The Experimental HWRF-HEDAS system:

Model Evaluation in Preparation for Satellite Microwave Data Assimilation Inside the Hurricane Precipitation Area

Svetla Hristova-Veleva[1], Sundararaman Gopalakrishnan[2], Tomislava Vukicevic[2], Ziad Haddad[1] and Thiago Quirino[2]

[1] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 91109
[2] NOAA/Hurricane Research Division/Atlantic Oceanographic Meteorological Laboratory, Miami, FL

Motivation – the large-scale models

- Data assimilation of satellite observations outside precipitation has lead to significant improvement in the global models' representation of the synoptic environment.
  - This resulted in measured improvement in their hurricane track forecast skill.
- Improving the forecast accuracy of hurricane intensity changes remains very challenging because of:
  - limited ability, due to the use of convective parameterizations
  - Cannot resolve convective scale events and their interaction with the large-scale environment.

Motivation – the regional models

- **Inner-core dynamics are important - need to properly reflect small scale complex processes**
  - **high-resolution regional models**
  - **realistic physical parameterizations**
- There is still large uncertainty regarding the assumptions used by the convective-scale parameterizations:
  - parameterizations of the microphysical processes,
  - the boundary layer processes and
  - the ocean-atmosphere fluxes, etc.
- **Need to improve hurricane forecasts by**
  - **Validating and improving the models**
  - **Advanced assimilation of observations inside the hurricane precipitating core to produce a more realistic initialization of the asymmetric structure of the hurricane vortex.**

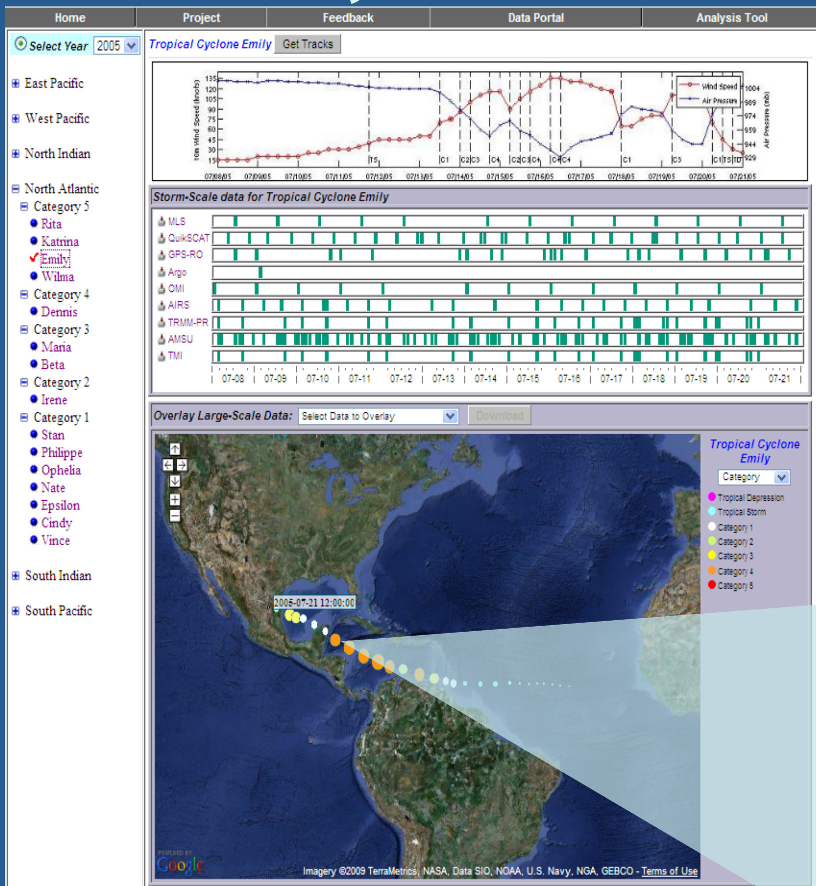
How to Evaluate the Models

- In situ 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 model physics 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**

Tropical Cyclone – Integrated Data Exchange and Analysis System (TC-IDEAS) –funded by NASA's **Hurricane Science Research Program**

Joint NASA Jet Propulsion Lab and Marshall Space Flight Center Project

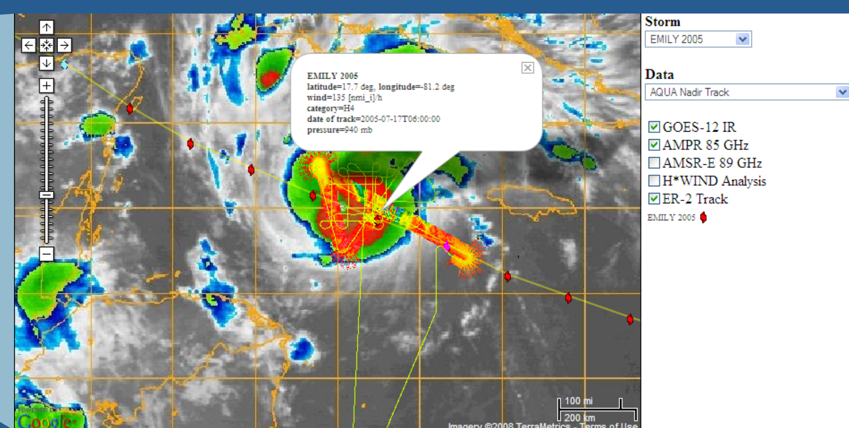
The JPL iTCIS



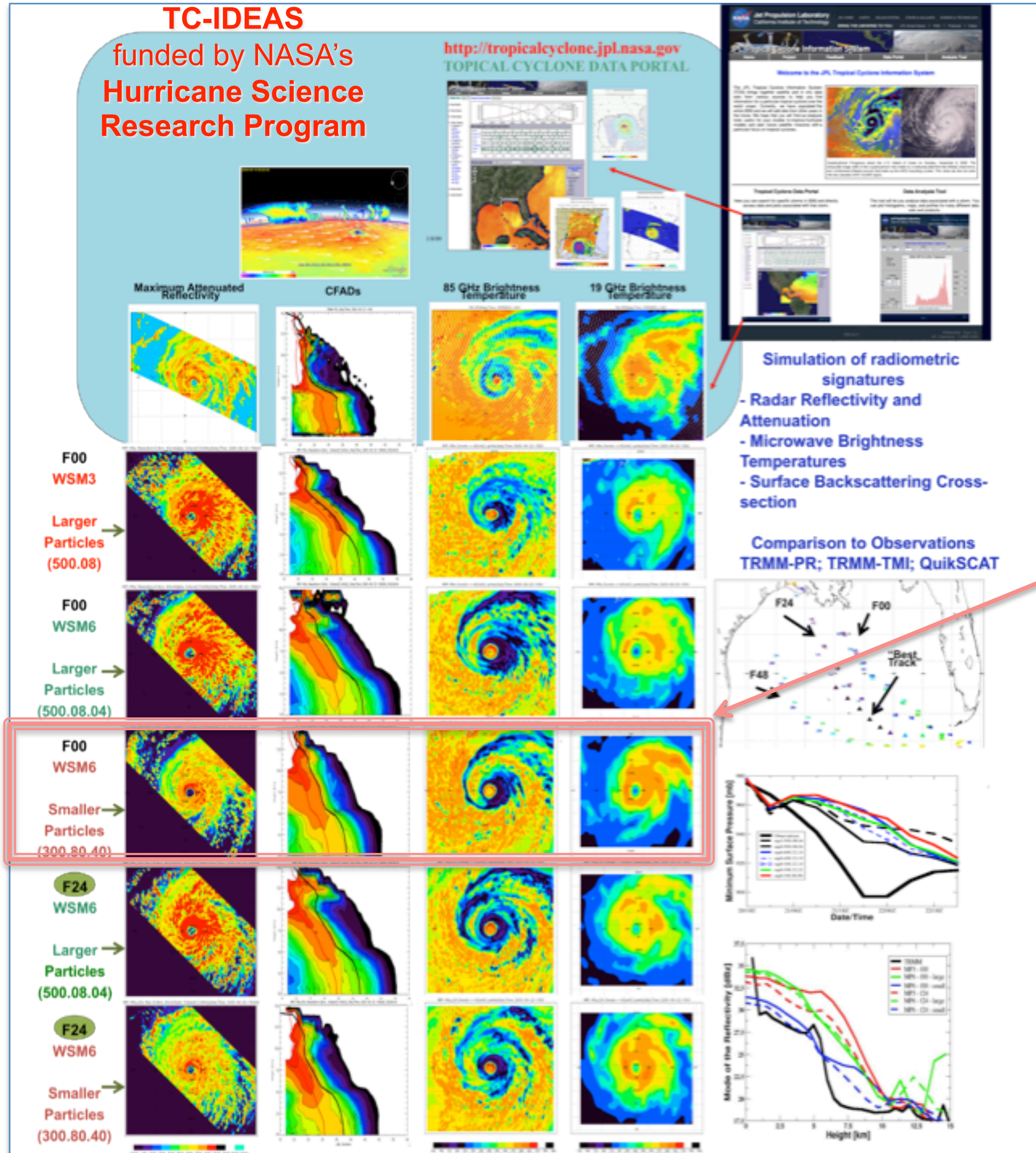
Select by basin, name, or category with corresponding data availability timelines

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
- 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 overlaid on GOES IR



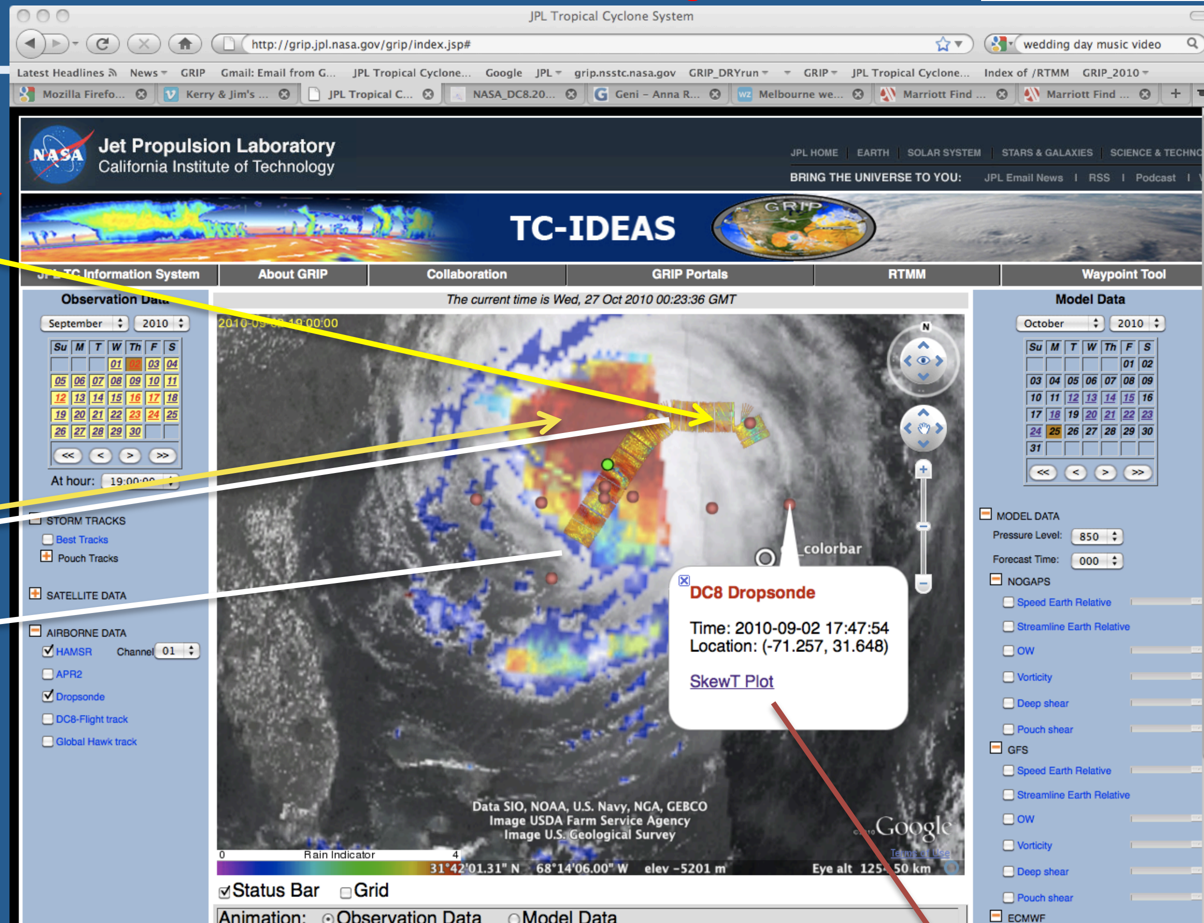
- Using instrument simulators and multiparameter satellite observations we can discriminate between WRF model forecasts using different microphysical assumptions.
- Assuming hydrometeor distributions with smaller particles results in model forecasts with radiometric signatures that are closer to observations.
- Will have impact in two ways:
  – providing guidance on the optimal set of physical parameterizations
  – improving the data assimilation outcome by designing model forecasts whose radiometric signatures are close to the observed ones, increasing the relative importance of the observations during the assimilation.
- Improved understanding of the PSD characteristics will lead to decrease in the uncertainty of satellite retrievals of precipitation.

Hurricane Earl in the JPL GRIP portal

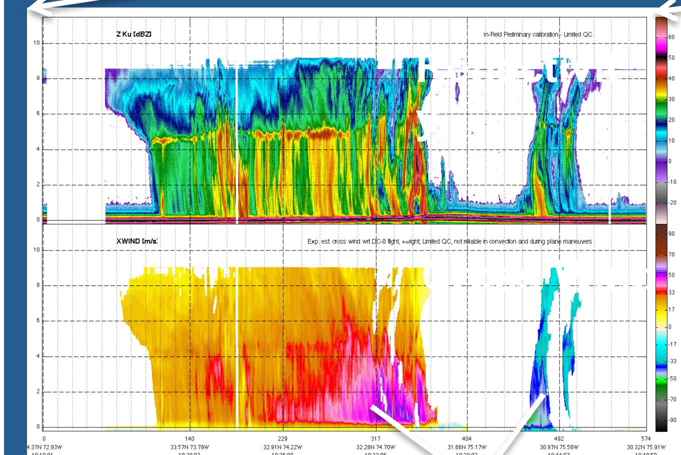
http://grip.jpl.nasa.gov

JPL participated with two instruments (**HAMSR** and **APR2**) and the JPL GRIP portal which blends satellite and airborne observations with model data. The dedicated portal was developed to facilitate the 2010 NASA/NOAA/NSF hurricane field campaigns

Rain from AMSR-E on AQUA

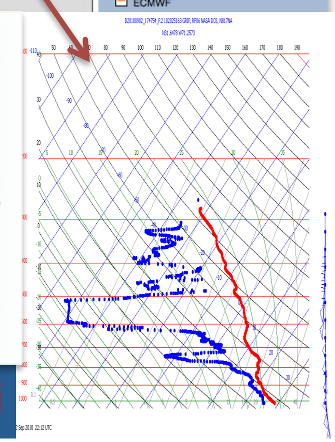


APR2



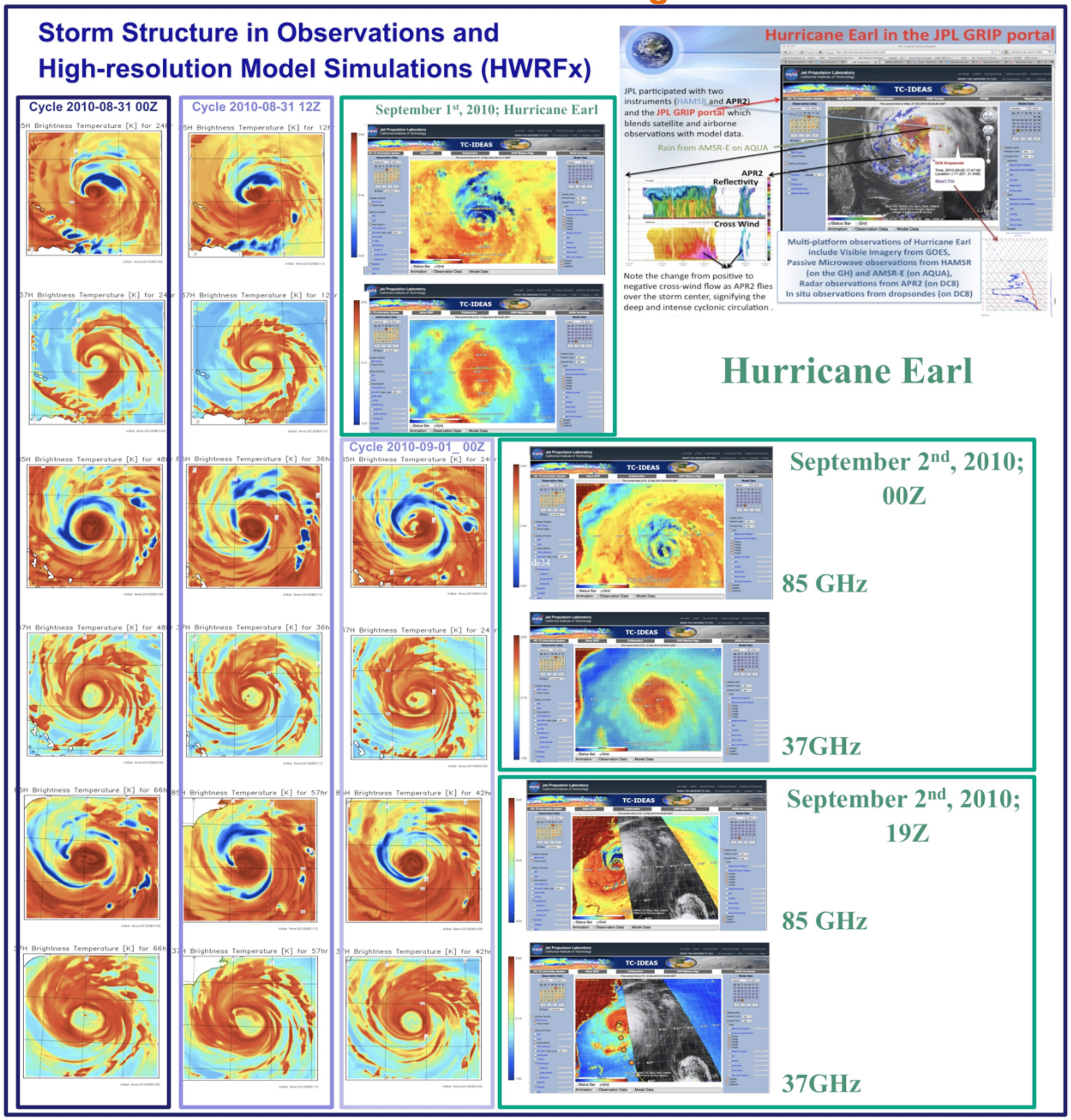
Note the change from positive to negative cross-wind flow as APR2 flies over the storm center, signifying the deep and intense cyclonic circulation .

Multi-platform observations of Hurricane Earl include Visible Imagery from GOES, Passive Microwave observations from HAMSR (on the GH) and AMSR-E (on AQUA), Radar observations from APR2 (on DC8) In situ observations from dropsondes (on DC8)



S. Durden, S. Hristova-Veleva, B. Lambrigtsen, S. Tanelli

Poster # A41B-0086 - 2010 Fall AGU meeting – Hristova-Veleva et al.



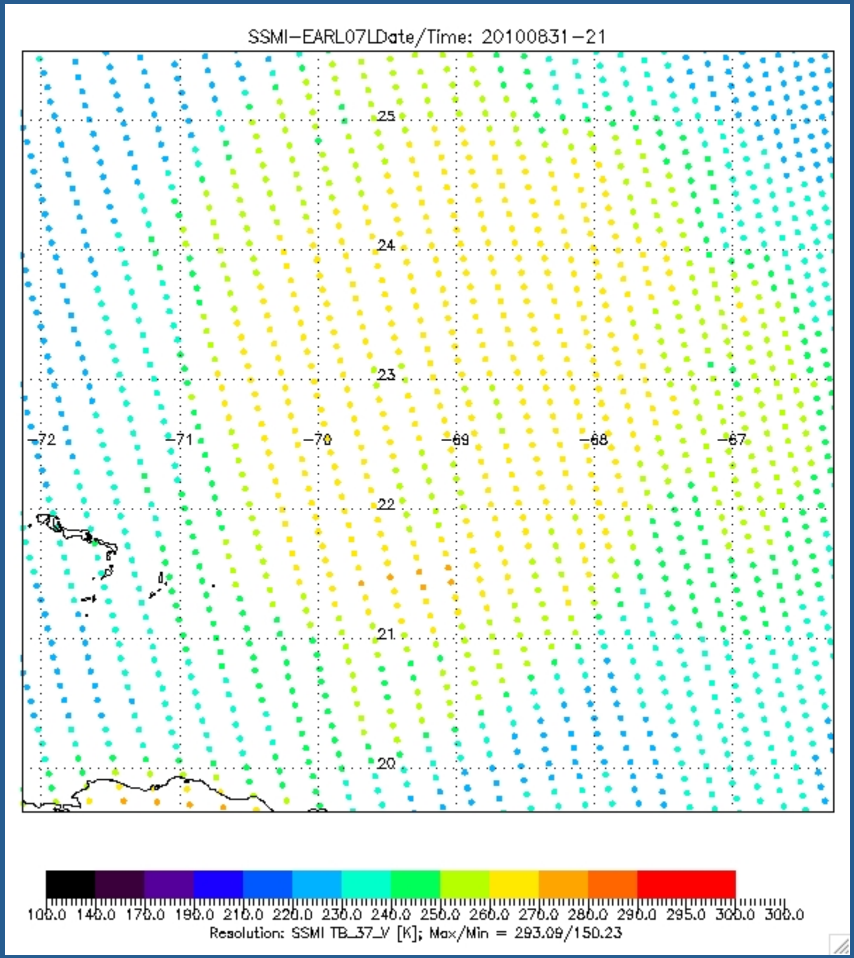
- Used the JPL GRIP portal to identified a number of cases to use for the evaluation of different hurricane forecasts.
- Focused on evaluating the the Experimental version of HWRF (HWRFX) in forecasting **hurricane Earl.**
- In a previous study, used the model forecast of the thermodynamic and hydrometeor fields to forward simulate satellite observables (HRD).
- Compared the structure of the observed and forecasted storms (from the brightness temperatures at 37 and 89 GHz channels). Found that the model was highly capable in depicting the 2D structure of the precipitation field and its evolution.

Beyond the image comparison …

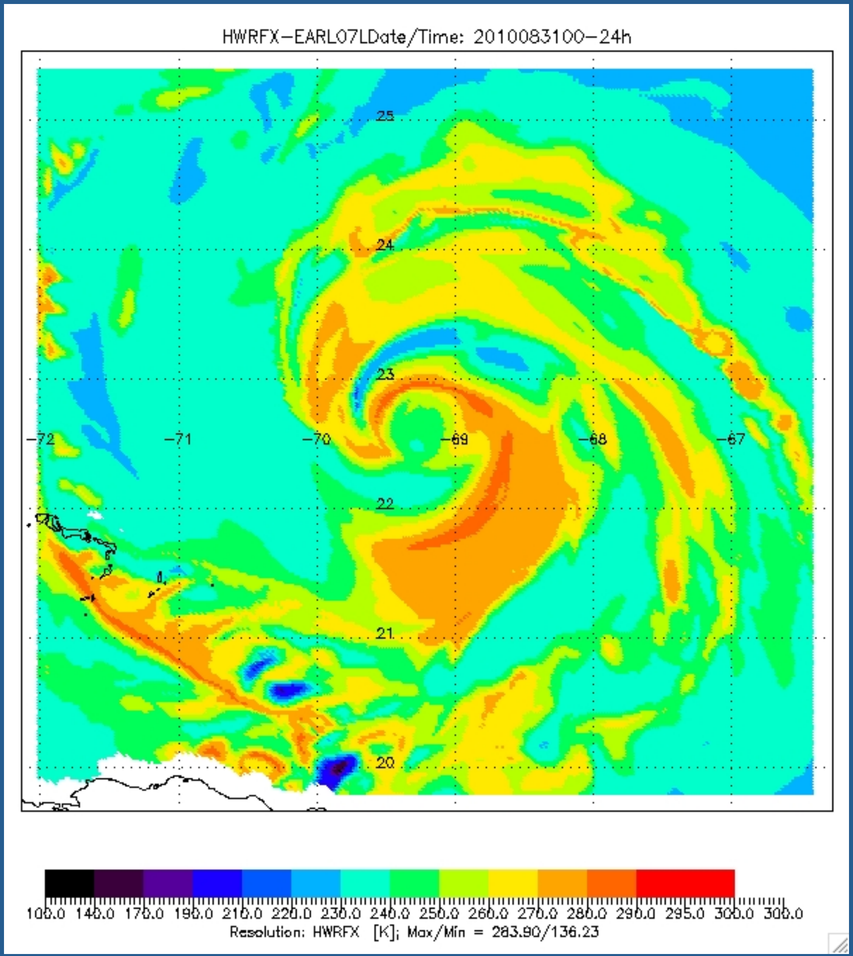
- In this study we again use the **HWRFX model forecast** of the thermodynamic and hydrometeor fields to forward simulate satellite observables **(brightness temperatures computed at HRD)**
- We use the digital data to evaluate the model forecast. We consider the impact of:
  - **Satellite sampling**
  - **Resolution of the satellite data**
  - **Physics-induced biases**

Sampling

SSMIS



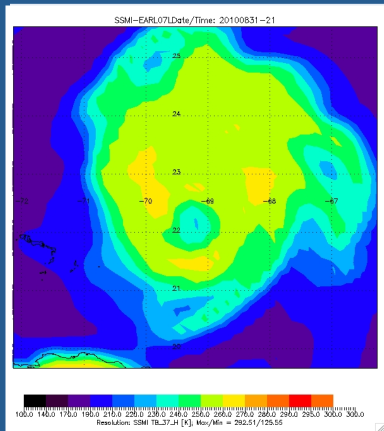
HWRFX



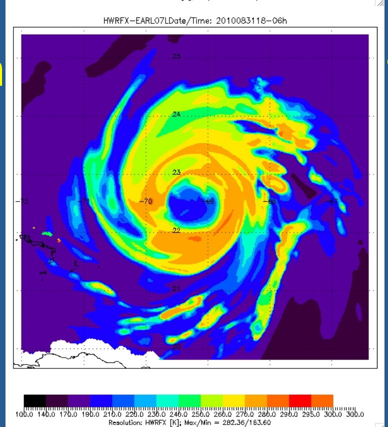
37 GHz H pol – September 01 2010 - Resolution

- Observed
- HWRFX – at the model resolution
- HWRFX – antenna-convolved to simulate brightness temperatures at the satellite resolution (37GHz - 27.5 x45.0km; 91GHz - 13.2x15.5)

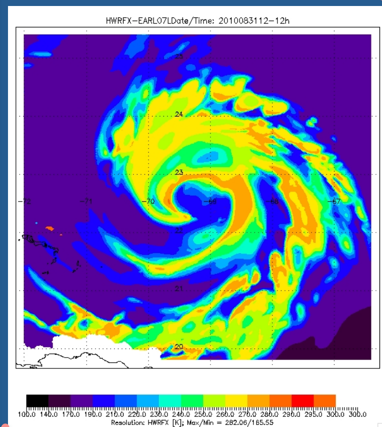
Observed



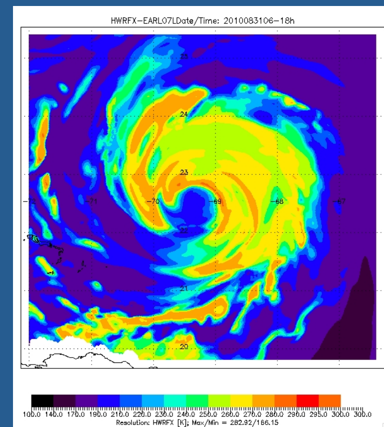
06h



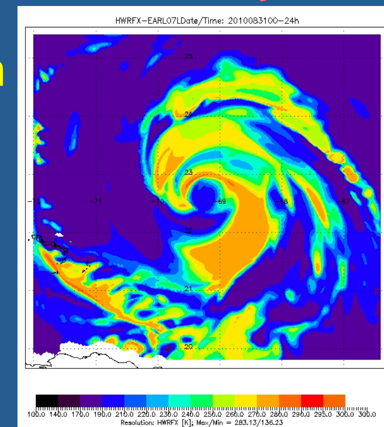
12h



18h



24h



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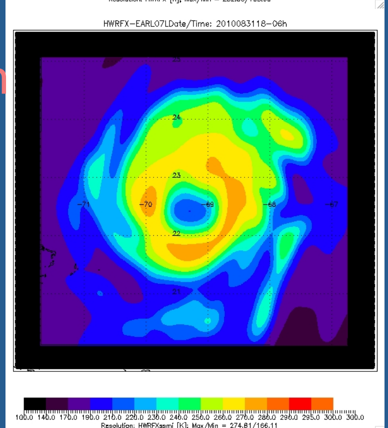

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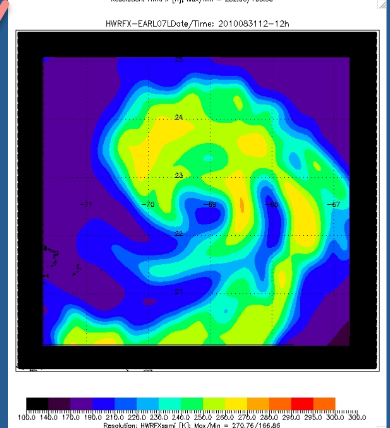

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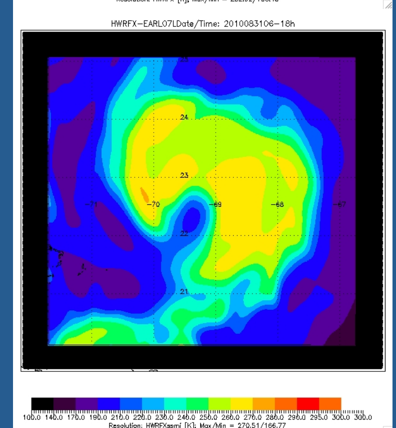

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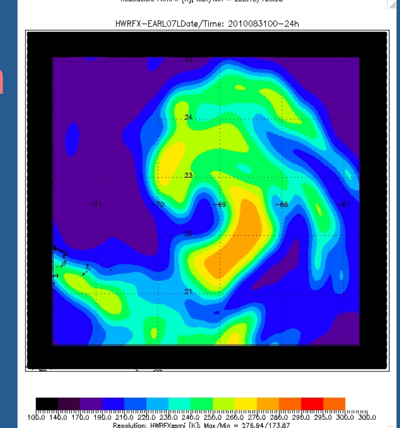
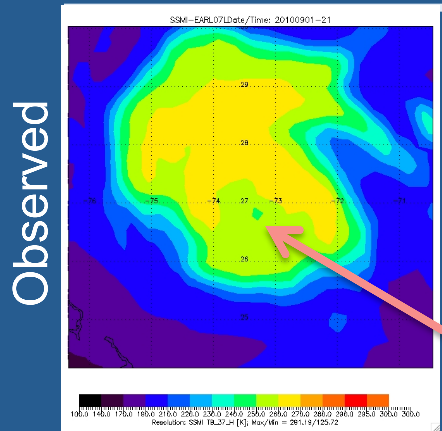
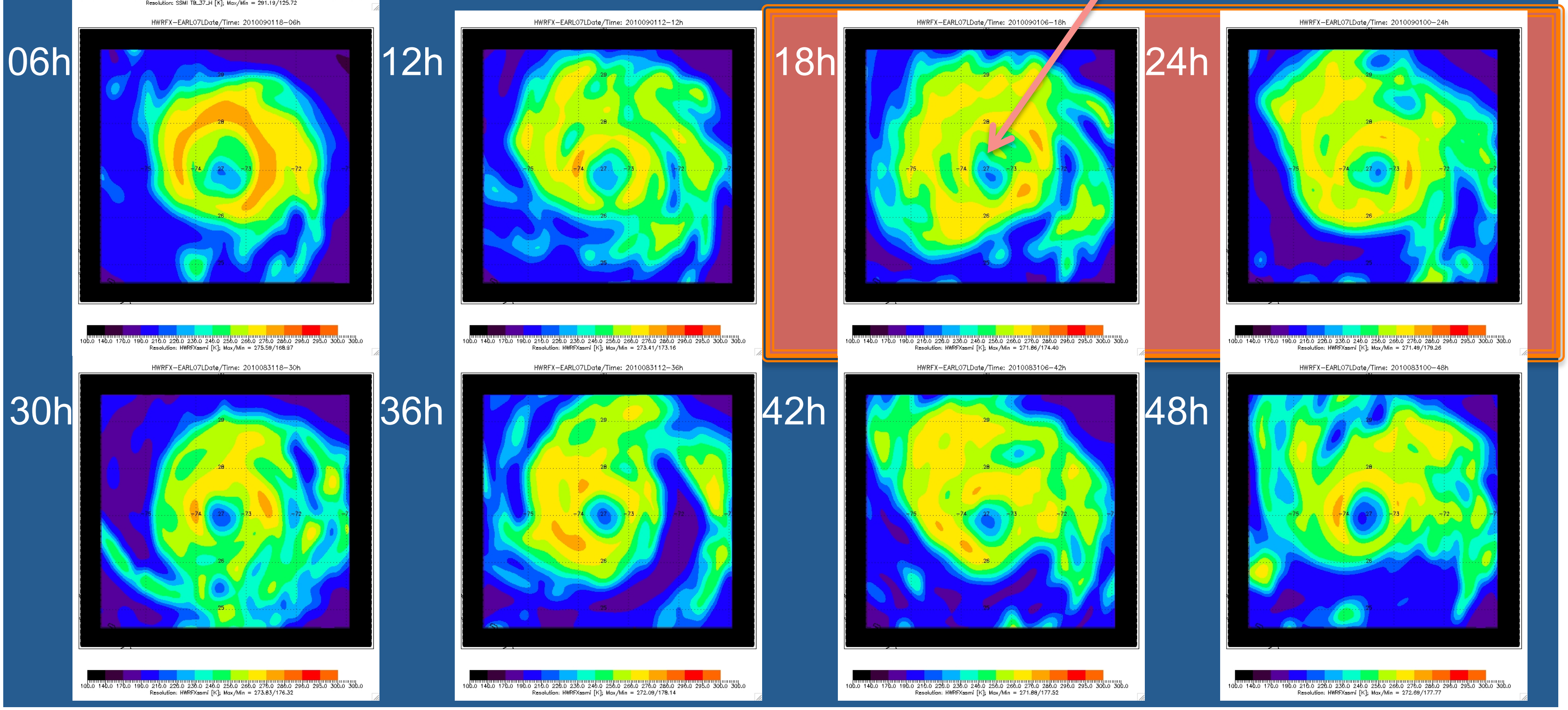


Structure

37 GHz H pol (satellite resolution) – 02 Sept. 2010

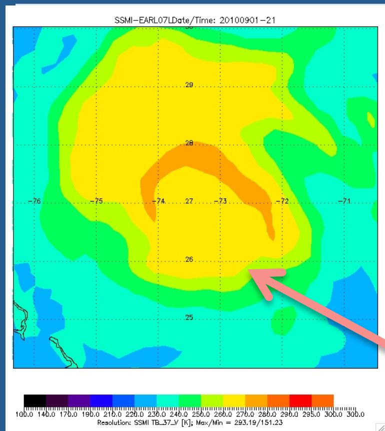
- Note that the realistic storm structure does not develop until **(12) 18 – 24h** into the forecast cycle
- The realism decreases after the 42h forecast
- The model has a well defined eye, not so visible in the observations.





Structure

37 GHz V pol (satellite resolution) – 02 Sept. 2010



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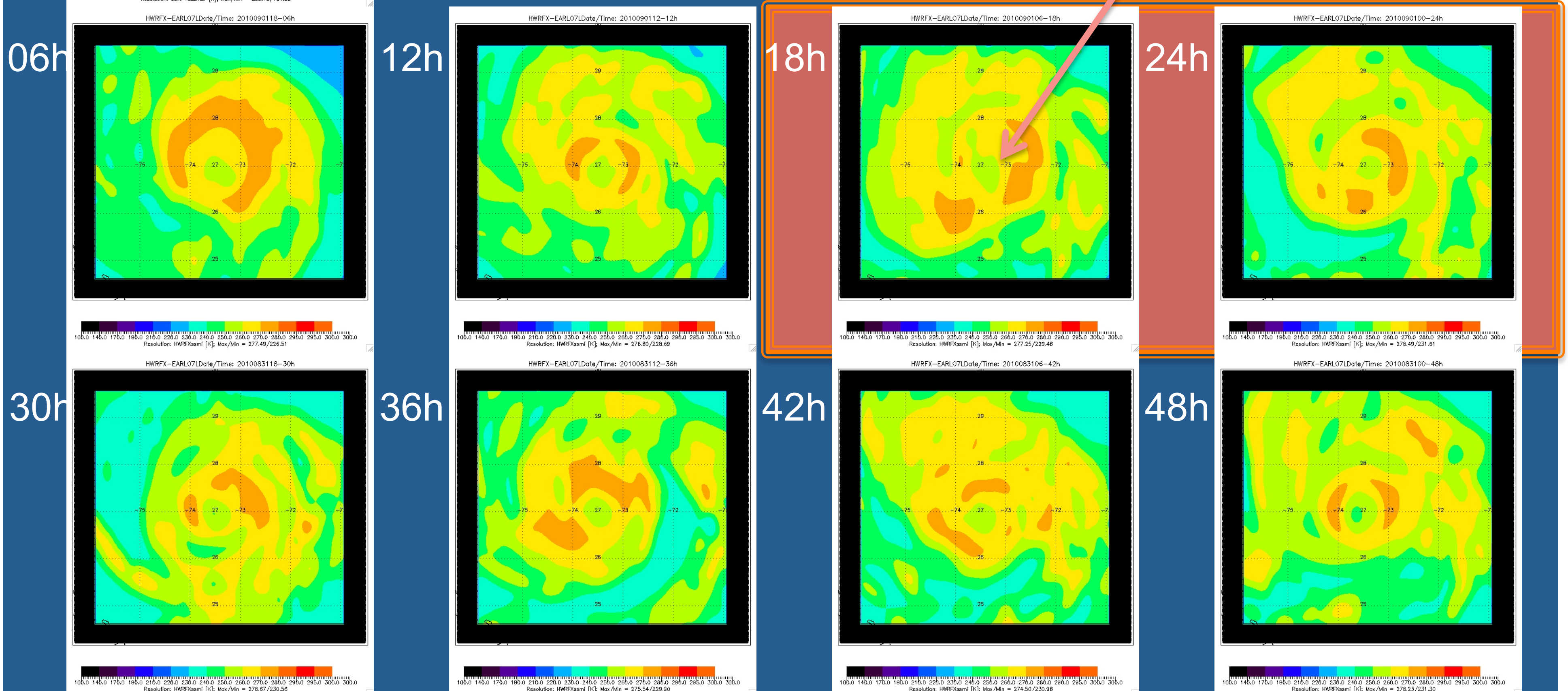
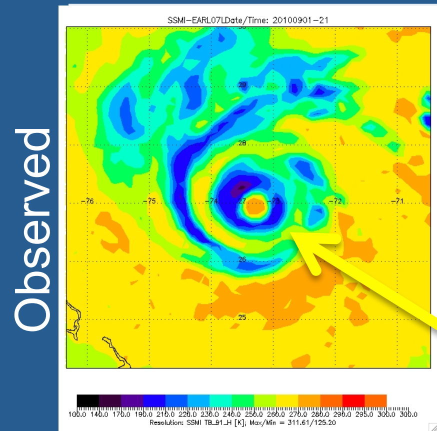


STRUCTURE

85/91 GHz H pol (sat. resolution) – 02 Sept. 2010



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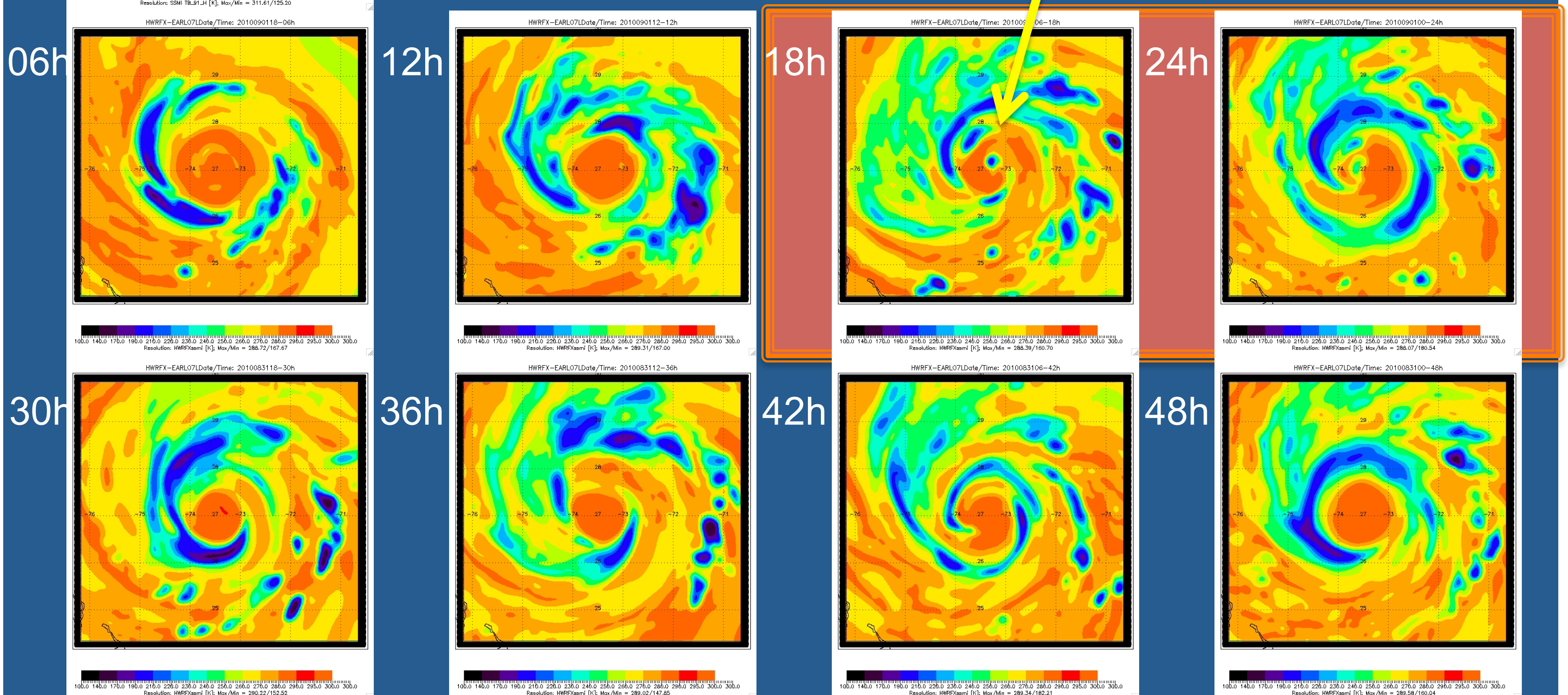
- **The model has a very large eye and does not show the observed eyewall replacement cycle**



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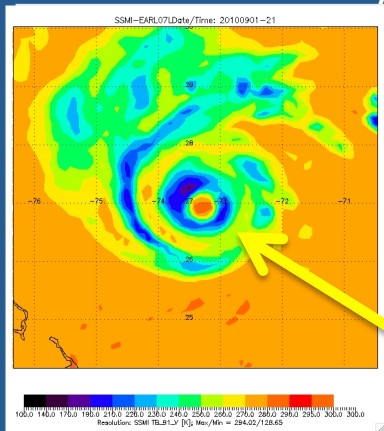
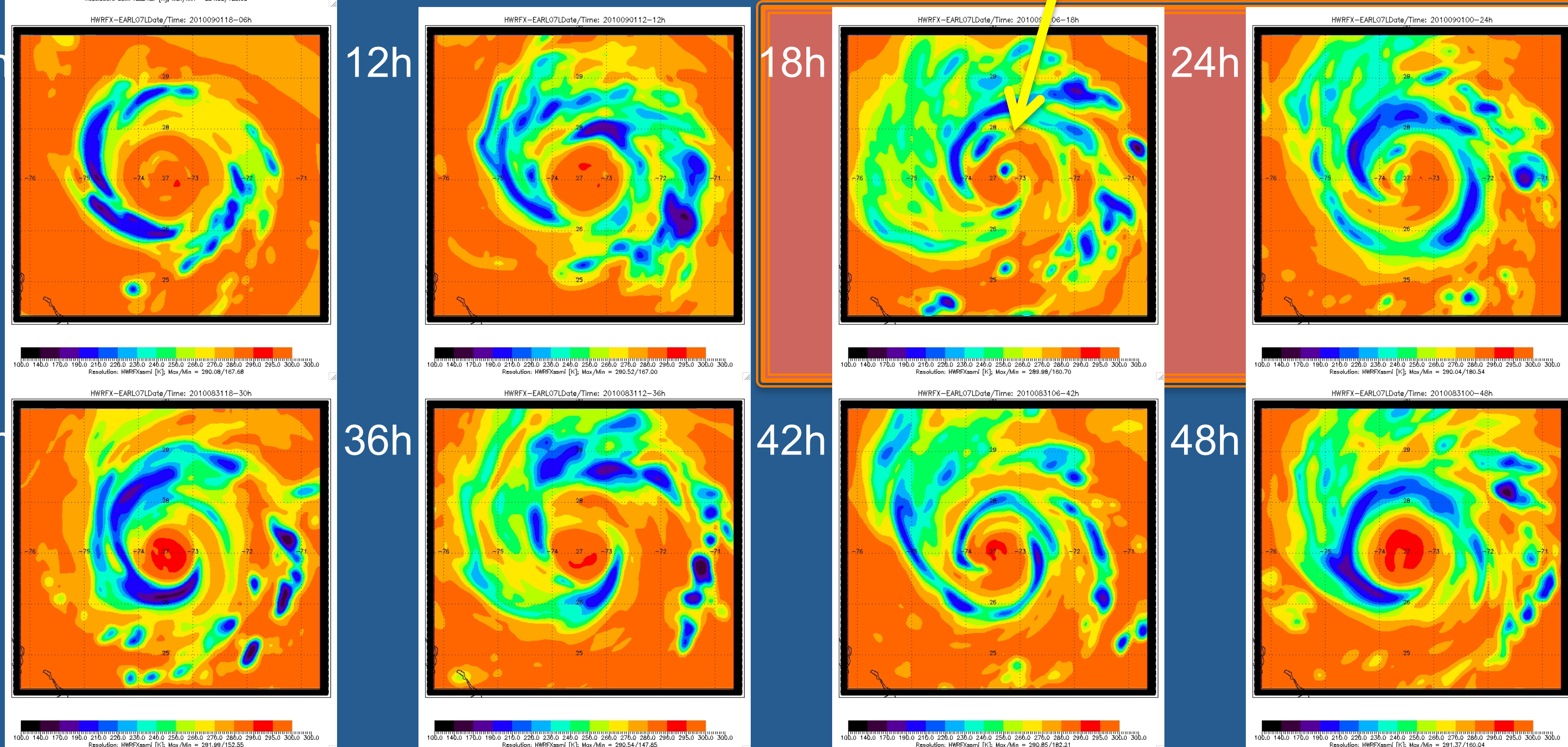
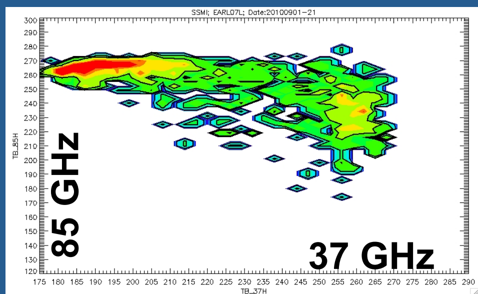




Statistical Comparison – Joint PDFs

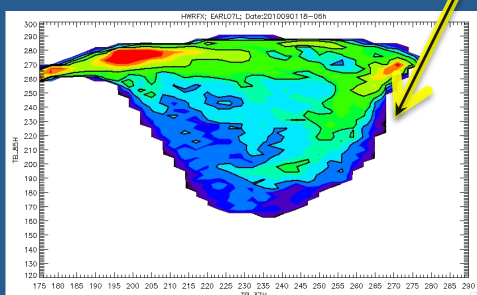
(85H/37H)(sat. resolution) – 02 Sept. 2010

Observed



- The statistical relationship between the 37GHz TBs and the 85 GHT TB presents information on the vertical structure of the storm
- The sloping branch indicates too much scattering
- Note that the more realistic does not develop until 12-18h into the forecast cycle

06h



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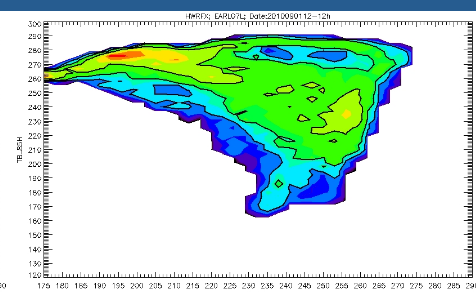

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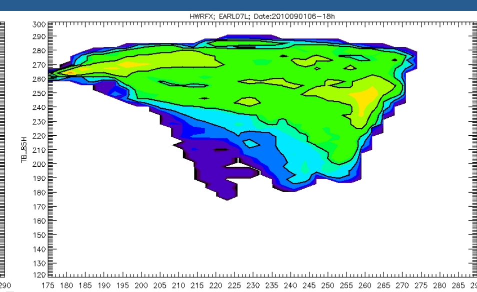

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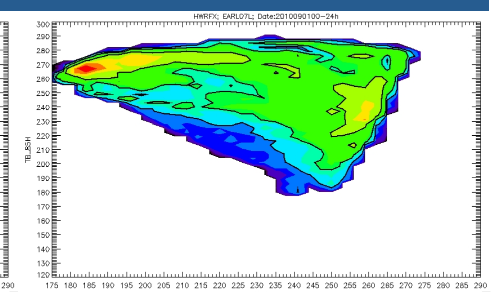
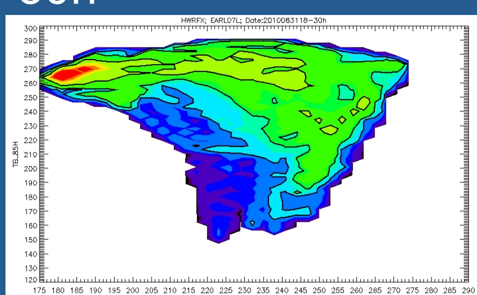
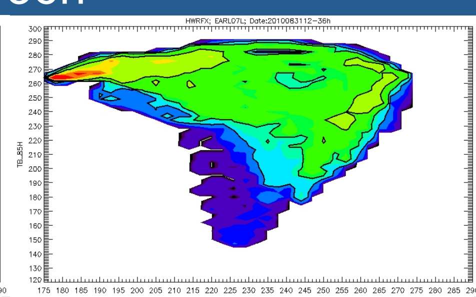


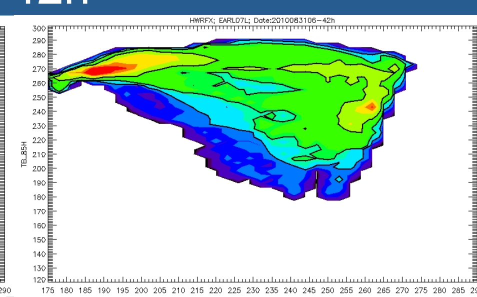
30h



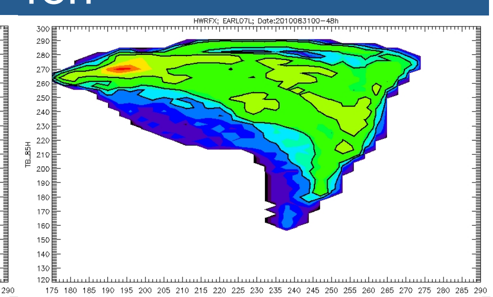
36h



42h



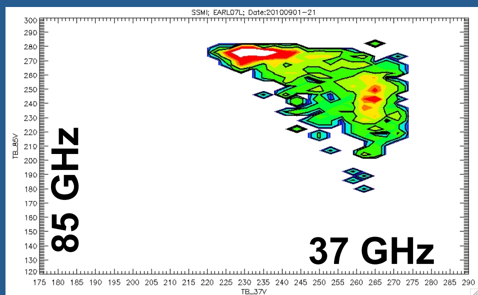
48h



Statistical Comparison – Joint PDFs

(85V/37V)(sat. resolution) – 02 Sept. 2010

Observed



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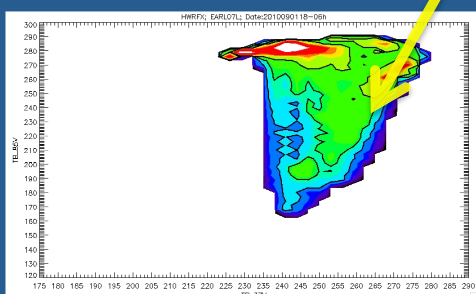
06h



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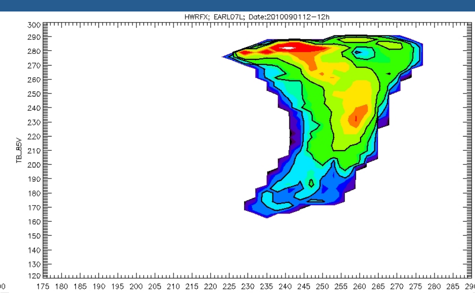

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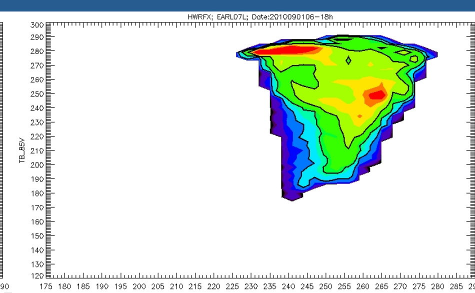

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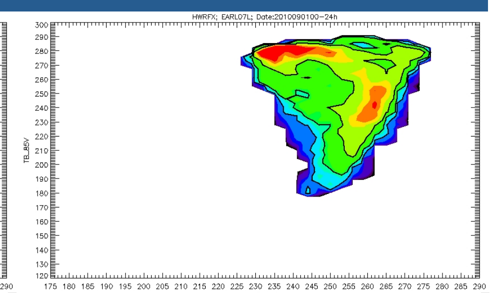

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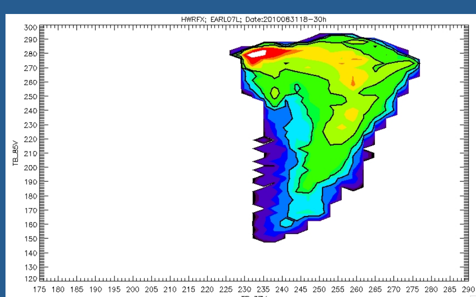

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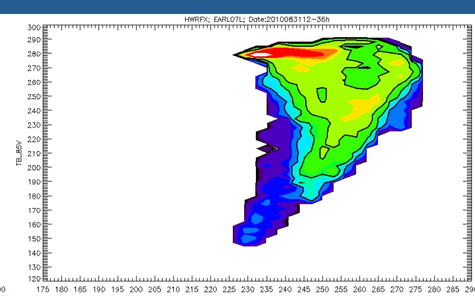

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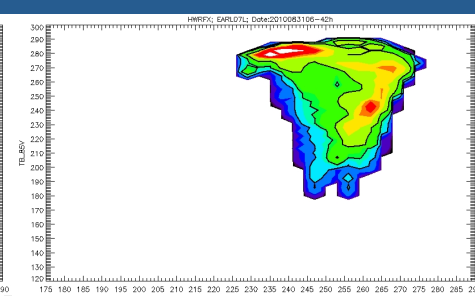

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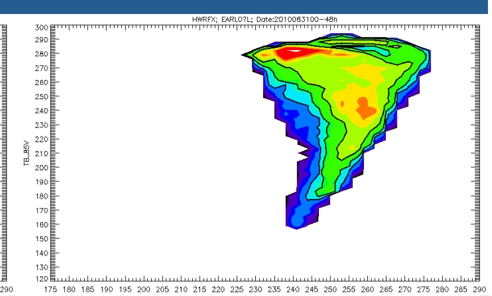
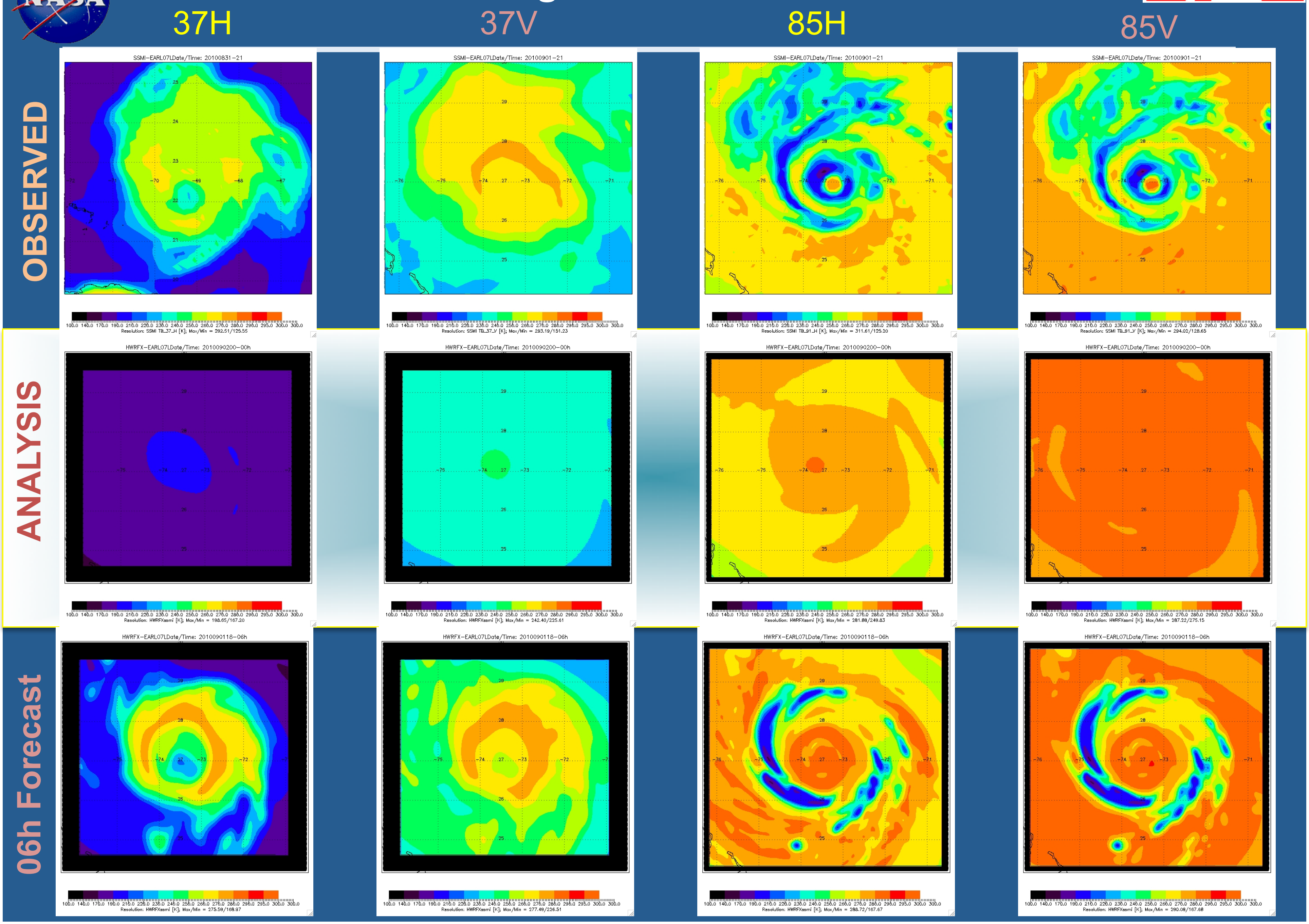


- The HWRFX forecasts show a great dose of realism in capturing the essential asymmetry.
- However, there are some outstanding issues
  - The forecasted eye is too wide in the modeled 85 GHz TBs and the observed eyewall replacement is not captured
  - The simulated 37 GHz TBs show a well defined eye, not seen in the observations
  - **It takes 12 to 18h to even 24h for the model to develop realistic structures!**
  - **By that time the forecasted storm position has likely drifted from the observed and the modeled storm is developing in conditions different from that of the observed!**

Evaluating the initial conditions



Summary

1. The long spin-up time might be the result of sub-optimal initial conditions which do not contain the observed precipitation structures.

2. During the model initialization we should make every effort to assimilate the microwave satellite information inside the precipitating hurricane core in order to incorporate:

   – **the precipitation-related thermodynamics**

   – **the important vortex asymmetries**

Summary (cont.)

During the assimilation we cannot, and should not:

- assimilate at the resolution of the model
- but should assimilate at the resolution of the observations.

More importantly, we should assimilate the important structural information (position, size and intensity of the eyewall and the rainbands) and not the details of the storms that are not reliably simulated by the hurricane models today.

We should evaluate and understand the performance of the model physics by comparing composites from observed and forecasted storms and by performing model sensitivity studies.

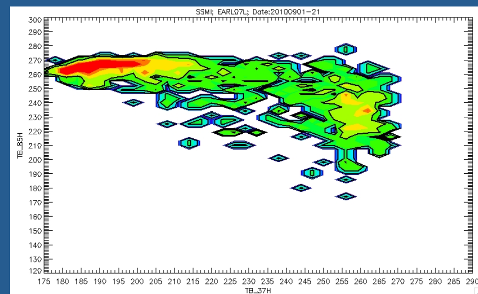
We should determine the biases we cannot remove (through model physics improvements) and should account for them during the assimilation processes.

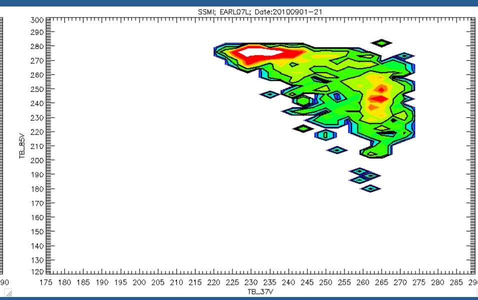
BACKUP

Evaluating the initial conditions

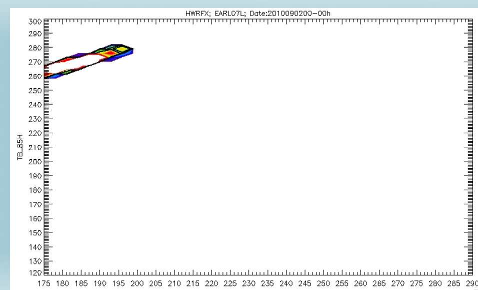
85H/37H　　　　85V/37V

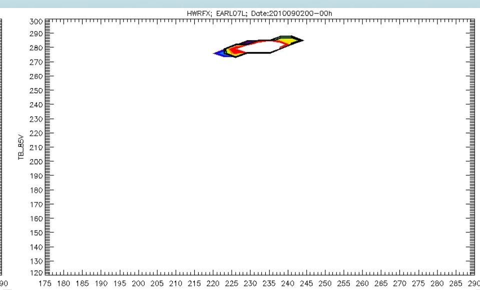
OBSERVED





ANALYSIS





06h Forecast