Understanding the Rapid Intensification of hurricane Karl from observations and models: Using NASA's airborne and satellite observations to evaluate the operational forecast model HWRF
The observations.

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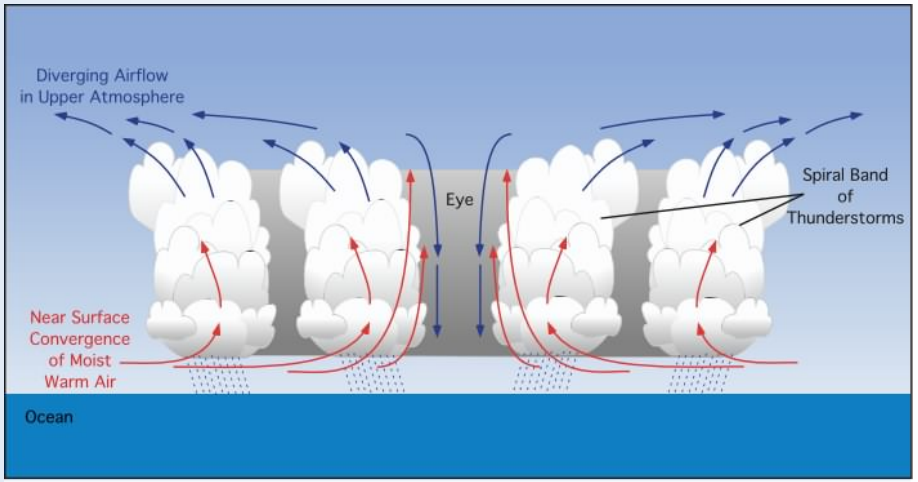
66th IHC – March 6th, 2012

The challenges

- **Understanding and forecasting hurricane rapid intensity changes (and storm structure) remains a significant challenge for the operational and research communities. As stated in a recent NRA (the NASA's Hurricane Science Research Program) this is due to:**
  - ***Poor understanding of the process involved in intensity change***
  - ***Deficiencies in the model physics***
  - ***Limited ability to obtain detailed measurements of the storm environment and inner core region***

The processes – Environment vs Inner-core

- **Many environmental factors can play a limiting role** in determining storm evolution and intensity (Kaplan and DeMaria, 2003).
  - increased vertical shear of the horizontal wind (Frank and Ritchie, 1999, 2001; Rogers et al., 2003; Braun et al., 2006; Braun and Wu, 2007)
  - the presence of midlevel dry layers (Braun et al.,2011),
  - oceanic regions with low SST and Ocean Heat Content (OHC).
- However, **recent studies have identified the inner-core convective processes as contributing more directly to the dynamics of hurricane intensity changes** (Gopalakrishnan et al, 2011, Jiang et al., 2011, Zhang and Chen, 2012).

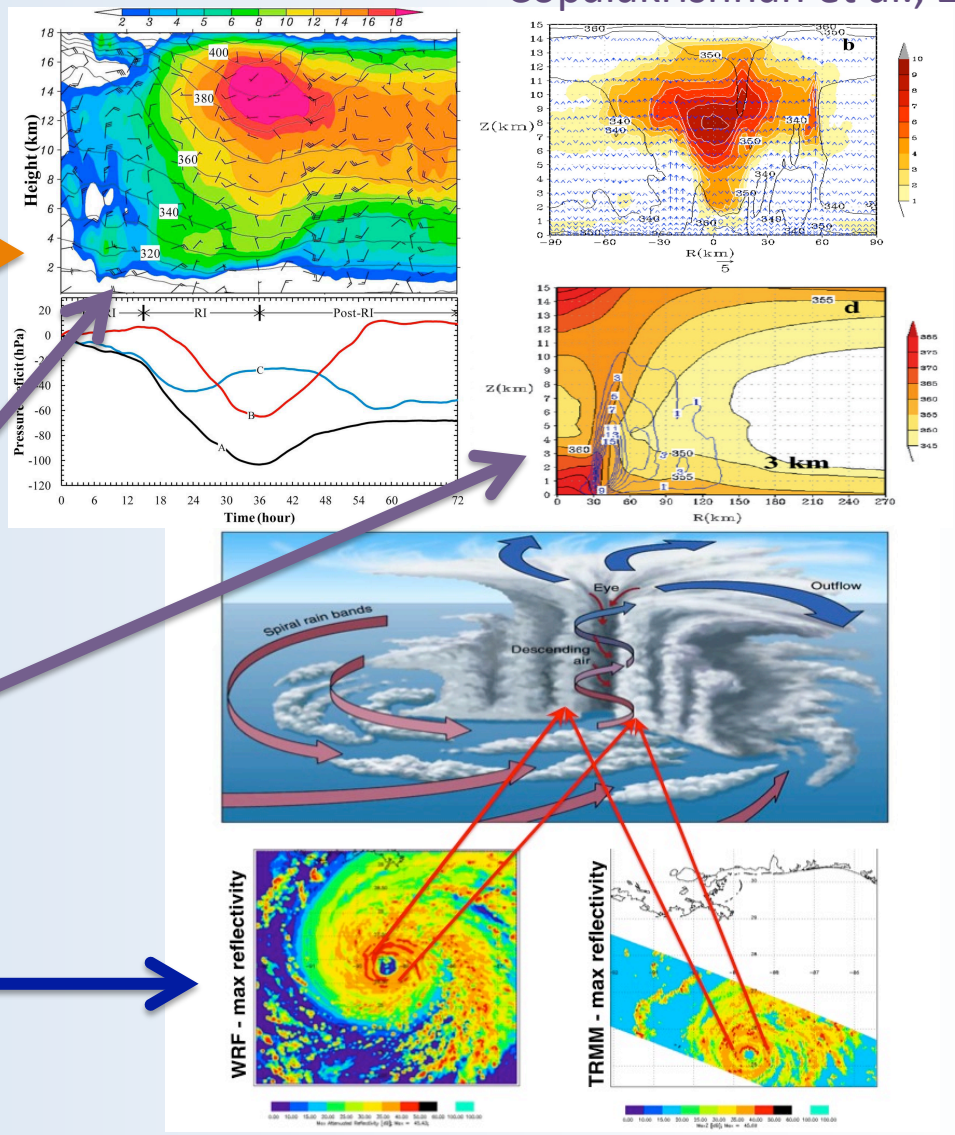


Focus on the inner–core; The questions:

- In a series of studies we will analyze observations and model to address the following questions:
  - **How does the warm core structure evolve and what is its origin?**
  - **What is the role of vortical hot towers versus that of the ordinary, weaker updrafts, that represent the bulk of the vertical velocity distribution?**
  - **What is the role of convective organization in relation to the warm core?**

Zhang and Chen, 2012

Rogers, 2010
Copalakrishnan et al., 2011



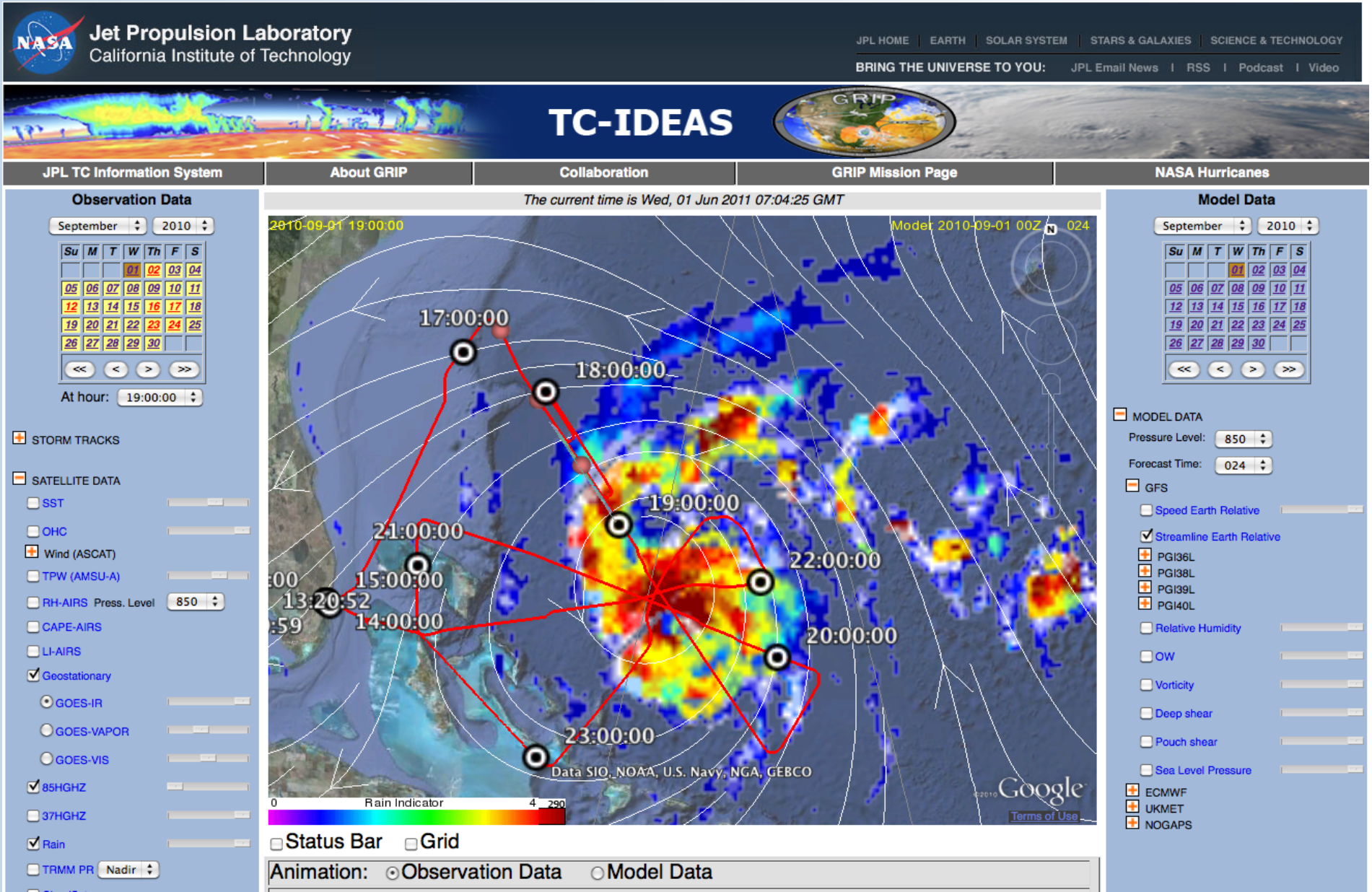
Jiang et al., 2011; M. Kieper (AMS 2008, 2010);

The GRIP/PREDICT/IFEX campaign

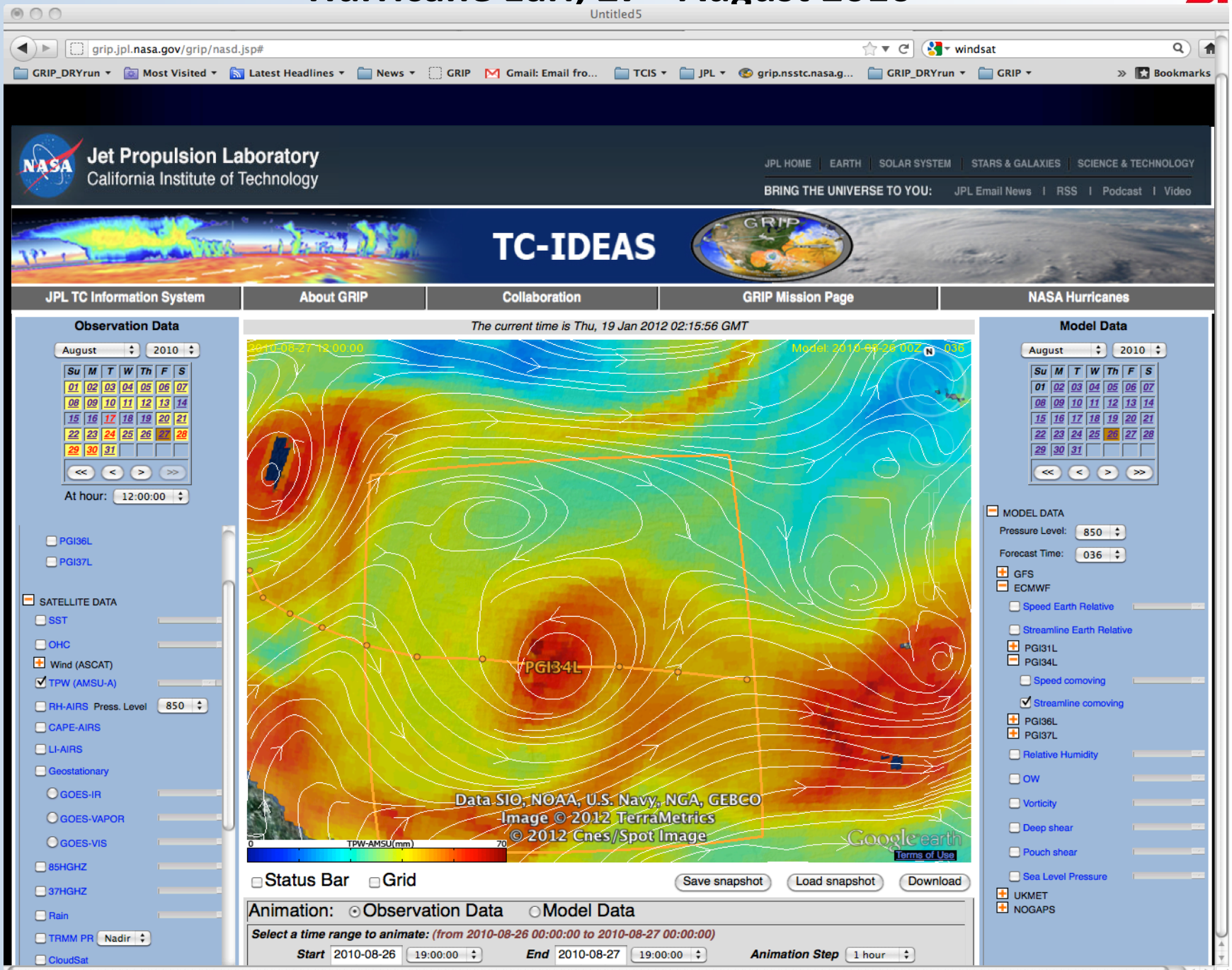
- A major goal of NASA's Hurricane Science Research is improving the knowledge about the critical physical processes and evaluation of their representation in numerical models.
- NASA's Genesis and Rapid Intensification Processes **(GRIP)** field **campaign was designed to provide new observational insights (Braun et al., 2012).**
- **It was conducted in the summer of 2010 in close coordination with NOAA's Intensity Forecast Experiment (IFEX) and NSF's PREDICT experiment which had similar goals.** A total of 7 aircrafts with new and mature observing technologies were flown in highly coordinated missions.
- **Our JPL team, in collaboration with CIMSS, NRL, NCAR and MSFC, developed a database and web portal (http://grip.jpl.nasa.gov) to present a comprehensive set of satellite and airborne observations and products in a manner that allows for easy comparison of a number of different storm parameters (Hristova-Veleva et al., 2010, 2011b). Large-scale model data and analyses are incorporated in collaboration with the Naval Postgraduate School (Michael Montgomery and Mark Boothe at NPS).**

The JPL GRIP Portal – grip.jpl.nasa.gov

Hurricane Earl of 2010 – Bringing together model flow with satellite observations of precipitation and providing the context for the airborne observations



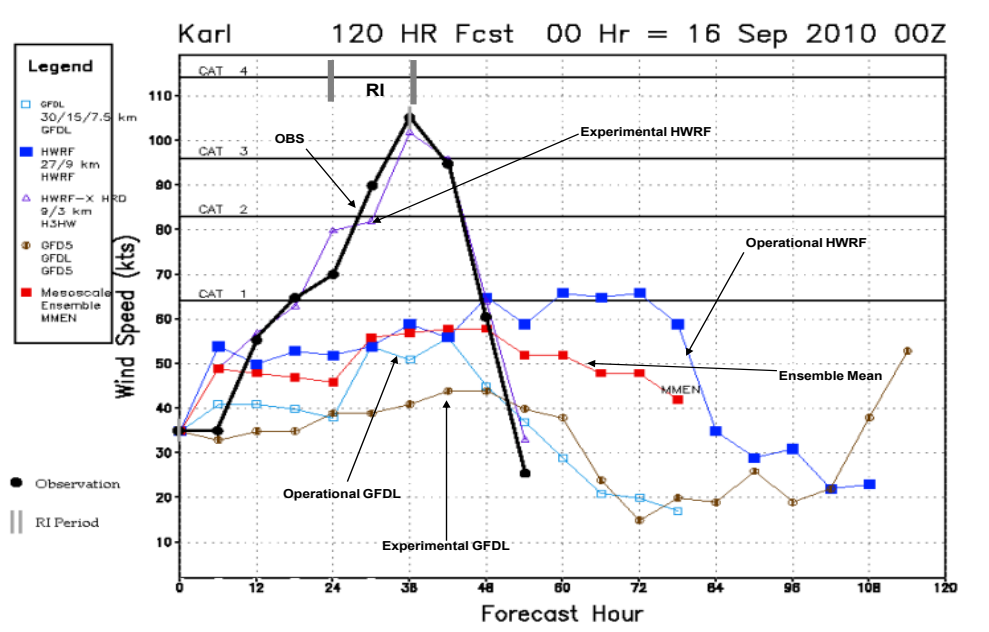
Hurricane Earl, 27th August 2010



Karl – forecast and questions

- **The GRIP campaign provided an unprecedented high-resolution view into the vortex evolution throughout a 13-hour period of continuous Global Hawk observations during the RI of hurricane Karl. These observations were complemented by flights of NASA's DC-8, NOAA's P-3s and NSF's G-V.**
- **The goal of our longer-term research is to use the detailed airborne observations to describe the storm evolution and to evaluate the operational hurricane model, asking the question:**

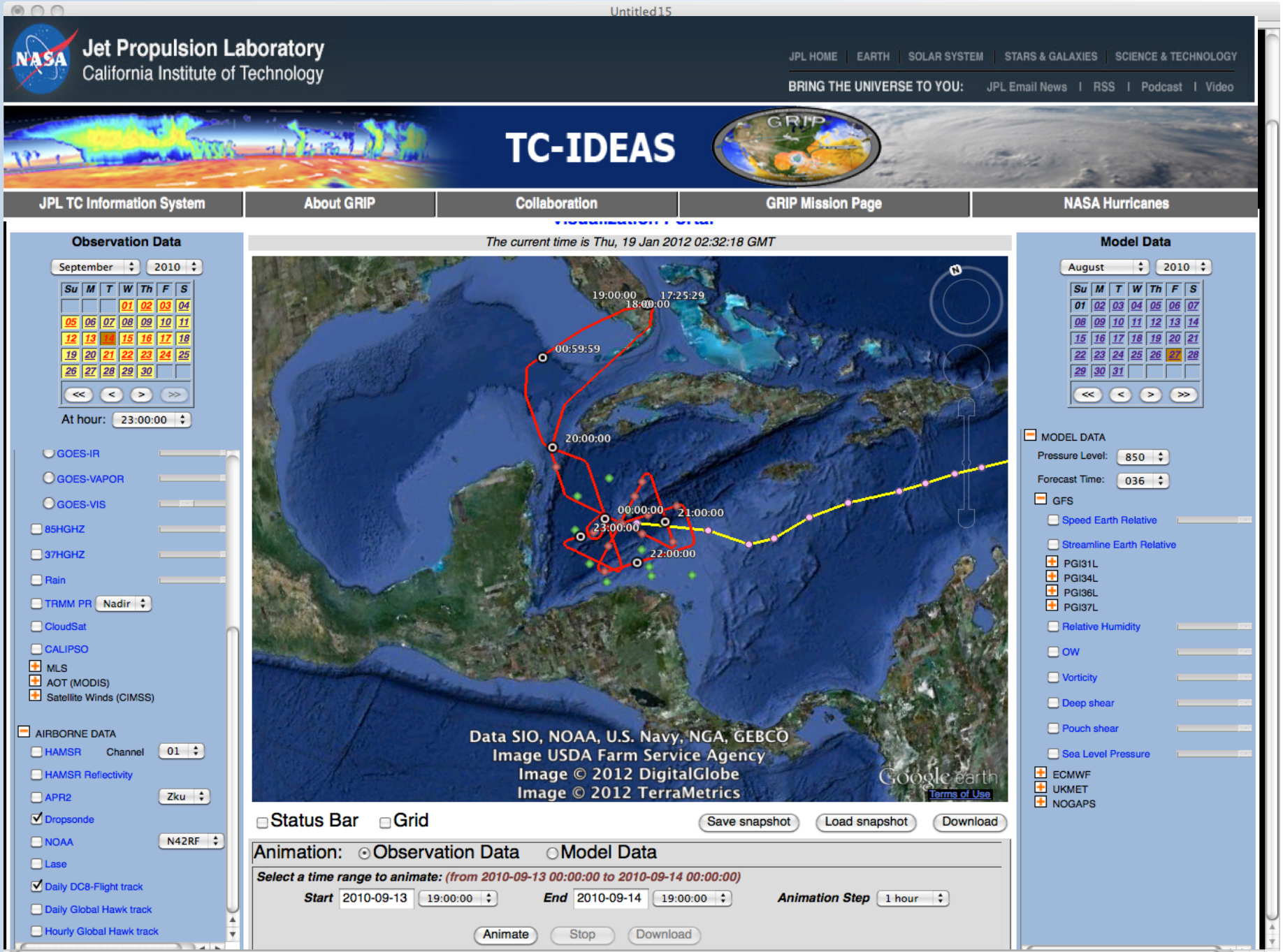
"How does a model undergo a rapid intensification process and how representative is this process versus the reality?"



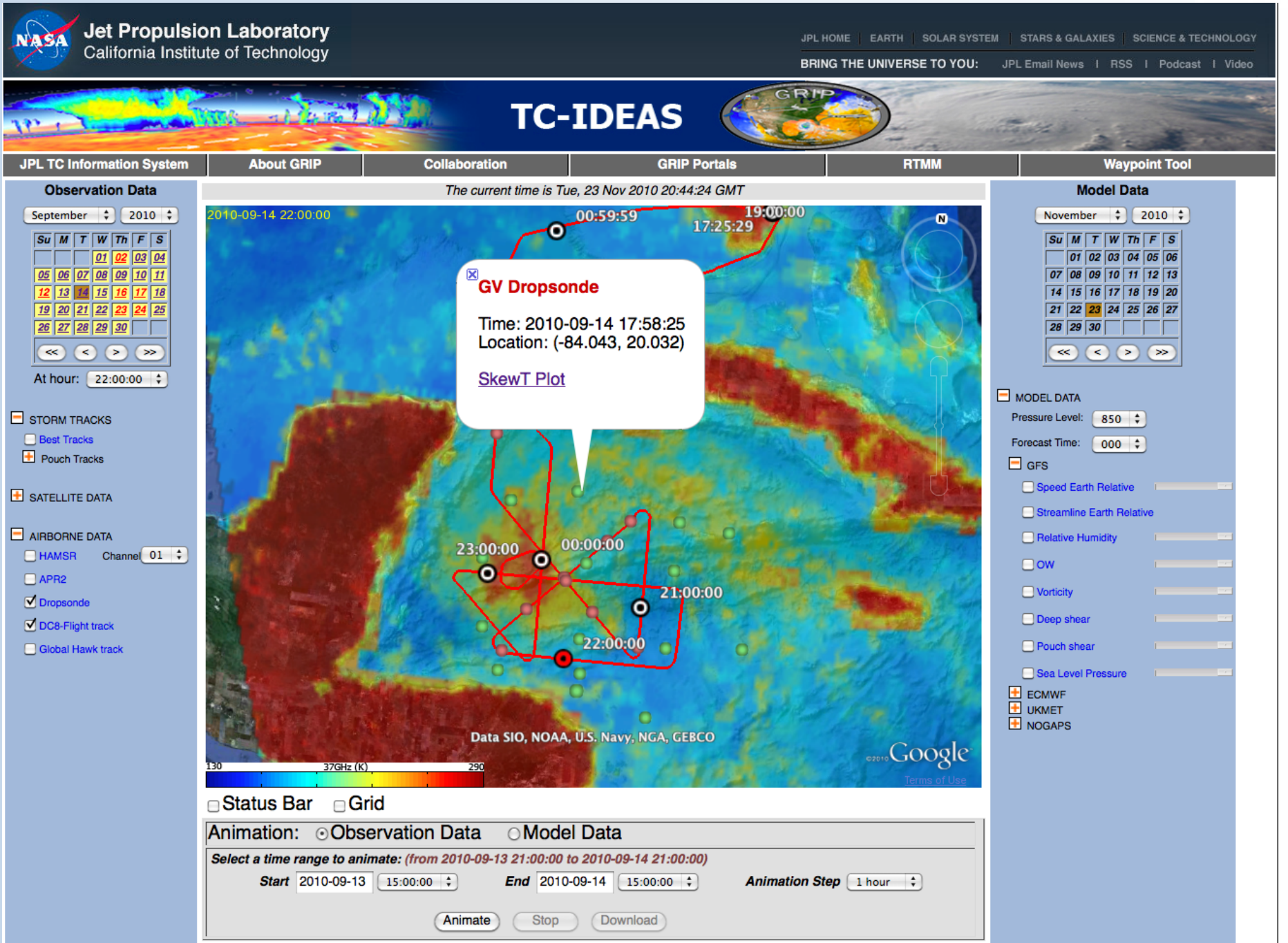
Wind speed forecasts from various models. The observed wind is shown as the black line. MME is the mean of HWRF, GFDL, and Experimental HWRF (Gopalakrishnan - personal comm.).

Note that only one model, HWRFx, was capable of capturing the evolution of hurricane Karl during its RI while all other models had very significant problems. Furthermore, it is still unclear how repeatable that good performance is.

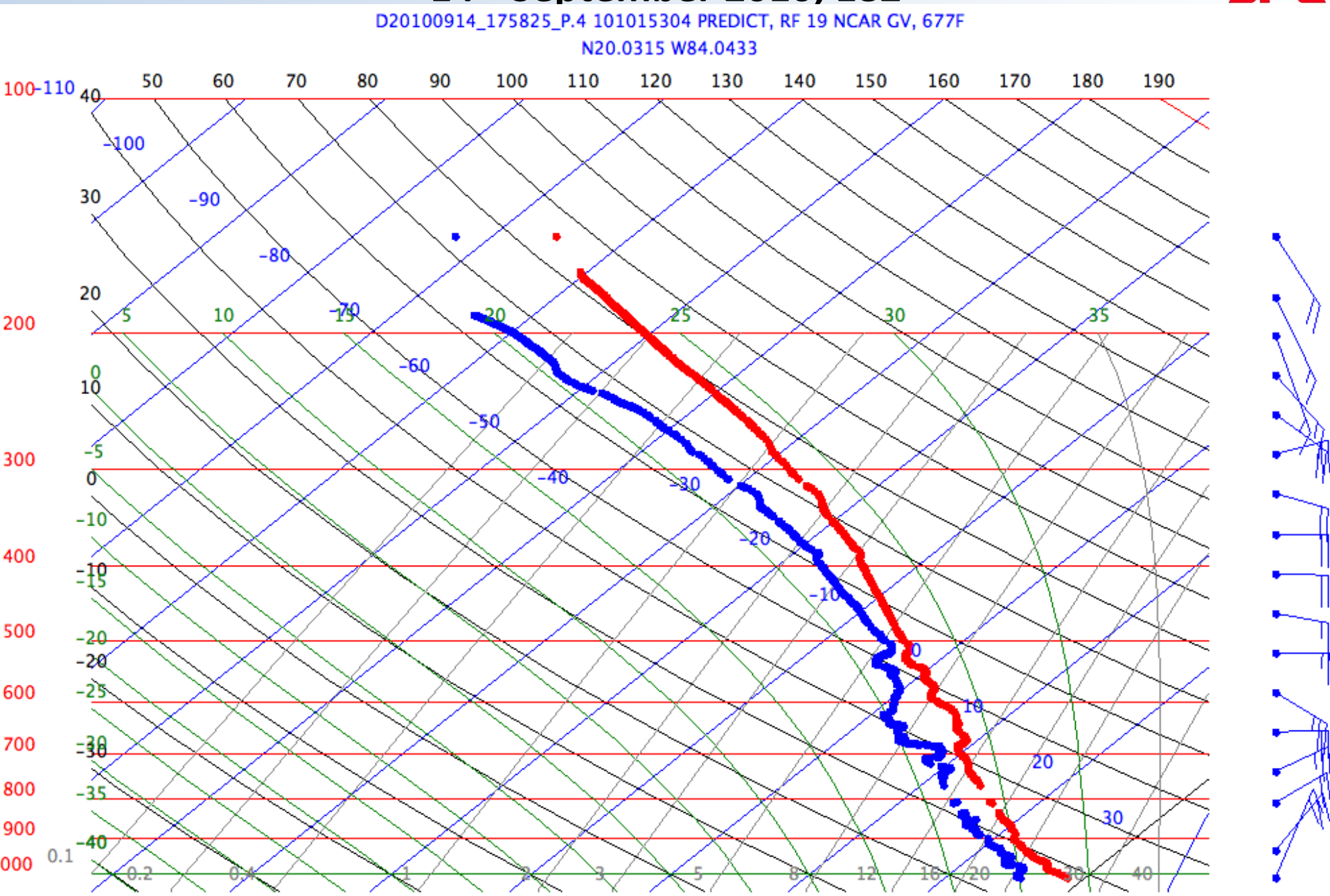
Just after genesis - 14th September 2010, 23Z



Just after genesis - 14th September 2010, 23Z



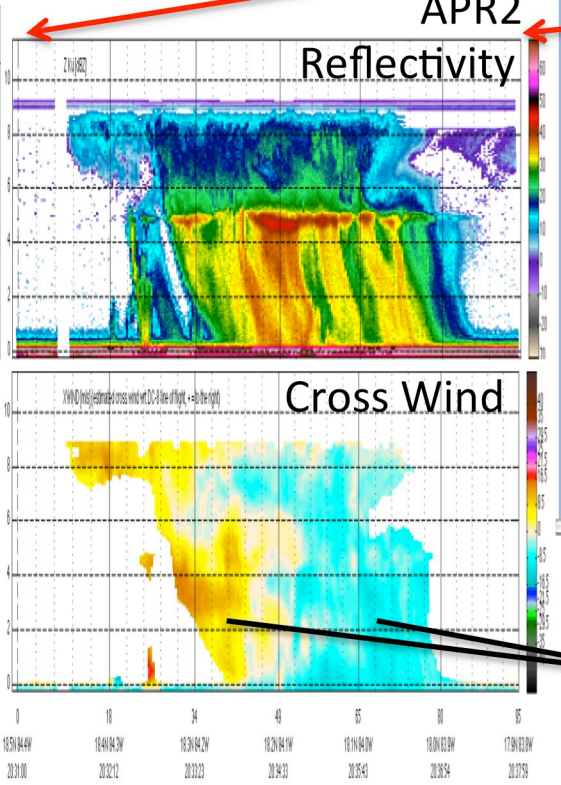
14th September 2010, 18Z

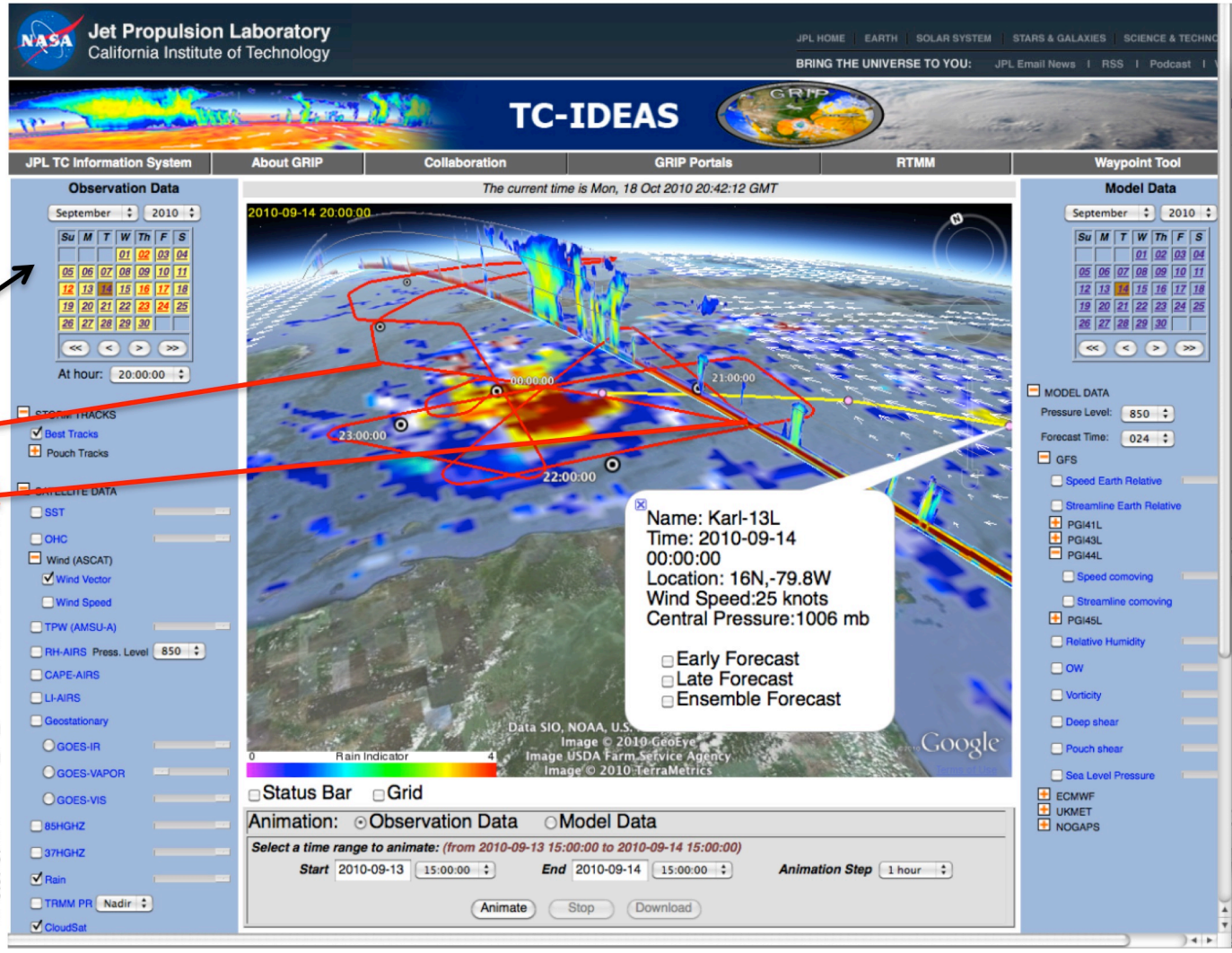


Hurricane Karl, September 14 2010

The 2010 NASA's GRIP Hurricane Field Experiment was aimed at better understanding hurricane cyclogenesis and rapid intensity changes.

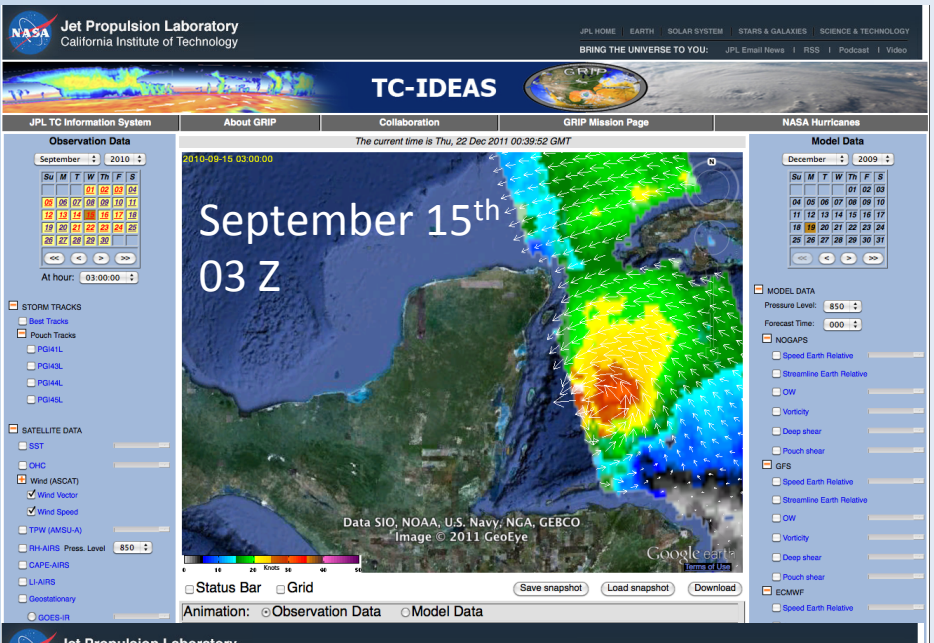
JPL participated with two instruments (HAMSR and APR2) and the JPL GRIP portal which blends satellite and airborne observations with model data.

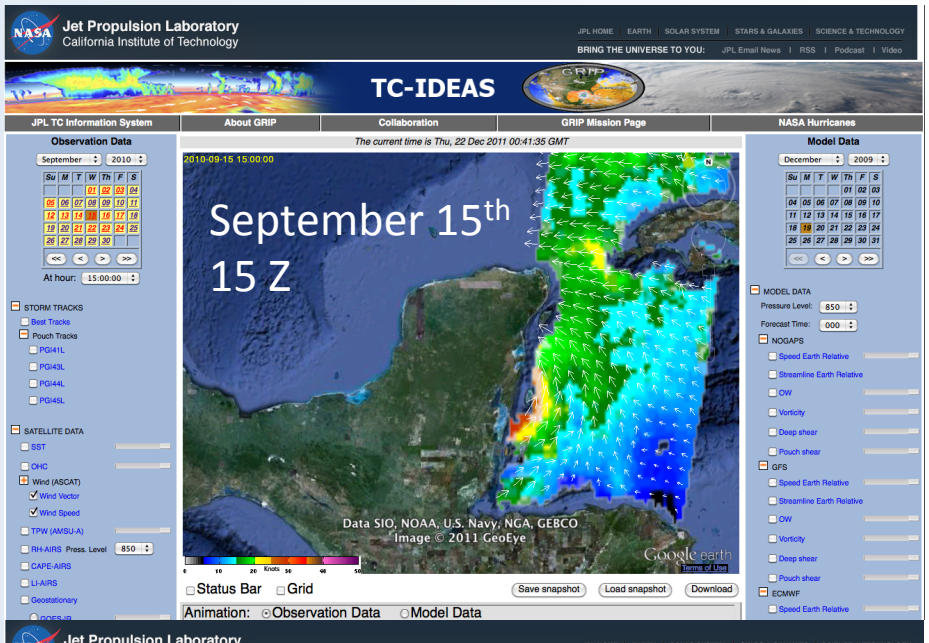


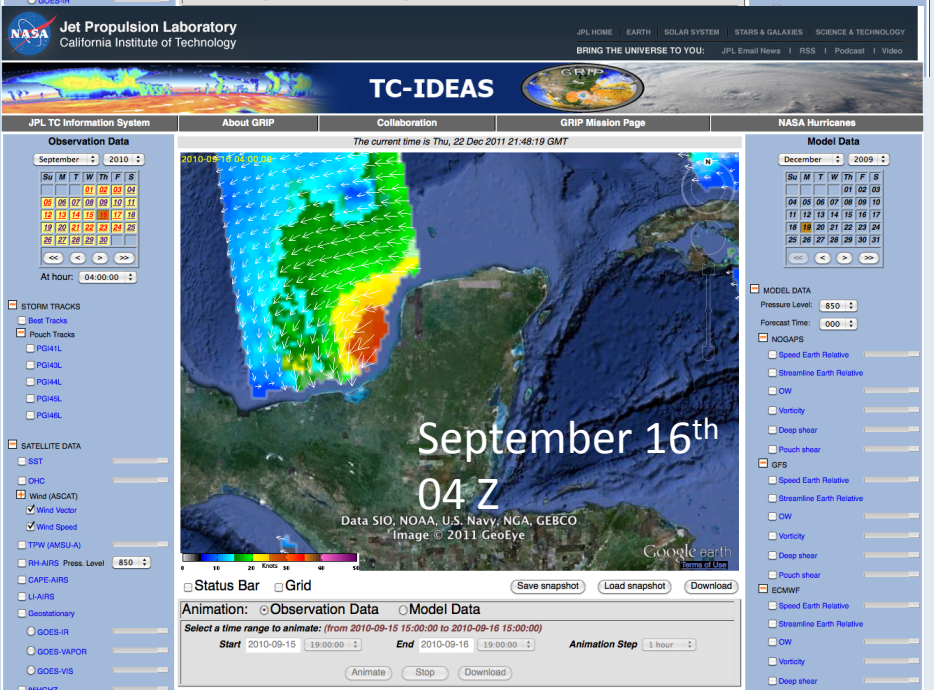


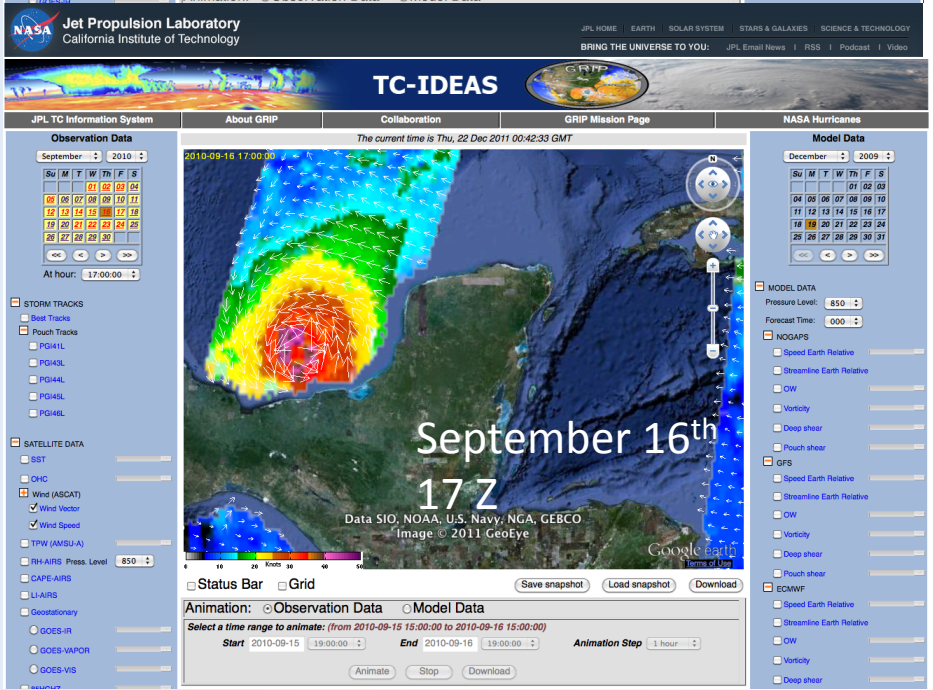
Note the change from positive to negative cross-wind flow as APR2 flies through the storm center, signifying the deep cyclonic circulation of the storm. APR2 observed the storm just a couple of hours after the long-awaited cyclogenesis.

The Wind Structure

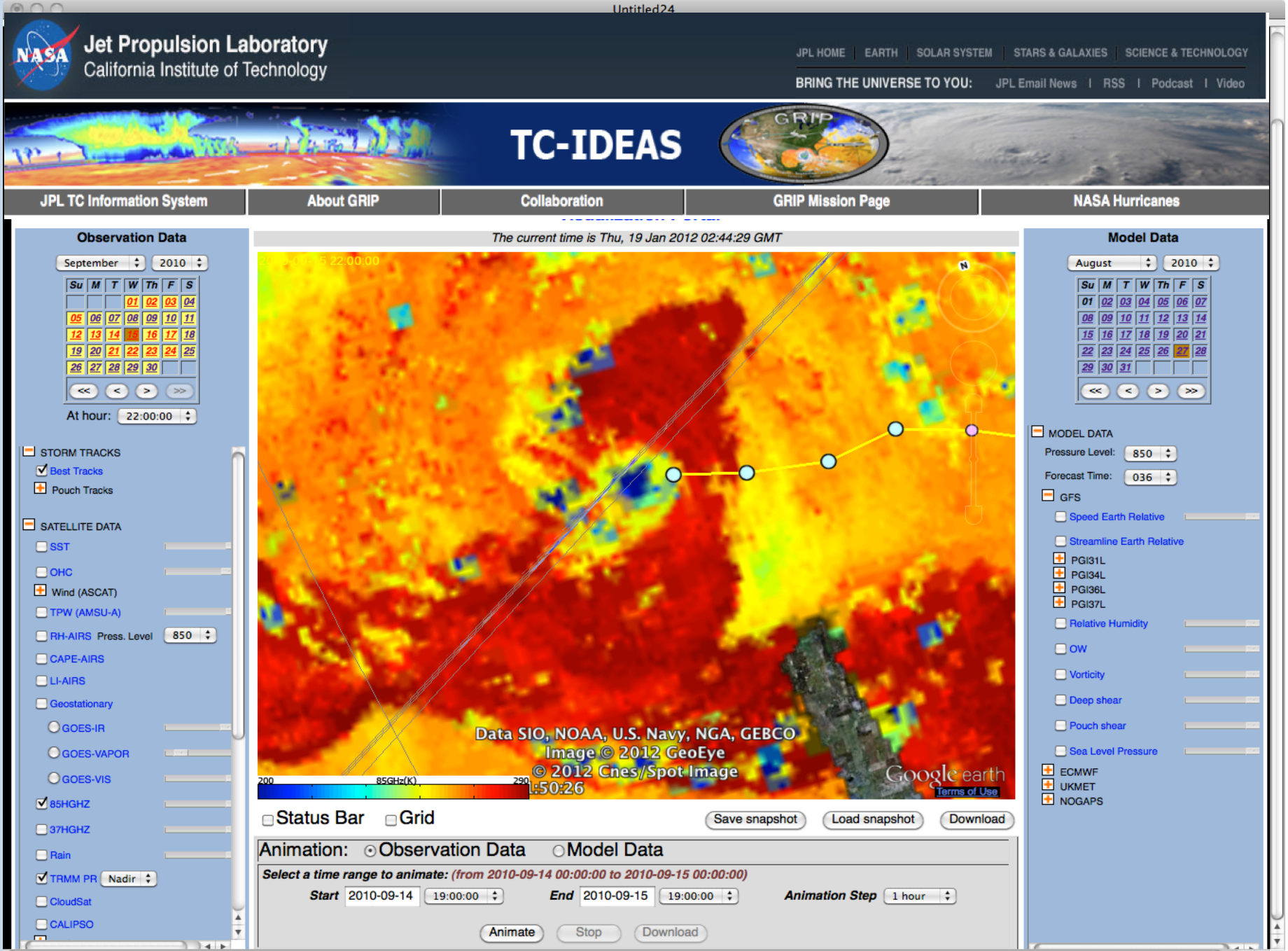




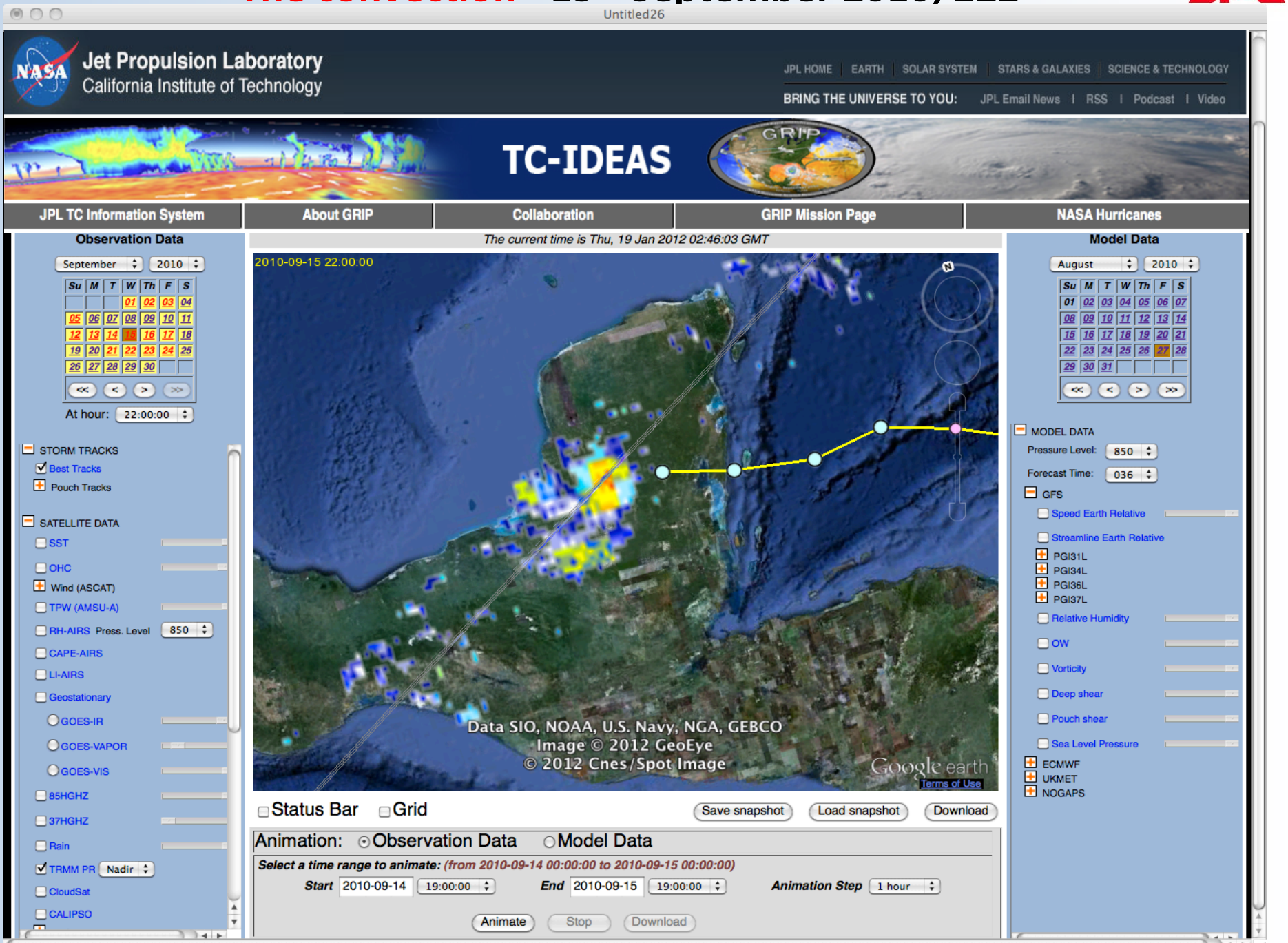




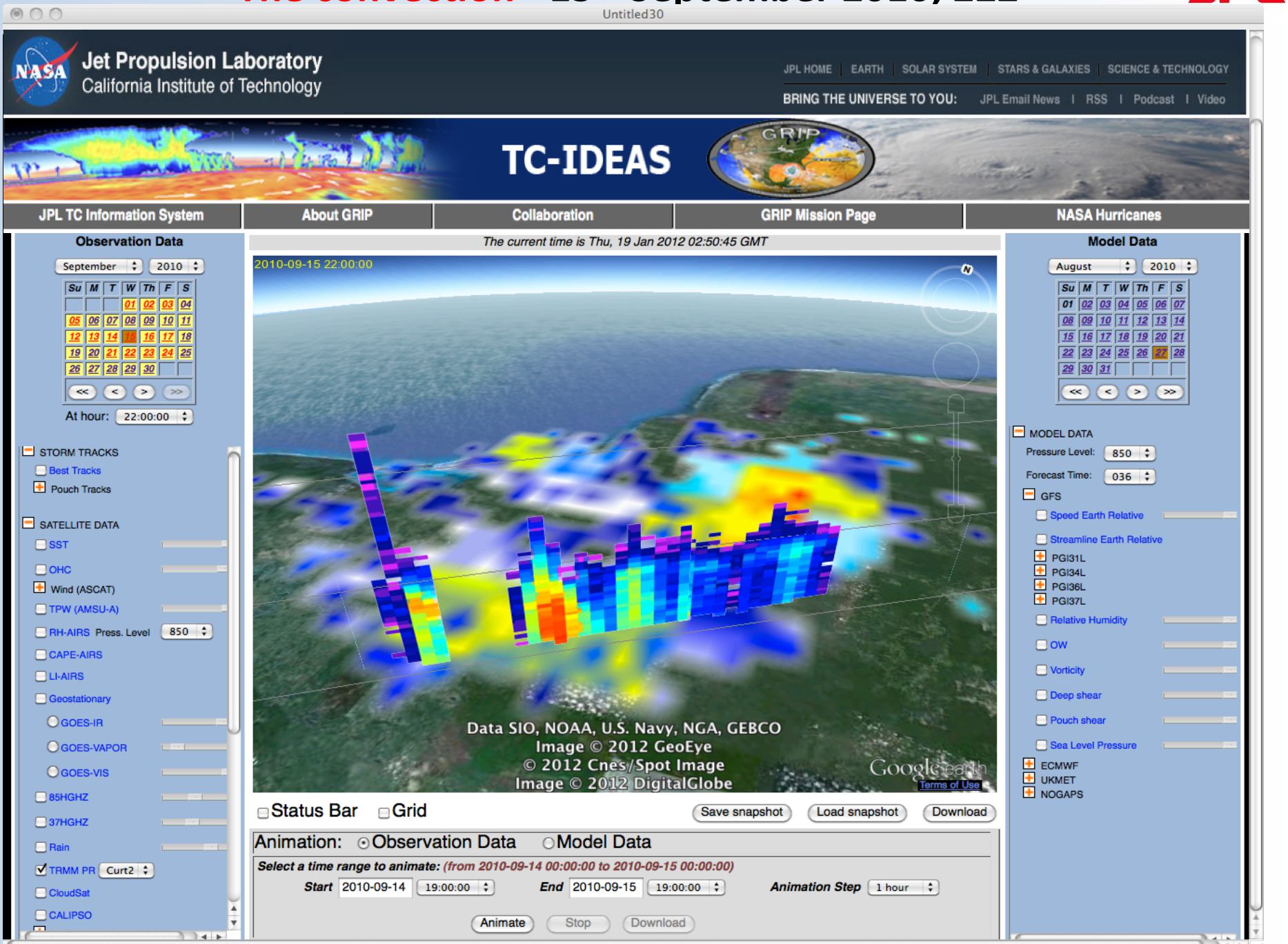
The convection - 15th September 2010, 22Z



The convection - 15th September 2010, 22Z



The convection - 15th September 2010, 22Z



The convection - 15th September 2010, 22Z

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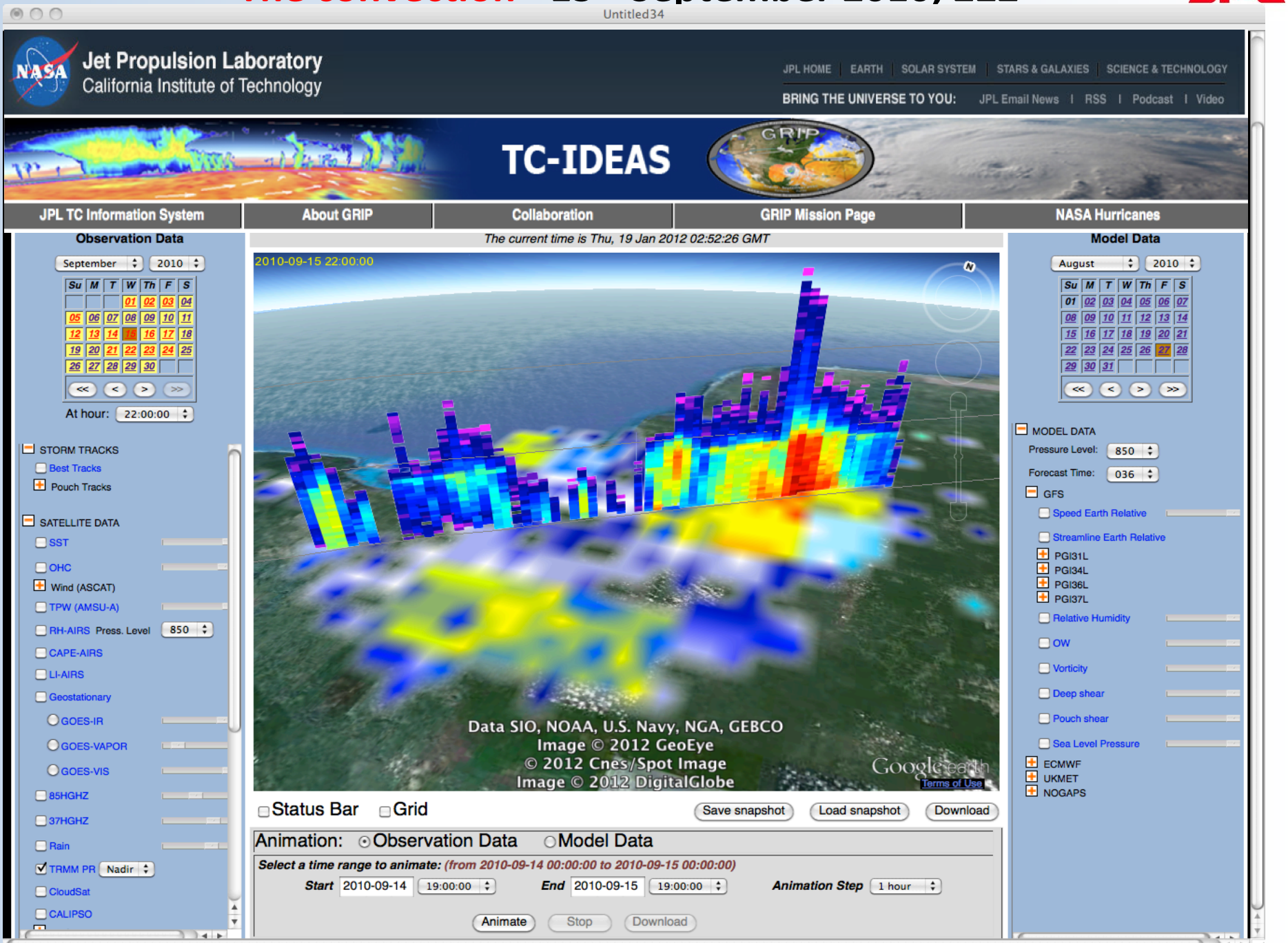
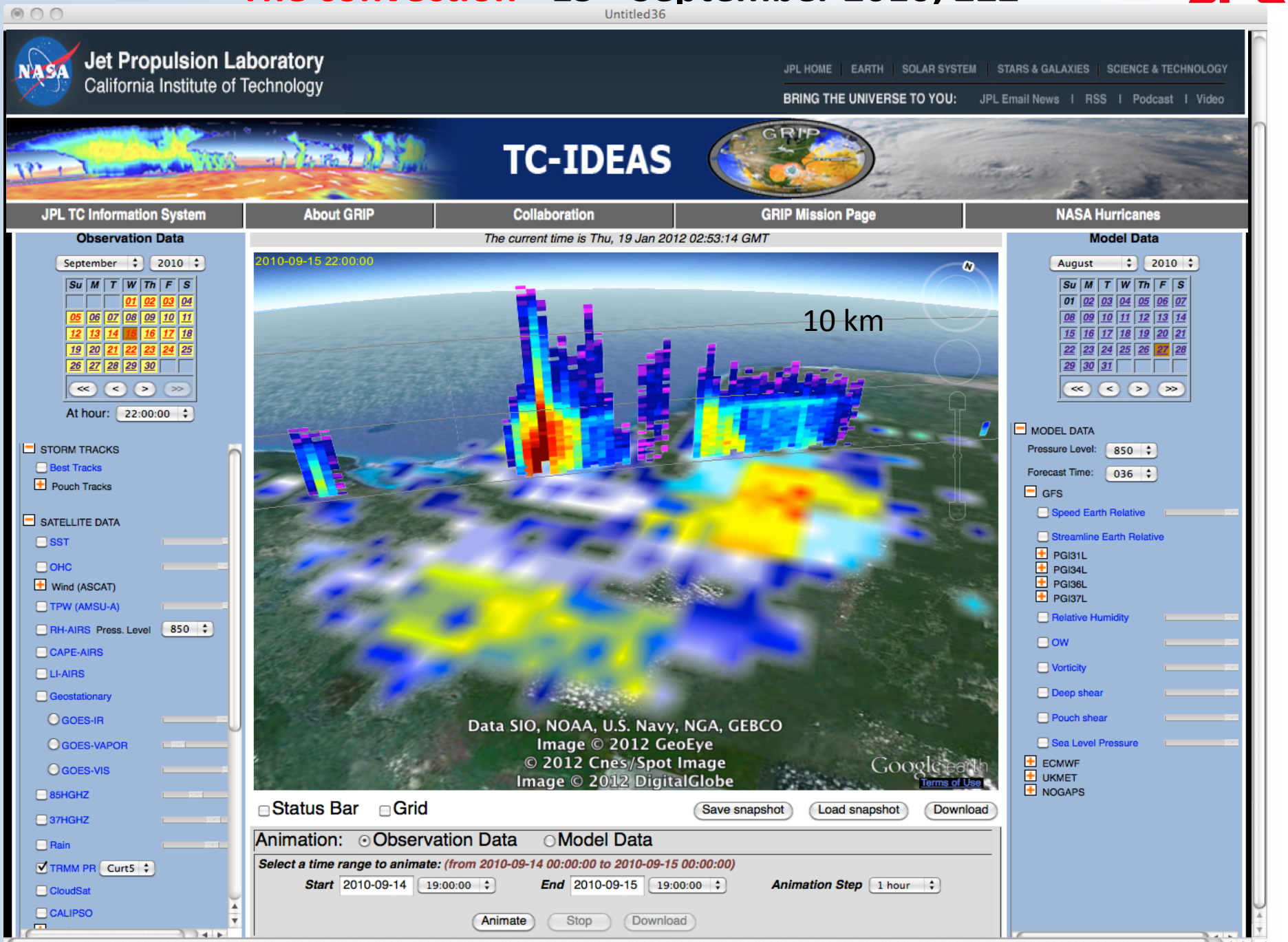
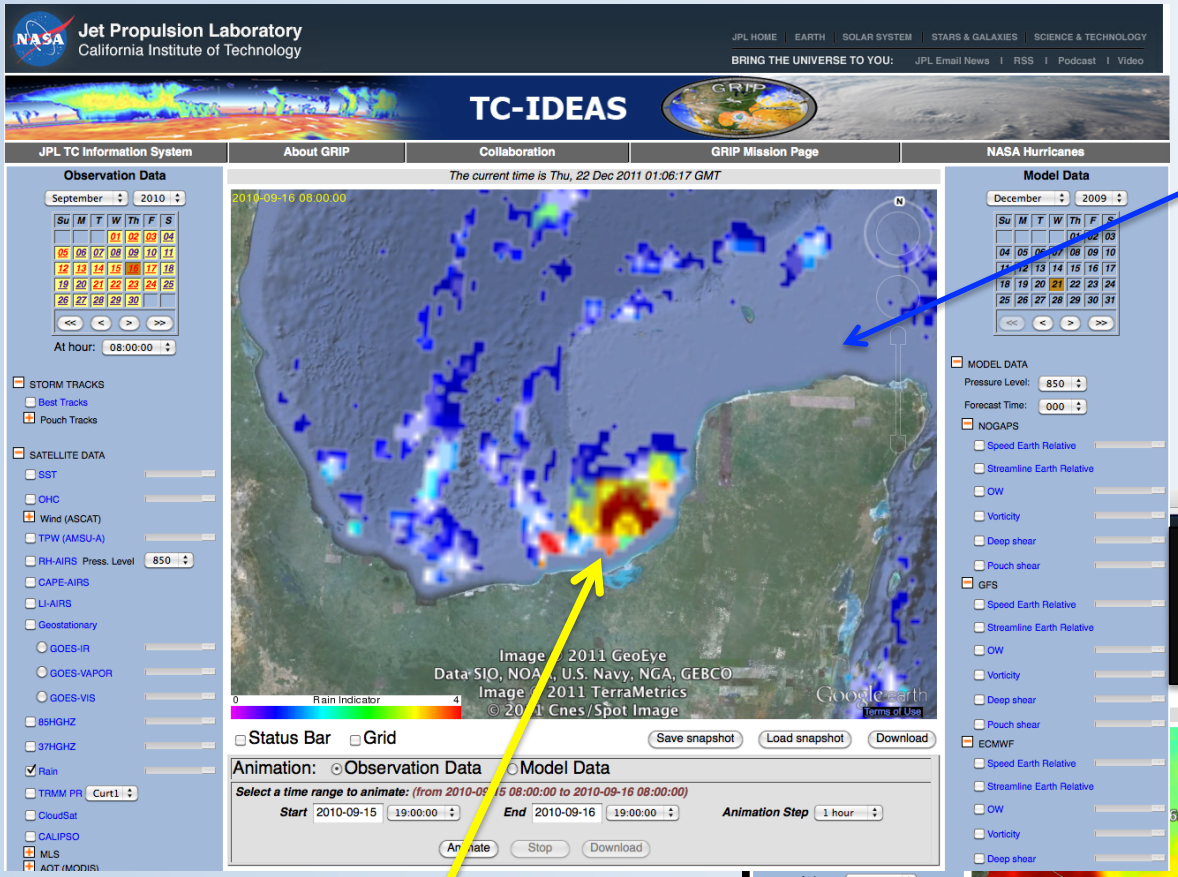


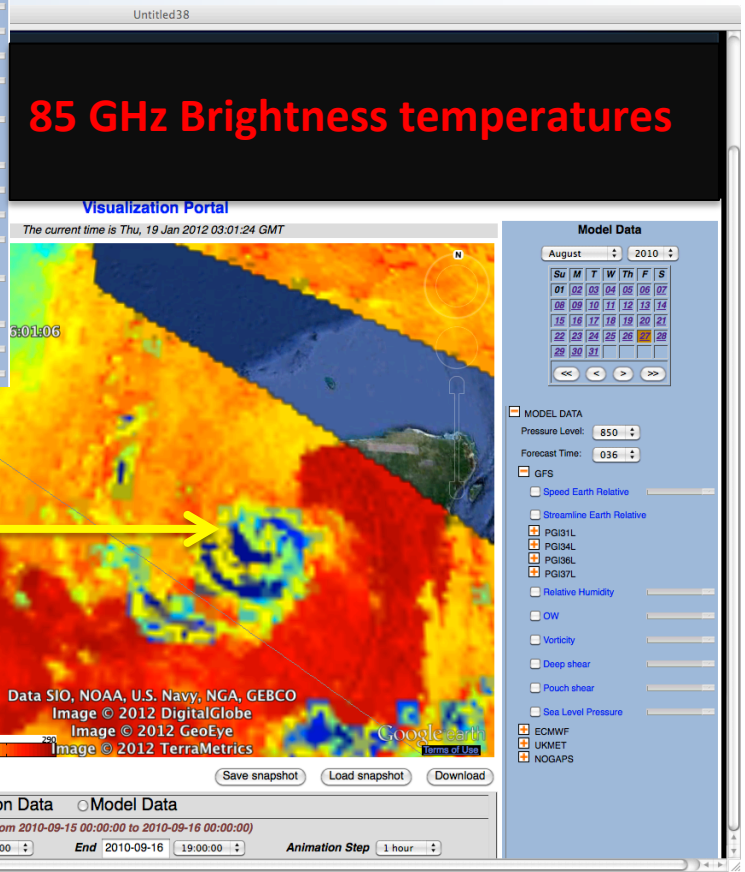
The convection - 15th September 2010, 22Z



The convection - 16th September 2010, 07Z

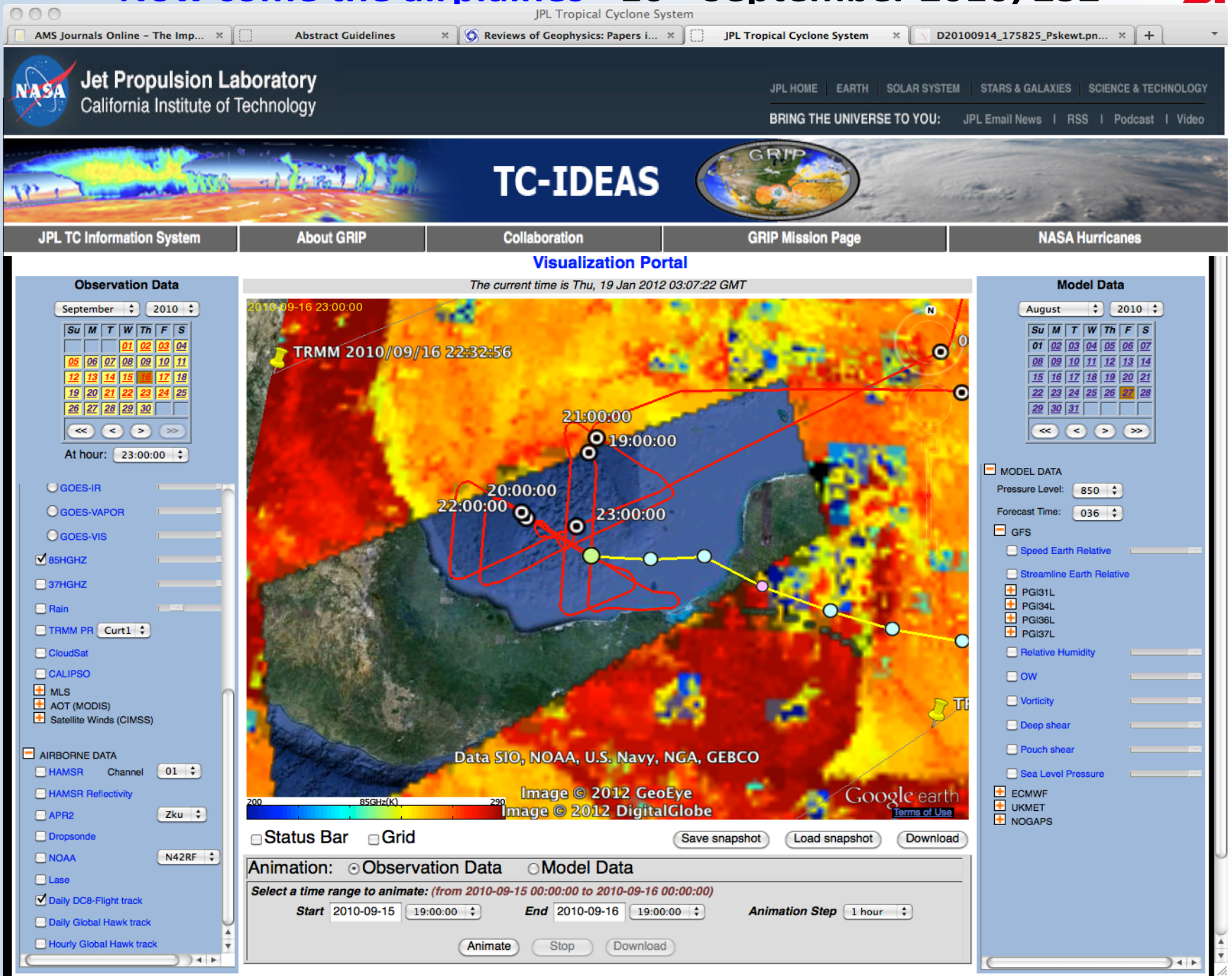


Rain Indicator – a multi-channel passive microwave index



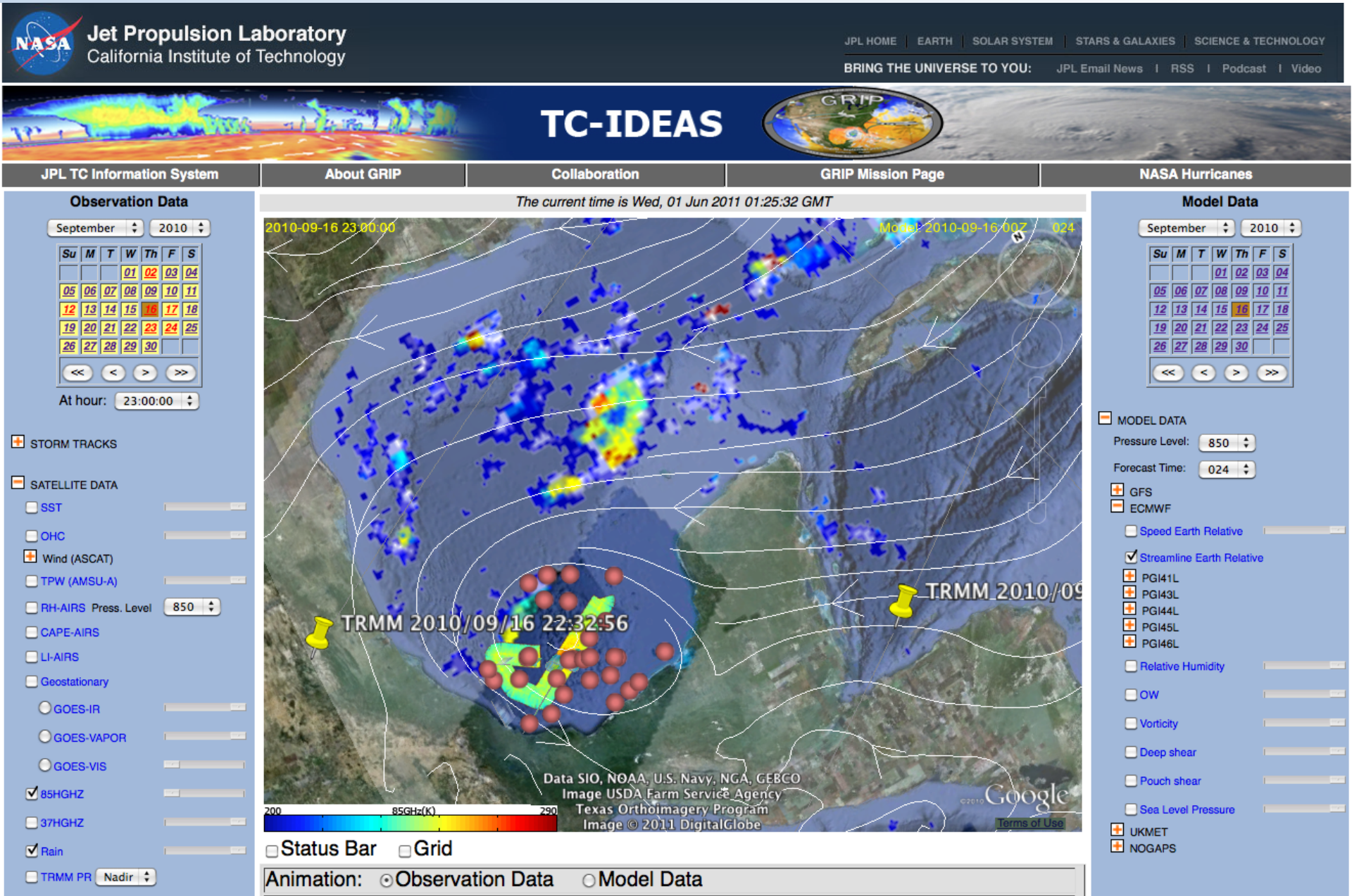
Note the ring of convection

Now come the airplaines - 16th September 2010, 23Z



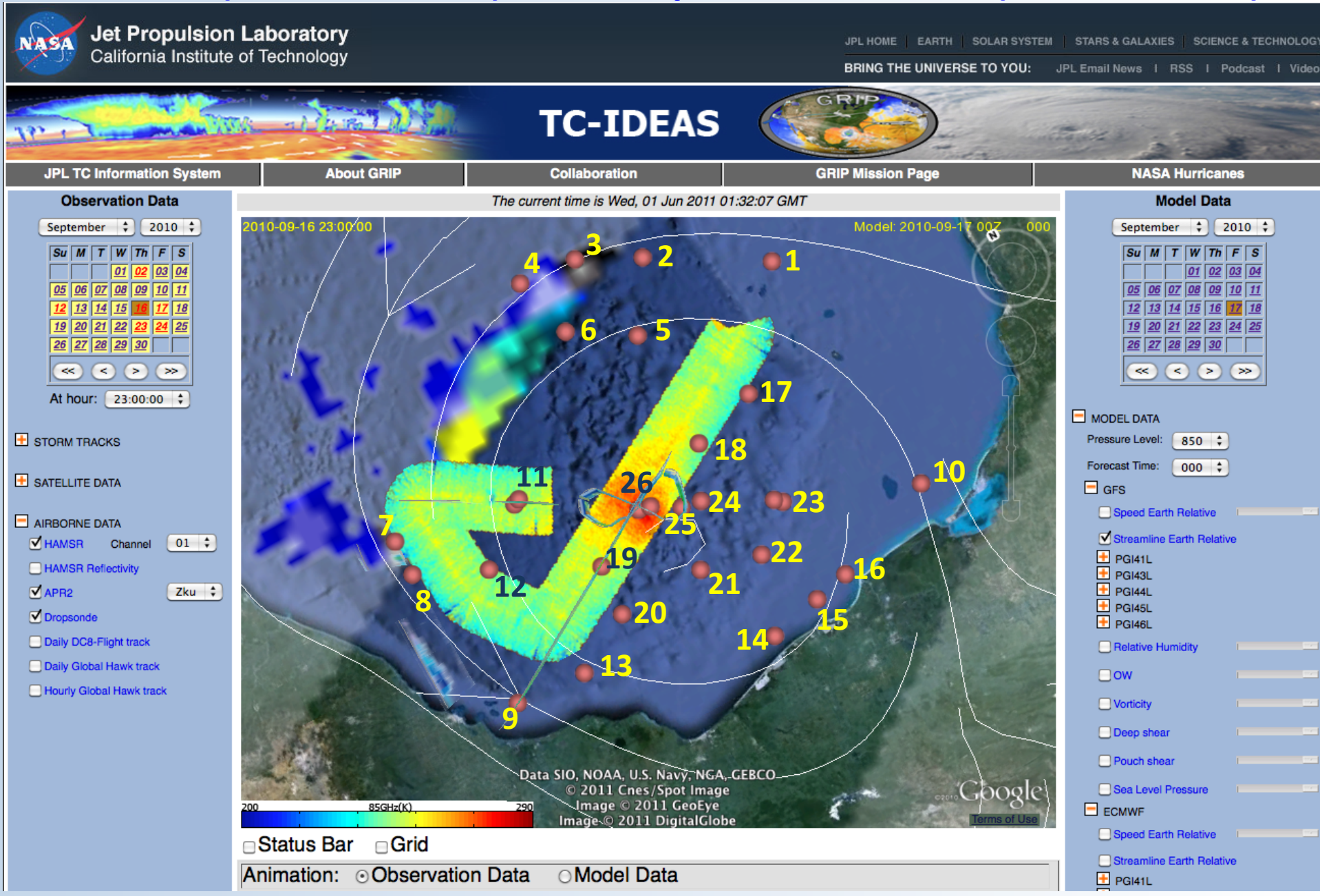
Hurricane Karl, September 16th

Rain Index (satellite PMW), GFS 850mb winds, DC8 dropsondes, HAMSR



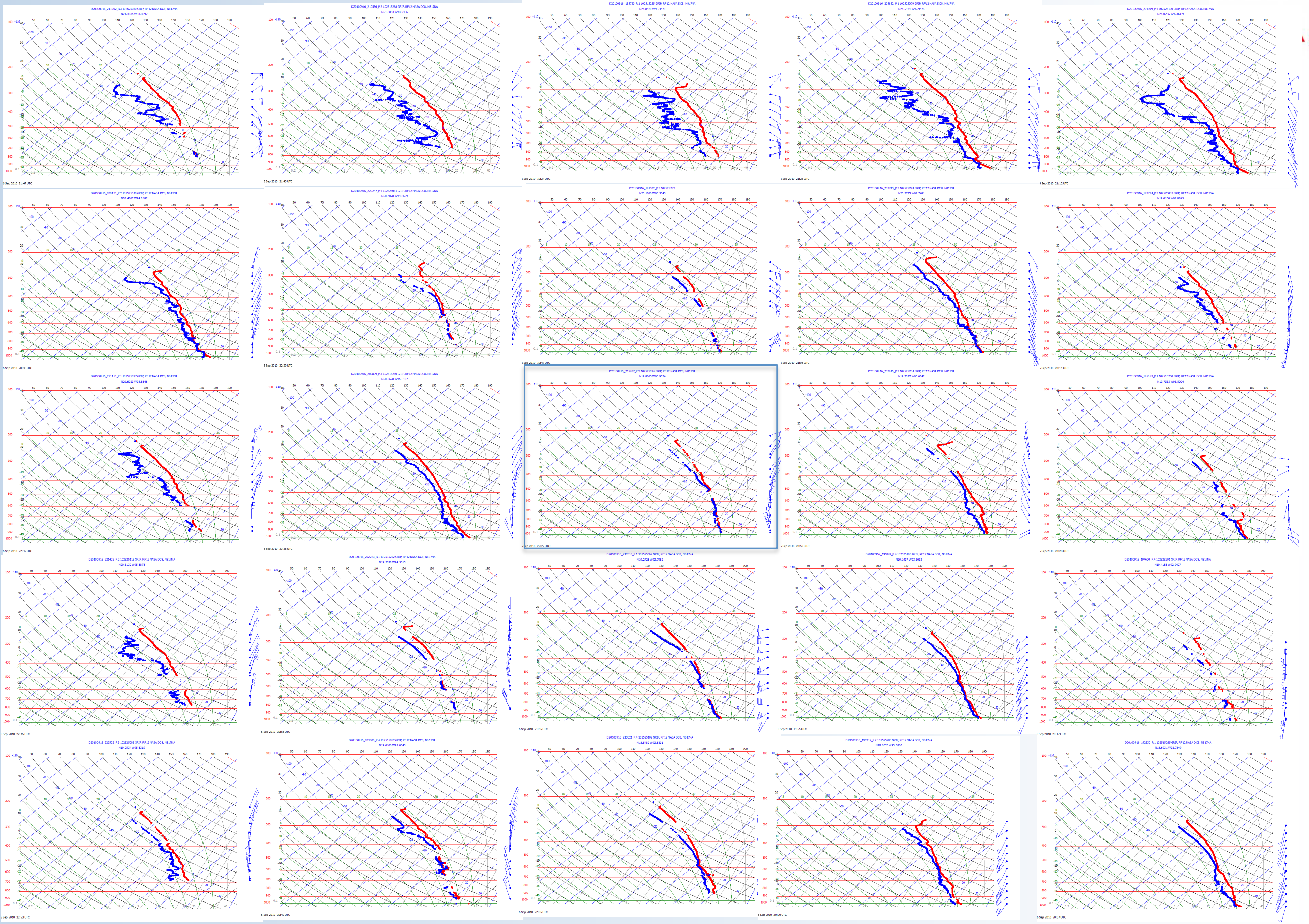
Hurricane Karl, September 16th

Rain Index (satellite PMW), DC8 dropsondes, HAMSR (ch. 6 – 55Ghz)



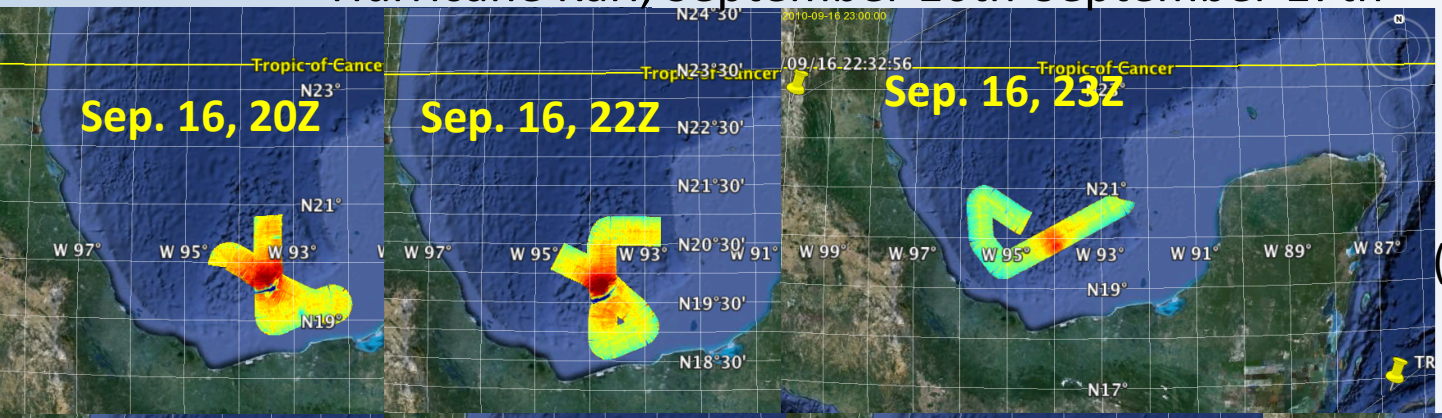
Layout of the soundings on the next slide,
using the dropsonde numbers from the previous slide

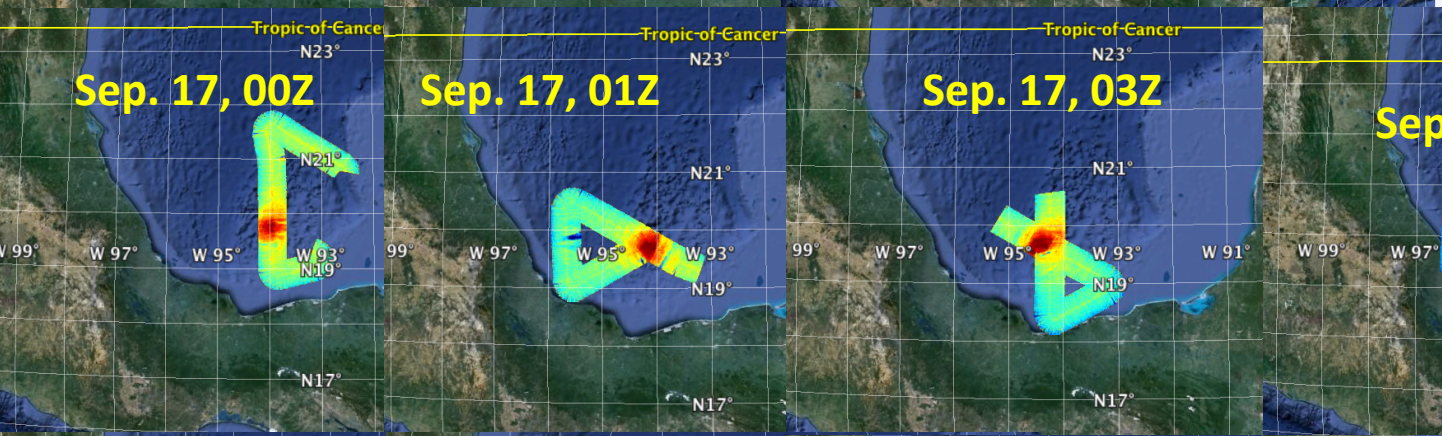
6	4	3	2	1
11a	11b	18	17	10
7	12	26	25	24
8	20	21	22	23a
9	13	14	15	16

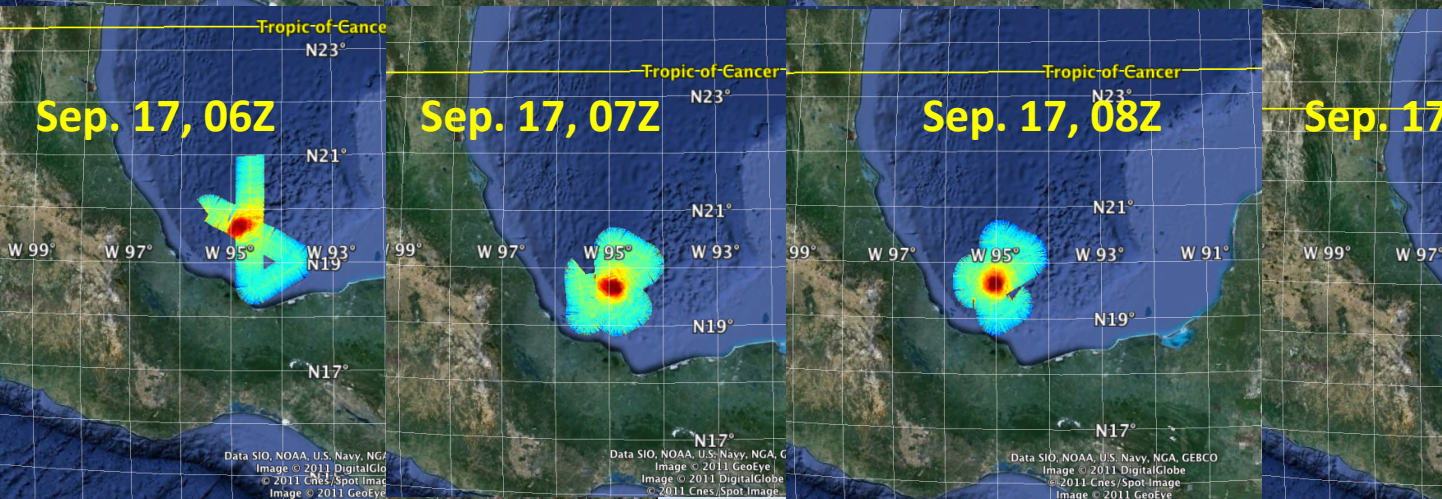


The Warm Core

Hurricane Karl, September 16th-September 17th





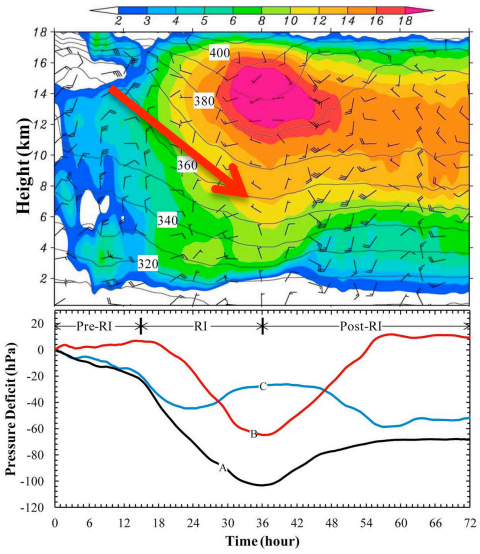


Warm core evolution as seen by HAMSR

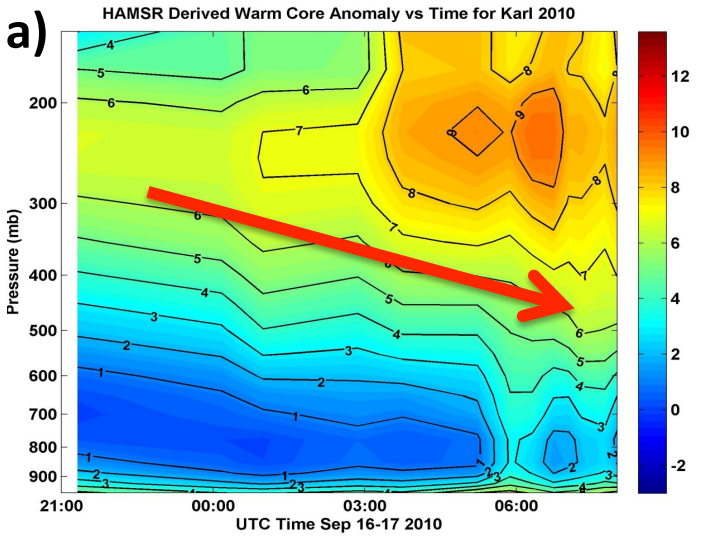
(brightness temperatures Channel 6)

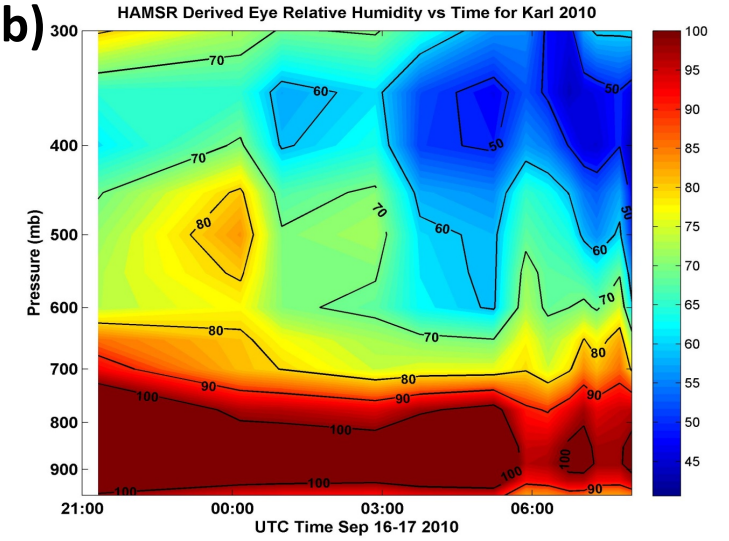
Analysis of the warm core evolution using HAMSR observations (Brown and all, 2011, AGU fall meeting).

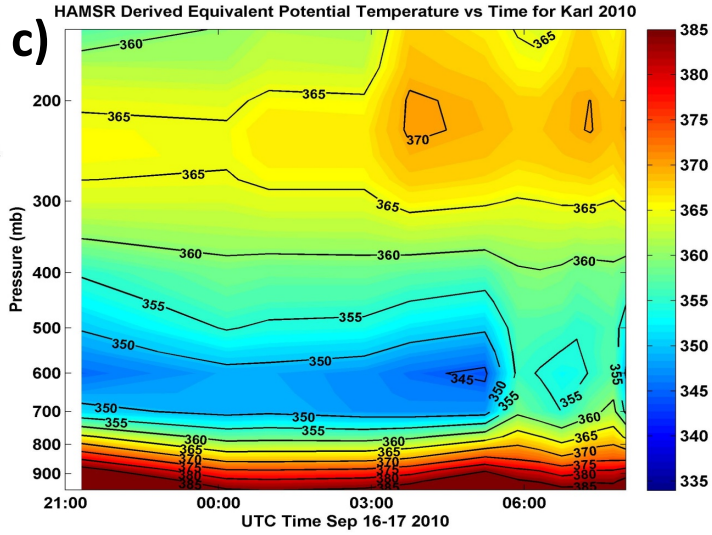
Zhang and Chen, 2012 Analysis of model output

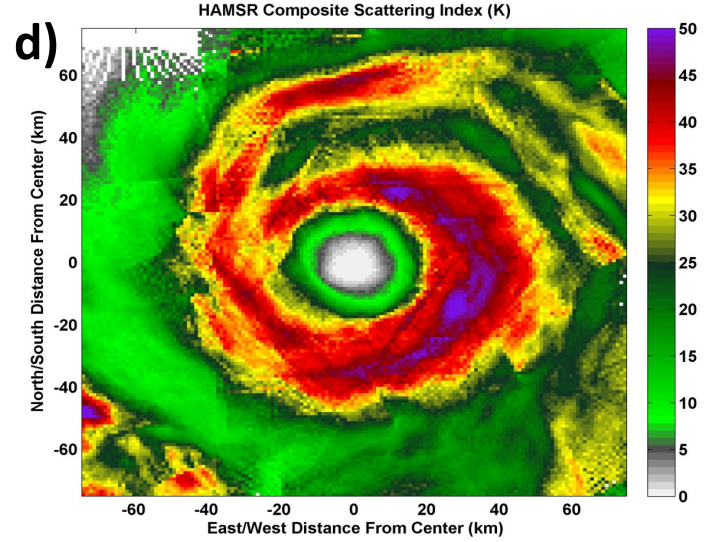


Time









16th September 2010, 23Z

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Observation Data

September 2010

Su	M	T	W	Th	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		

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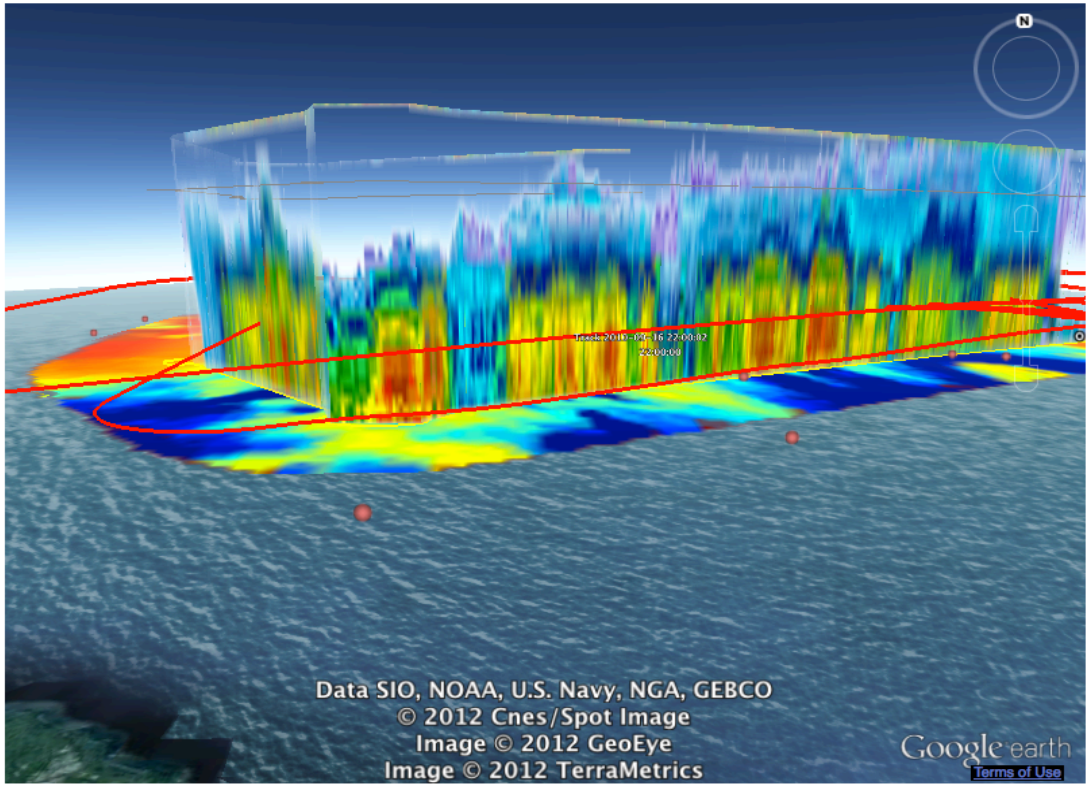
At hour: 23:00:00

- STORM TRACKS
  - Best Tracks
  - Pouch Tracks
- SATELLITE DATA
- AIRBORNE DATA
  - HAMSR Channel 09
  - HAMSR Reflectivity
  - APR2 Zku
  - Dropsonde
  - NOAA N42RF
  - Lase
  - Daily DC8-Flight track
  - Daily Global Hawk track
  - Hourly Global Hawk track

The current time is Thu, 19 Jan 2012 03:18:59 GMT



Status Bar | Grid | Save snapshot | Load snapshot | Download

Animation: Observation Data | Model Data

Select a time range to animate: (from 2010-09-15 19:00:00 to 2010-09-16 19:00:00)

Start 2010-09-15 19:00:00 *End* 2010-09-16 19:00:00 *Animation Step* 1 hour

Animate | Stop | Download

Model Data

September 2010

Su	M	T	W	Th	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		

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- MODEL DATA
  - Pressure Level: 850
  - Forecast Time: 000
  - GFS
    - Speed Earth Relative
    - Streamline Earth Relative
    - PGI41L
    - PGI43L
    - PGI44L
    - PGI45L
    - PGI46L
    - Relative Humidity
    - OW
    - Vorticity
    - Deep shear
    - Pouch shear
    - Sea Level Pressure
  - ECMWF
  - UKMET
  - NOGAPS

16th September 2010, 23Z

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Observation Data

September 2010

Su	M	T	W	Th	F	S
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  - Lase
  - Daily DC8-Flight track
  - Daily Global Hawk track
  - Hourly Global Hawk track

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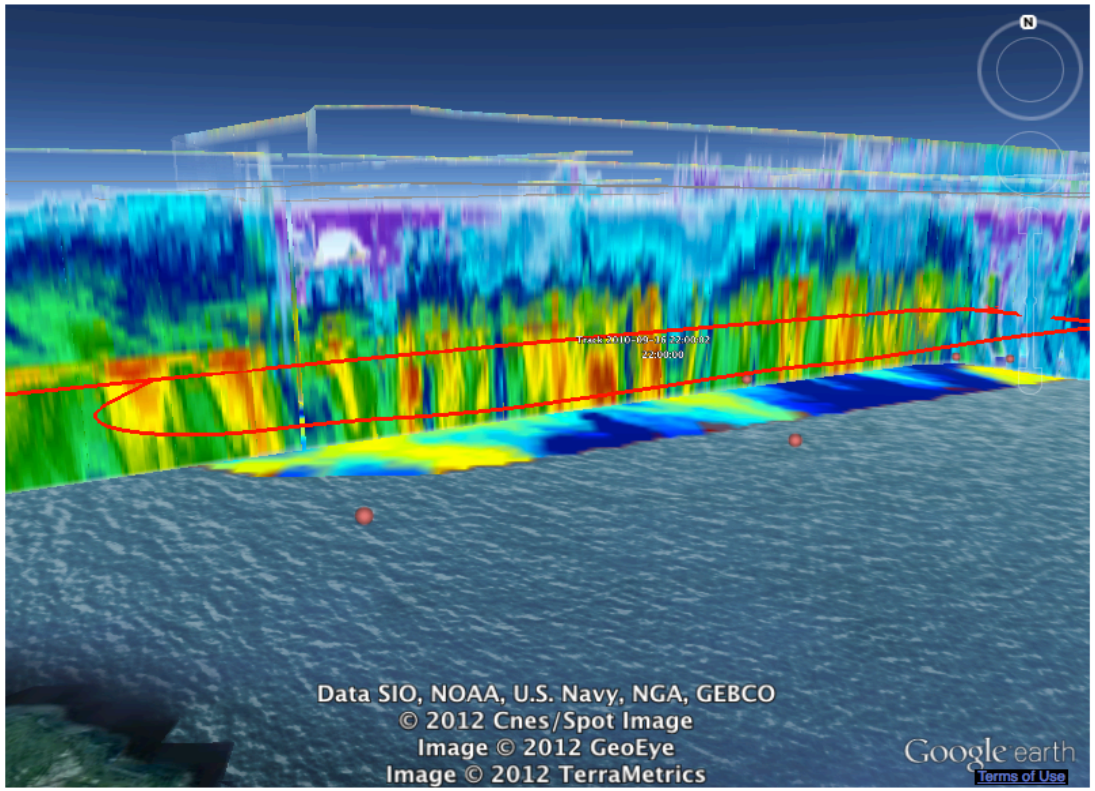

Status Bar | Grid | Save snapshot | Load snapshot | Download

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Select a time range to animate: (from 2010-09-15 19:00:00 to 2010-09-16 19:00:00)

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Animate | Stop | Download

Model Data

September 2010

Su	M	T	W	Th	F	S
			01	02	03	04
05	06	07	08	09	10	11
12	13	14	15	16	17	18
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  - Pressure Level: 850
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  - GFS
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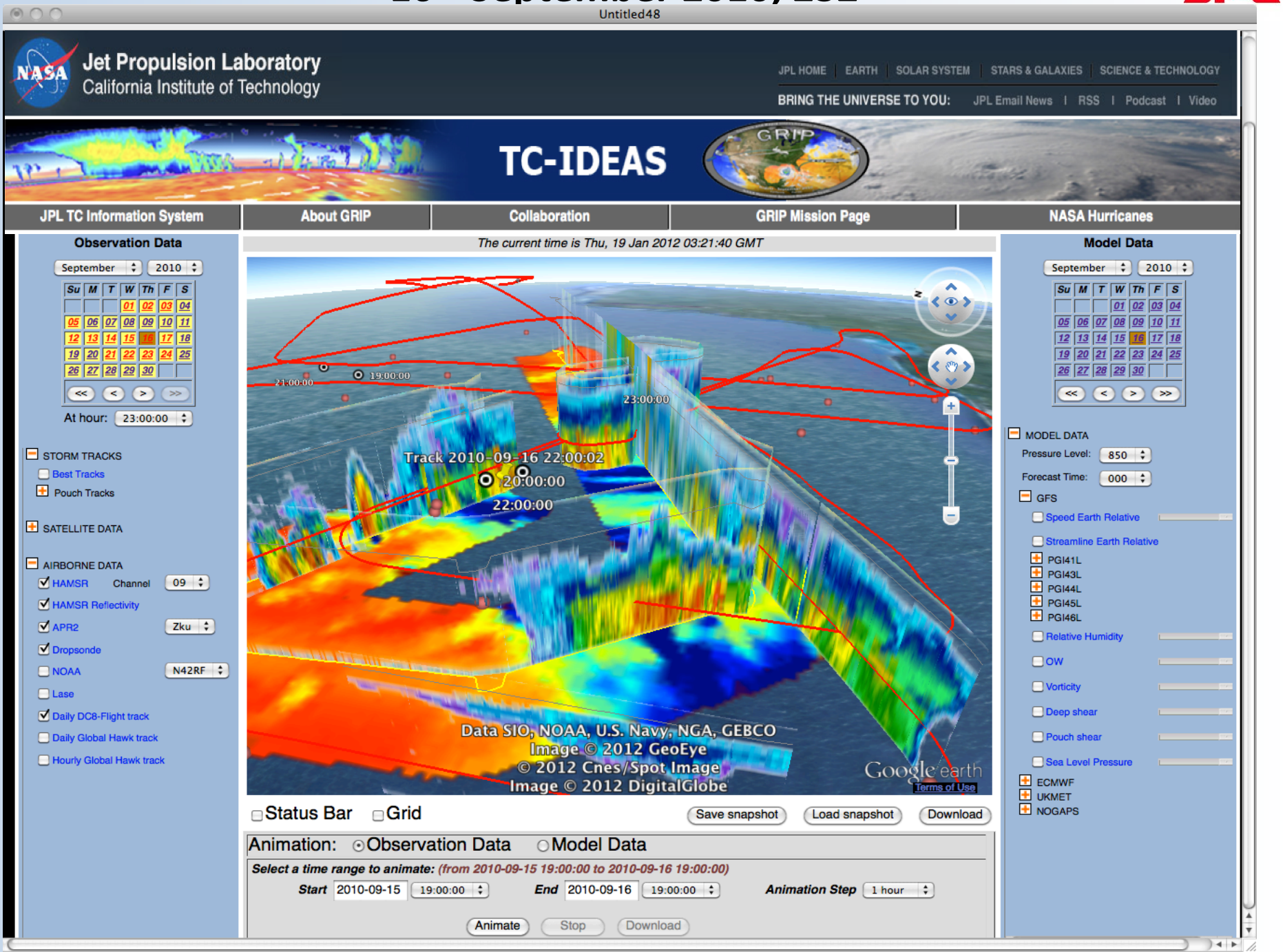
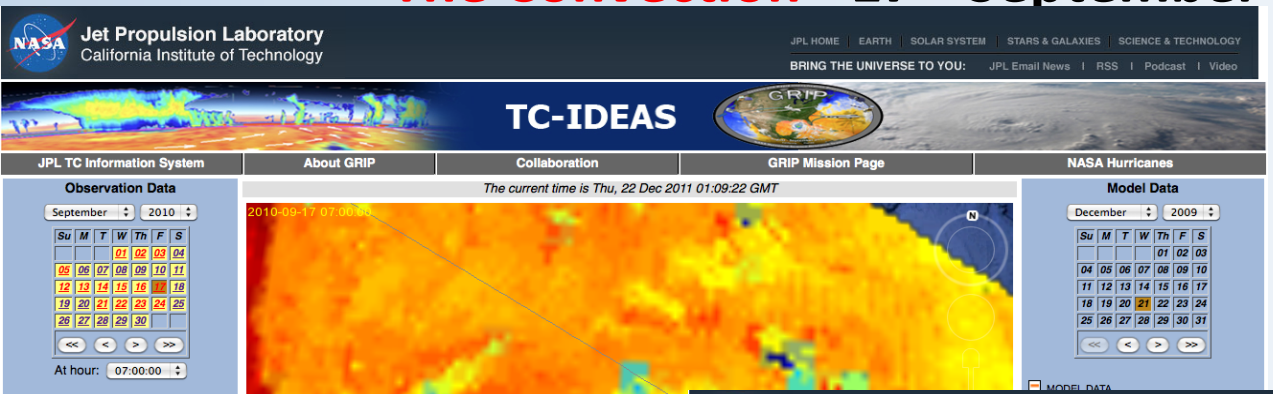
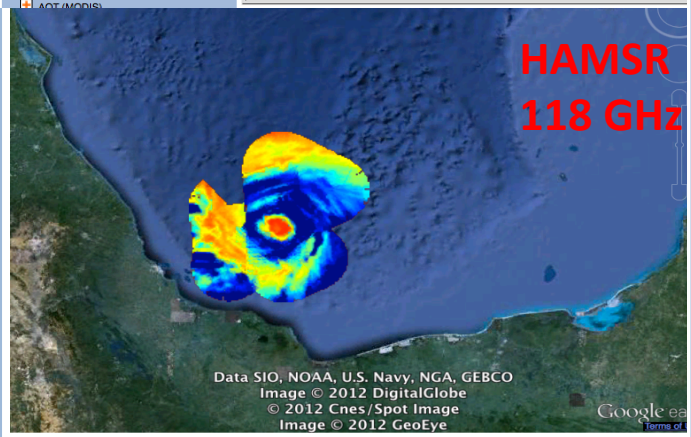
16th September 2010, 23Z



The Convection - 17th September 2010, 07Z



The ring



17th September 2010, 07Z

17th September 2010, 21Z

Summary

- **The try-agency GRIP/PREDIC/IFEX field campaign of 2010 provided unprecedented set of observations of hurricane Karl, covering its life, from genesis, through Rapid Intensification and landfall.**
- We will use these data for a comprehensive evaluation of the HWRF forecast addressing the following questions:
  - **Does HWRF properly represent the environment – temperature, humidity, shear?**
  - **Are the convective processes represented correctly?**
  - **Are the correlations (evolution) of the warm core and the convective processes properly reflected?**
  - **Is the forecasted convective organization close to the observed?**
  - **When the model forecast is good, is it for the right reason ?**
- Longer- term goals
  - What is the role of the initial conditions?
  - Does assimilation of observations of the environment and/or the inner core processes help improve the model depiction of the rapid intensification?

Fusion of hurricane models and observations: Developing the technology to improve the forecasts

PI: Svetla Hristova-Veleva / JPL

Objective

To develop the technology to provide the fusion of observations and operational model simulations to help improve the understanding and forecasting of the hurricane processes.

Specifically,

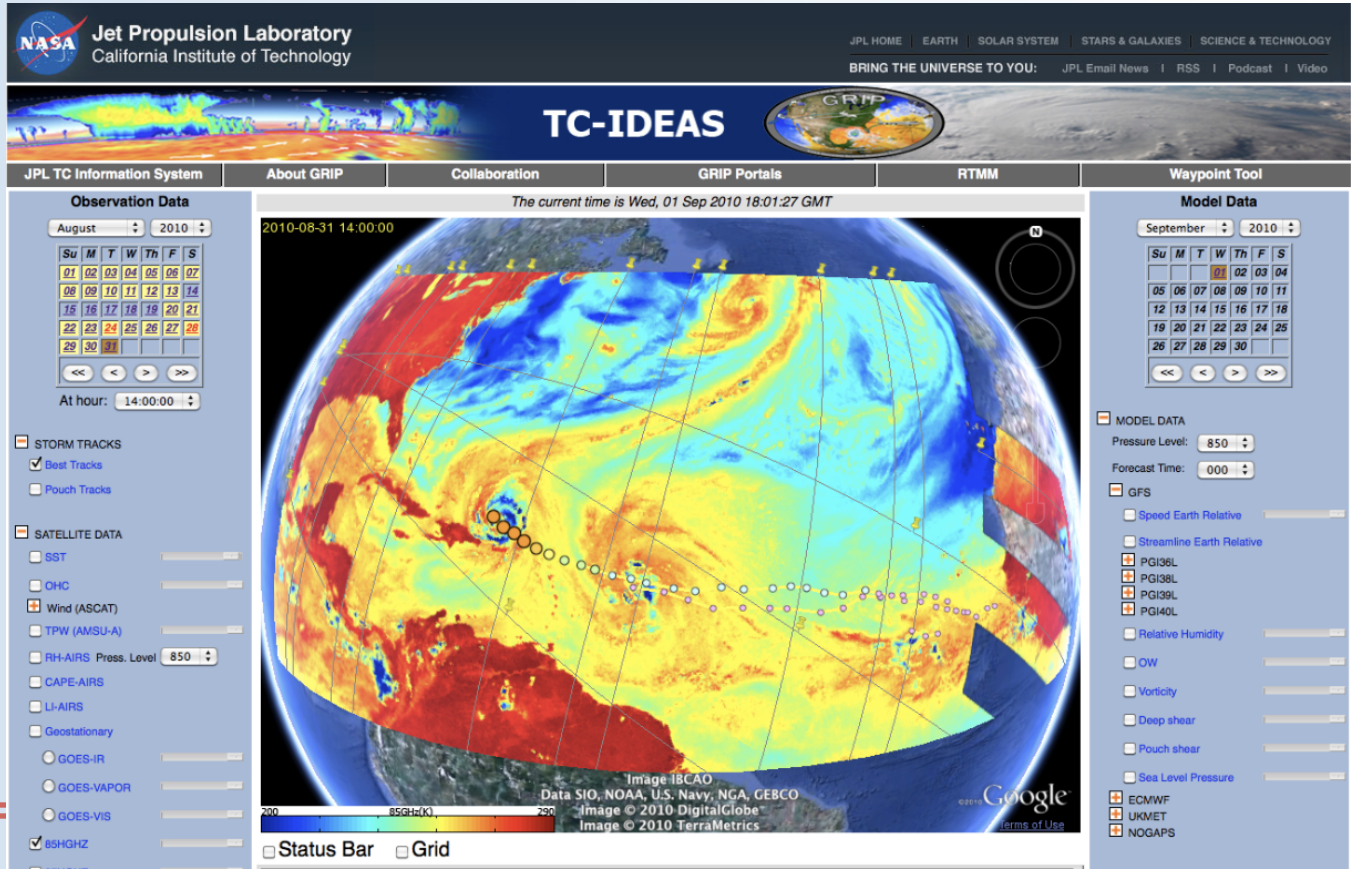
- To develop processing techniques to enable multi-source data fusion across hurricane forecast models, satellite data, and *in-situ* sensors,
- To develop tools to manage the validation and assessment of model comparisons to more easily evaluate the performance of different numerical models,
- To develop interactive visualization techniques to enable analysis of highly complex systems.

Approach:

Integration of the ISSARS instrument simulator with operational hurricane forecast models and incorporation of simulated satellite observables into the existing database of satellite and airborne observations.

Development of a set of advanced analysis tools

Development of data immersion to enable real-time interaction with the models, and visualization of highly complex systems



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