Tropical Cyclone – Interactive Data Exchange and Analysis System (TC-IDEAS)

Combining Airborne Field Data Global Satellite Observations and Model Simulations of Tropical Cyclones

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JPL MSFC

7 April 2009

Outline of Presentation

- ❖ Introductions

1. Real Time Mission Monitor (RTMM)
2. Integrated Tropical Cyclone Information System (iTCIS)
3. TC - IDEAS

TC-IDEAS Joint Team Members

Marshall Space Flight Center

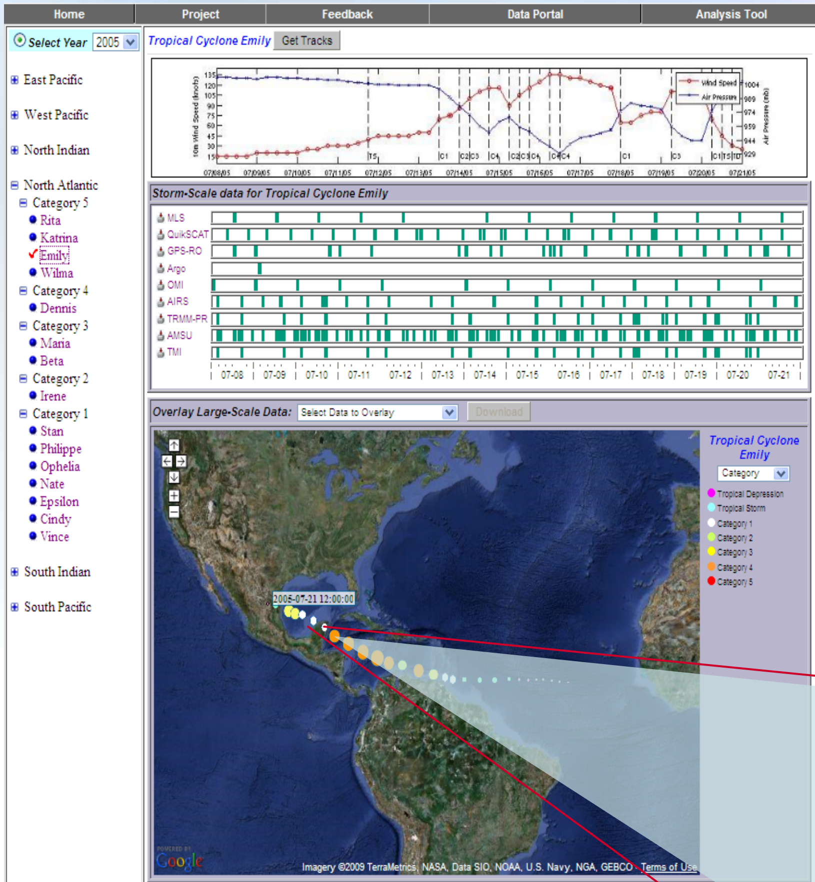
- Michael Goodman / NASA
- Helen Conover / University of Alabama Huntsville
- Joe Turk / JPL (formerly NRL)

Jet Propulsion Lab

- Svetla Hristova-Veleva / JPL
- Bjorn Lambrigtsen / JPL
- Ziad Haddad / JPL
- Yi Chao / JPL
- Simone Tanelli / JPL
- Hui Su / JPL
- Rob Rogers / NOAA HRD
- Sharanaya Majumdar / Univ. Miami RSMAS

Tropical Cyclone – Integrated Data Exchange and Analysis System (TC-IDEAS)

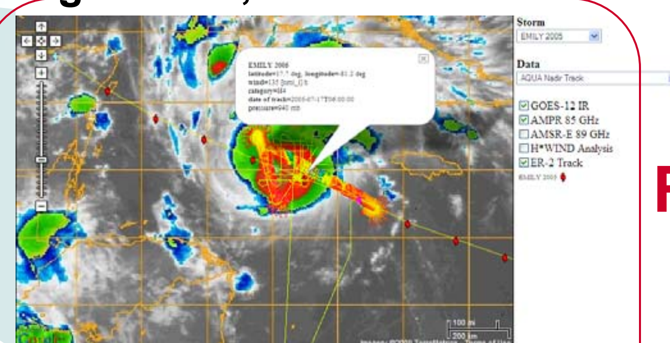
Joint NASA Jet Propulsion Lab and Marshall Space Flight Center Project



Select by basin, name, or category with corresponding data availability timelines

Objective: To provide fusion of multi-parameter hurricane observations (satellite, airborne and *in-situ*) and model simulations with the purpose of:

- supporting both research and field campaigns (incorporating RTMM)
- understanding the physical processes
- improving hurricane forecast by facilitating model validation and data assimilation
- enabling the development of new algorithms, sensors and missions.



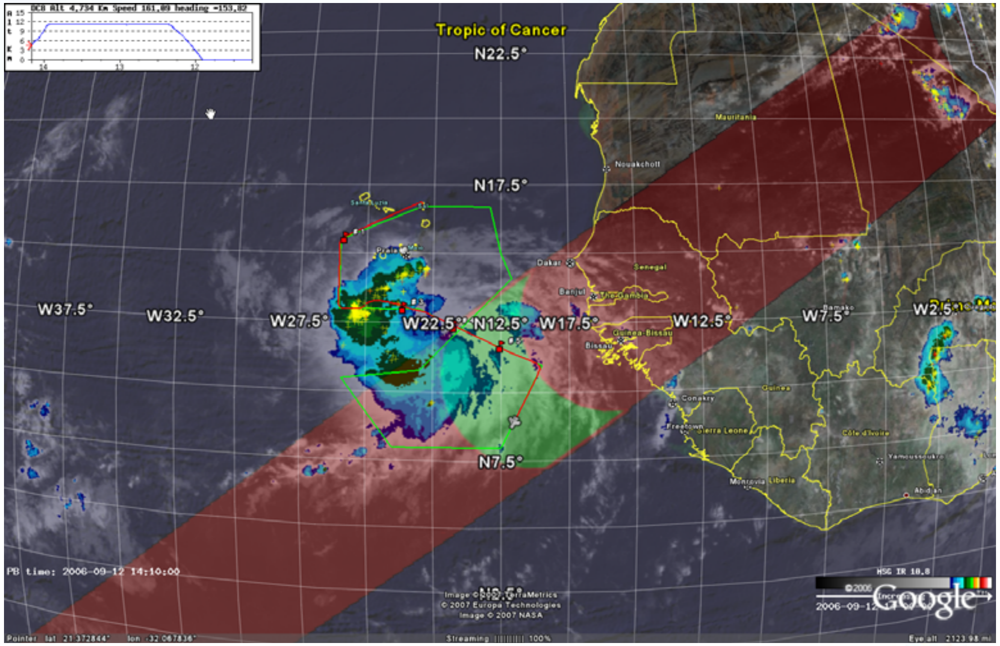
ER-2 /AMPR data over GOES IR

RTMM

Part 1: The RTMM - a Component of TC-IDEAS

The Real Time Mission Monitor (RTMM) is an interactive visualization application that provides situational awareness and field asset management to enable adaptive and strategic decision making during airborne field experiments.

- Integrates satellite, airborne, and surface data sets
- Tracks airborne vehicle state information
- Displays model and forecast parameter fields

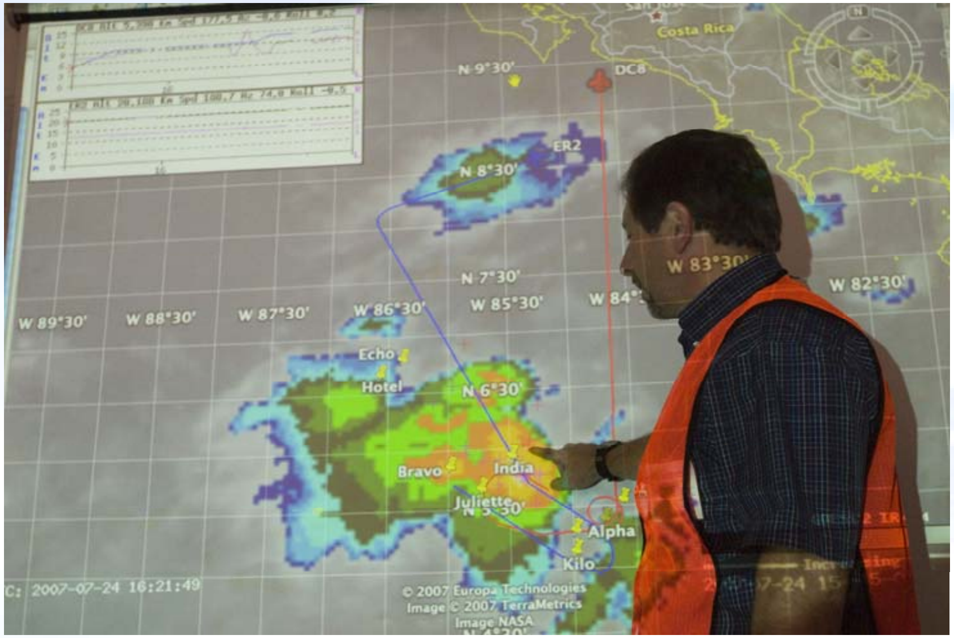


To paraphrase the BASF television commercial:
"We don't make the science, we make the science easier"

Planning, Support and Analyses

RTMM facilitates:

- Pre-flight planning
  - Interactive waypoint tool
  - Satellite overpass predicts
  - Forecast parameters
- In-flight monitoring and adaptive flight strategies
  - Operations center focal point
  - Current weather conditions
  - Plane-to-plane data transfer
  - Enables real time collaborations
- Post-flight analyses, research, and assessments
  - Encapsulate and replay missions

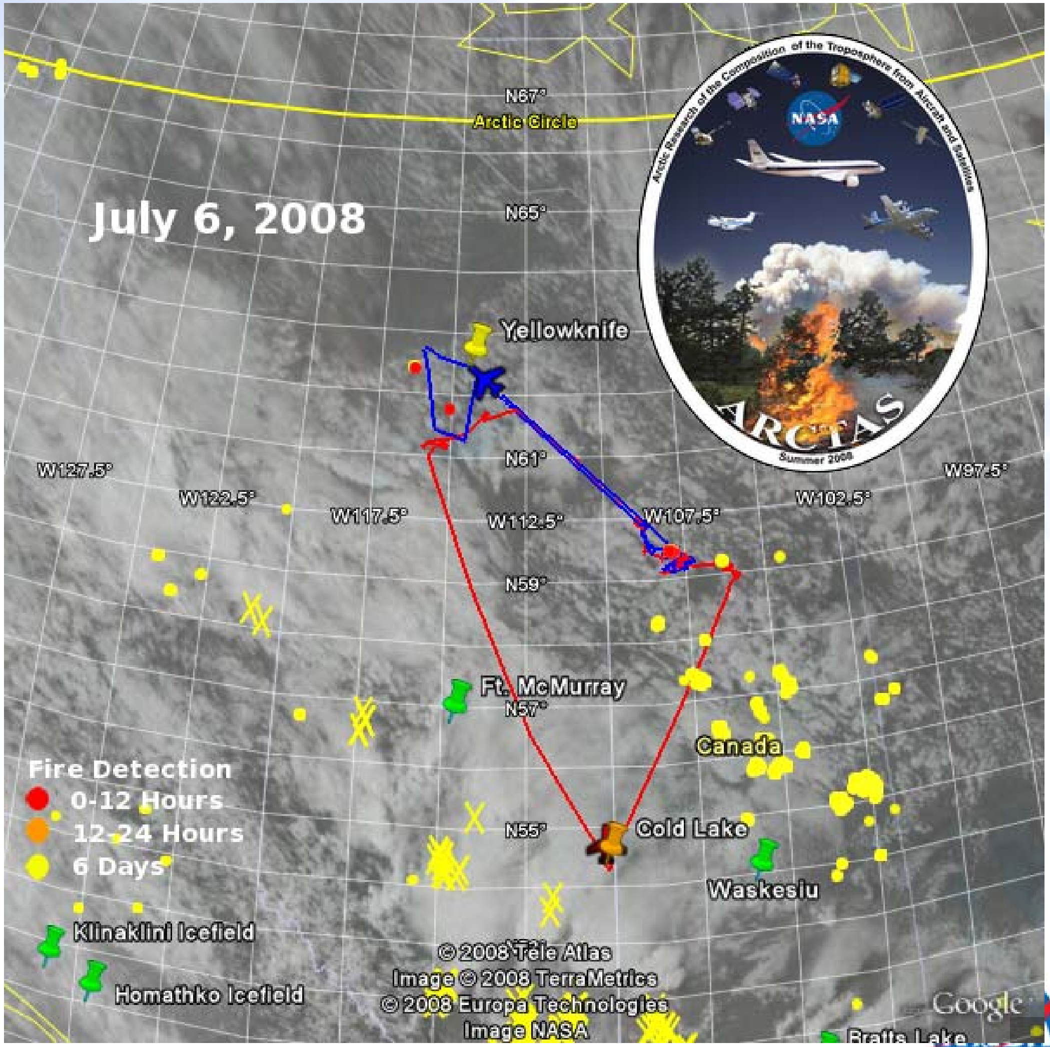


- RTMM used by:
  - Scientists
  - Program Managers
  - Educators and Students
  - Media and Public Affairs

Recent Use of RTMM in ARCTAS

Arctic Research of the Composition of the Troposphere from Aircraft and Satellite

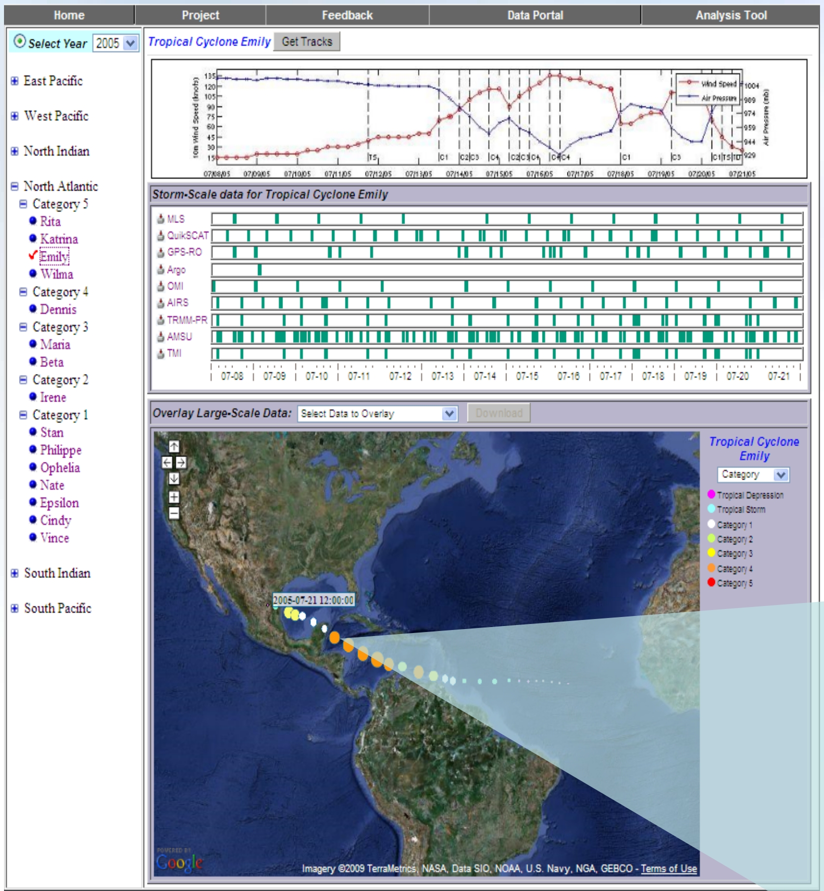
- **ARCTAS Summer focused on boreal forest fires**
- **Searching for the elusive pyrocumulo-nimbus**
- **Tracked multiple aircraft and performed plane-plane transfer of HSRL Lidar data**
- **Waypoint Planning Tool used to plan the P-3 missions**



Part 2: iTCIS - a Component of TC-IDEAS

Joint NASA Jet Propulsion Lab and Marshall Space Flight Center Project

The JPL iTCIS



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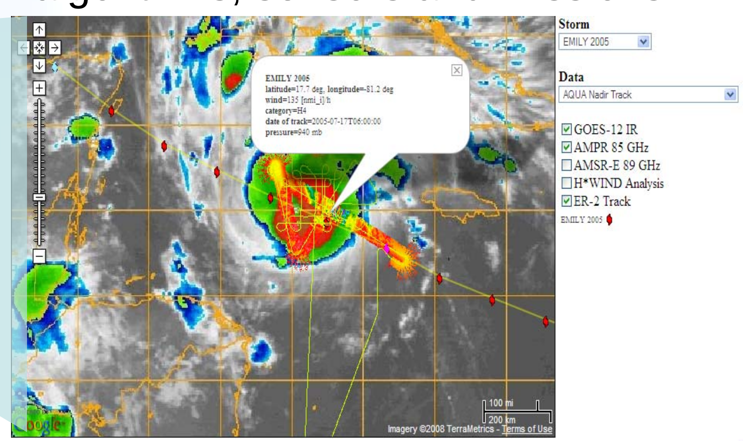
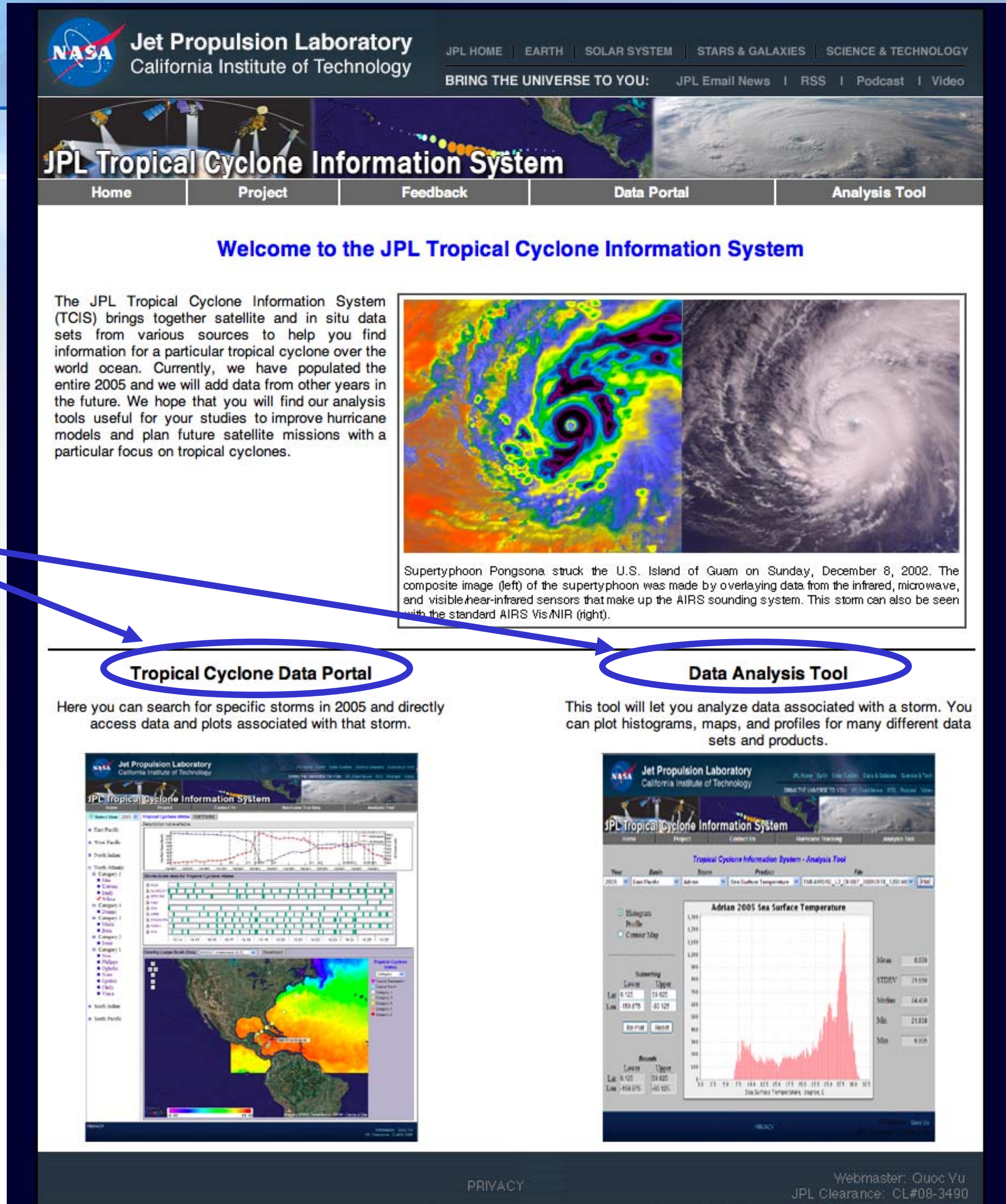


ER-2 /AMPR data overlaid on GOES IR

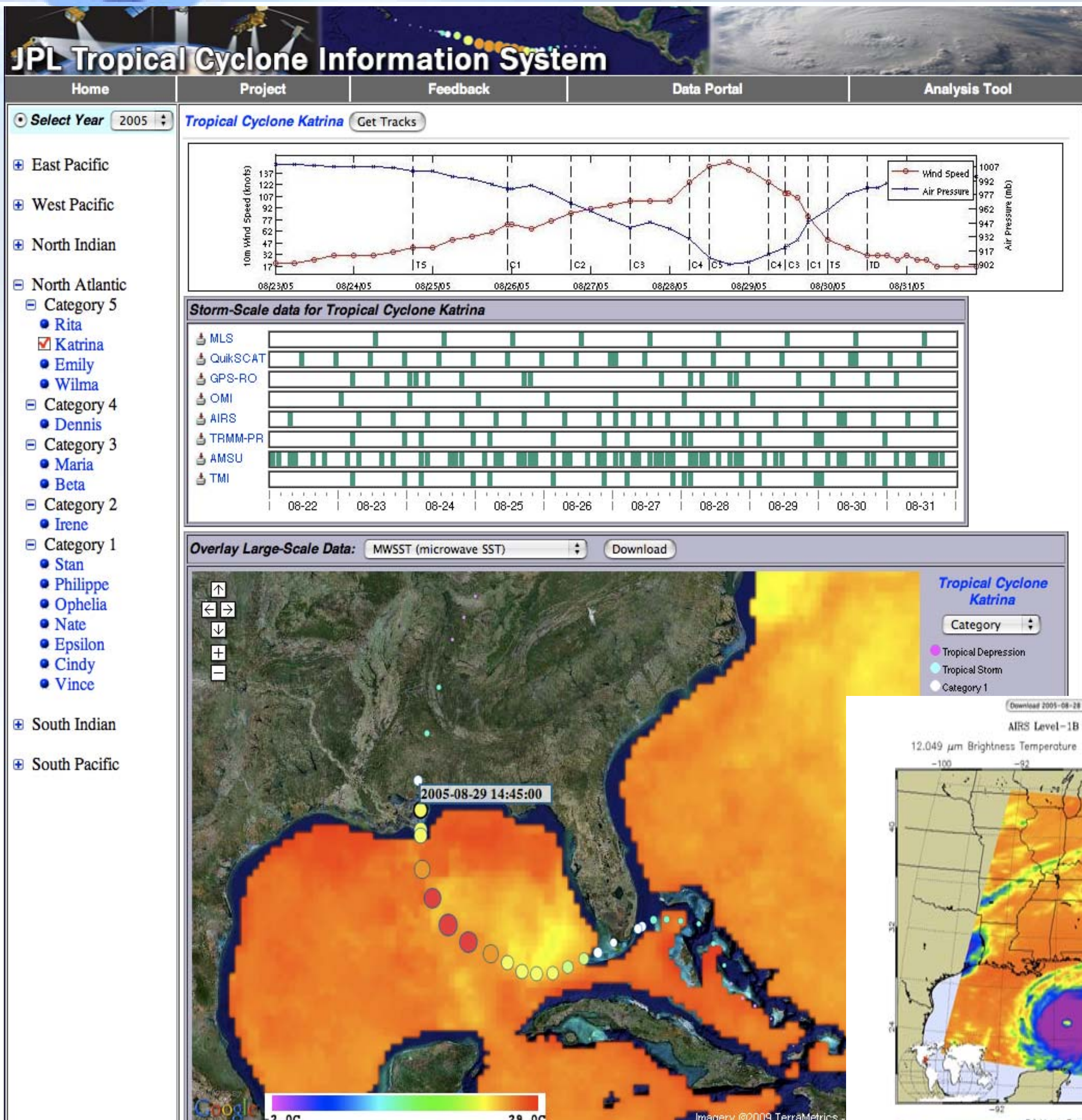
Motivation for Developing iTCIS and TC-IDEAS

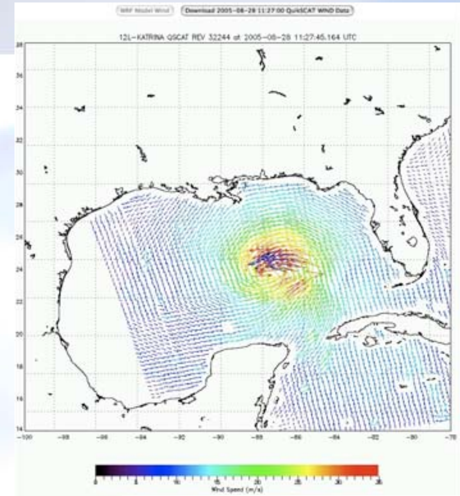
- In spite of recent improvements in hurricane track forecast accuracy, there are still many unanswered questions about the physical processes that determine hurricane genesis, track and intensity.
- Furthermore, there is a pressing need to validate and improve hurricane forecast models!!
- None of this can be accomplished without bringing together models and observations into a common analysis system which does not yet exist
- The JPL-MSFC team is very well positioned to accomplish that because of our:
  - extensive experience with satellite and airborne observations and intimate knowledge about retrieved products
  - ability to bring observations and models together by developing instrument simulators that use the model output and generate satellite "observables" needed:
    - for model-data comparisons
    - for data assimilation
    - for algorithm, instrument and mission design

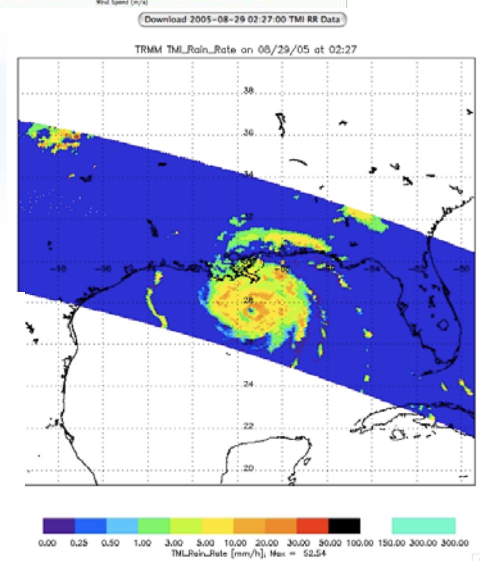
2 main components
In the current
JPL iTCIS

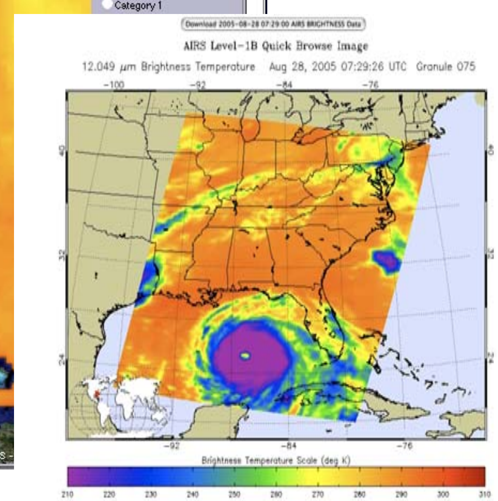


Tropical Cyclone Data Portal – Current Status

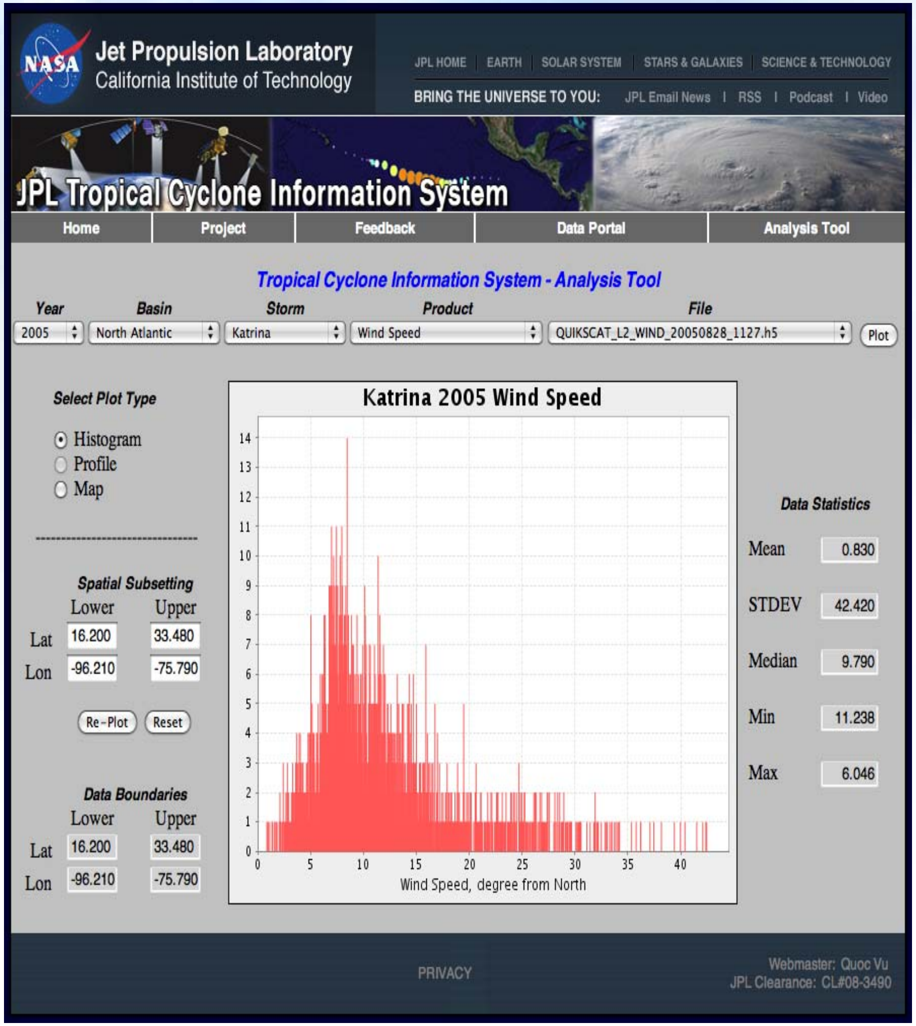


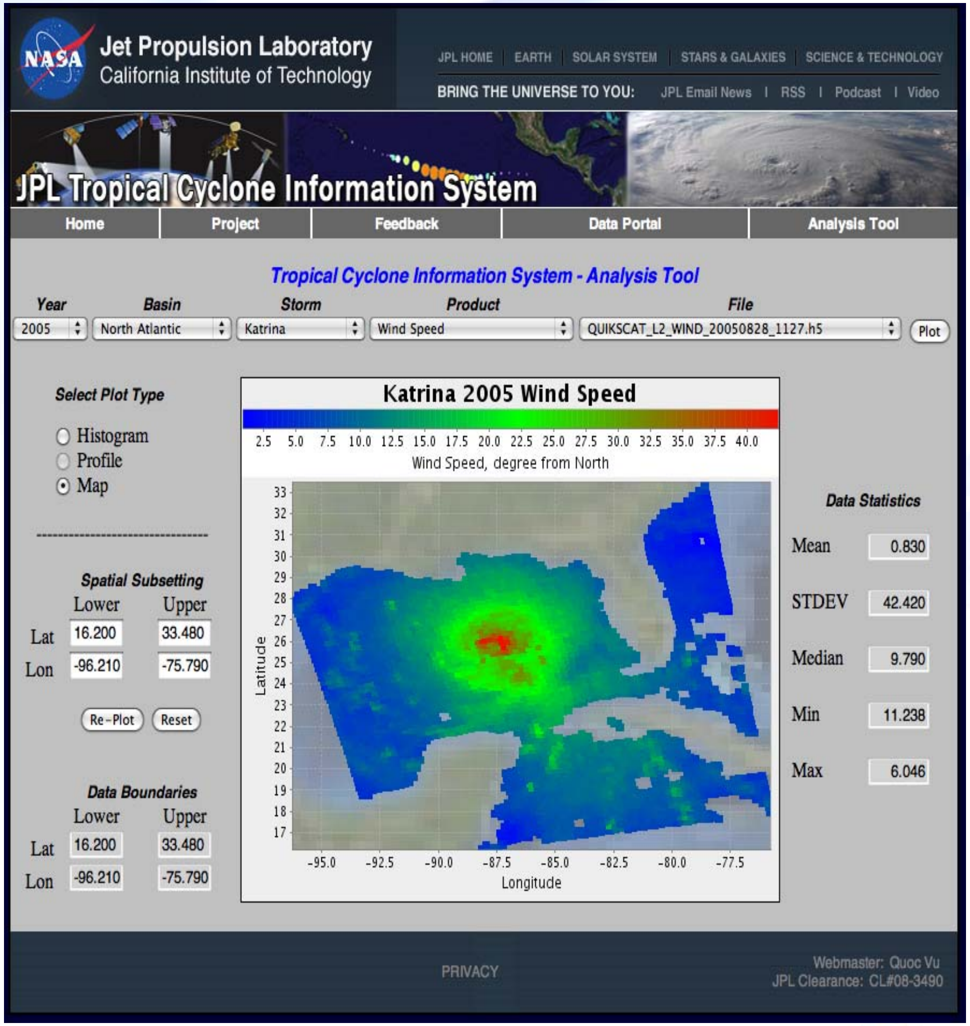






Analysis Tools – Current Status
Single Parameter Statistics





High Resolution Modeling – to be included soon

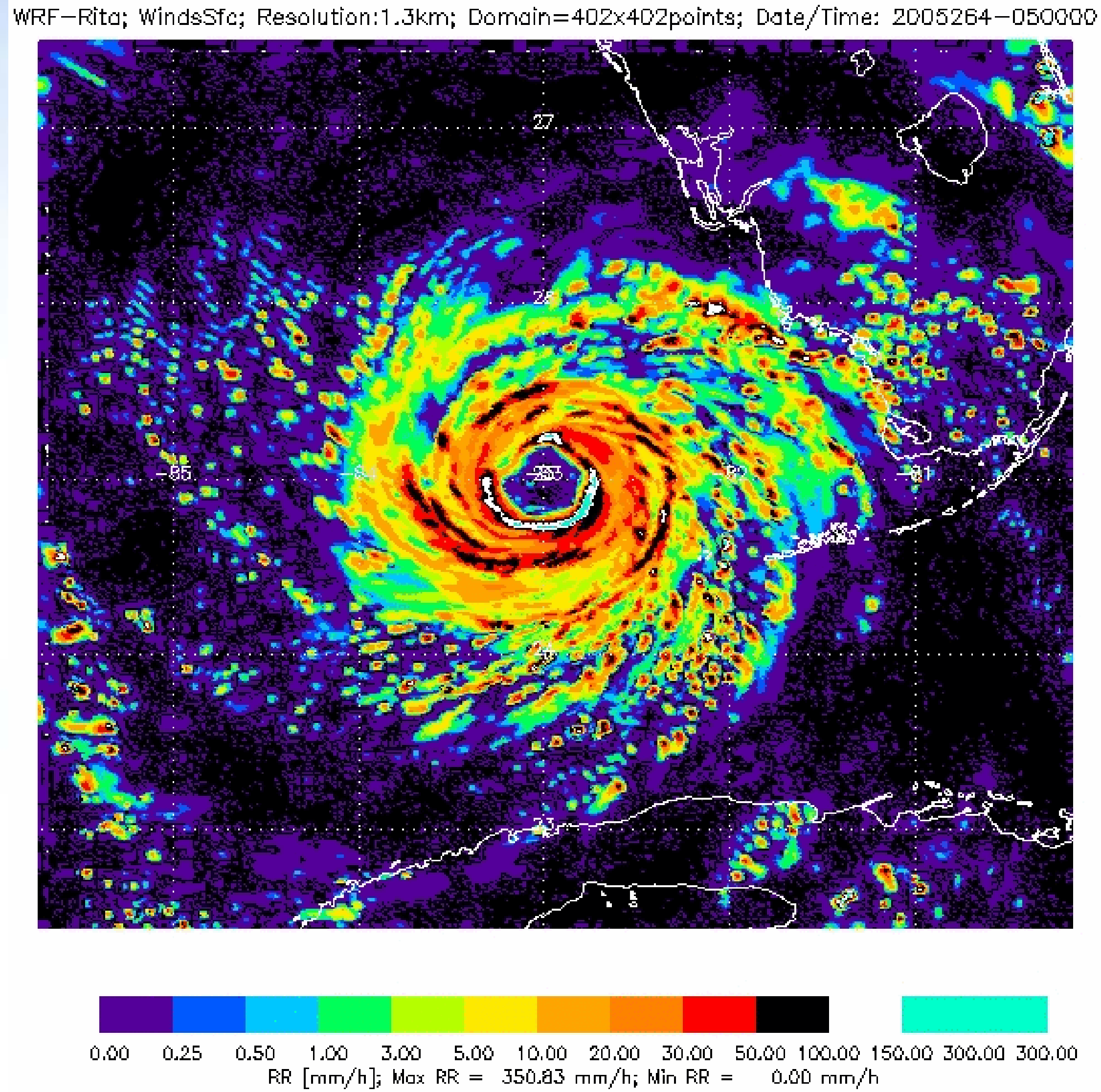
WRF Model Simulations - RITA, September, 2005

High-resolution model simulations provide a very detailed information on the structure and evolution of hurricanes. Observations with such high-resolution in both space and time do not yet exist!

We could learn a lot about hurricane processes by studying model simulations.

However, this is true ONLY if we trust the model simulations ...

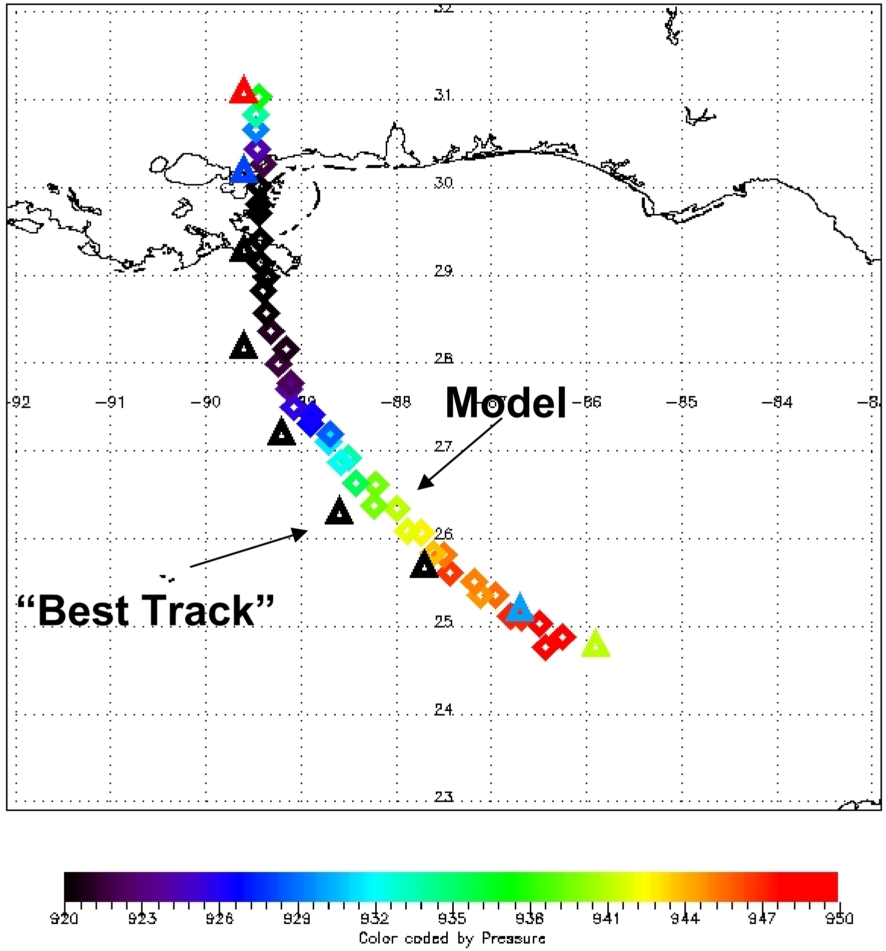
Detailed model - data comparisons are needed to validate and improve the models.



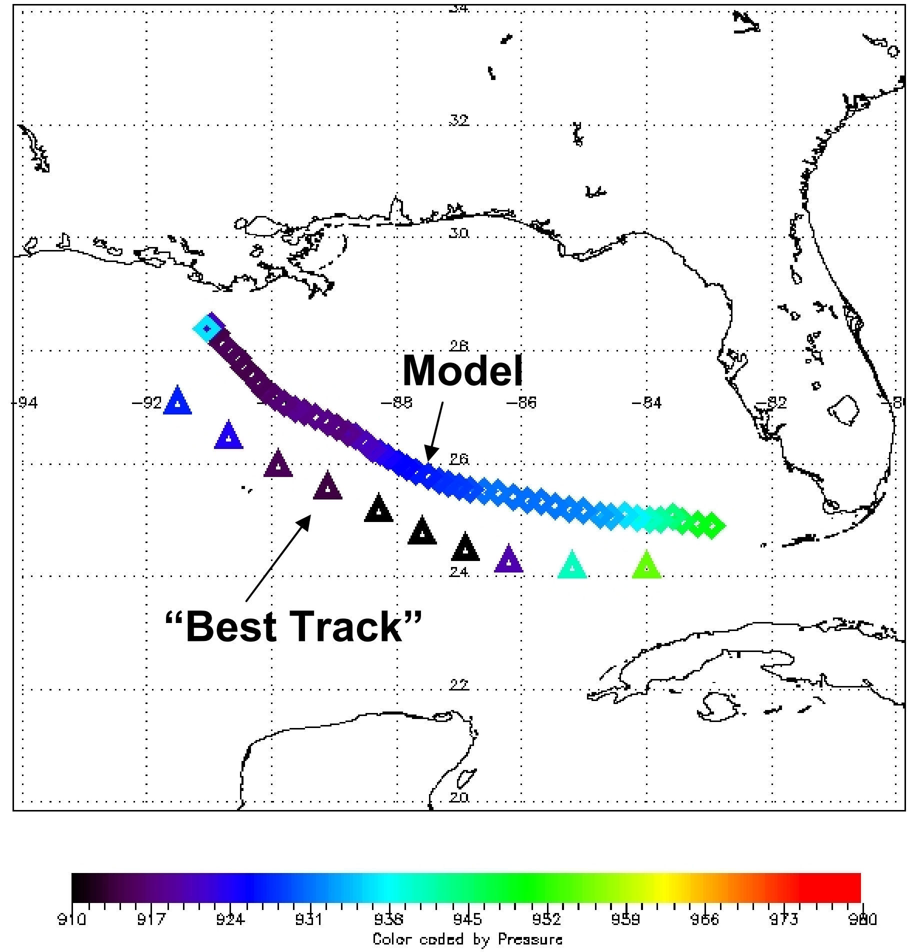
Evaluating hurricane simulations….

Tracks of simulated and observed storms

KATRINA - 2005

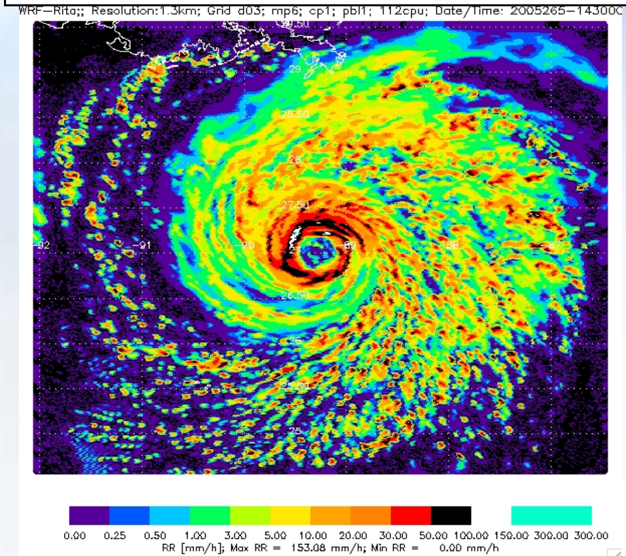


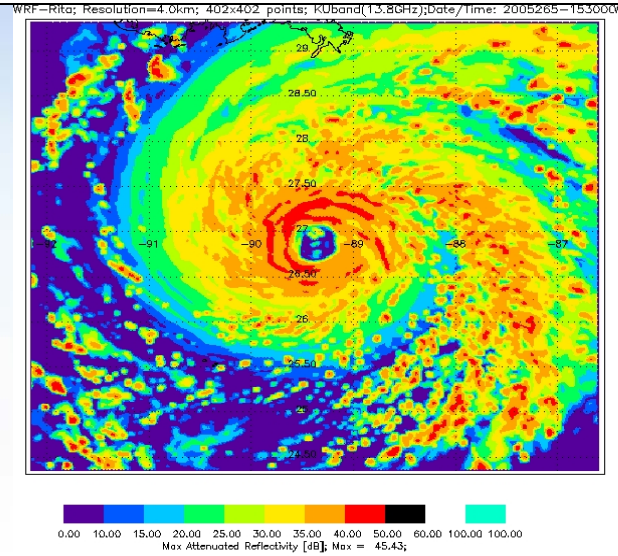
RITA - 2005

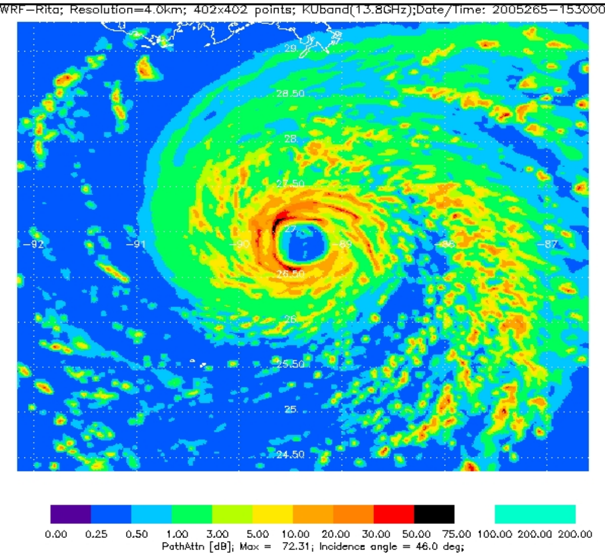


Instrument Simulators for Model Evaluation

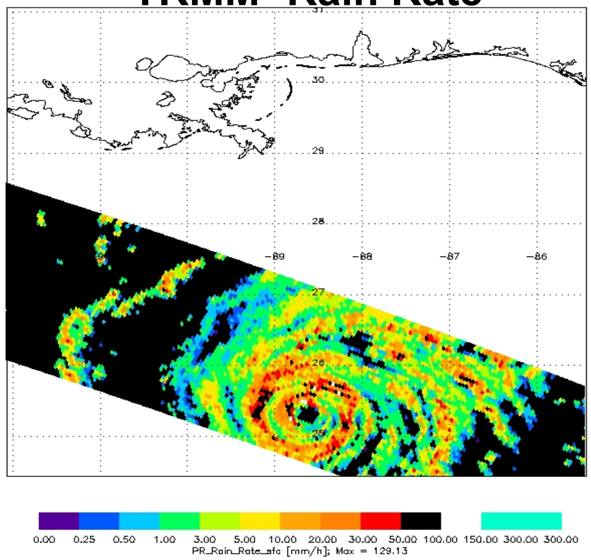
WRF - Rain Rate	WRF - max reflectivity	WRF - Path Attenuation



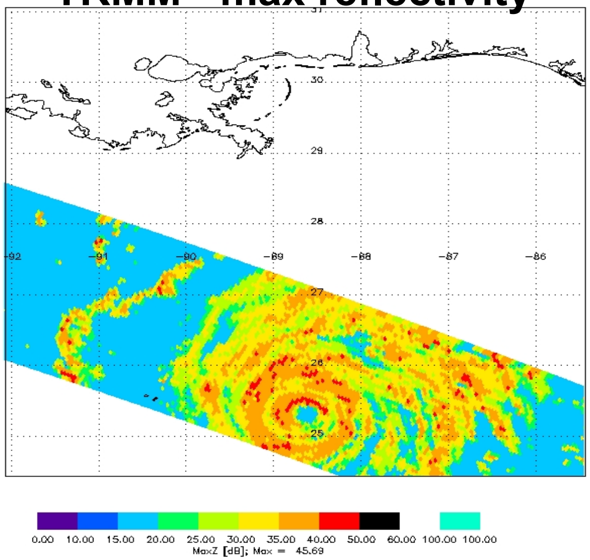




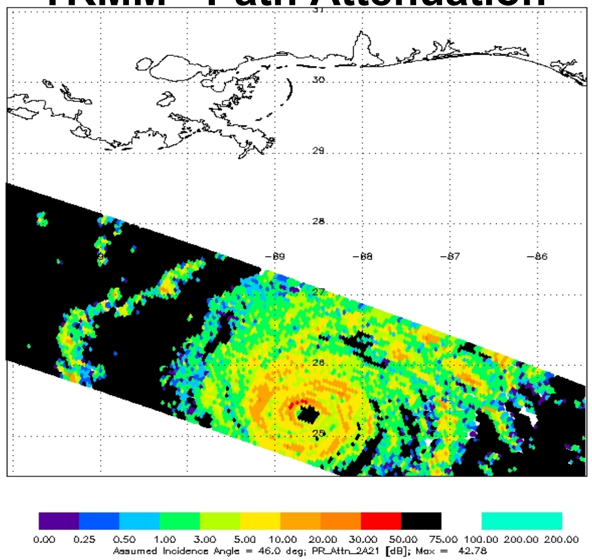
TRMM -Rain Rate



TRMM - max reflectivity



TRMM - Path Attenuation

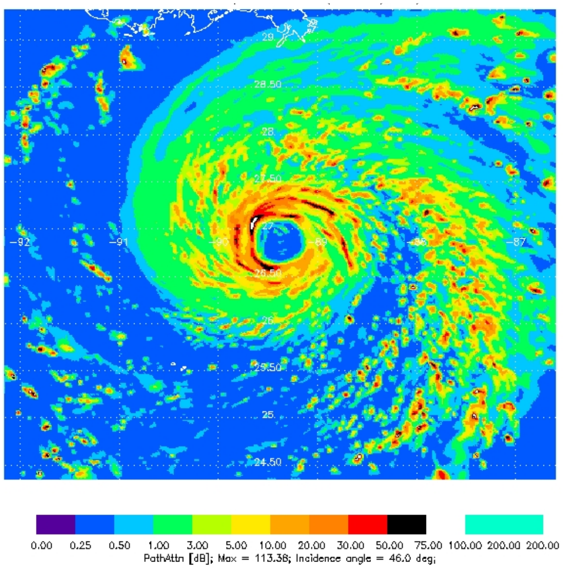


Hurricane Modelling and Instrument Simulators for Mission Design

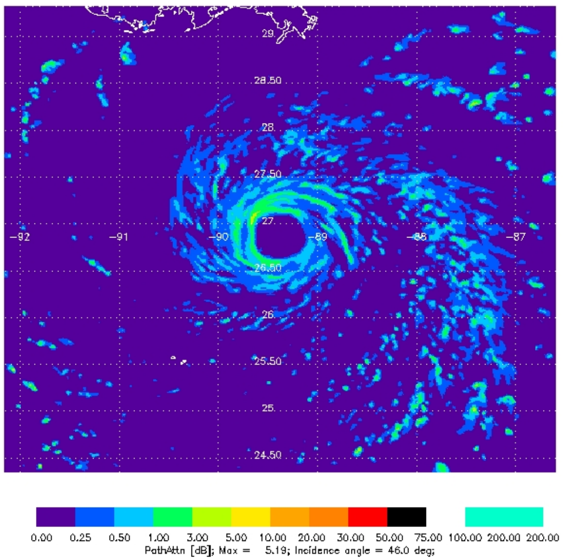
WRF output fields can be used as input to instrument simulators
(e.g. Volume Backscatter, Path Integrated Attenuation, Wind-Induced Sigma0)

Example: enable the design of the future scatterometers
by simulating rain-associated contributions to the wind sigma0
for Rita – 15:30Z, Sep. 22, 2005

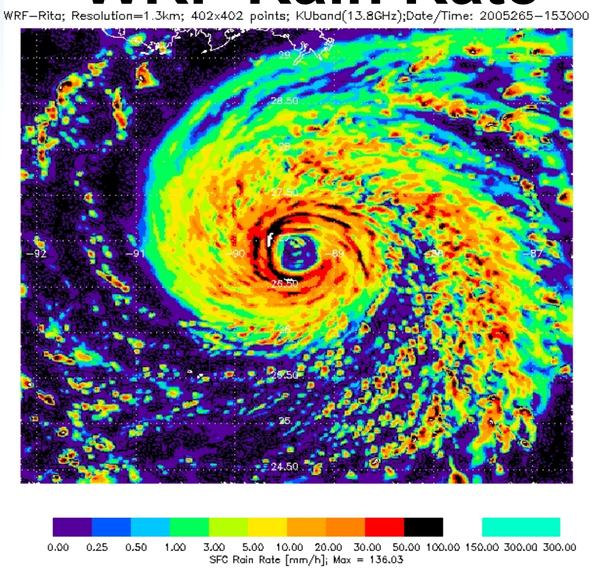
Ku band - Attenuation



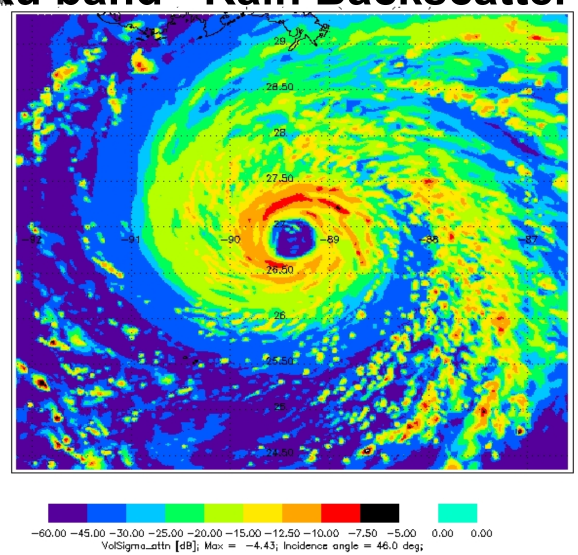
C band - Attenuation



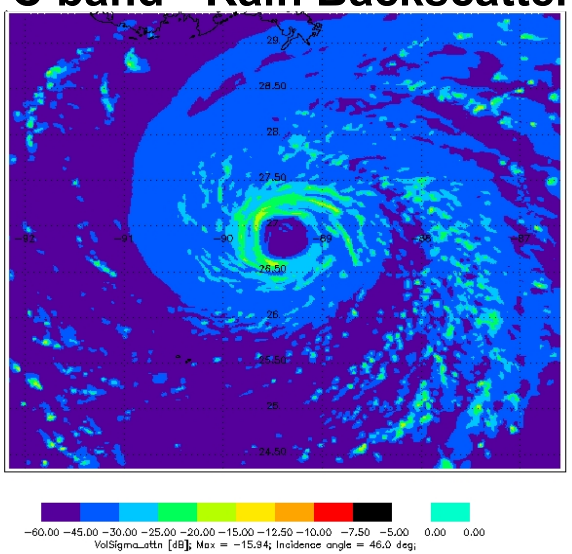
WRF Rain Rate



Ku band - Rain Backscatter



C band - Rain Backscatter



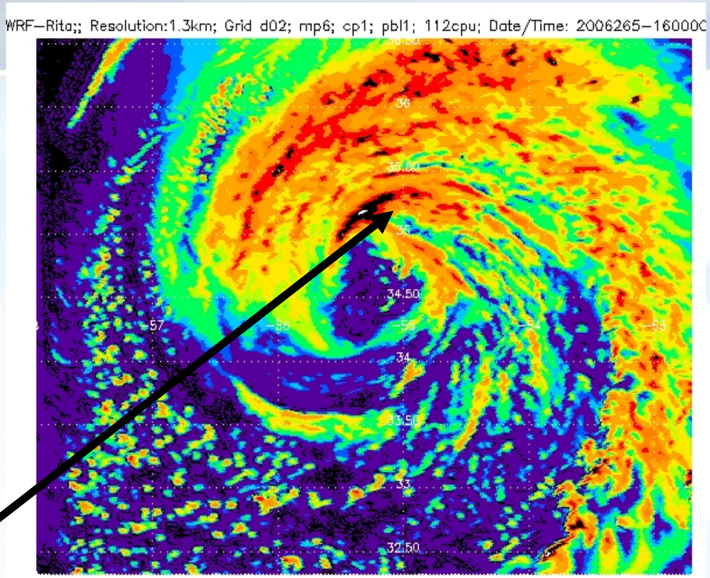
Evaluating Hurricane Simulations….

Impact of model microphysics

The treatment of microphysical processes in hurricane models has impact on the structure and the intensity of the forecasted storms.

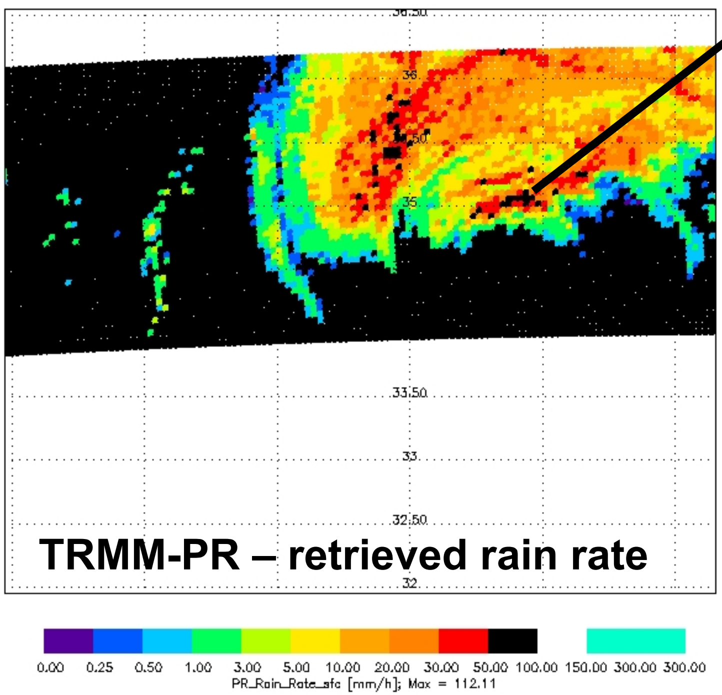
The question is whether satellite observations provide enough information to help select the microphysical parameterization that produces the most realistic storms.

Preliminary research shows that, indeed, satellite observations can help discriminate between simulations with different microphysics and select the most appropriate one.

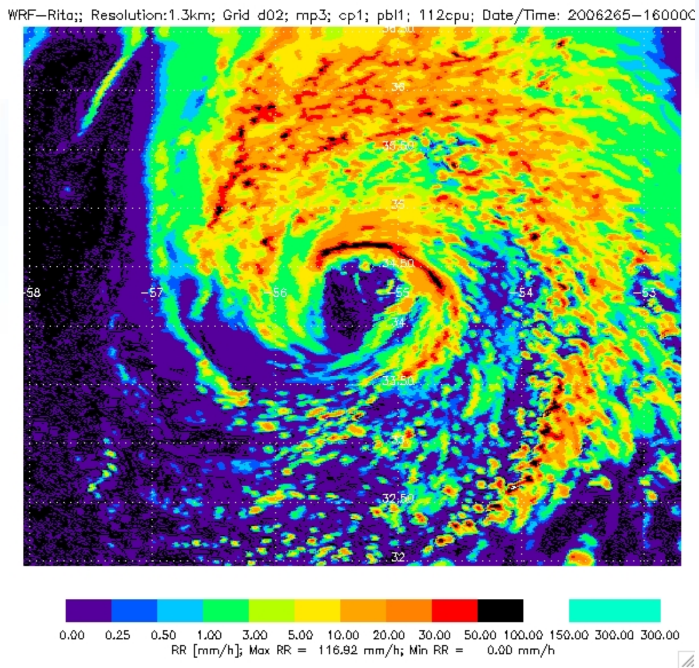


Micro6

Better?



TRMM-PR – retrieved rain rate

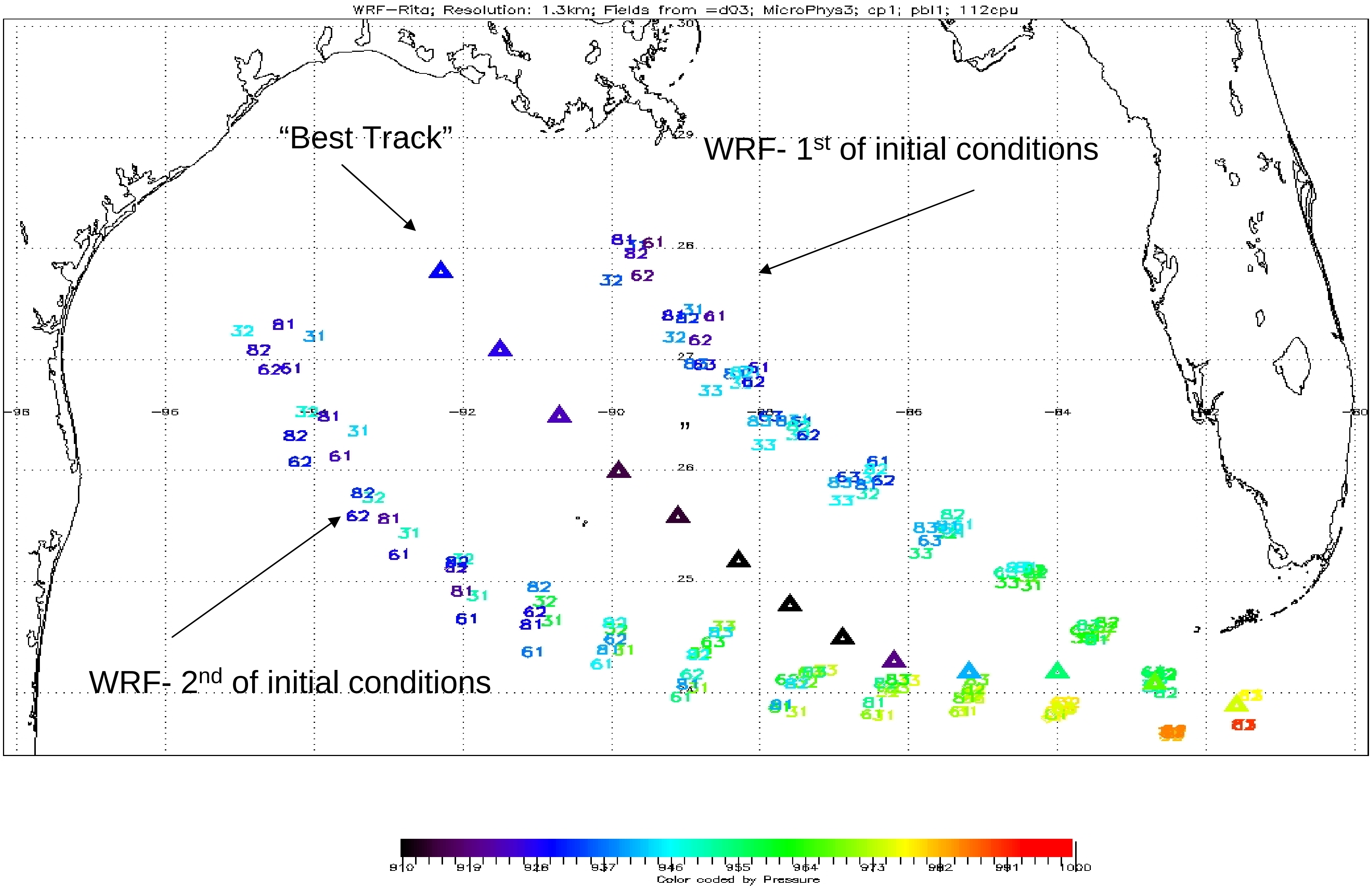


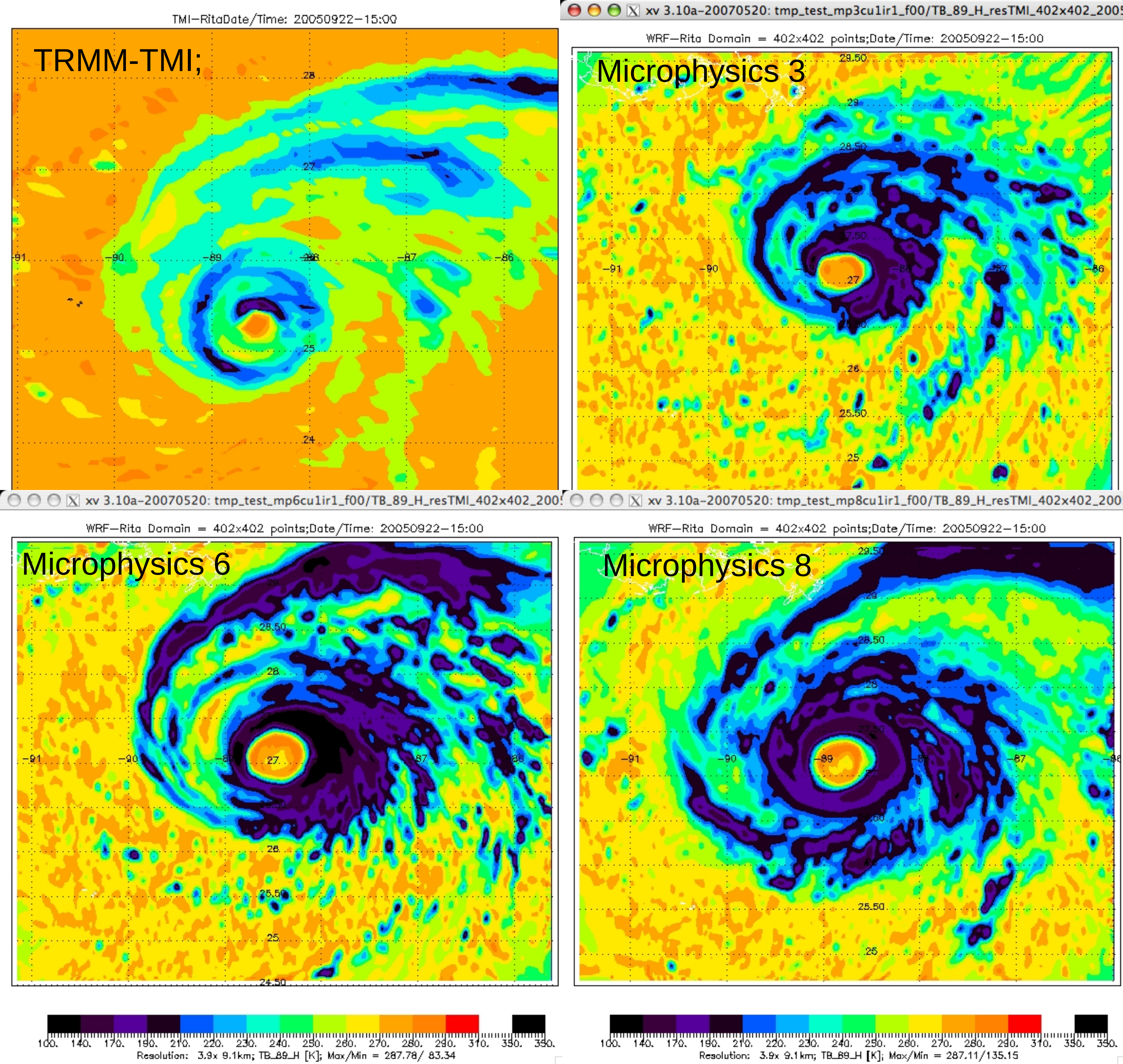
Micro3

31 - microphysics 3; convective scheme 1
32 - microphysics 3; convective scheme 2
33 - microphysics 3; convective scheme 3

61 - micro. 6; conv. 1
62 - micro. 6; conv. 2
63 - micro. 6; conv. 3

81 - micro. 8; conv. 1
82 - micro. 8; conv. 2
83 - micro. 8; conv. 3





Example of

Using

Instrument simulators

and

Object Comparison

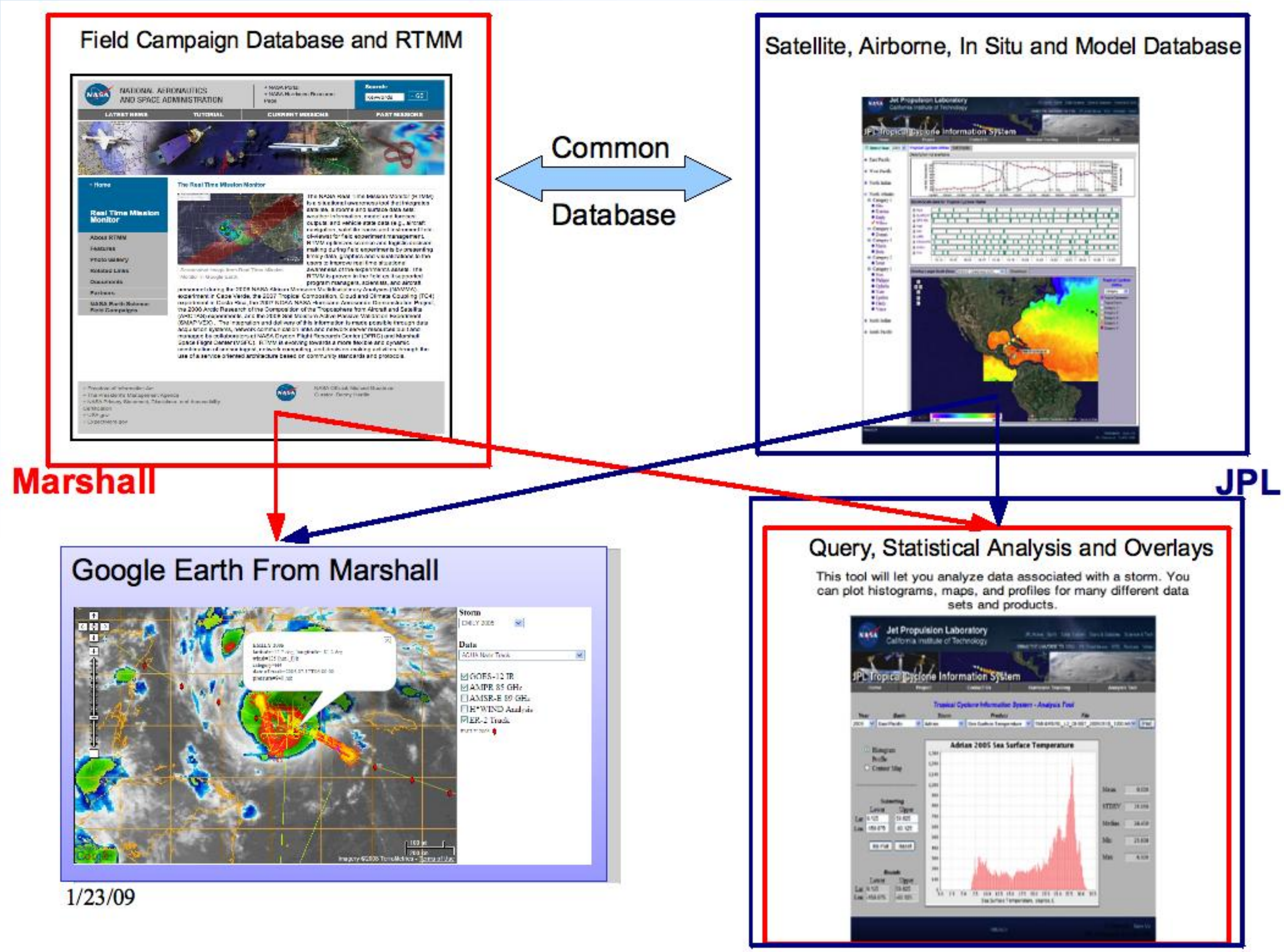
to investigate

the impact

of microphysics

on storm structure

Part 3: TC-IDEAS Combining Databases, Tools and Applications



The Components of TC-IDEAS

- **Observations**
  - Satellite, airborne, *in-situ*
  - Large scale and storm scale (centered on the storm)
  - Atmosphere and Ocean
  - Data and images - organized to determine coincident obs
- **Real Time Mission Monitoring (RTMM) and on-demand overlay of various observations**
- **High-resolution model simulations**
- **Instrument simulators**
  - (e.g. radar reflectivity, brightness temperatures etc. at the geometry of current and future missions)
- **Analysis tools**
  - Principal Component Analysis; CFADs (Contoured Frequency by Altitude Diagrams)
  - Multi-parameter, spatial and temporal covariances for use in data assimilation

Joint TC-IDEAS Tasks

1. Develop, populate and update a distributed inter-center TC-IDEAS database
2. Add high resolution model simulations
3. Increase functionality of the JPL analysis tools
4. Provide standards based visualization services for field campaign data
5. Develop a Google web browser plug-in application linked to TC-IDEAS database
6. Harvest additional historical satellite TC imagery with / without annotations and grids
7. Develop prototype near real time TC web site
8. Develop a tropical cyclone tracking tool

1. Develop, Populate and Update TC-IDEAS Database

– Add Airborne Field Campaign Data to JPL database; Available for analysis and download from there as well as from MSFC

FY	2009	2010	2011	2012
	TSCP	NAMMA & GRIP	CAMEX-4	NHC/HRD?

– Add New Data Types

- Add AMSR-E and global IR data (8km resolution, hourly data)
- Consider adding SSM/I, SSMI/S
- Anything else ?

– Add More years

FY	2009	2010	2011	2012
Current Year	Yes	Yes	Yes	Yes
Previous Years	Finish CY2005	CY2006	CY2001	2007 &2008

- Other suggestions ??
- Global or over the Atlantic and East Pacific only ?

2. Add High Resolution Model Simulations

- **Develop the framework for including high-resolution model simulations in TC-IDEAS. This task has three components**
  - including the model simulations in the database
  - incorporating them in the analysis system; will address issues related to sampling equalization (subsetting and resolution adjustments) needed for satellite-model comparison.
  - making them available for input into the instrument simulators during the last year of the project.
- Use only a limited number of model simulations to illustrate the capability.
  - Will include the already produced at JPL WRF high-resolution simulations of: Katrina (2005); ensemble simulations of Rita (2005) and several simulations of Helene (2006).
  - Will consider the including a limited number of simulations from HWRF
  - Inclusion of additional model simulations available from the community will be made at a later time, given additional funding opportunities.
- We will present the plan to the Science Team at the end of the first year and will ask for input on priorities and strategies.

3. Increase Functionality of the JPL Analysis Tools

- **Increase the functionality of the analysis tools**
  - adding time-series analysis (lead/lag);
  - developing ability for temporal and spatial subsetting and composites;
  - convective/stratiform separation algorithm
  - development of Principal Component Analysis, CFADs and Skew-T analysis;
  - adding multivariate analysis including joint PDFs, scatter plots, conditioned subsetting, computation of covariances.
- A special effort will be dedicated to developing model-observations comparison strategies and visualization. An emphasis will be put on developing sampling equalization as a component of the model-observations comparison.
- Instrument simulators will be developed in a companion effort sponsored by AIST and lead by Dr. Simone Tanelli of JPL. The instrument simulators will be incorporated in the TC-IDEAS during the fourth year of the project.

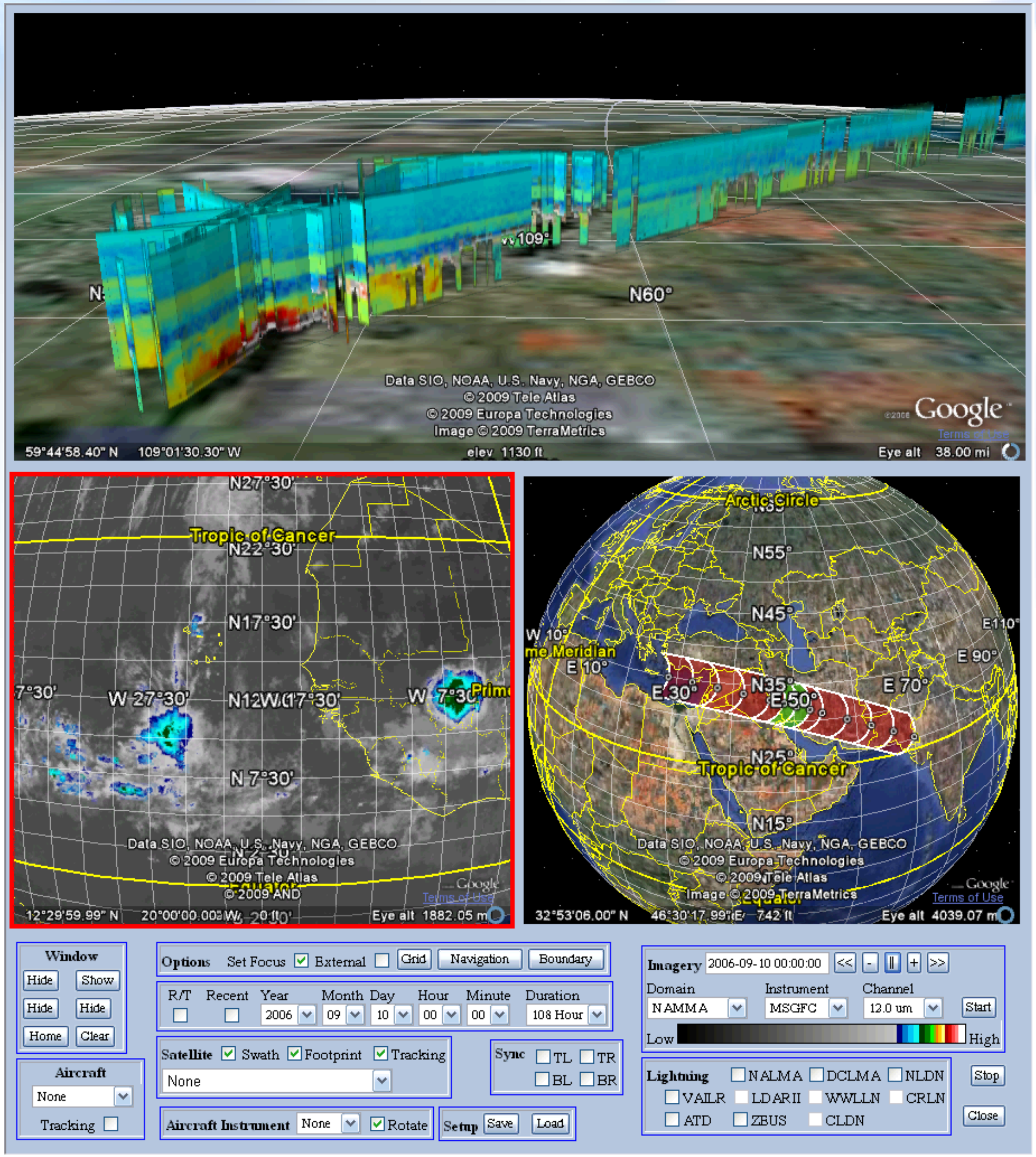
4. Provide Standards-based Visualization Services

- Implement and apply Open Geospatial Consortium standards and protocols
  - Web Map Services (WMS)
  - Sensor Observation Services (SOS)
  - Time-enabled Keyhole Model Language (KML)
- Users may import / integrate standards-based data into own visualization systems

5. Develop Google Apps Linked to TC-IDEAS Database

Simultaneous multiple views

Animations, looping, storm tracks, and aircraft tracks

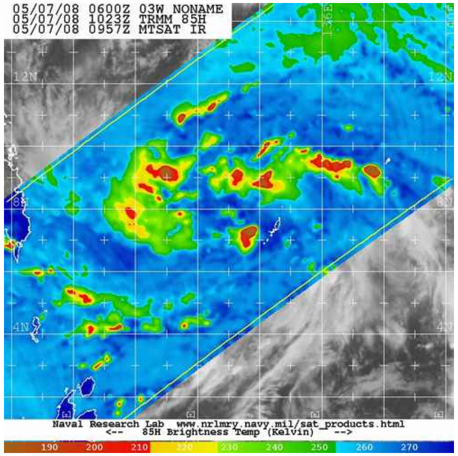


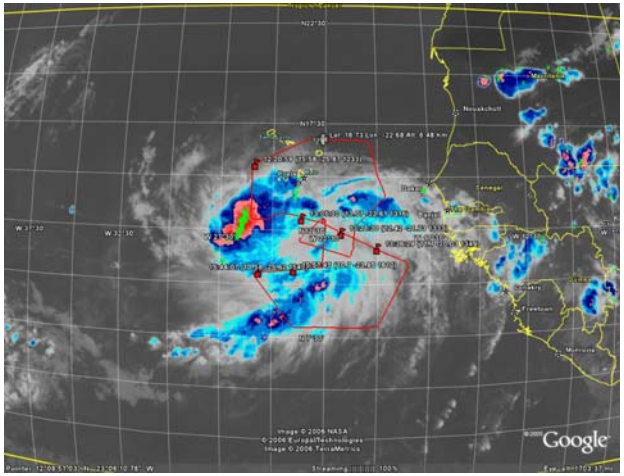
Curtain views

Real time and predictive satellite tracks

6. Harvest Additional Historical Satellite TC imagery

- Harvest satellite database
- Two sets of imagery will be generated
  - With gridlines and/or boundaries
    - For standalone services
  - Support for virtual Earth applications
    - No overlay annotations, no grid lines nor boundaries





7. Develop Prototype Near Real Time TC Web Site

- **Separate component designed to reflect the needs of a field campaign operation**.
  - develop capability for creating a database of NRT satellite products and connect them to the analysis system.
  - develop imagery - the images will be displayed in both the NRT TC-IDEAS framework as well as in the RTMM.
  - The goal is to set up a system that could be operational during the 2010 GRIP field campaign.
- During the first year - develop the NRT TC capabilities and test the system on a couple of cases.
- The development will involve testing the NRT latency of a number of satellite data **(e.g., TRMM, CloudSat, AMSR-E, AIRS, AMSU, MLS, OMI, GOES, MODIS, QuikSCAT, JPL Global 1-km SST (G1SST), OHC, LIS and surface lightning, buoy, some forecast model …).**
- We will present a status at the next HSRP science team meeting and seek feedback on instruments and products to be included

8. Develop a Hurricane Track Tool

- Create a map of all historical hurricane tracks for a given time period (possibly from 1980s through to the present date).
    - Requires evaluation and reconciliation of existing storm track databases at JPL, MSFC, NHC and IBTrACS (International Best Track Archive for Climate Stewardship) database.
    - Using Google Maps technology, display any or all the tracks of a given hurricane season in a particular basin or globally.
    - MSFC will leverage existing OGC WFS and SOS services to provide standards-based access to these storm tracks for interactive display (e.g., to RTMM).
  - Allow users to run basic statistical analyses for each hurricane season (on a basin or global basis).
    - average wind speed, average pressure, min and max storm counts, and frequency of a particular storm category – all for a user-defined set of seasons.
    - query storm tracks by basin, year, month, landfall, genesis location, and lifespan.
- As with all our efforts, we will seek Science Team input for the priority and the scope of this task

More Information

To learn more about RTMM and to view movies and playbacks of individual flights, please go to the RTMM web site at:

http://rtmm.nsstc.nasa.gov

To learn more information about TCIS, search for specific storms, directly access data, and plot histograms, maps, and profiles for many different data sets and products, please go to:

http://tropicalcyclone.jpl.nasa.gov/hurricane/

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