Late Forecast  
 Ensemble Forecast

Site Manager: Svetia M Hristova-Veleva

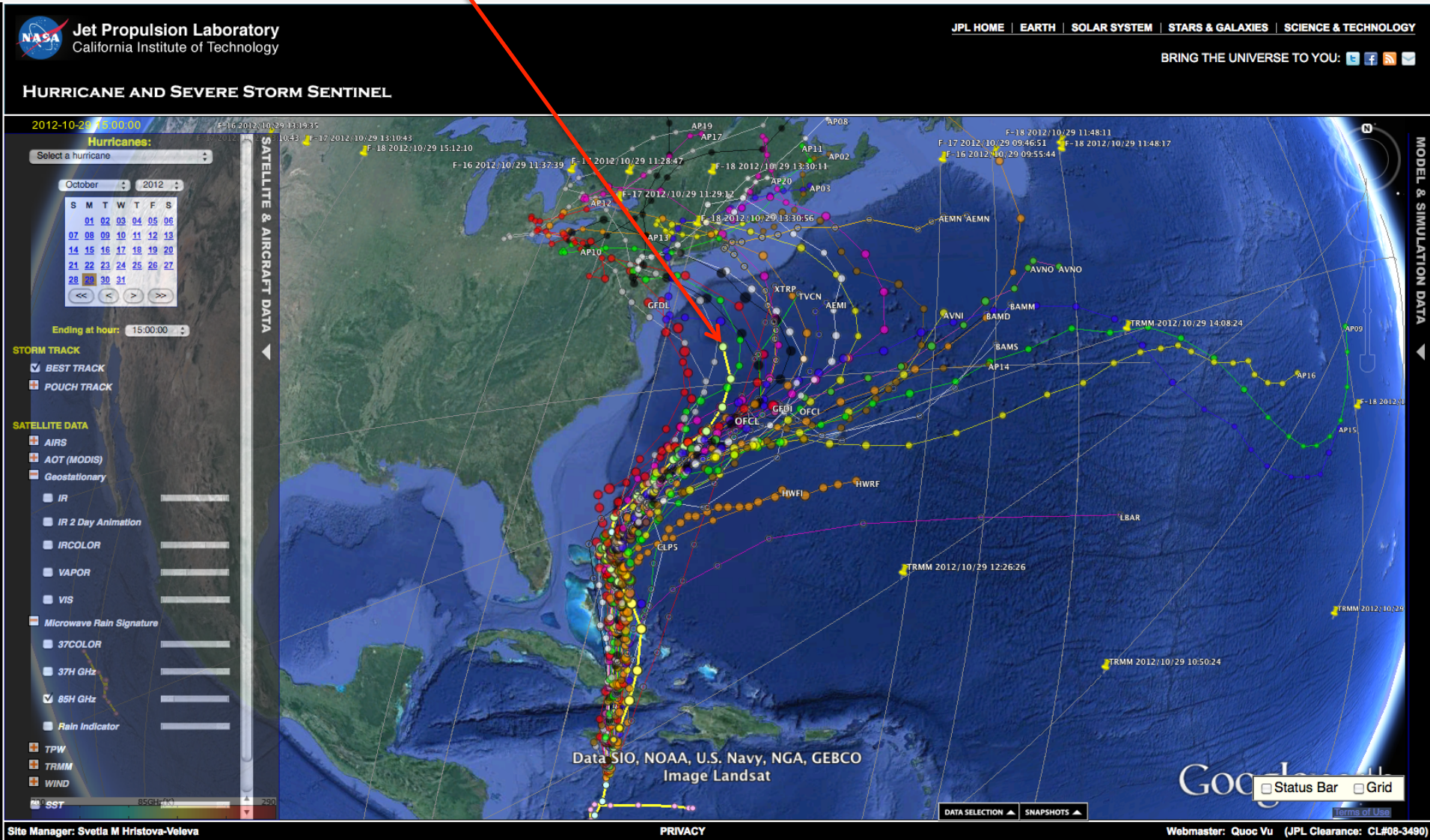
PRIVACY

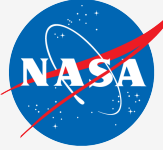
Webmaster: Quoc Vu (JPL Clearance: CL#08-3490)



# 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 7:00:00

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

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

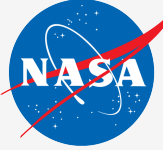
GOOGLE Earth

Status Bar Grid

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 11:29:00

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

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

DATA SELECTION | SNAPSHOTS

Status Bar | Grid

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 screenshot displays the Hurricane and Severe Storm Sentinel interface. At the top left is the NASA Jet Propulsion Laboratory logo. The main header reads "HURRICANE AND SEVERE STORM SENTINEL". The central map shows a hurricane system over the Atlantic Ocean, with a color-coded precipitation field and white streamlines representing mid-level flow. A red arrow points from the text "Is the dry air in the environment (low TPW, from satellite observations) entering the storm ???" to the "TPW" (Total Precipitable Water) data selection menu on the left. A green arrow points from the text "It does not appear so looking at the midlevel flow from the model." to the "STREAM-EARTH" option in the "MODEL & SIMULATION DATA" menu on the right. The interface includes a date selector for October 2012, a calendar, and various data selection options for satellite and model data. The bottom of the page contains site management information, a privacy policy link, and a webmaster contact.

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HURRICANE AND SEVERE STORM SENTINEL

2012-10-25 18:00:00

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: 18:00:00

STORM TRACK  
 BEST TRACK  
 POUCH TRACK

SATELLITE DATA  
 AIRS  
 Geostationary  
 Microwave Rain Signature  
 37COLOR  
 37H GHz  
 85H GHz  
 Rain Indicator  
 TPW  
 6 HR Composite  
 Two Day Animation  
 T-Rain  
 WIND  
 ASCAT SPEED  
 ASCAT VECTOR  
 SST

MODEL & SIMULATION DATA  
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

MODEL  
 SWIRP  
Press: 600  
Forecast Time: 01Z  
 DATA SUMM  
 OW  
 PMSL  
 POUCH-SHEAR  
 RH  
 STREAM-EARTH  
 WORTON  
 GFS  
 NOGAPS  
 UKMET

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)

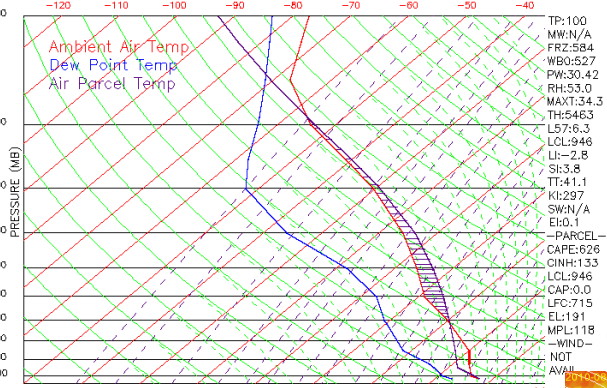




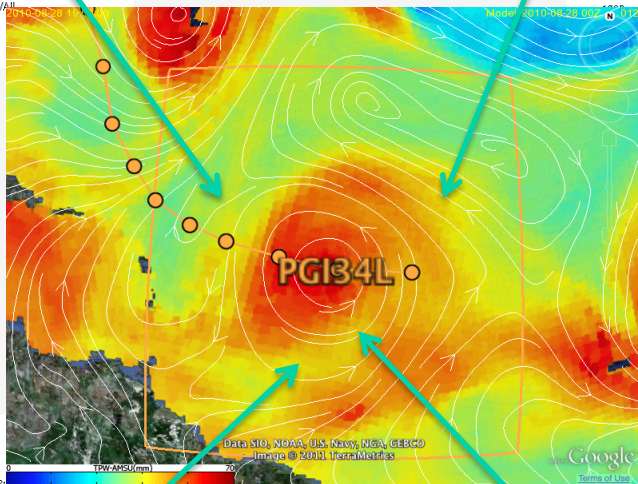
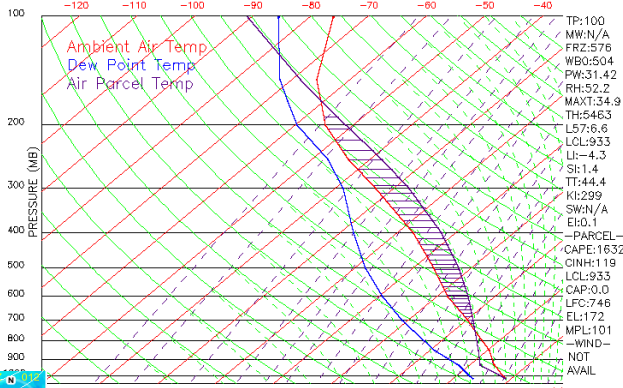
# The thermodynamics from AIRS

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

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

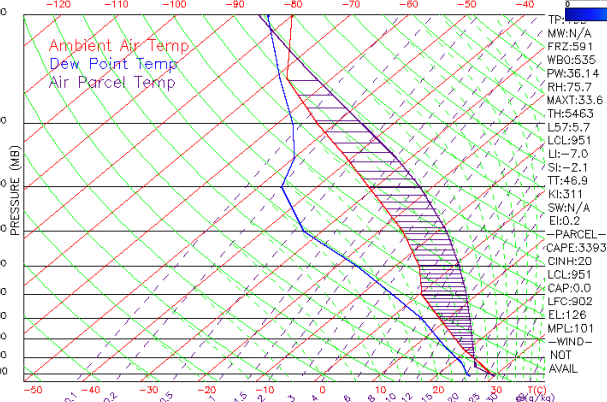


AIRS SkewT Diagram 2010-08-28/16:42:38.87 (Lat/Lon 19.81/-45.90 deg)

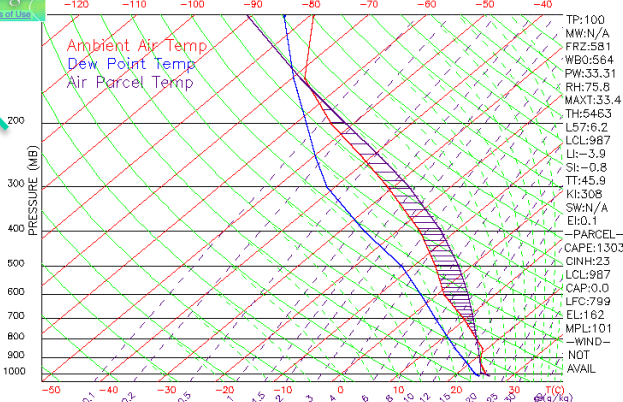


1. TPW from AMSU
2. Soundings from AIRS
3. Pouch-relative flow from ECMWF

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



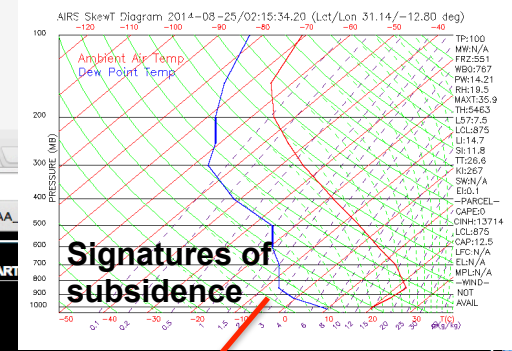
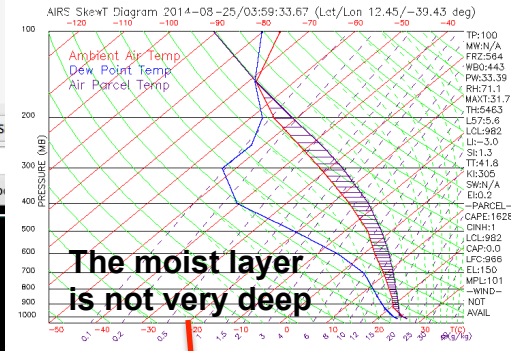
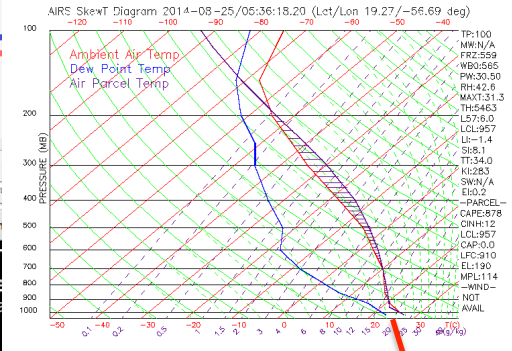
AIRS SkewT Diagram 2010-08-28/16:40:35.67 (Lat/Lon 11.84/-49.18 deg)





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

## The thermodynamics from AIRS



The moist layer is not very deep

Signatures of subsidence

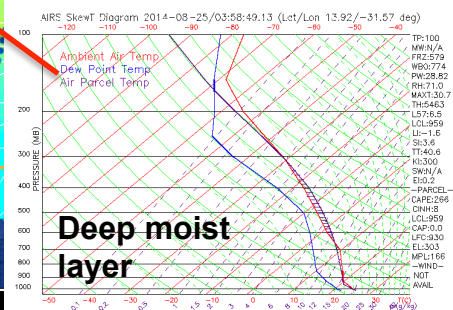
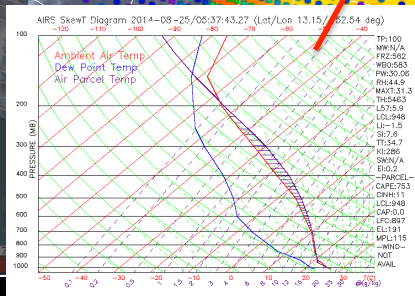
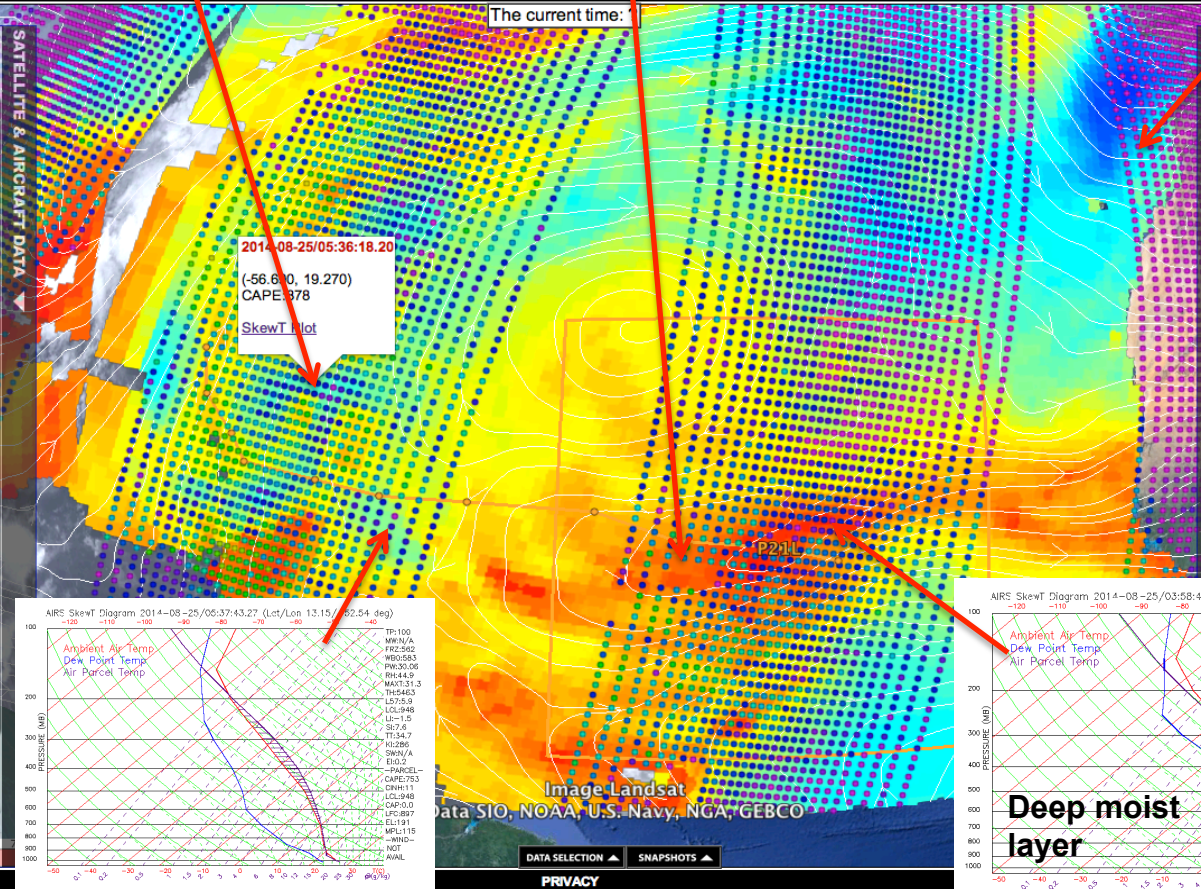
### HURRICANE AND SEVERE STORM SENTINEL [HS-3]

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: 4500
  - TRMM



Deep moist layer

Tropical Cyclone Information System - HS3 Portal

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 & SIMULATION DATA

MODEL: ECMWF

Press: 850

Forecast Time: 01Z

- SPEED-COMOVING
- STREAM-COMOVING
- P21L
- P22L
- P23L
- DEEP-SHEAR
- OW
- PMSL
- POUCH-SHEAR

Bar Grid

Site Manager: Svetla M Hristova-Velva

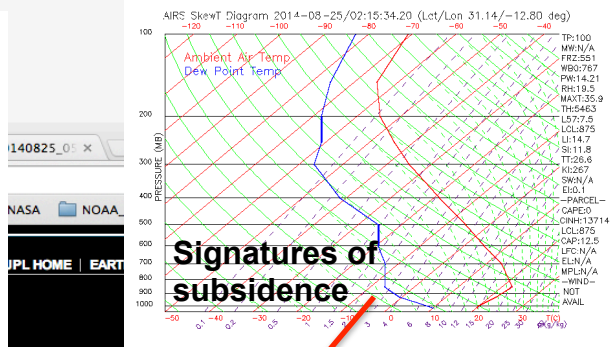
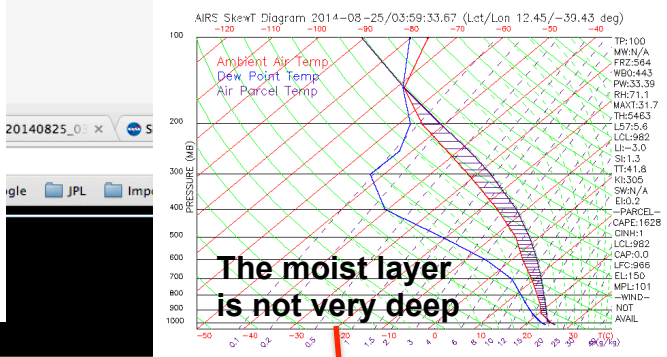
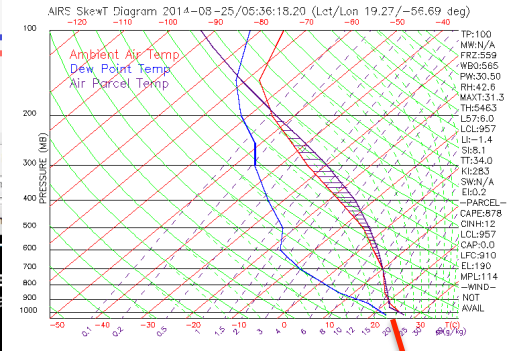
PRIVACY

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



### 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
- TEMP 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
- CAPE 4500
- WIND

MODEL & SIMULATION DATA

Model: 2014-08-25 00Z 012

August 2014

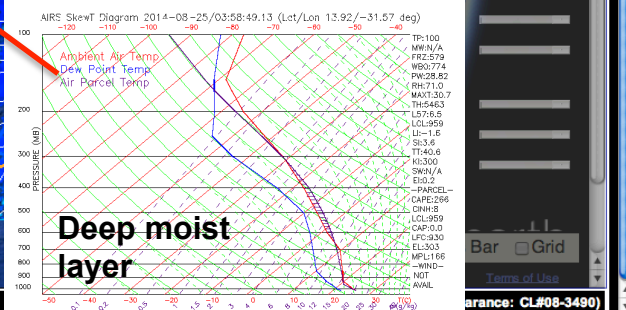
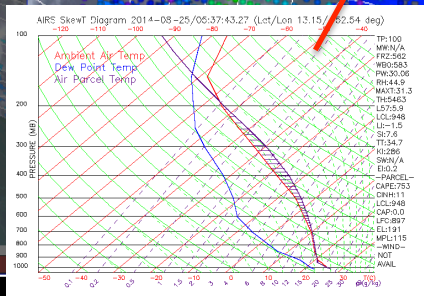
MODEL

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

Image Landsat

DATA SIO, NOAA, U.S. Navy, NGA, GEBCO

Deep moist layer





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

Browser address bar: 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

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**

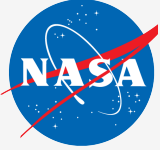
- ECMWF
  - Press: 925
  - Forecast Time: 012
  - SPEED-COMOVING
  - STREAM-COMOVING
    - P13L
  - P17L
  - DEEP-SHEAR
  - OW
  - PMSL
  - POUCH TRACK
  - RH
  - SPEED-EARTH
  - STREAM-EARTH
  - TEMP
  - TPW
  - VORTICITY
- GFS
- NAVGEM
- UKMET

**SIMULATION**

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

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

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 RH in the boundary layer

HS3

mwsci.jpl.nasa.gov/hs3/#

Apps | Gmail: Email from G | JPL Tropical Cyclone | Mozilla Firefox Start | Google | JPL | Imported From Firef | AIST | WRF | TCIS | HS3 | JOURNALS | NASA | NOAA\_DOE\_NRL\_etc | FIELD Campaign | EXTRATROPICAL

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## HURRICANE AND SEVERE STORM SENTINEL [hs3]

Tropical Cyclone Information System > HS3 Portal

2014-08-11 12:00:00

Model: 2014-08-11 00Z 012

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
- 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

Terms of Use

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

DATA SELECTION | SNAPSHOTS

Site Manager: Svetla M Hristova-Velova

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 [H33]

Tropical Cyclone Information System > H33 Portal

2014-08-11 12:00:00

Model: 2014-08-11 00Z 012

**SATellite & AIRCRAFT DATA**

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
- VAPOR
- VIS
- Microwave Rain Signature
- TPW
- TRMM
- WIND
- CALIPSO
- CloudSat
- SST

**MODEL & SIMULATION DATA**

August 2014

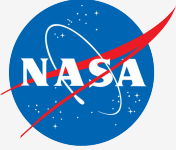
S	M	T	W	T	F	S
					01	02
03	04	05	06	07	08	09
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

**MODEL**

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

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

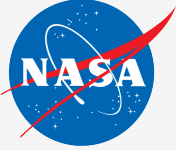
Site Manager: Svetla M Hristova-Veleva  
PRIVACY  
Webmaster: Quoc Vu (JPL Clearance: CL#08-3490)



# 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.

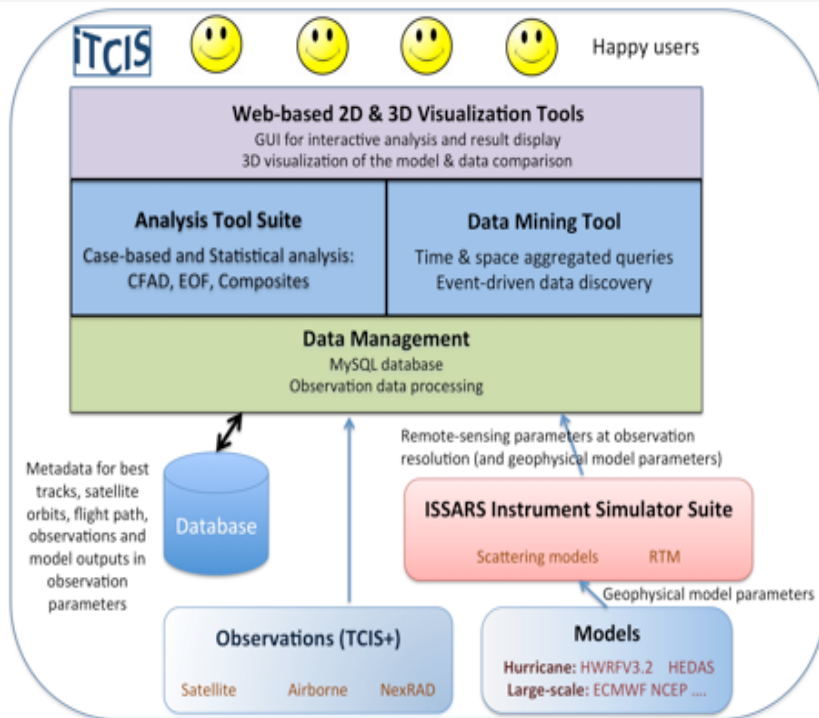
We are developing three critical components to allow the merger of observations with model forecasts:

**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)

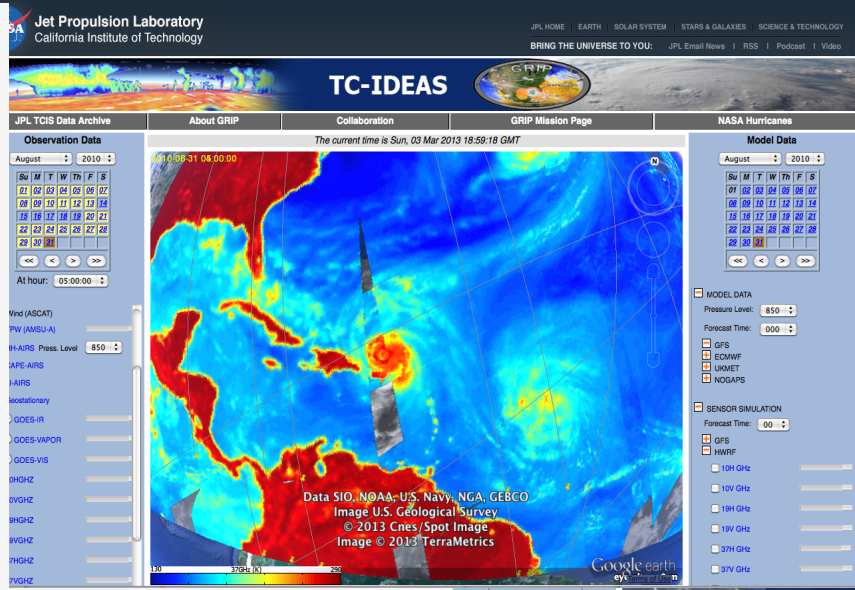




# FUSION OF MODELS AND OBSERVATIONS

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

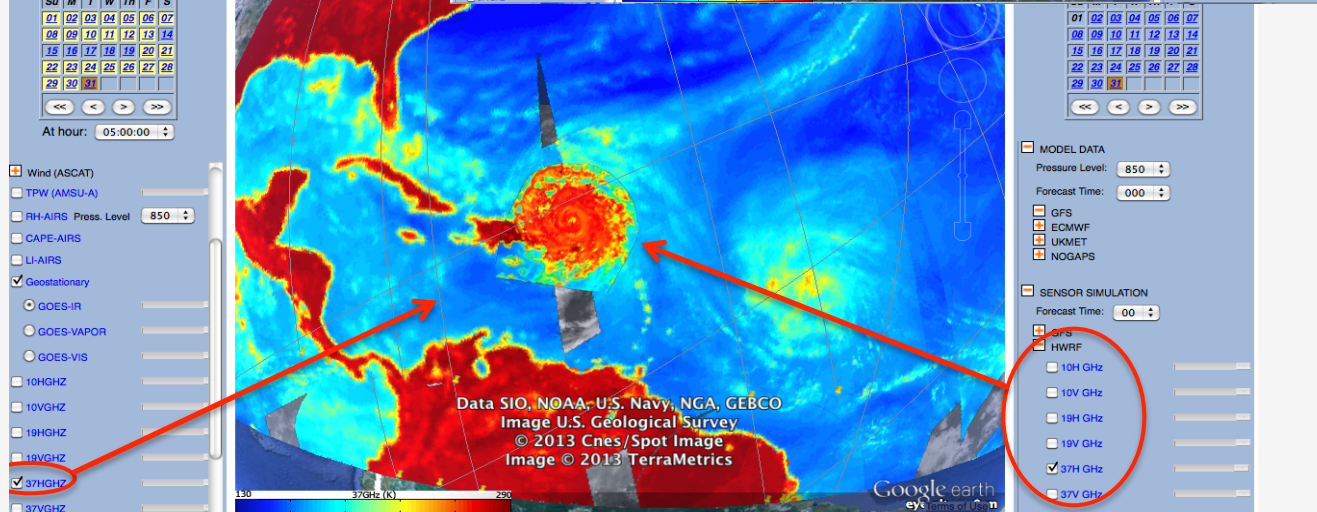
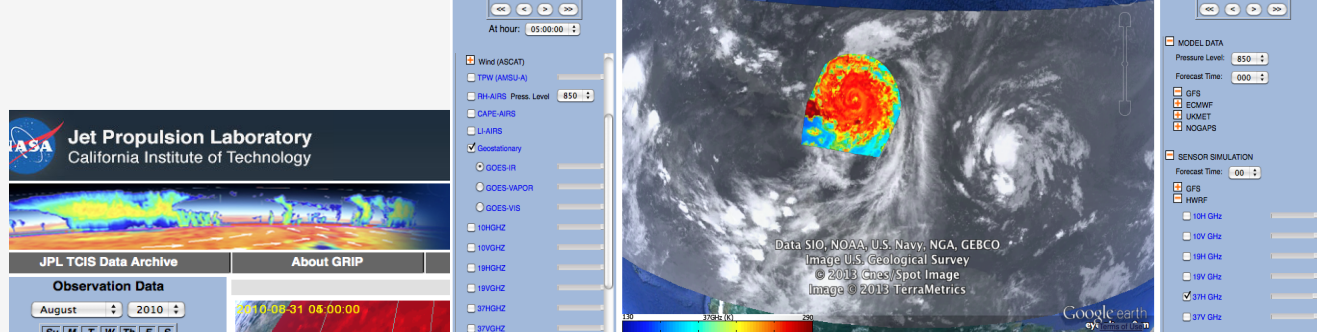
- Research HWRF model forecasts were used as input to NEOS<sup>3</sup>
- Considered are the model microphysical assumptions; the instrument characteristics and sampling
- The synthetic “satellite observations” were:
  - Incorporated in the database of satellite obs.
  - Visualized in the portal
- Limited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



## Satellite Observations



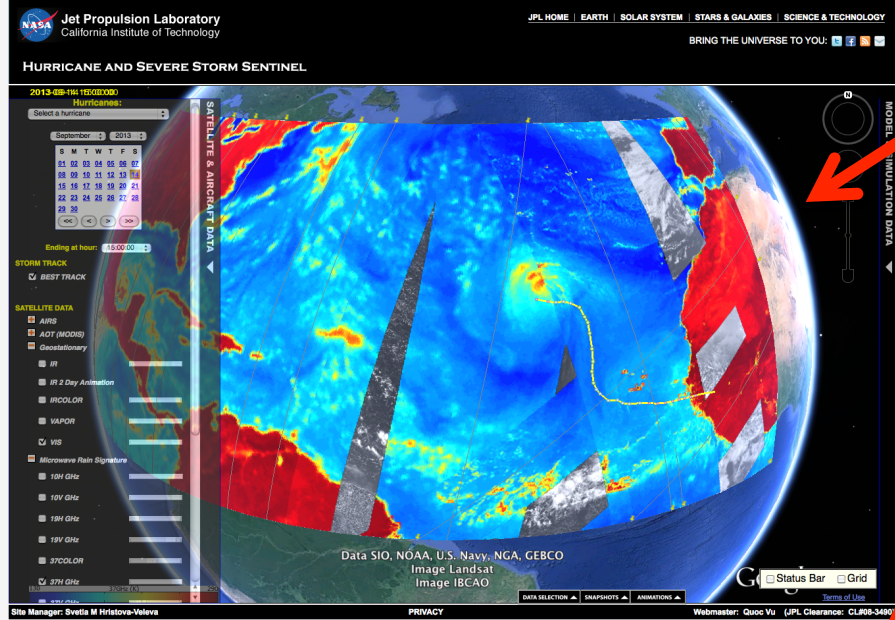
## Synthetic Observations from Model



# FUSION OF MODELS AND OBSERVATIONS

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

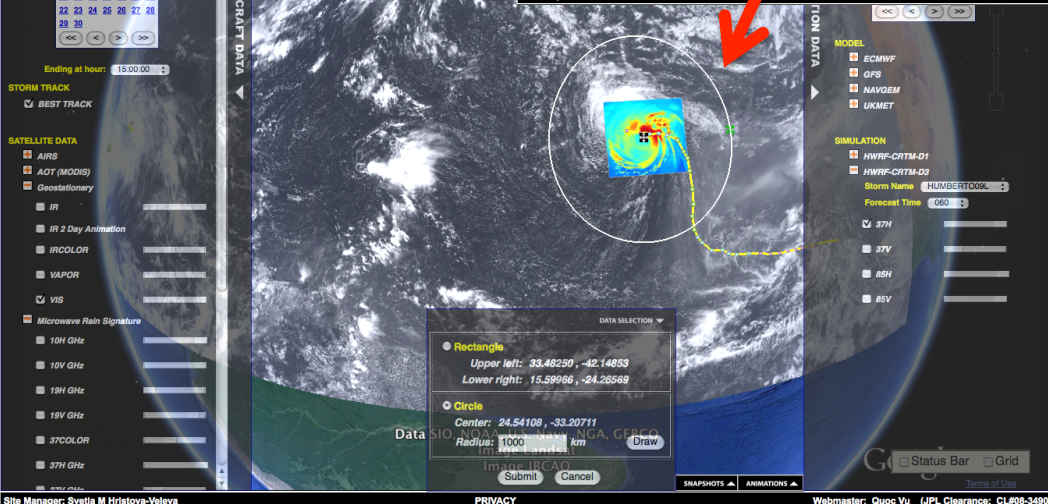
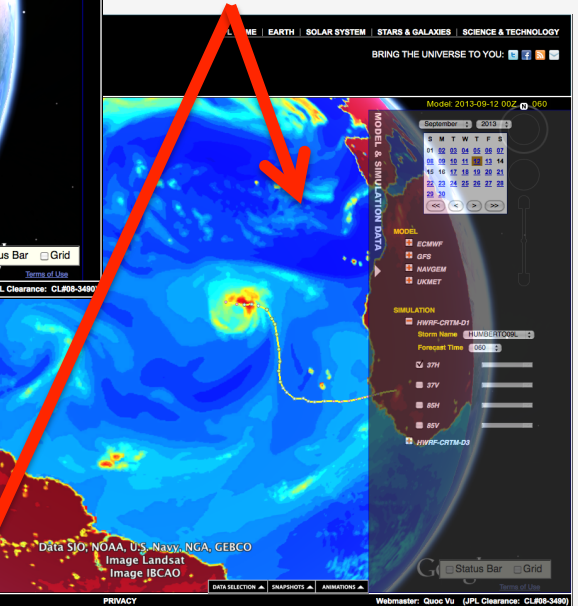
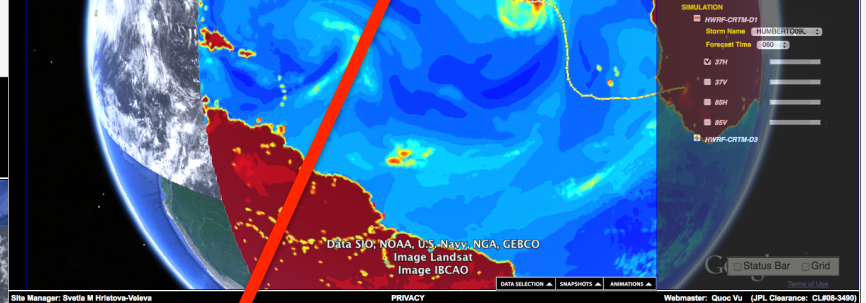
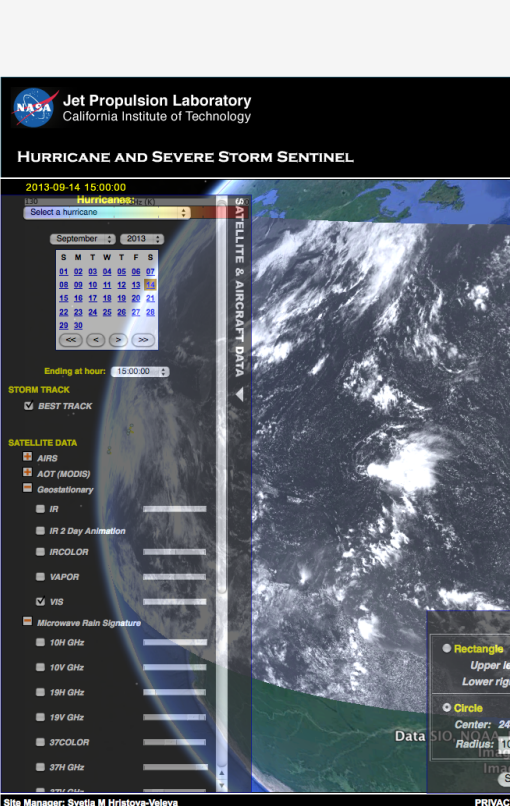
- Operational HWRF model forecasts are used as input to CRTM, provided courtesy of EMC
- Including synthetic satellite observations from the same model (HWRF) but produced by different forward simulators (NEOS<sup>3</sup> and CRTM) will be of high interest in revealing the uncertainty that comes from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

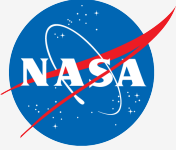


Satellite Observations



Synthetic Observations from Model

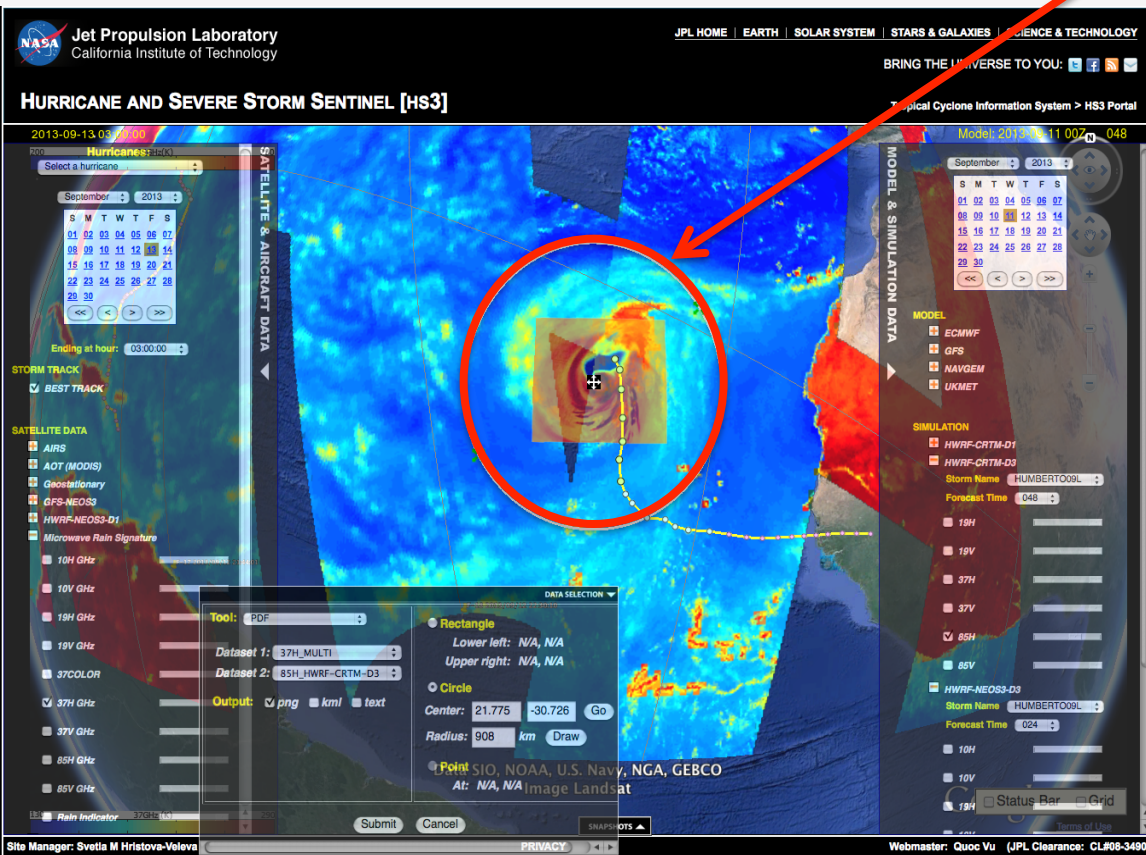


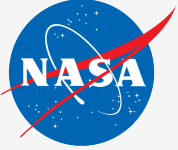


## 2. Analysis Tools

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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California Institute of Technology

**HURRICANE AND SEVERE STORM SENTINEL**

013 009 310 10000

**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

**SATELLITE & AIRCRAFT DATA**

**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 Draw

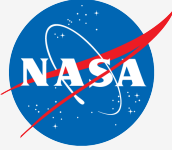
Point  
At: N/A, N/A

Submit Cancel

Site Manager: Svetla M Hristova-Veleva

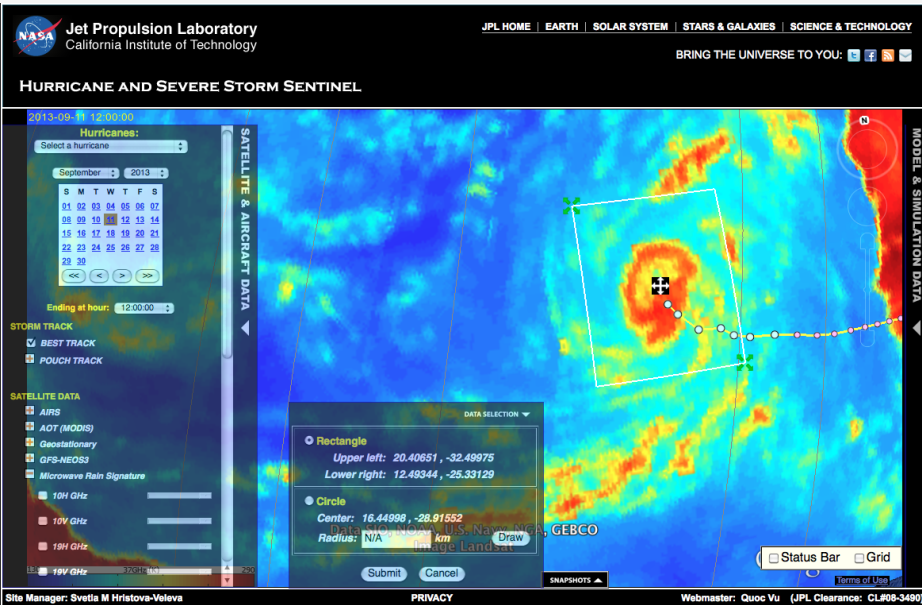
PRIVACY

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

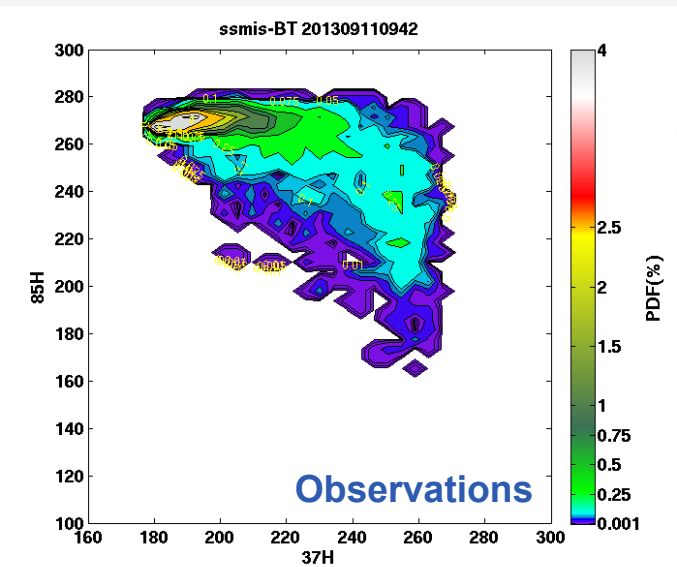


# Statistical Tool: Joint Distribution of Brightness Temperatures

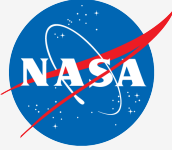
## Example: The Joint PDF of 37GHz and 85GHz TBs; Humberto



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

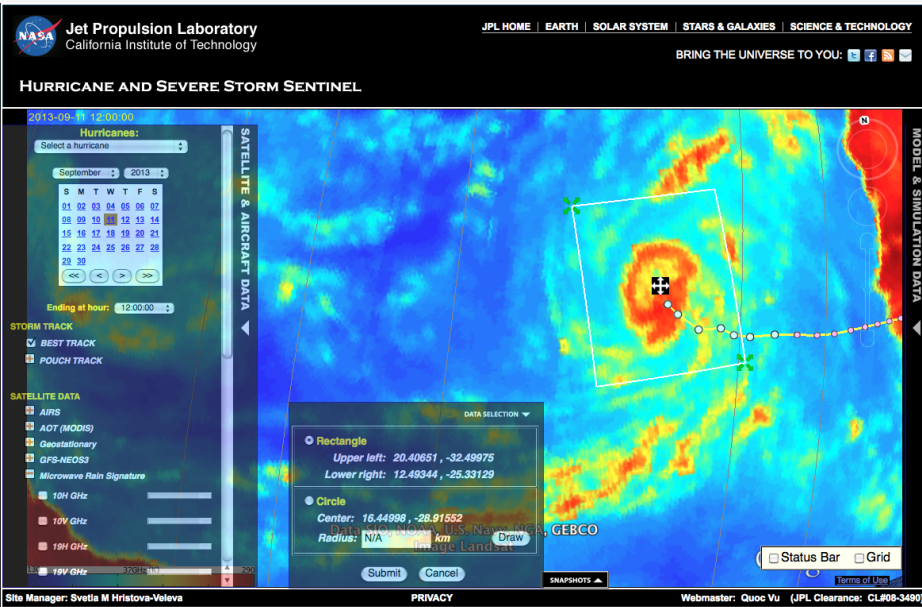


- The Joint PDF illustrates this relationship

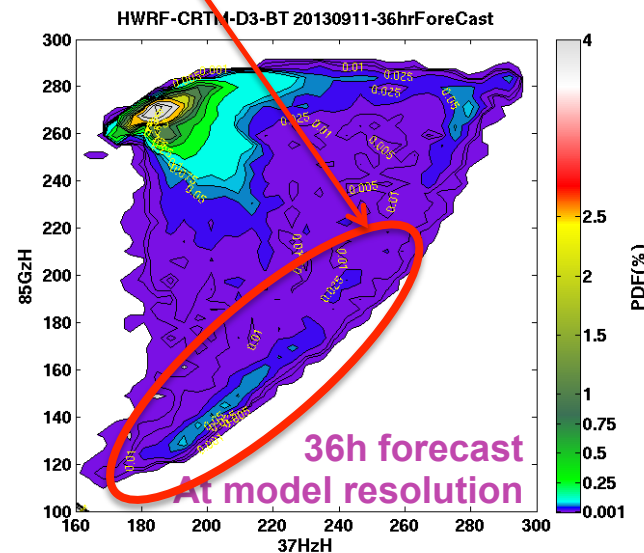
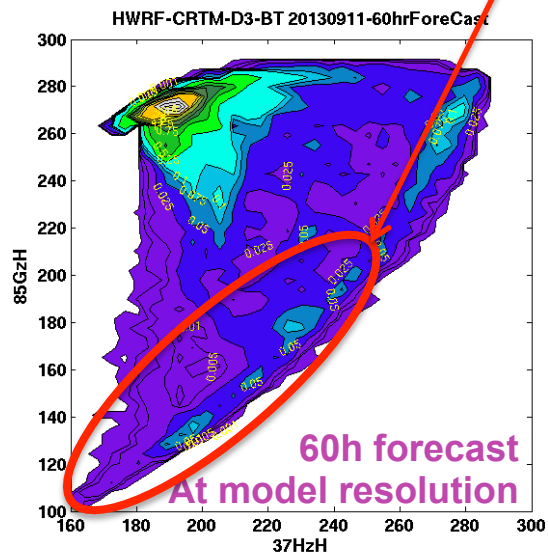
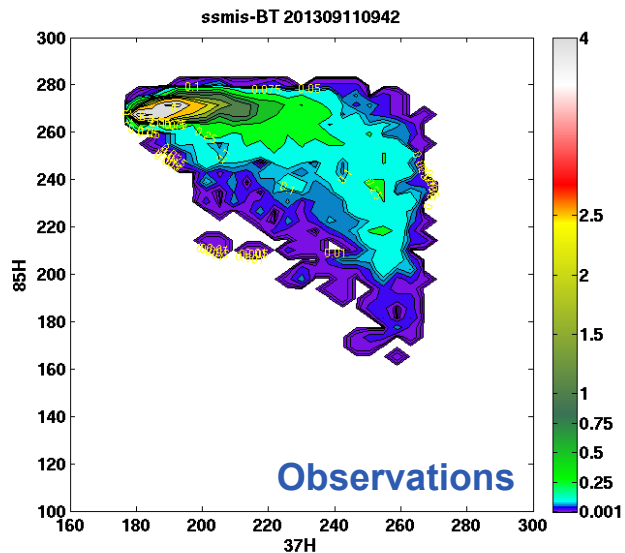


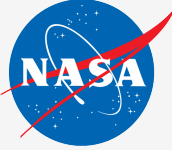
# Statistical Tool: Joint Distribution of Brightness Temperatures

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



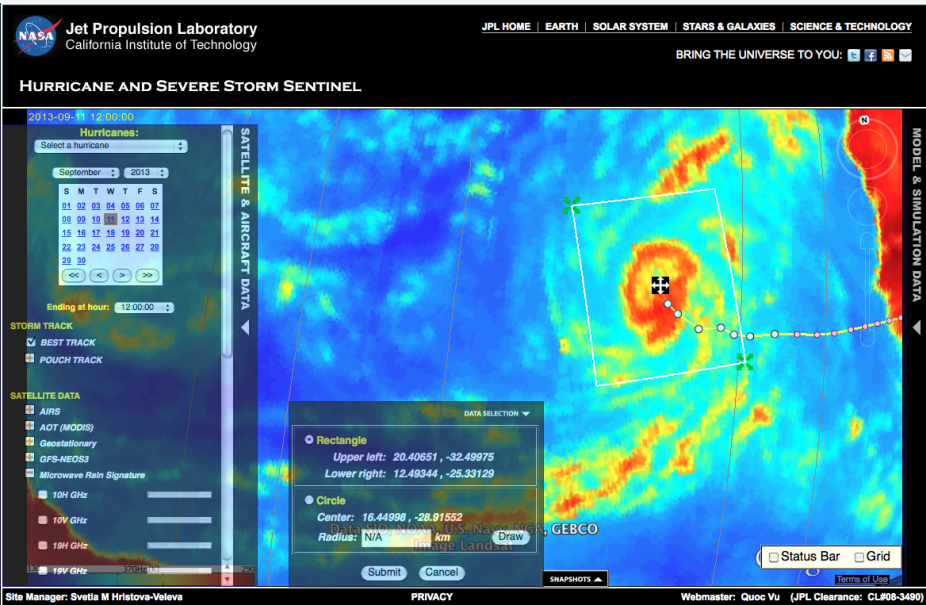
- The statistical relationship between the 37 GHz TBs and the 85 GHz TB presents information on the vertical structure of the storm
- The vertical branch indicates too much scattering of radiation by the frozen precipitation



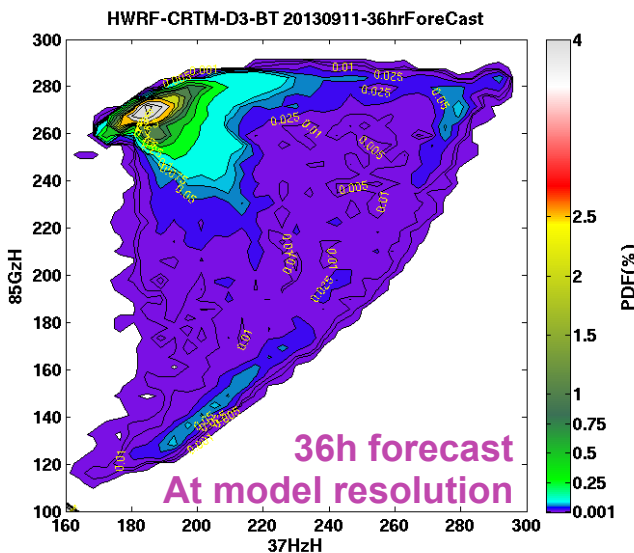
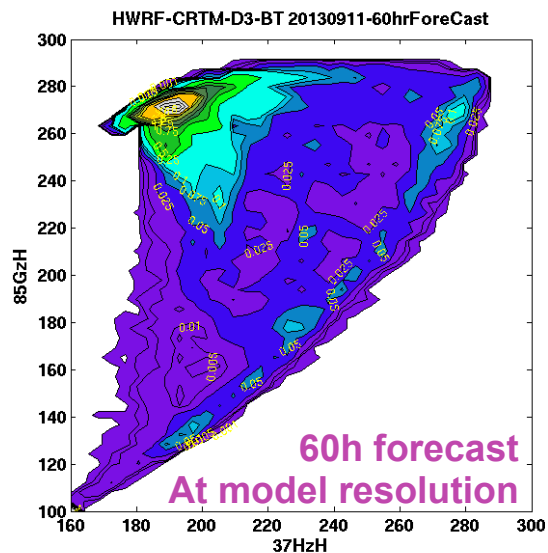
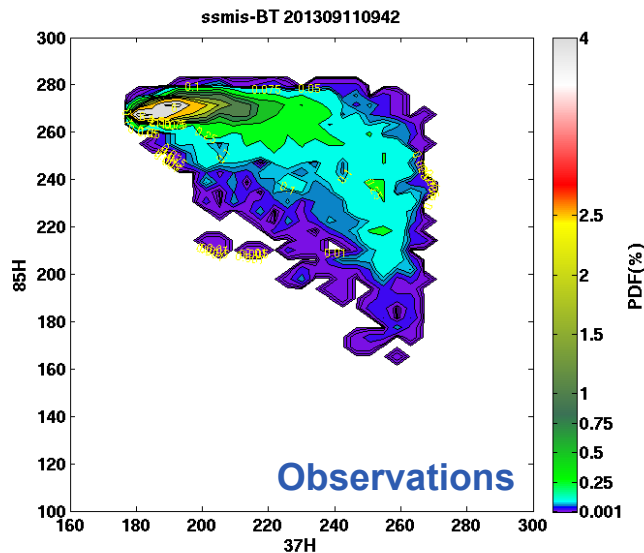


# Statistical Tool: Joint Distribution of Brightness Temperatures

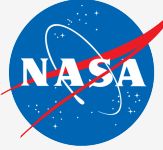
## Example: The Joint PDF of 37GHz and 85GHz TBs; Humberto



- 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!





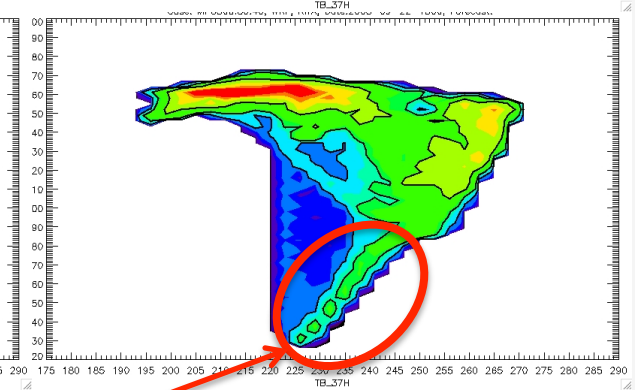
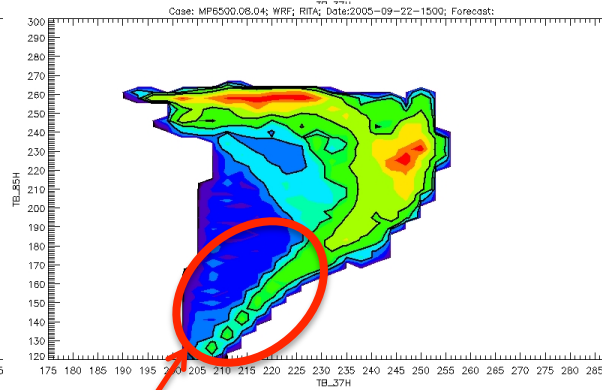
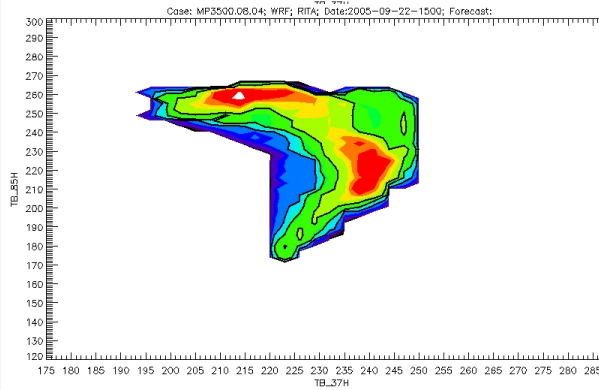
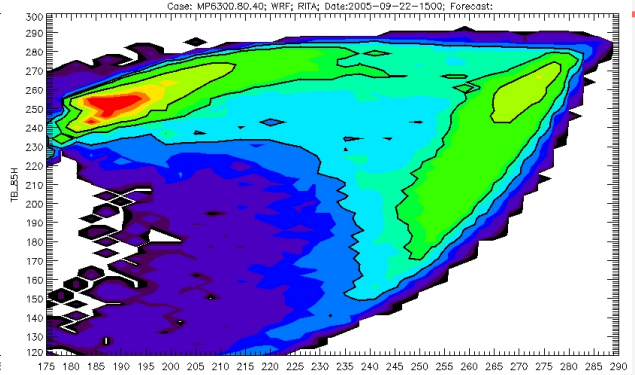
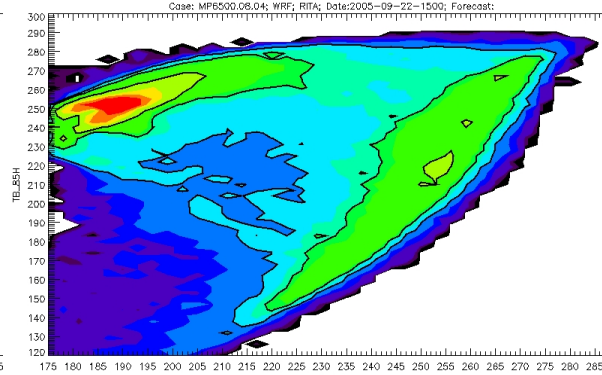
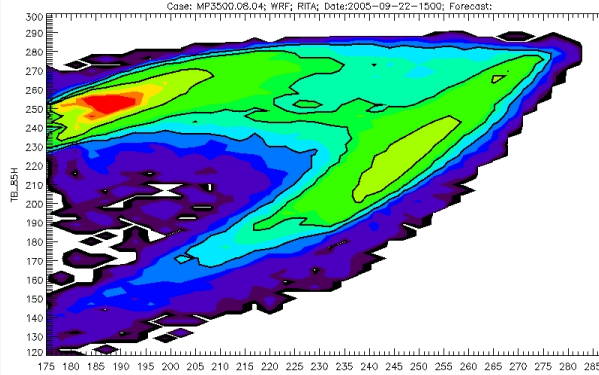


# Joint Distribution (37H vs 85H) – Impact of Resolution

M3-500.08.04

M6-500.08.04

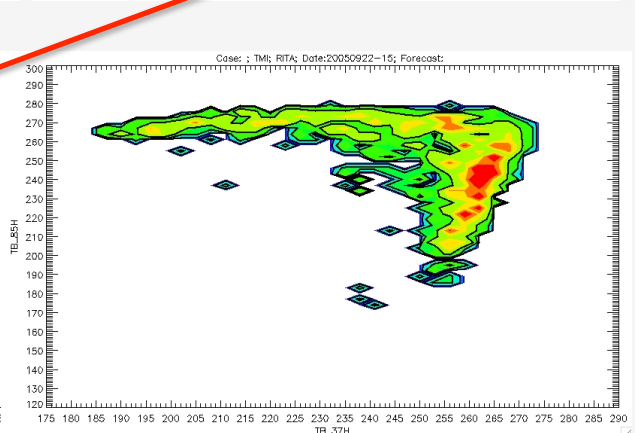
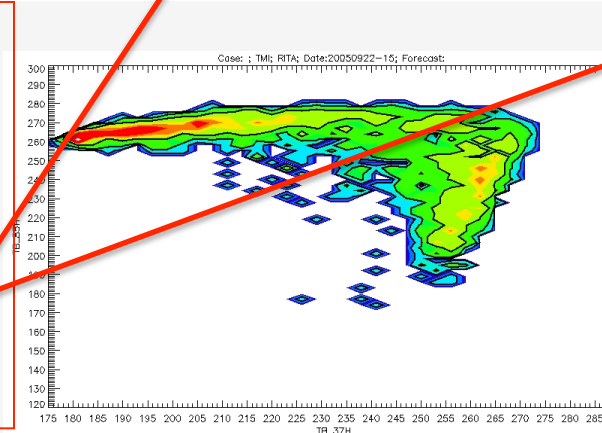
M6-300.80.40



WRF res.

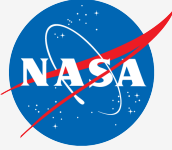
TMI res

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.



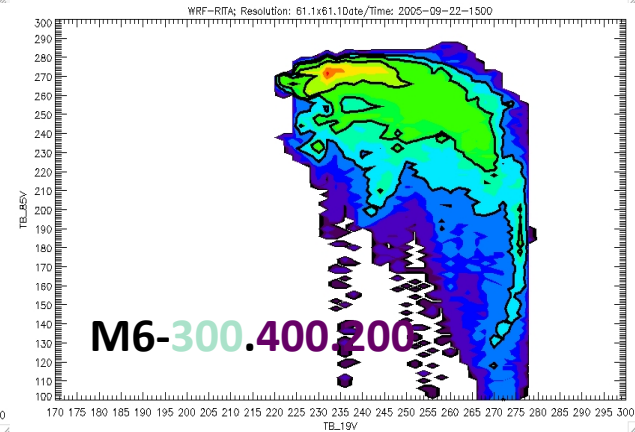
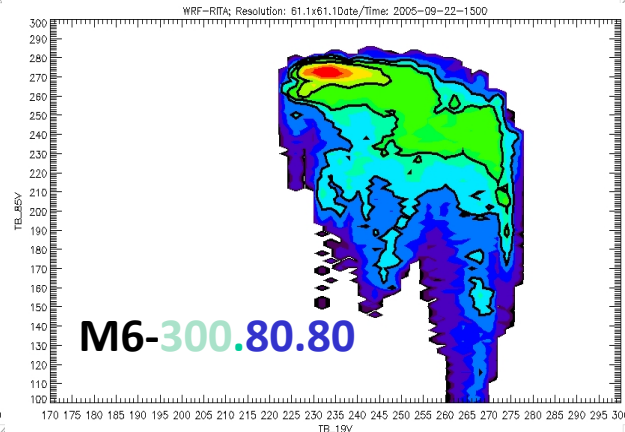
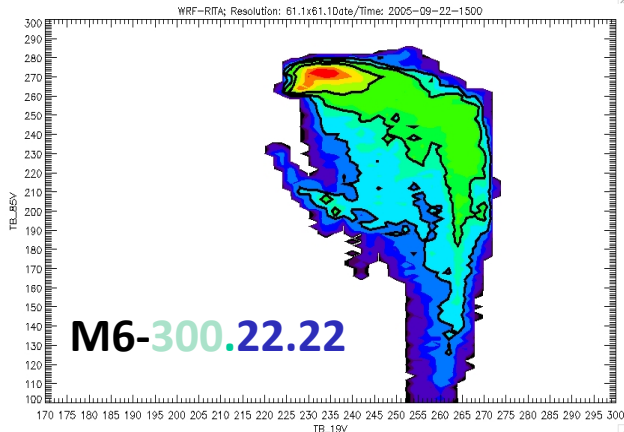
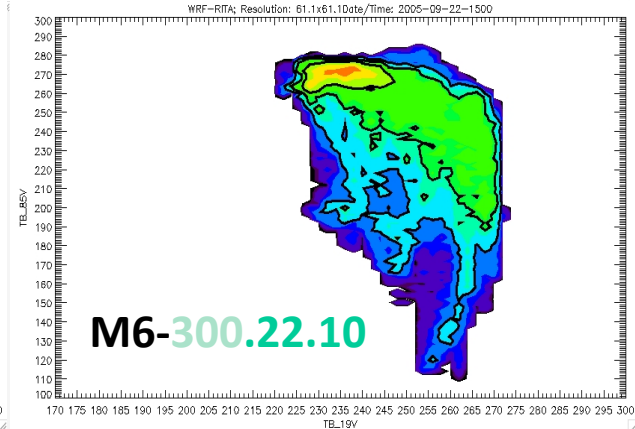
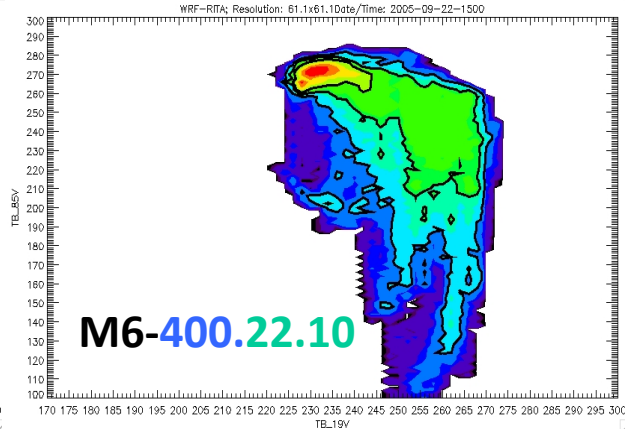
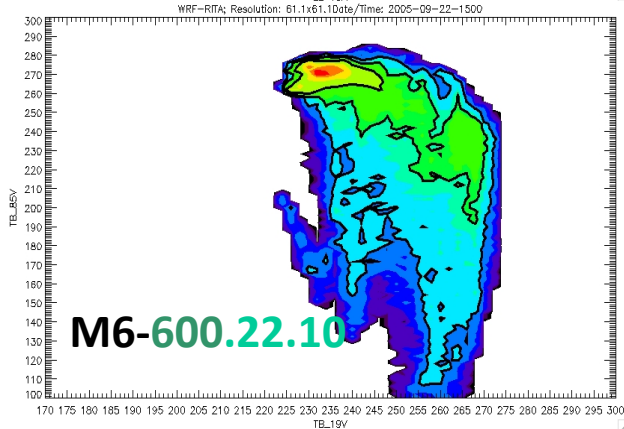
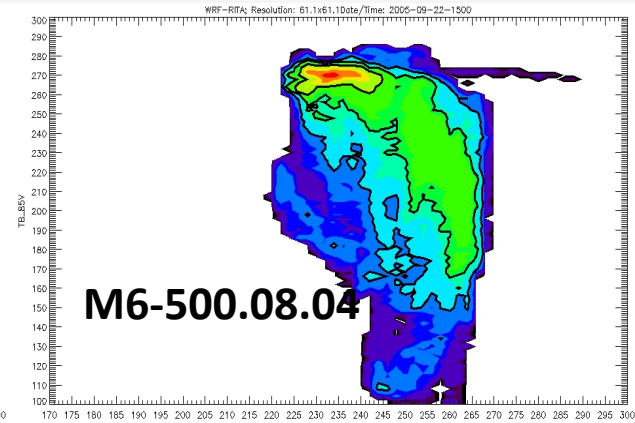
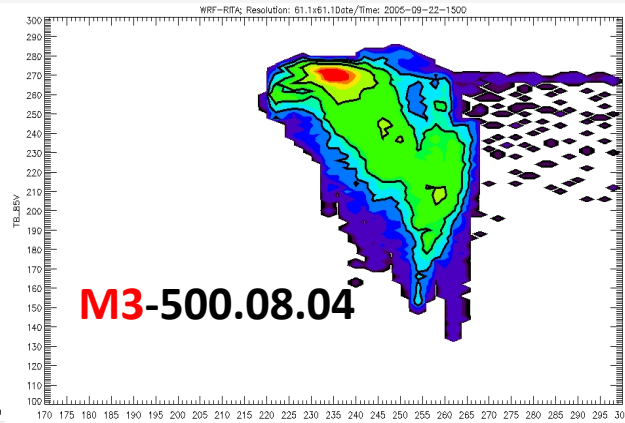
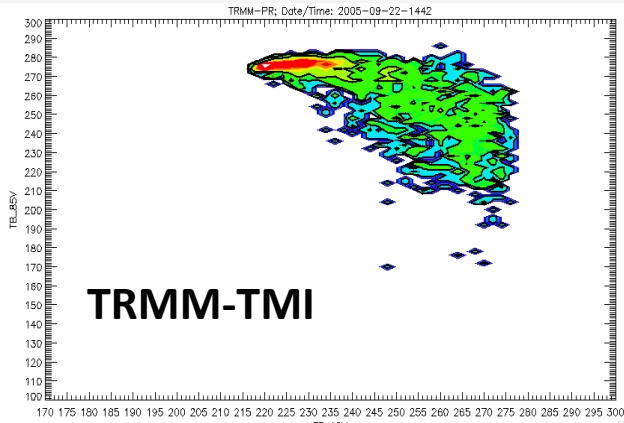
TMI obs.

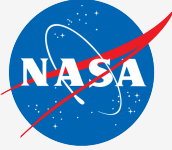




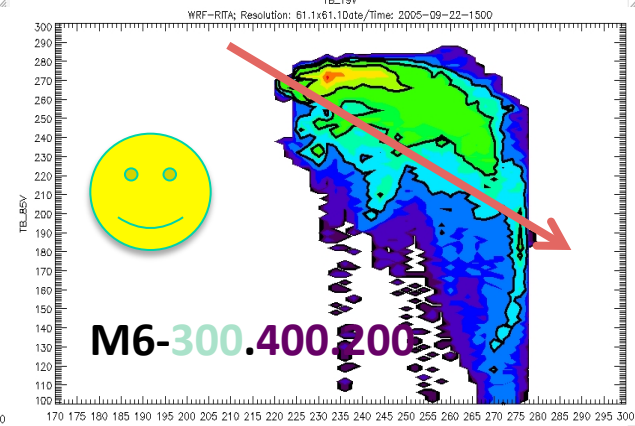
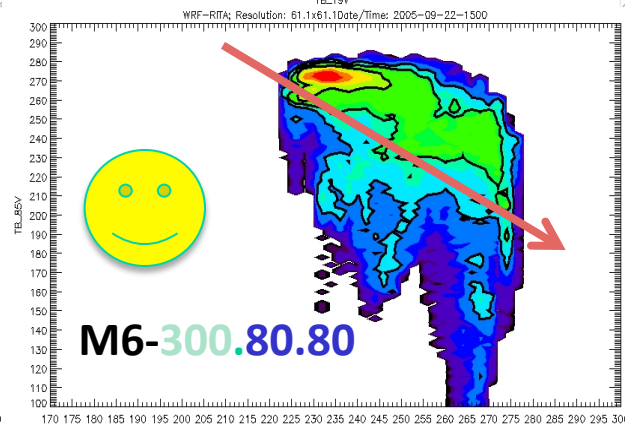
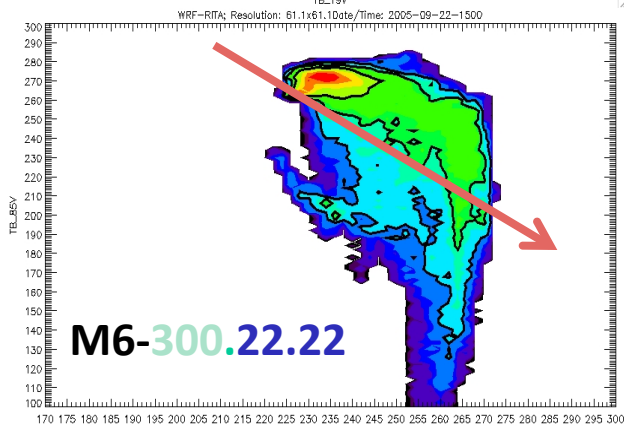
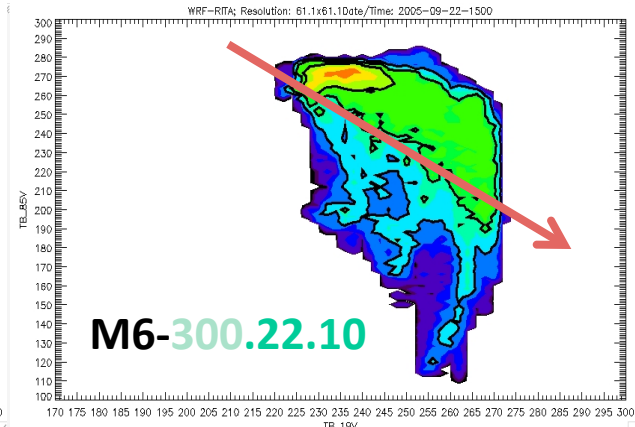
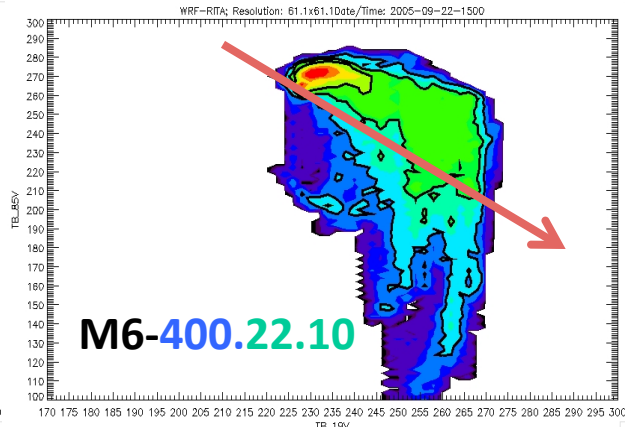
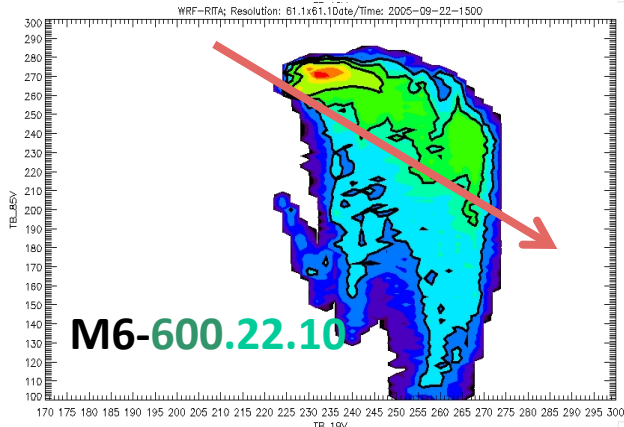
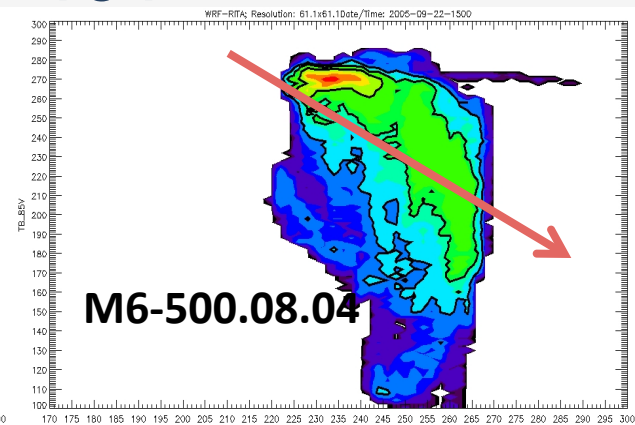
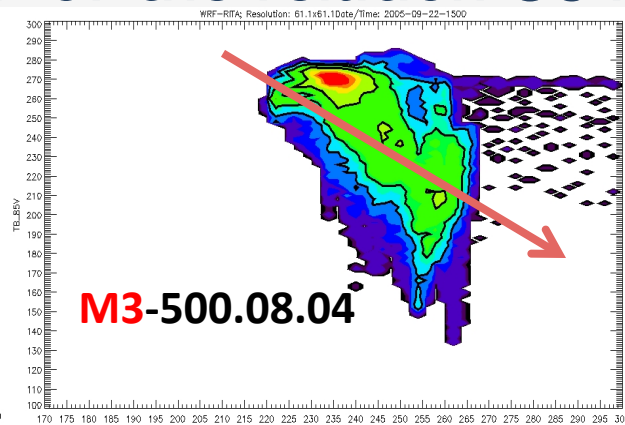
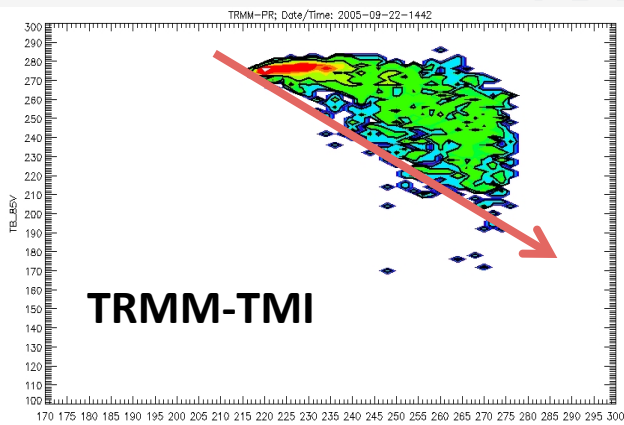
# Joint Distribution (19H vs 85H) – *Impact of Microphysics*

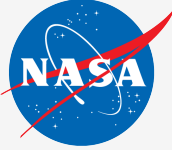
## PDF of the relation 85V-19V





# Joint Distribution (19H vs 85H) – *Impact of Microphysics* PDF of the relation 85V-19V

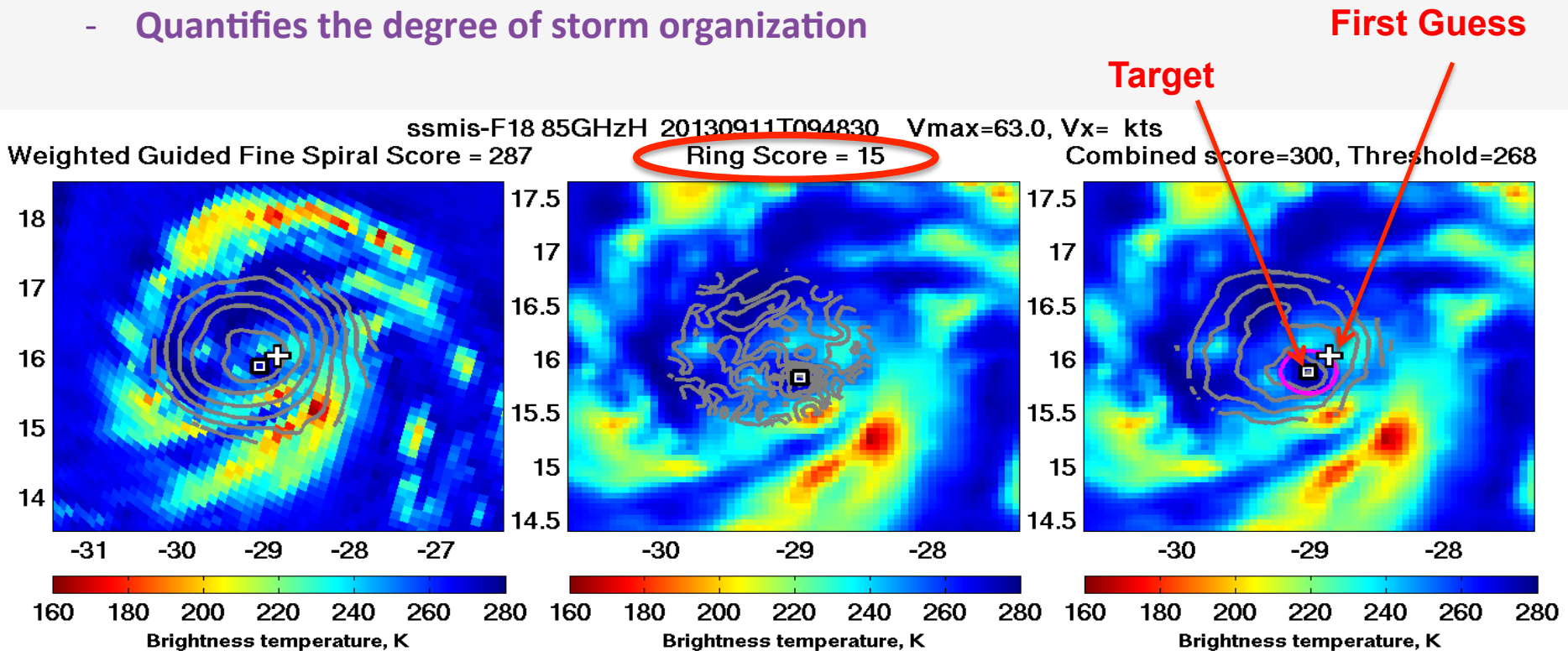




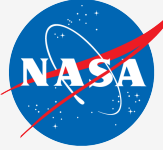
# Storm structure Tool: Degree of Organization

## 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



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.

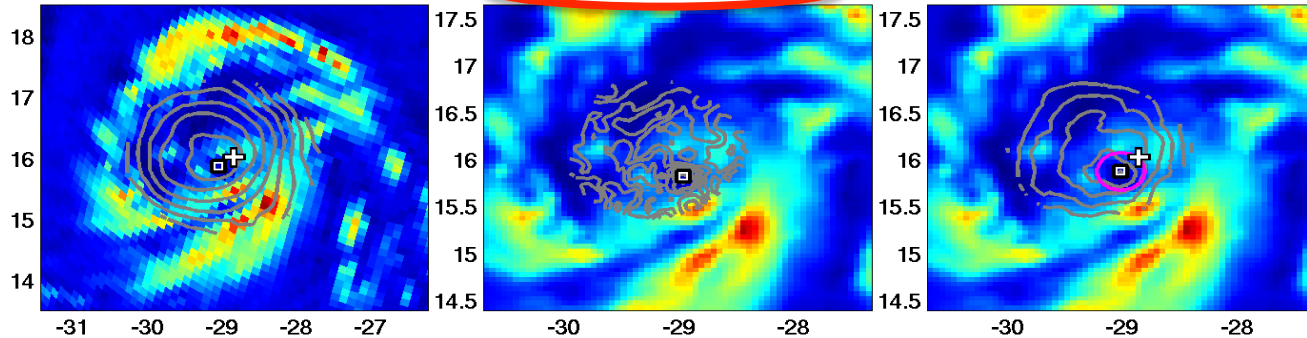


# Storm structure Tool: Degree of Organization

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

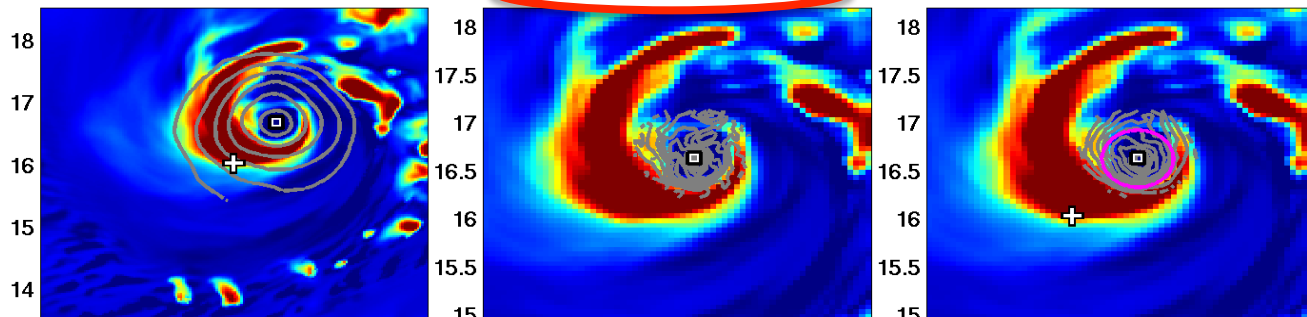
OBSERVED

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



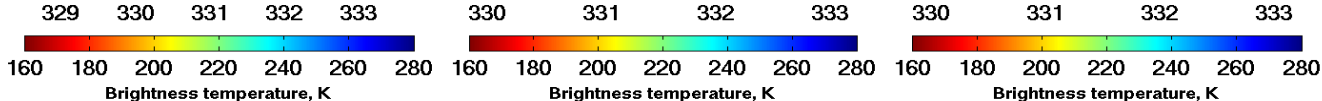
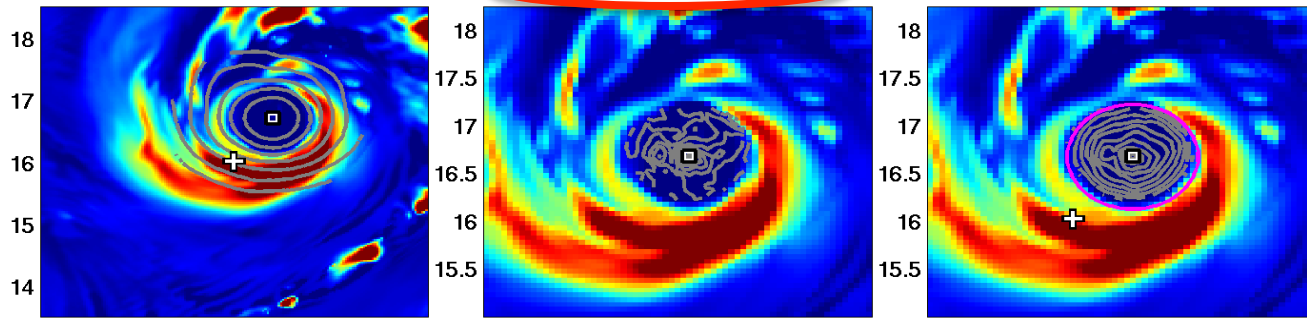
36h forecast

HWRP-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

HWRP-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)

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

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

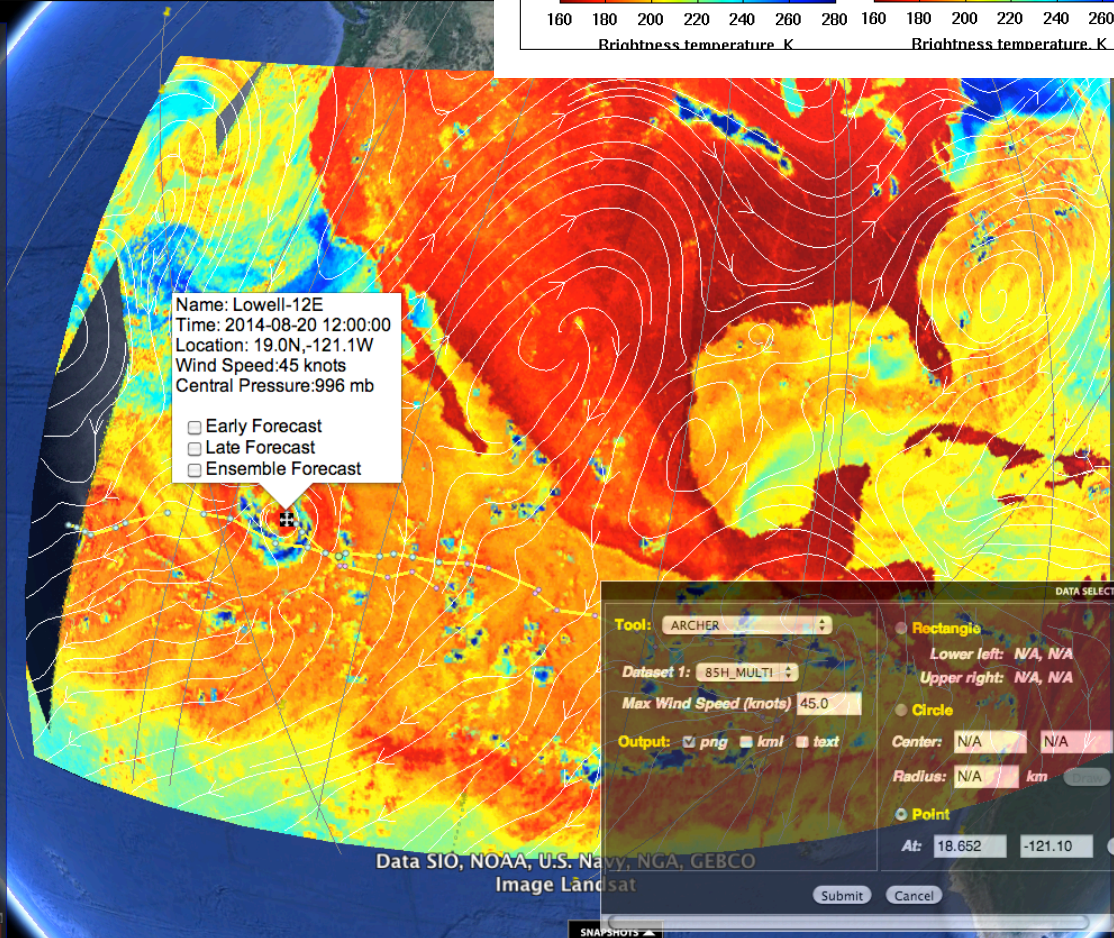
**SATELLITE DATA**  
 AIRS  
 AOT (MODIS)  
 Geostationary  
 Microwave Rain Signature

- 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

SATELLITE & AIRCRAFT DATA

Name: Lowell-12E  
 Time: 2014-08-20 12:00:00  
 Location: 19.0N, -121.1W  
 Wind Speed: 45 knots  
 Central Pressure: 996 mb

Early Forecast  
 Late Forecast  
 Ensemble Forecast



**DATA SELECTION**

Tool: ARCHER

Dataset 1: 85H\_MULTI

Max Wind Speed (knots): 45.0

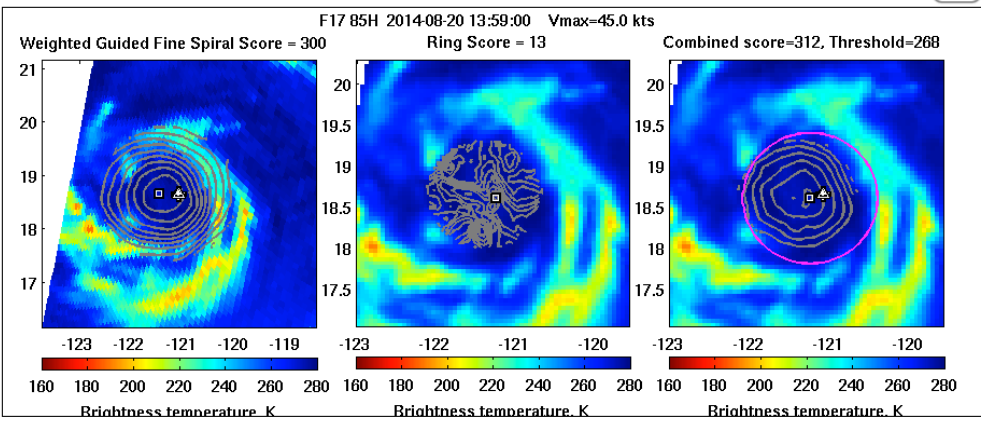
Output:  png  kml  text

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**

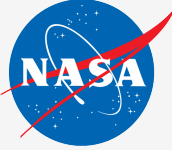
MODEL

- 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**

- HWRP-CRTM-D1
- HWRP-CRTM-D3

Google Status Bar Grid



# Storm structure Tool: Storm Size and Asymmetry

## The Wave Number Analysis Tool

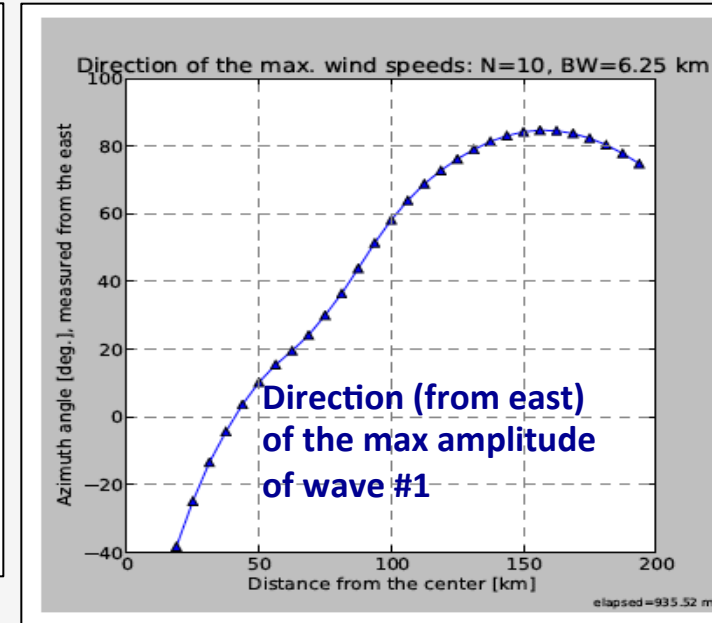
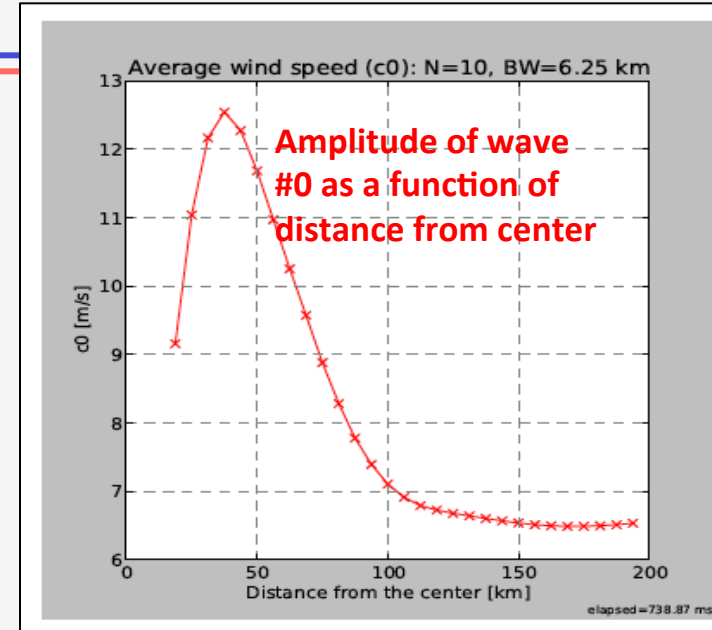
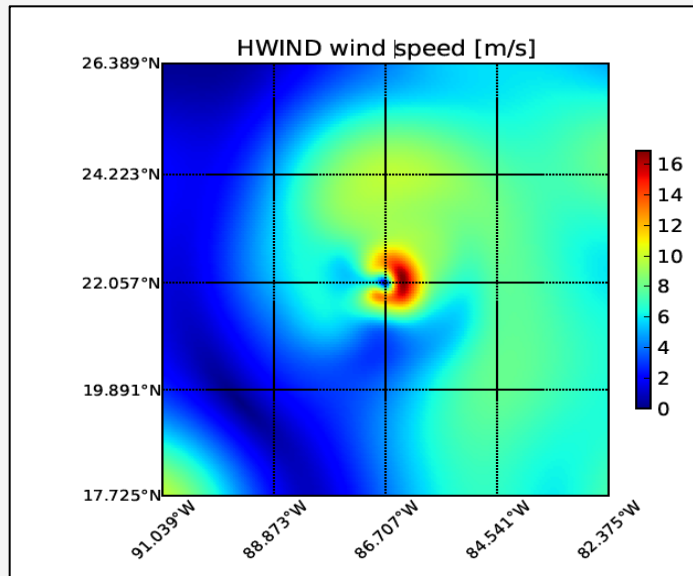
### First adopted and used by NOAA/AOML/HRD

- 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>

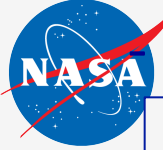
### Tool Developed for the JPL TCIS by

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

- Surface winds
- Rain Index







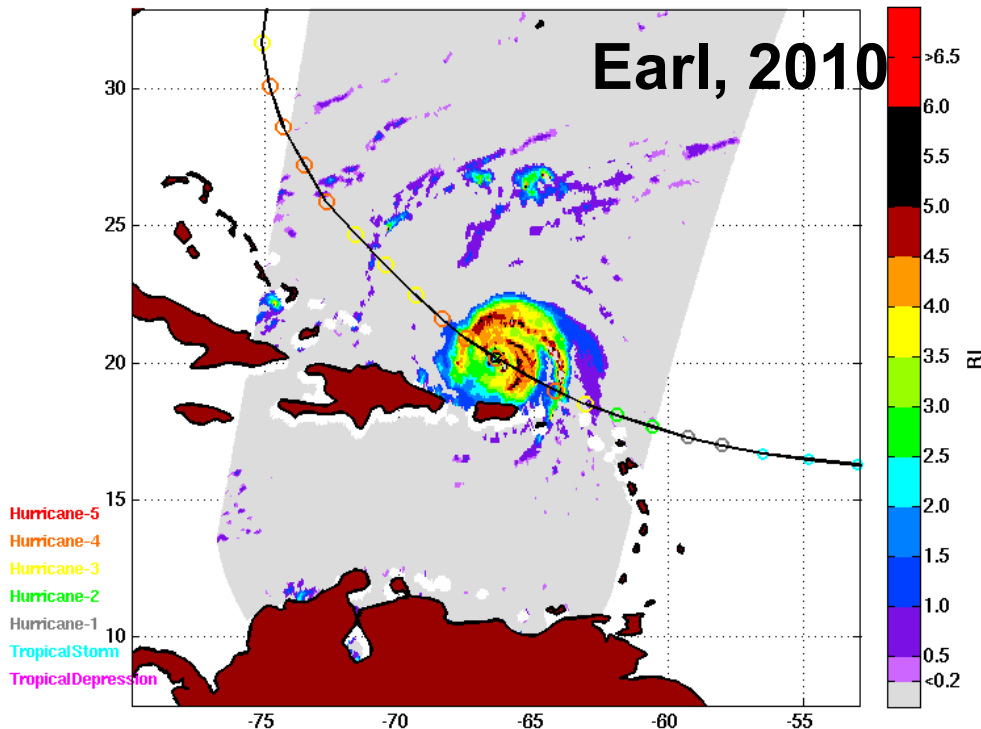
# The Rain Indicator – a multi-channel depiction of the storm structure

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

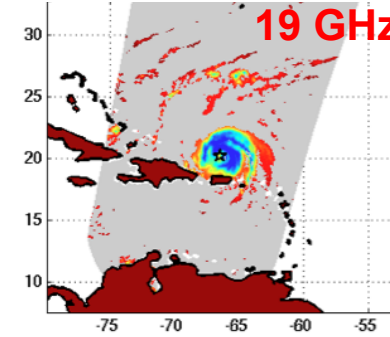
Microwave signals at the top of the atmosphere can be classified into two categories:

- **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.

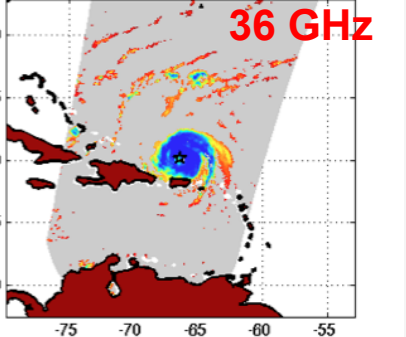
AMSRE AQUA-1 Rain Index(RI) Earl 2010/08/31 06:19:38



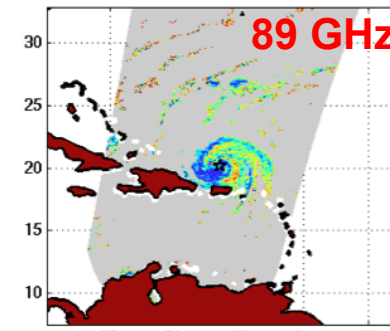
Polarization Difference



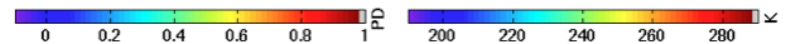
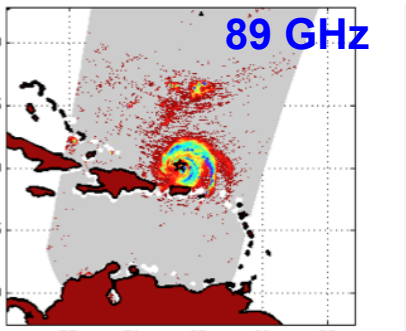
Polarization Difference

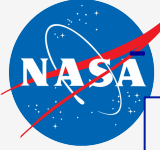


Polarization Diff



Polarization Corrected Temp.

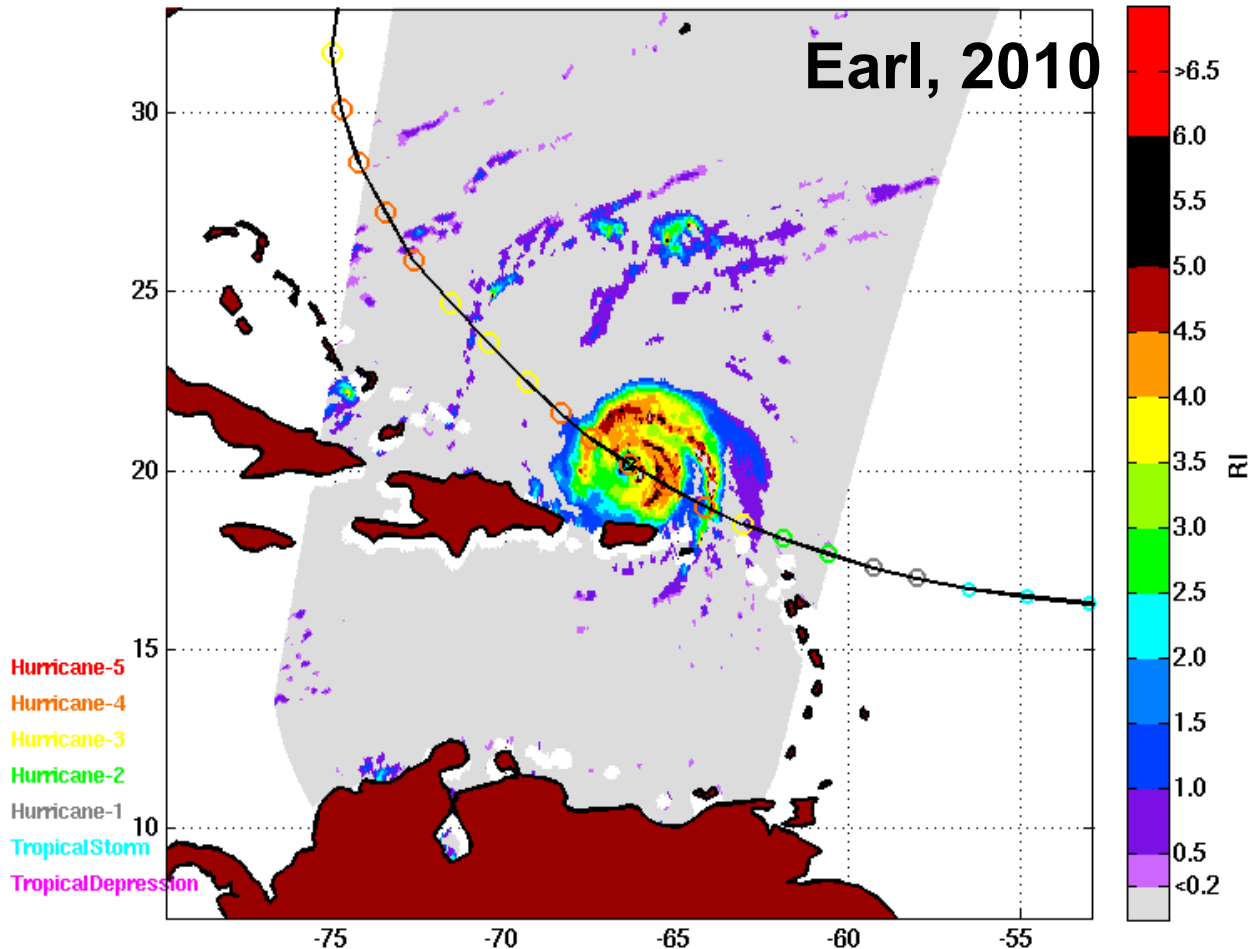




# The Rain Indicator – a multi-channel depiction of the storm structure

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)



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

2014-08-19 15:00:00

15 Hurricanes (mm)

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

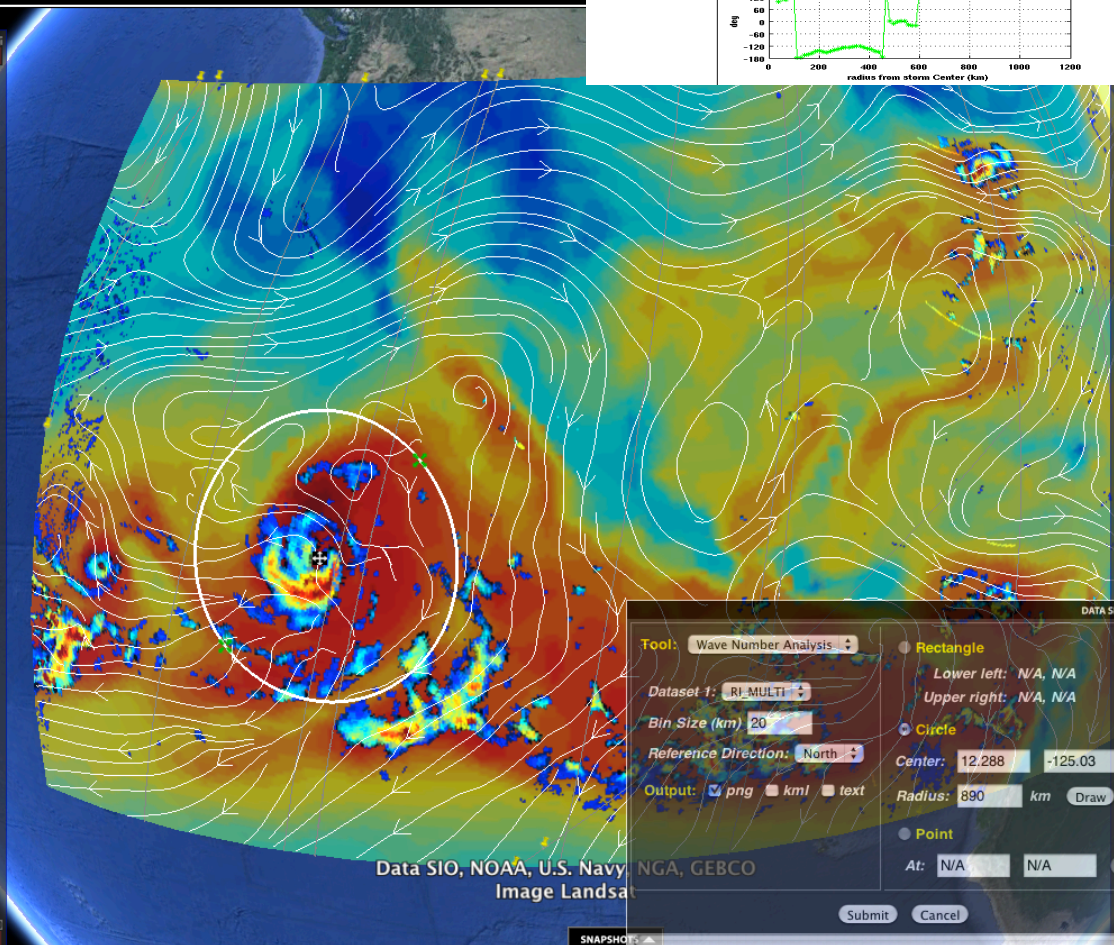
- IR
- IR 2 Day Animation
- IRCOLOR
- VAPOR
- VIS

Microwave Rain Signature

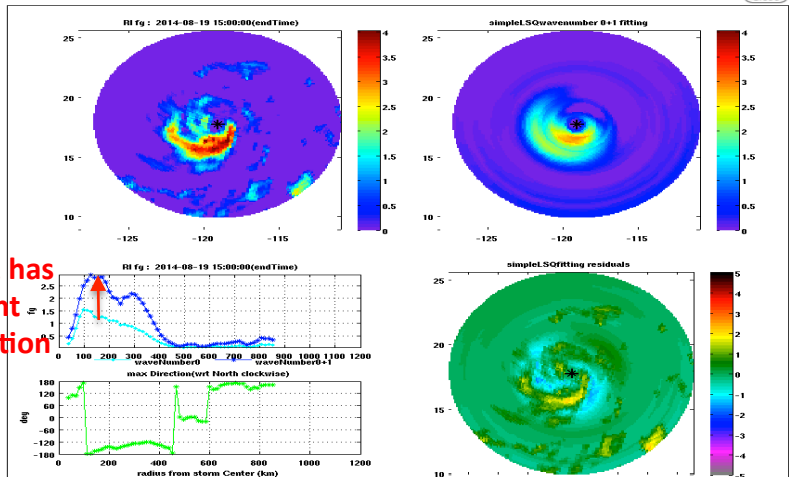
- 10H GHz
- 10V GHz
- 19H GHz
- 19V GHz
- 37COLOR
- 37H GHz
- 37V GHz
- 85H GHz
- 85V GHz

Rain Indicator

TPW Rain Indicator



Wave #1 has important contribution



L & SIMULATION DATA

MODEL

- ECMWF
- GFS

Press: 200

Forecast Time: 012

- SPEED-COMOVING
- STREAM-COMOVING
- DEEP-SHEAR
- OW
- PMSL
- POUCH-SHEAR
- RH
- SPEED-EARTH
- STREAM-EARTH
- TEMP
- TPW
- VORTICITY

NAVGENM

- UKMET

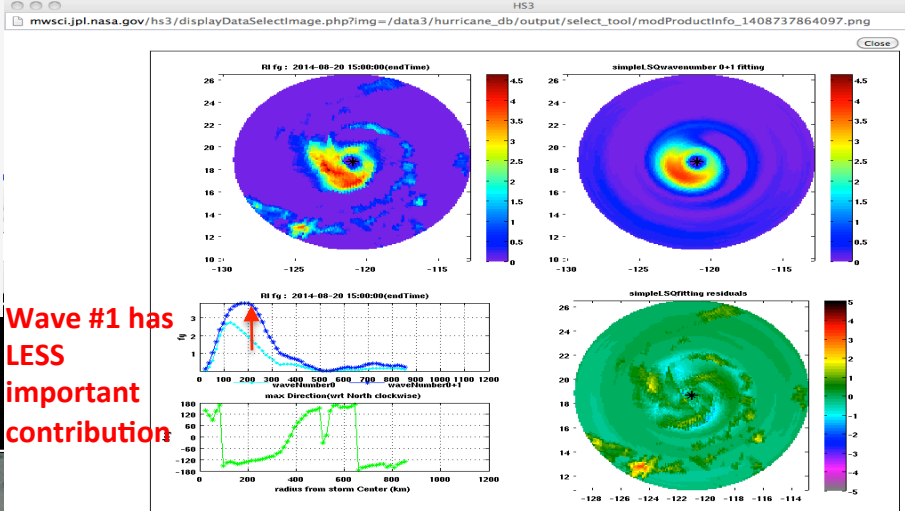
SIMULATION

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

# Storm structure Tool:

## Storm Size and Asymmetry

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

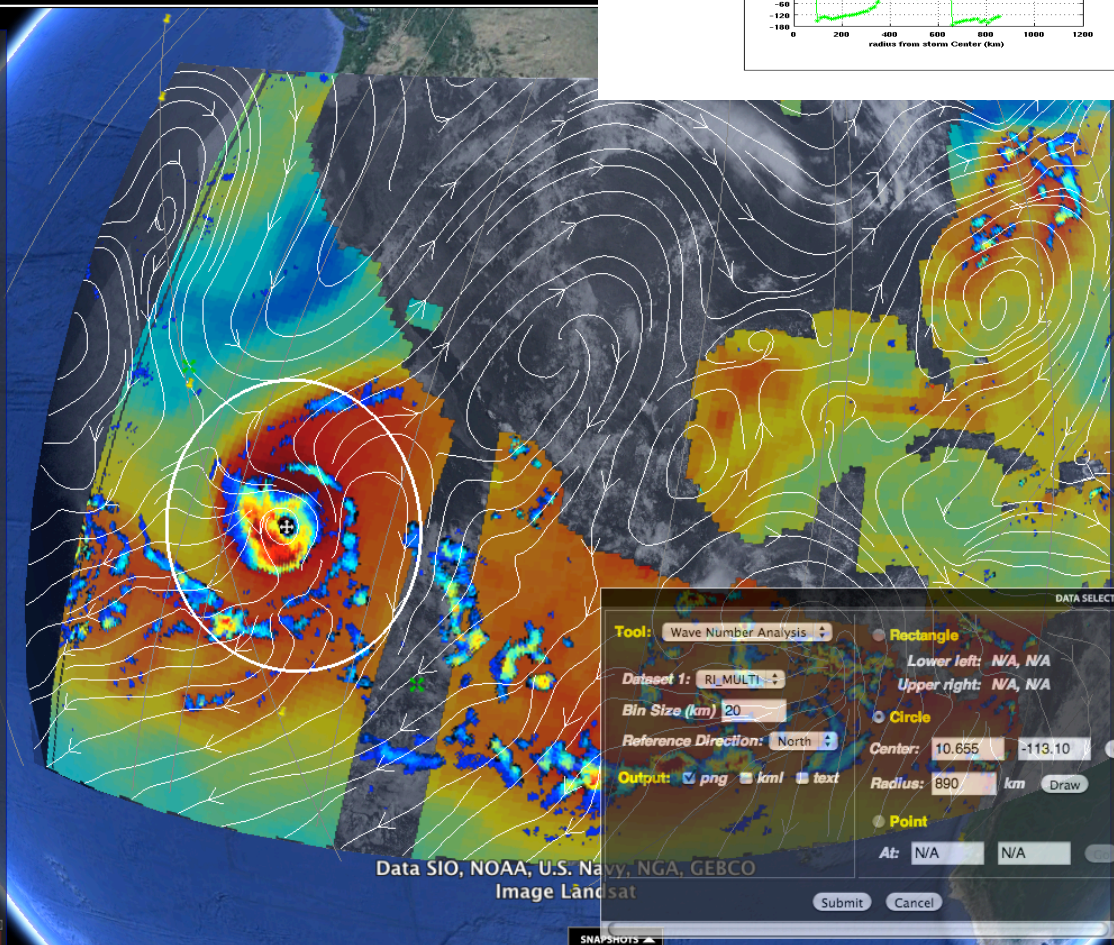


NASA Jet Propulsion Laboratory  
California Institute of Technology

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

2014-08-20 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
  - RH Composite
  - Two Day Animation



- 8. 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
- SIMULATION
  - HWRF-CRTM-D1
  - HWRF-CRTM-D3

# 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

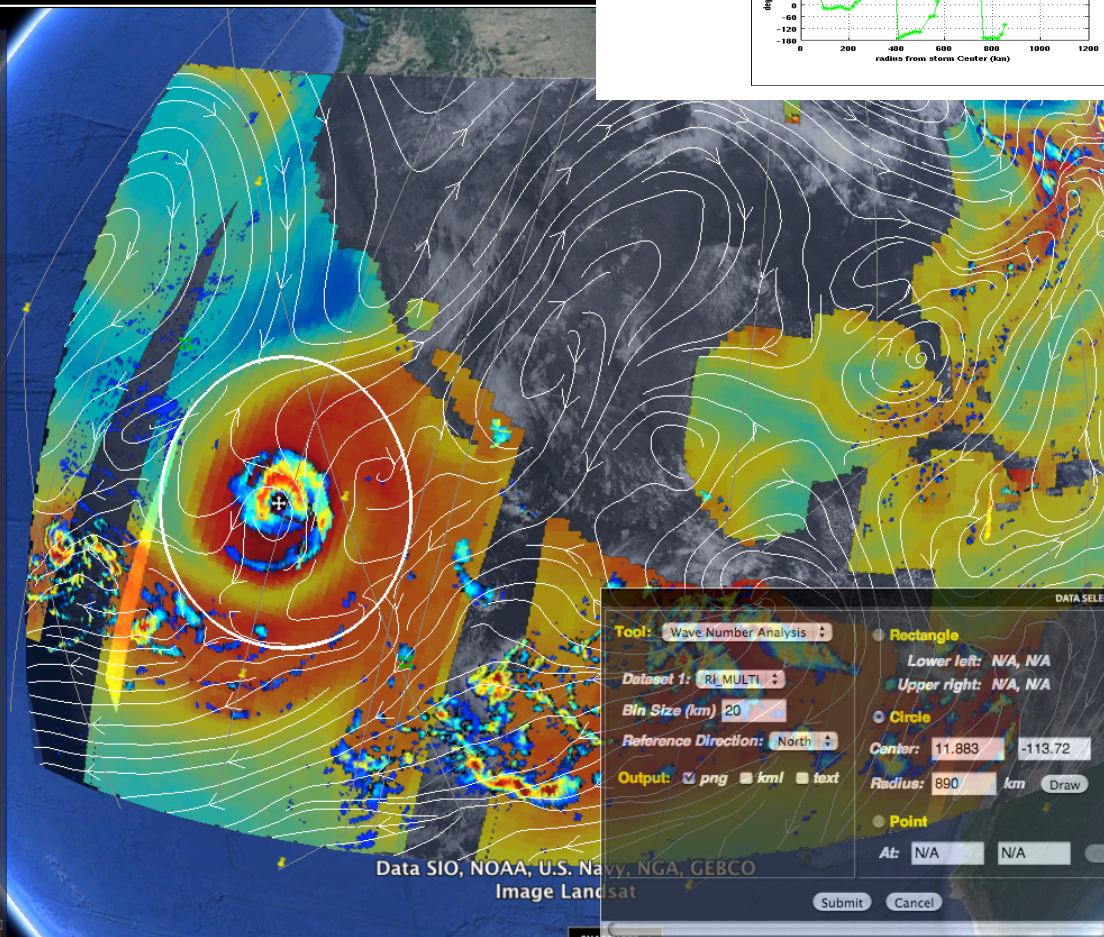
##### STORM TRACK

- BEST TRACK
- POUCH TRACK

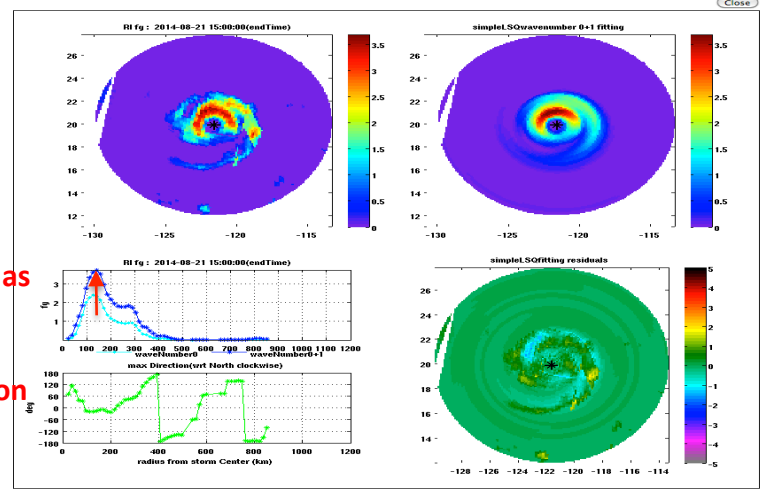
##### SATELLITE DATA

- 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

SATELLITE & AIRCRAFT DATA



Wave #1 has LEAST important contribution



DATA SELECTION

Tool: Wave Number Analysis

Dataset 1: RI\_MULT1

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

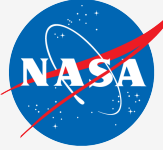
8. SIMULATION DATA

MODEL: ECMWF, GFS, Press: 200, Forecast Time: 012

SPEED-COMOVING, STREAM-COMOVING, DEEP-SHEAR, OW, PMSL, POUCH-SHEAR, RH, SPEED-EARTH, STREAM-EARTH, TEMP, TPW, PARTICITY, NAVGEM, UKMET

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

Google Earth Status Bar Grid

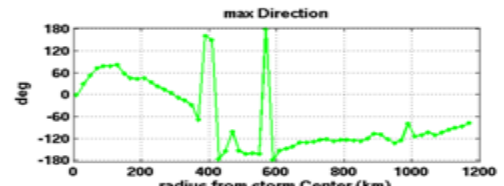
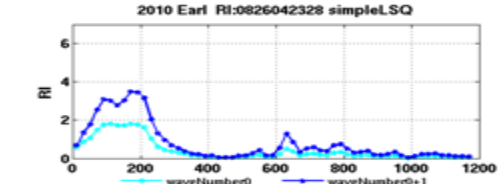
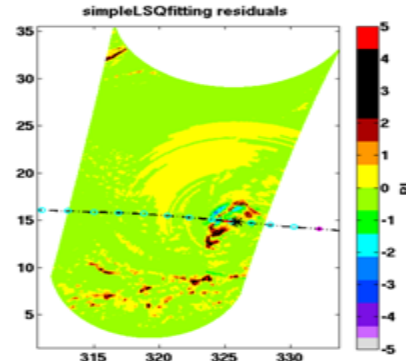
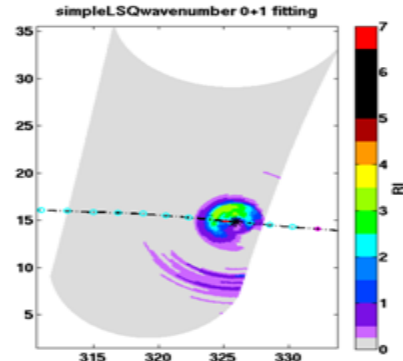
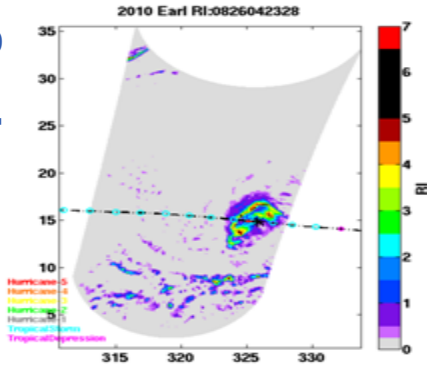


# Storm structure Tool: Storm Size and Asymmetry

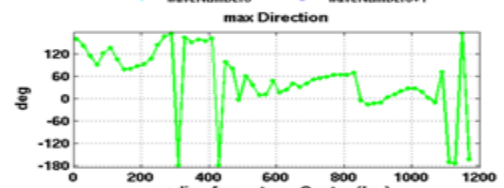
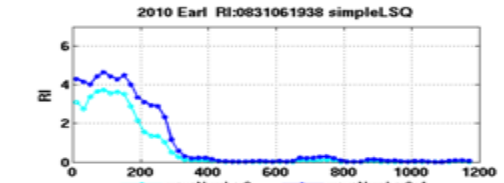
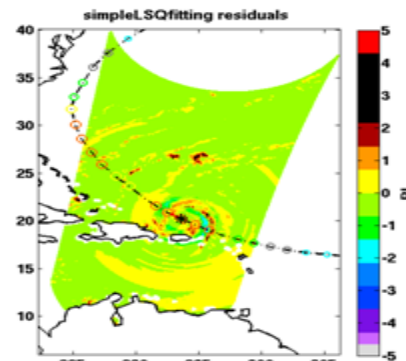
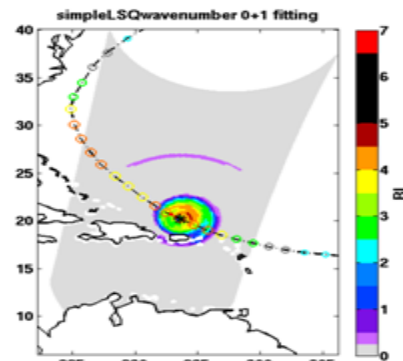
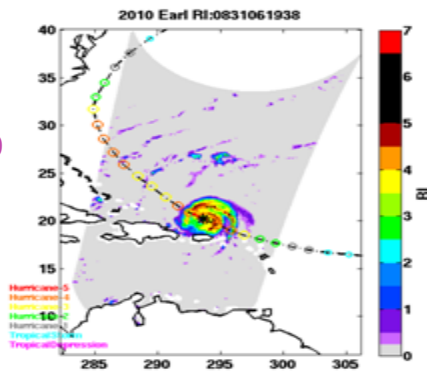
## The Wave Number Analysis Tool using the Rain Index (multi-channel PMW index)

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

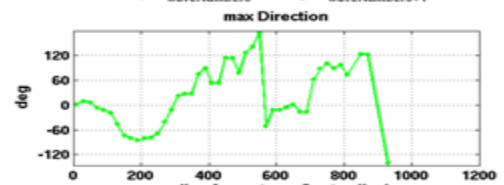
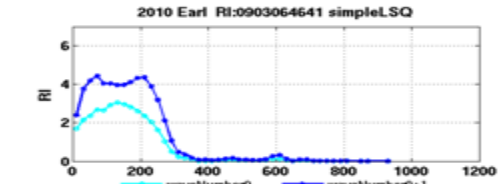
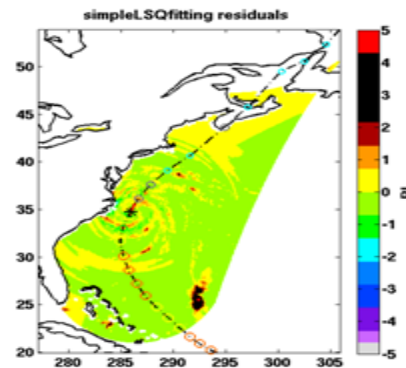
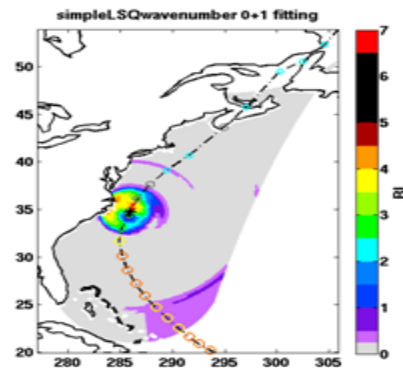
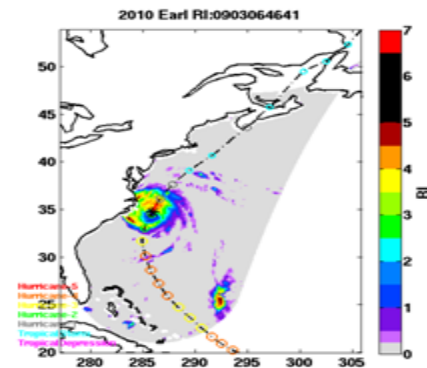
Developing

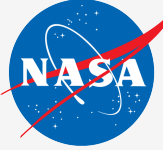


During RI



Mature



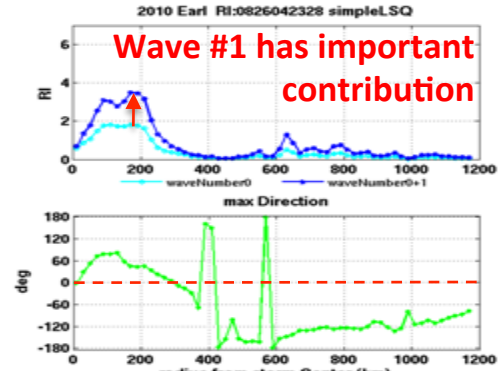
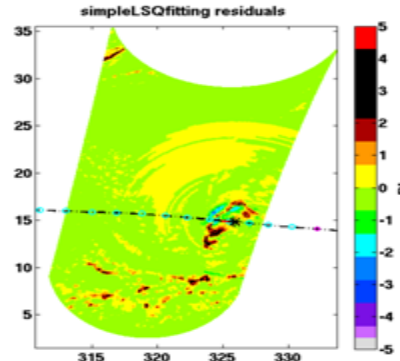
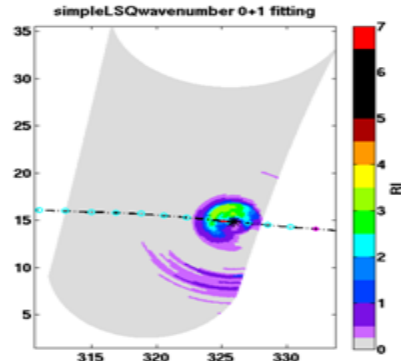
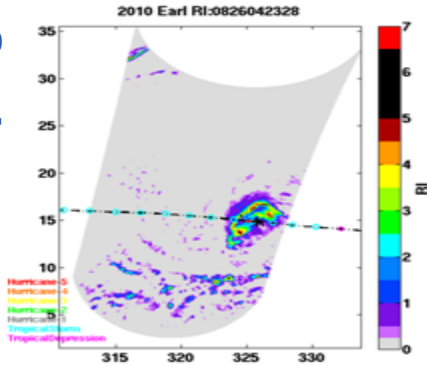


# Storm structure Tool: Storm Size and Asymmetry

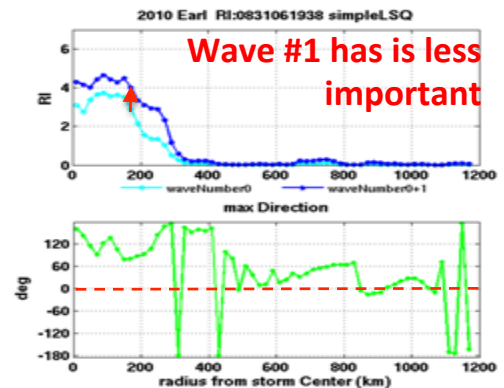
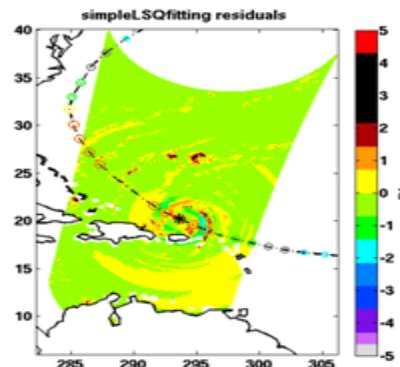
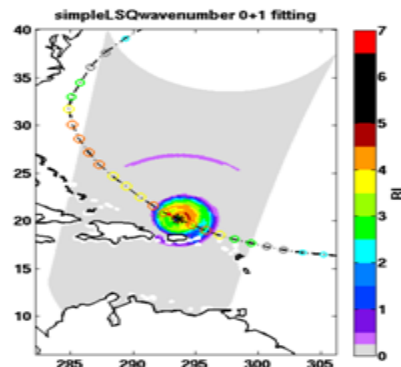
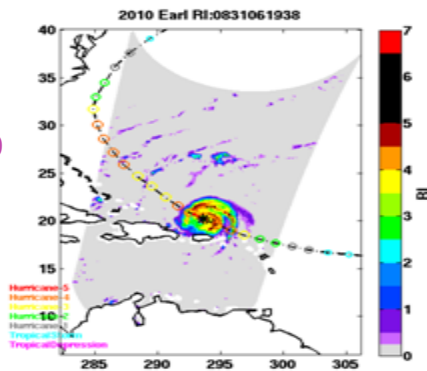
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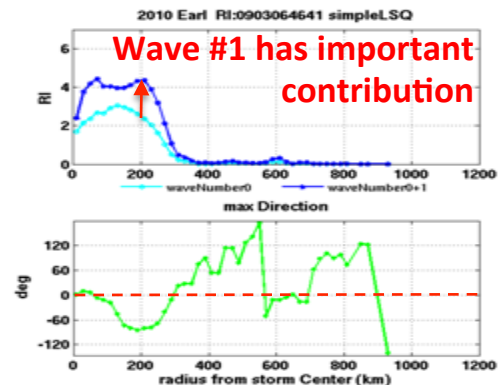
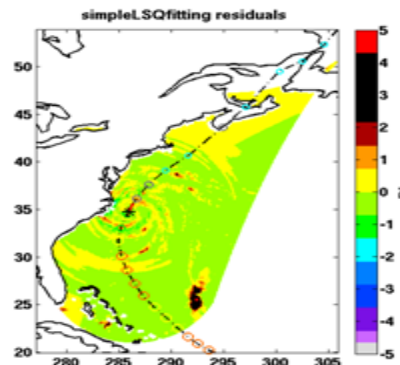
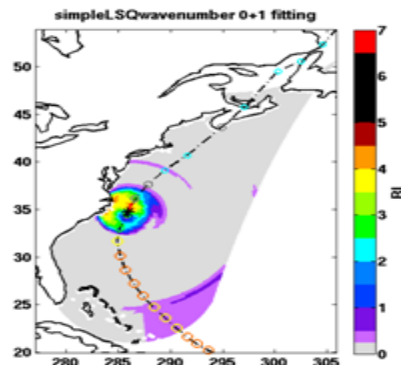
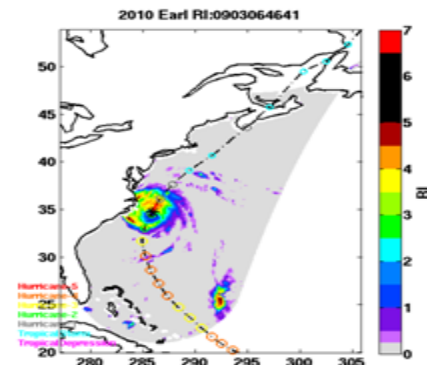
Developing

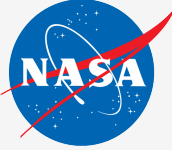


During RI



Mature





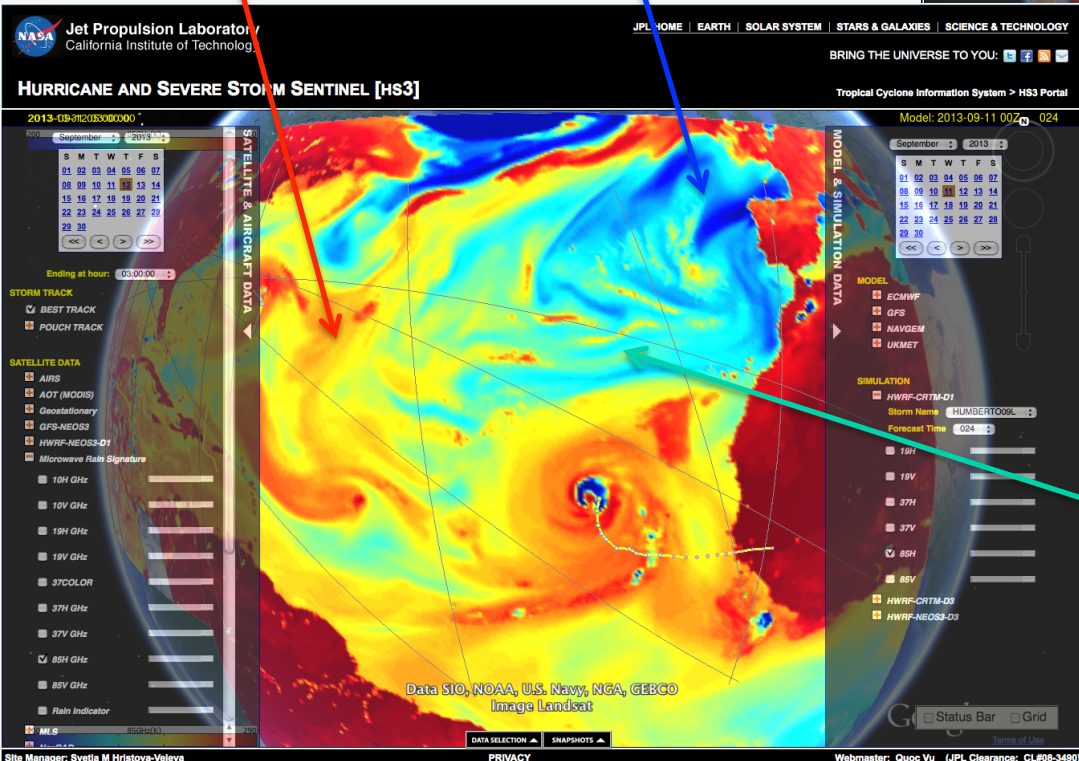
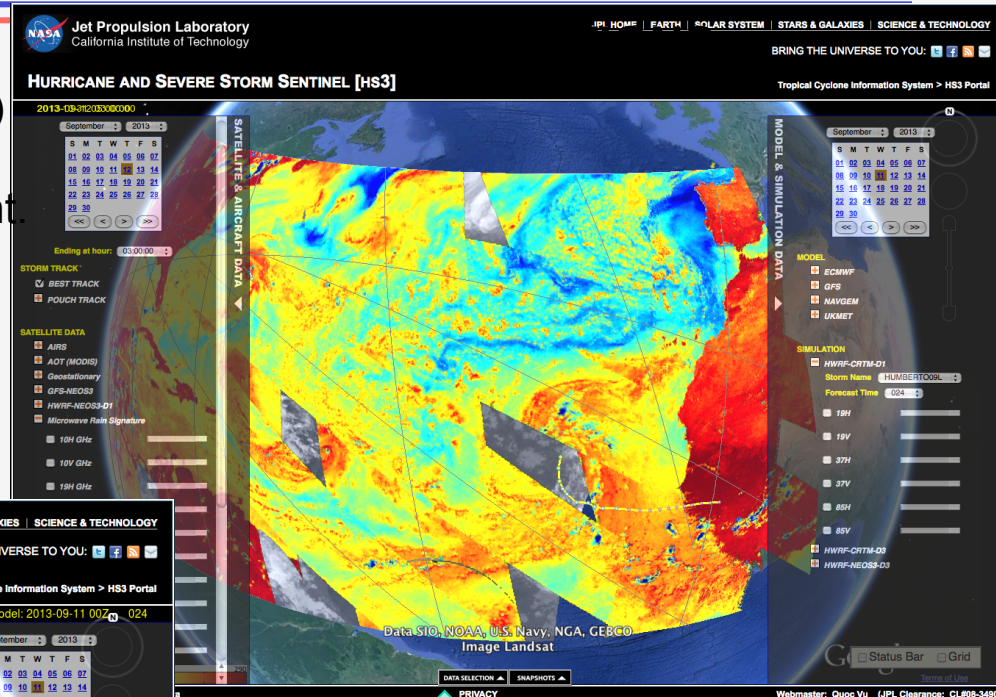
# Task Summary – Major Accomplishments

## 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.

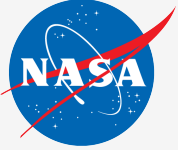
HWRF model based on (NEOS<sup>3</sup>) and the operational CRTM instrument simulators

**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

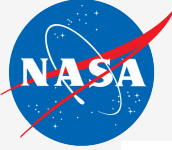




# Summary

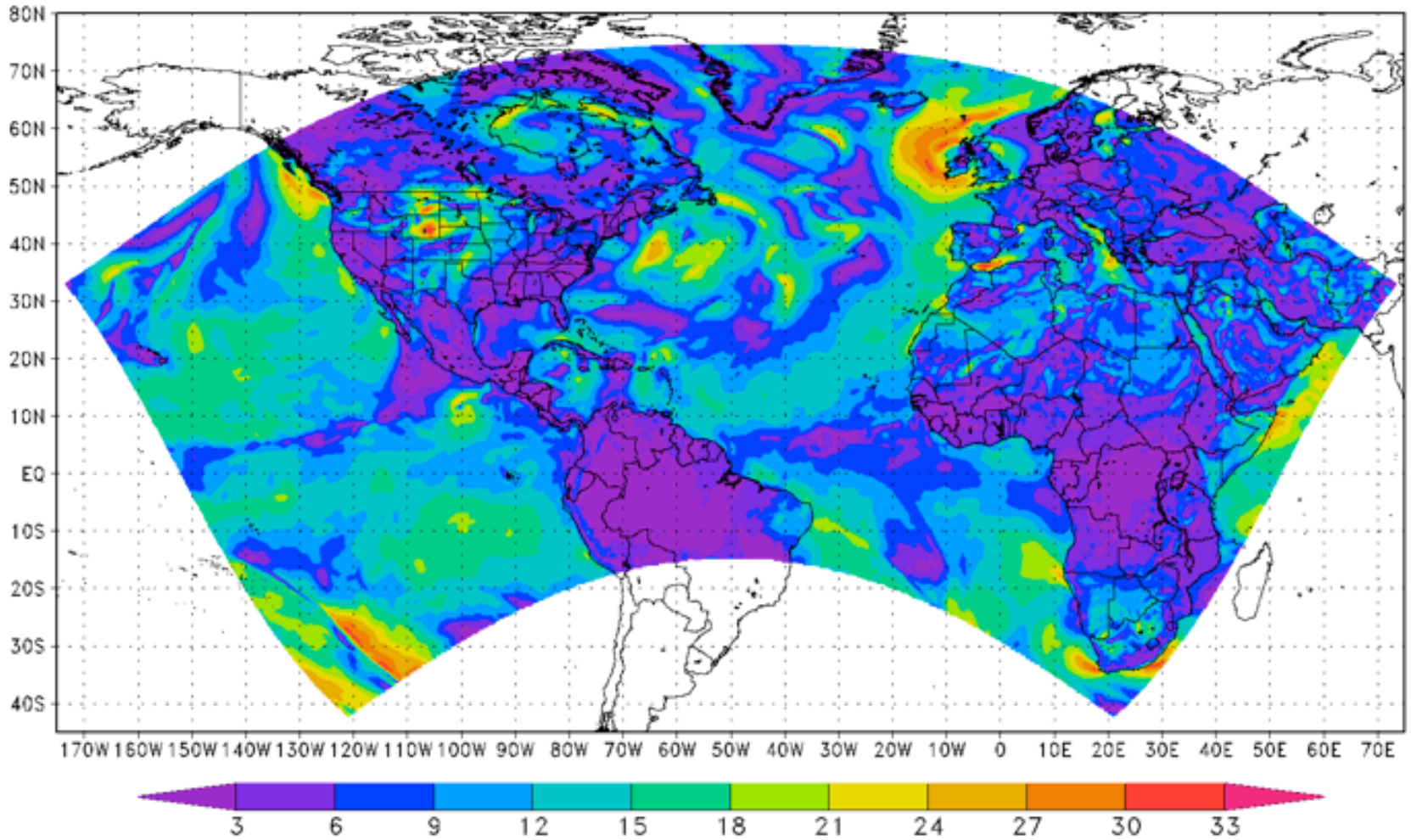
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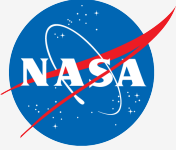
- To achieve the HFIP goals of improving the forecast accuracy of hurricane intensity, track and impact at landfall we first **need to understand whether the models properly reflect the physical processes and their interactions.**
- To address the need for improving the model physics, the 2013 annual 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 ... 😊



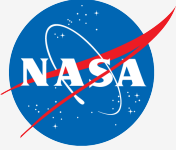
# Basin-scale HWRF – coming up!

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



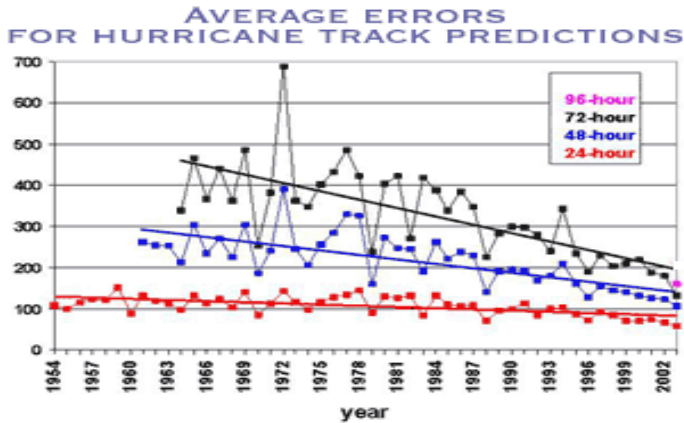


*Thank you !*

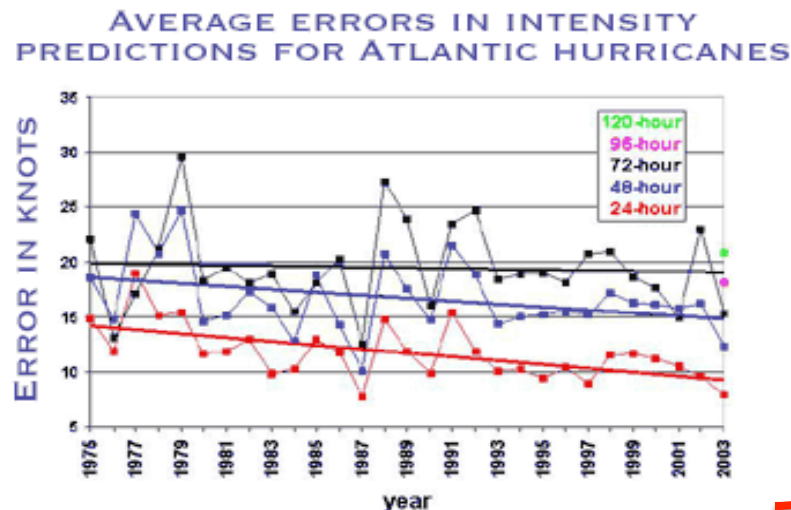


# Current state-of-the-art hurricane prediction

- **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).