

**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.**

**Svetla Hristova-Veleva¹, Sundararaman Gopalakrishnan²,
Bjorn Lambrigtsen¹, Shannon Brown¹,
Tomislava Vukicevic², Ziad Haddad¹ and Thiago Quirino²**

¹ Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA,

² NOAA/Hurricane Research Division/Atlantic Oceanographic Meteorological
Laboratory, Miami, FL

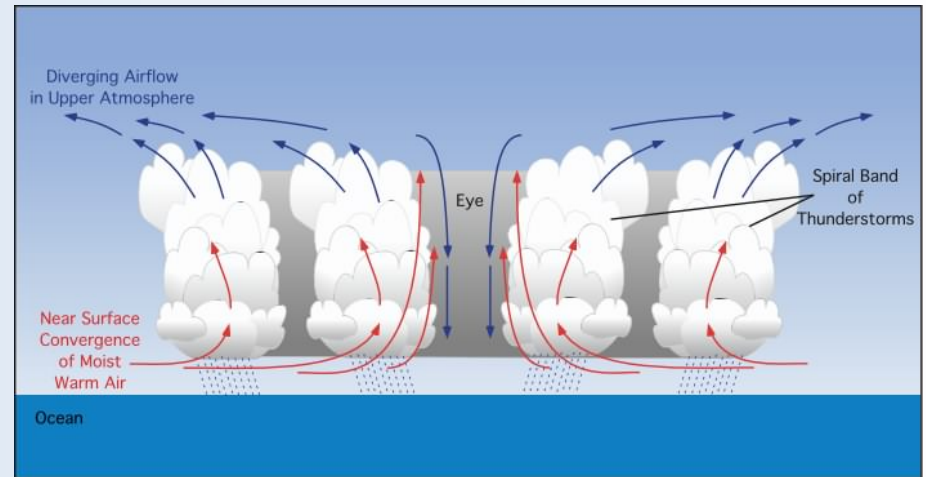
66th IHC – March 6th, 2012

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:

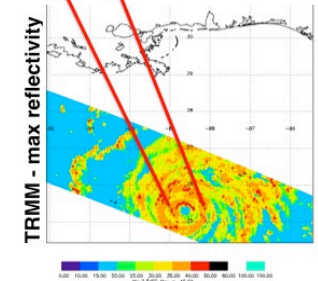
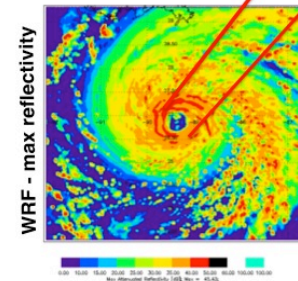
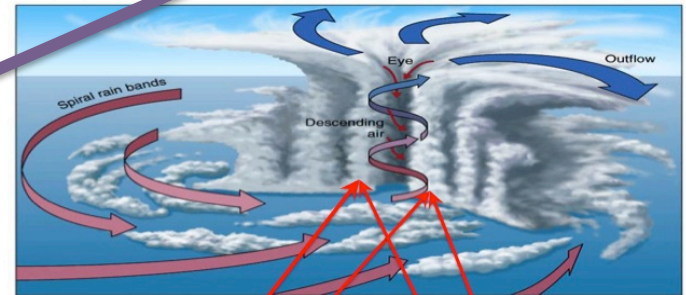
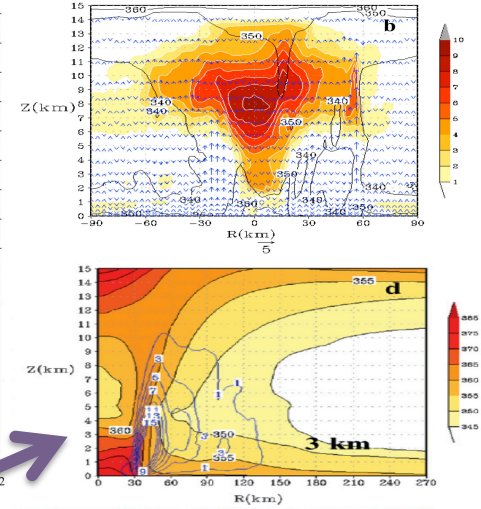
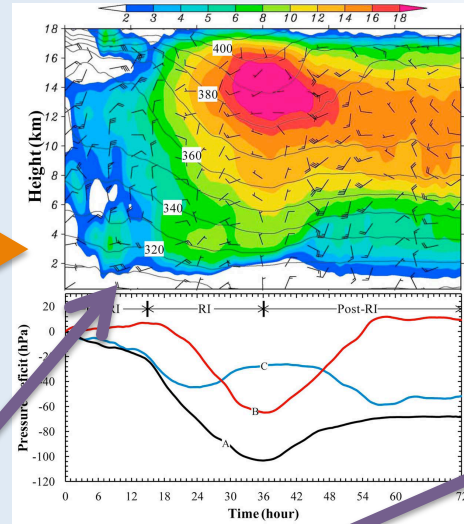
Zhang and Chen, 2012

Rogers, 2010

Copalakrishnan et al., 2011

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? →



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).**

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

TC-IDEAS



JPL TC Information System

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Collaboration

GRIP Mission Page

NASA Hurricanes

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		

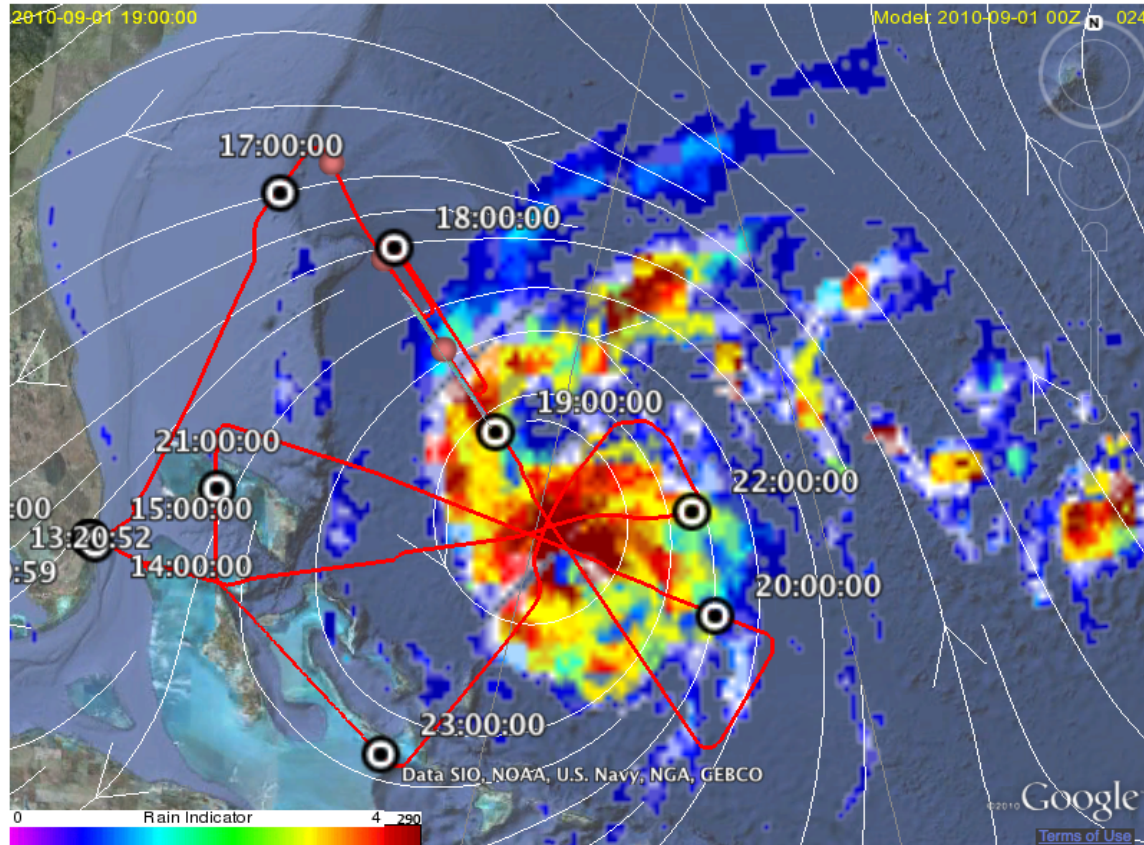
At hour: 19:00:00

STORM TRACKS

SATELLITE DATA

- SST
- OHC
- Wind (ASCAT)
- TPW (AMSU-A)
- RH-AIRS Press. Level 850
- CAPE-AIRS
- LI-AIRS
- Geostationary
 - GOES-IR
 - GOES-VAPOR
 - GOES-VIS
- 85GHZ
- 37GHZ
- Rain
- TRMM PR Nadir

The current time is Wed, 01 Jun 2011 07:04:25 GMT



Status Bar Grid

Animation: Observation Data Model Data

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		

MODEL DATA

Pressure Level: 850

Forecast Time: 024

GFS

- Speed Earth Relative
- Streamline Earth Relative
- PG136L
- PG138L
- PG139L
- PG140L
- Relative Humidity
- OW
- Vorticity
- Deep shear
- Pouch shear
- Sea Level Pressure

- ECMWF
- UKMET
- NOGAPS

Hurricane Earl, 27th August 2010



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NASA Hurricanes

Observation Data

August 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	31				

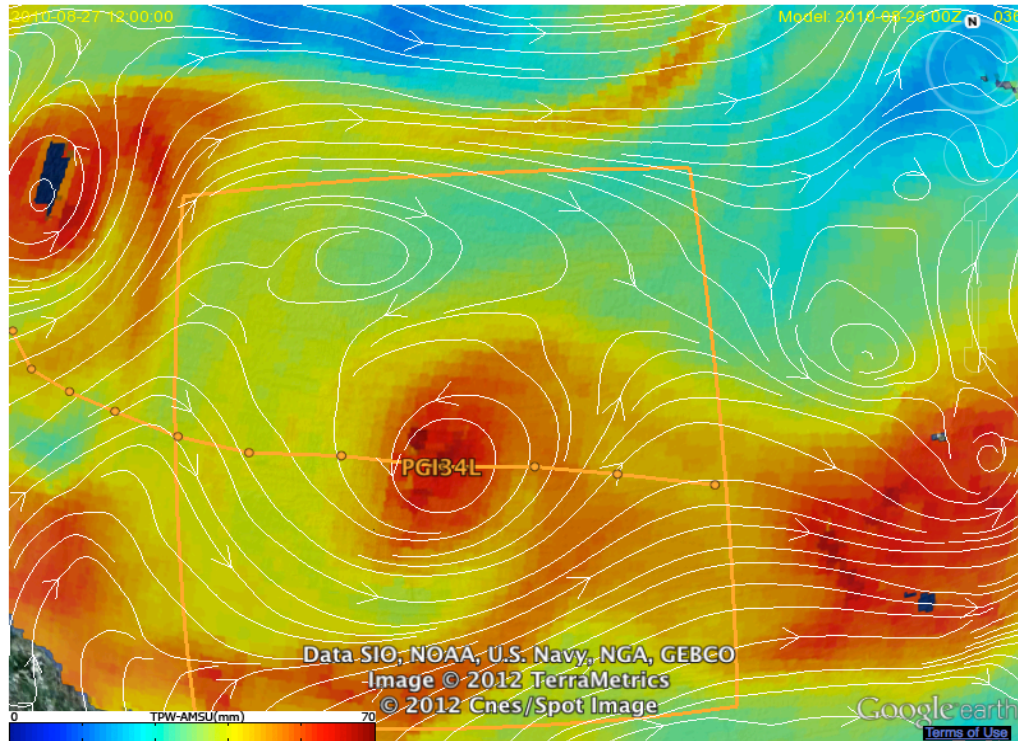
At hour: 12:00:00

- PGI36L
- PGI37L

SATELLITE DATA

- SST
- OHC
- Wind (ASCAT)
- TPW (AMSU-A)
- RH-AIRS Press. Level 850
- CAPE-AIRS
- LI-AIRS
- Geostationary
 - GOES-IR
 - GOES-VAPOR
 - GOES-VIS
- 85GHZ
- 37GHZ
- Rain
- TRMM PR Nadir
- CloudSat

The current time is Thu, 19 Jan 2012 02:15:56 GMT



Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2012 TerraMetrics
© 2012 Cnes/Spot Image



Status Bar Grid

Save snapshot Load snapshot Download

Animation: Observation Data Model Data

Select a time range to animate: (from 2010-08-26 00:00:00 to 2010-08-27 00:00:00)

Start 2010-08-26 19:00:00 End 2010-08-27 19:00:00 Animation Step 1 hour

Model Data

August 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	31				

MODEL DATA

Pressure Level: 850

Forecast Time: 036

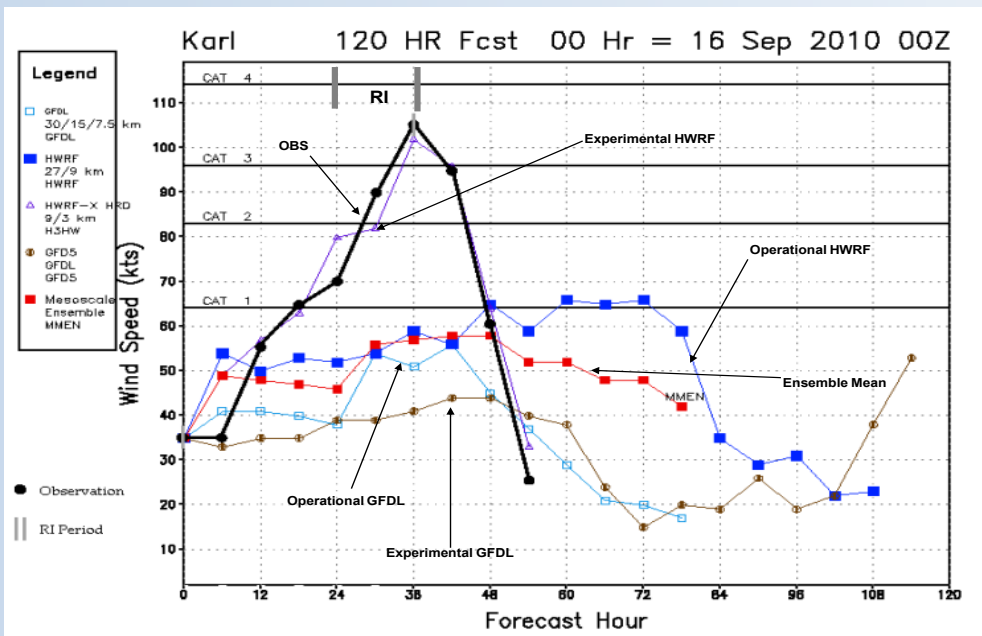
- GFS
- ECMWF

- Speed Earth Relative
- Streamline Earth Relative
- PGI31L
- PGI34L
 - Speed comoving
 - Streamline comoving
- PGI36L
- PGI37L
 - Relative Humidity
 - OW
 - Vorticity
 - Deep shear
 - Pouch shear
 - Sea Level Pressure
- UKMET
- NOGAPS

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.

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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		

At hour: 23:00:00

- GOES-IR
- GOES-VAPOR
- GOES-VIS
- 85GHZ
- 37GHZ
- Rain
- TRMM PR Nadir
- CloudSat
- CALIPSO
- MLS
- AOT (MODIS)
- Satellite Winds (CIMSS)

AIRBORNE DATA

- HAMS Channel 01
- HAMS 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 02:32:18 GMT

Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image USDA Farm Service Agency
Image © 2012 DigitalGlobe
Image © 2012 TerraMetrics

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Status Bar
 Grid
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Animation: Observation Data Model Data

Select a time range to animate: (from 2010-09-13 00:00:00 to 2010-09-14 00:00:00)

Start 2010-09-13 19:00:00 End 2010-09-14 19:00:00 Animation Step 1 hour

Animate Stop Download

Model Data

August 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	31				

- MODEL DATA
 - Pressure Level: 850
 - Forecast Time: 036
- GFS
 - Speed Earth Relative
 - Streamline Earth Relative
 - PG131L
 - PG134L
 - PG136L
 - PG137L
 - Relative Humidity
 - OW
 - Vorticity
 - Deep shear
 - Pouch shear
 - Sea Level Pressure
- ECMWF
- UKMET
- NOGAPS



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		

<< < > >>

At hour: 22:00:00

STORM TRACKS

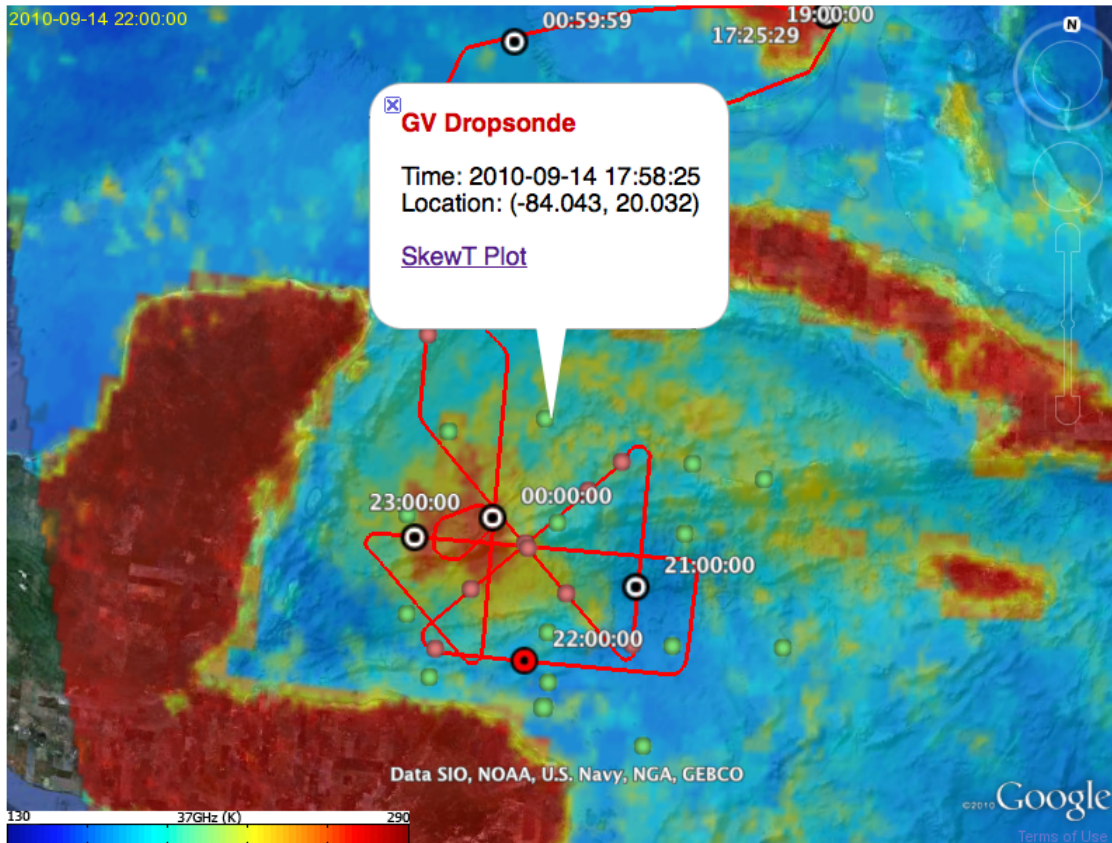
- Best Tracks
- Pouch Tracks

SATELLITE DATA

AIRBORNE DATA

- HAMSR Channel: 01
- APR2
- Dropsonde
- DC8-Flight track
- Global Hawk track

The current time is Tue, 23 Nov 2010 20:44:24 GMT



Status Bar Grid

Animation: Observation Data Model Data

Select a time range to animate: (from 2010-09-13 21:00:00 to 2010-09-14 21:00:00)

Start 2010-09-13 15:00:00 End 2010-09-14 15:00:00 Animation Step 1 hour

Animate Stop Download

Model Data

November 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				

<< < > >>

MODEL DATA

Pressure Level: 850

Forecast Time: 000

GFS

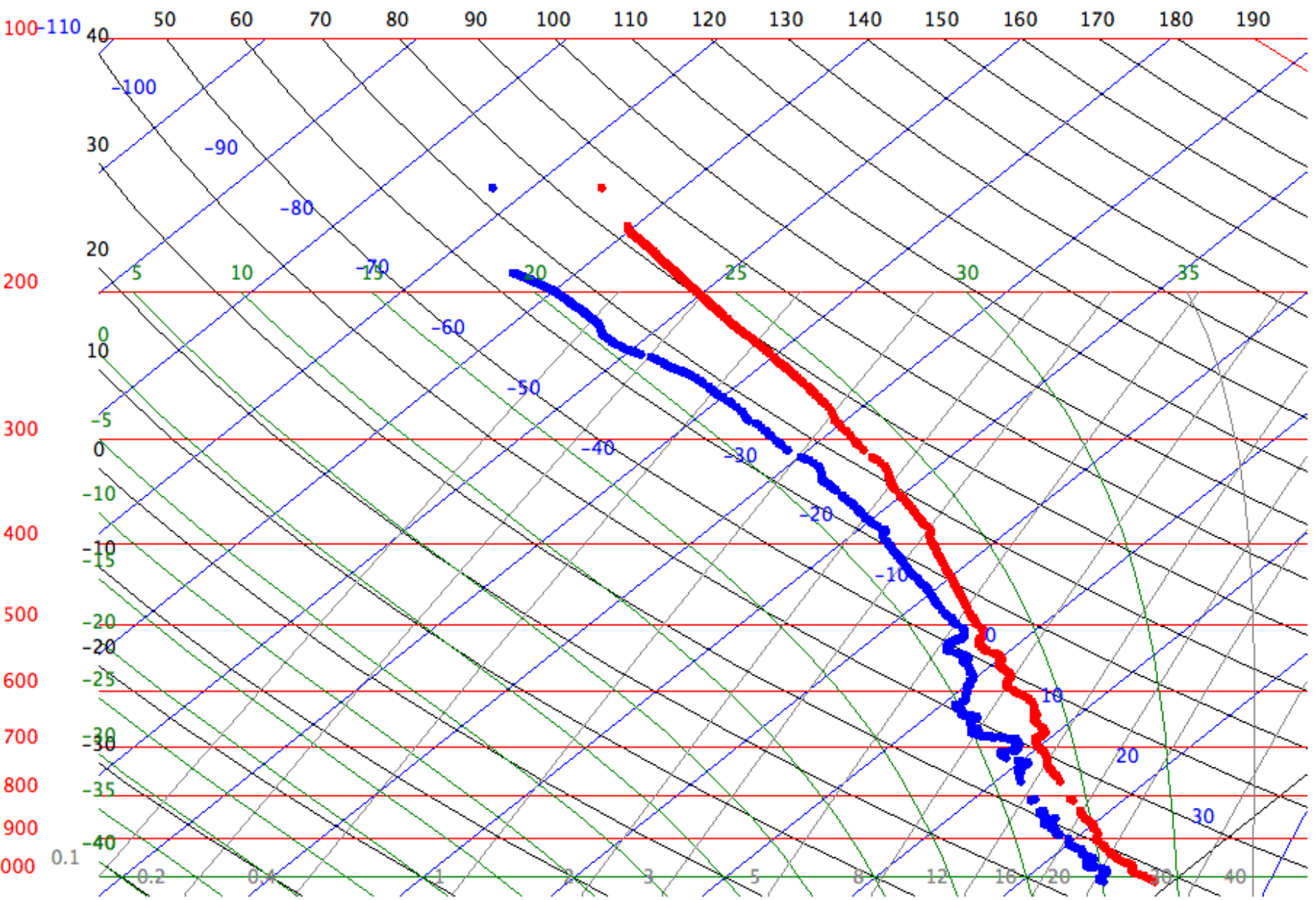
- Speed Earth Relative
- Streamline Earth Relative
- Relative Humidity
- OW
- Vorticity
- Deep shear
- Pouch shear
- Sea Level Pressure

- ECMWF
- UKMET
- NOGAPS

14th September 2010, 18Z

D20100914_175825_P.4 101015304 PREDICT, RF 19 NCAR GV, 677F

N20.0315 W84.0433



Hurricane Karl, September 14 2010

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

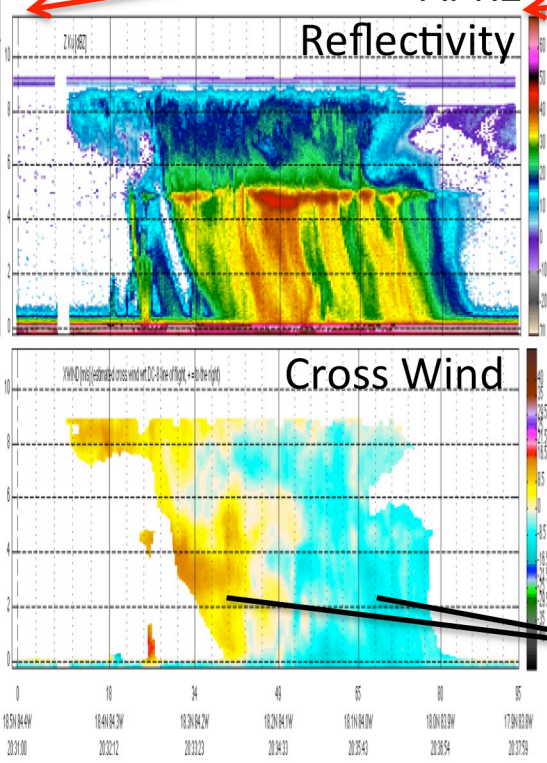
JPL participated with two instruments (HAMSR and APR2) and the JPL GRIP portal which blends satellite and airborne observations with model data.

The screenshot shows the JPL TC-IDEAS web portal interface. At the top, it displays the NASA logo and 'Jet Propulsion Laboratory California Institute of Technology'. The main header includes 'TC-IDEAS' and a 'GRIP' logo. Below the header are navigation tabs: 'JPL TC Information System', 'About GRIP', 'Collaboration', 'GRIP Portals', 'RTMM', and 'Waypoint Tool'. The central area features a 3D visualization of Hurricane Karl on September 14, 2010, at 20:00:00 GMT. The visualization shows the storm's structure with a color-coded intensity scale (0 to 4) and a 'Rain Indicator' bar. A callout box provides details: 'Name: Karl-13L', 'Time: 2010-09-14 00:00:00', 'Location: 16N,-79.8W', 'Wind Speed: 25 knots', and 'Central Pressure: 1006 mb'. To the left of the 3D view is a 'Calendar' for September 2010, with the 14th highlighted. Below the calendar are various data selection options for 'OBSERVATION DATA' (e.g., SST, OHC, Wind, TPW, RH-AIRS, CAPE-AIRS, LI-AIRS, Geostationary, GOES-IR, GOES-VAPOR, GOES-VIS, 85GHZ, 37GHZ, Rain, TRMM PR, CloudSat) and 'MODEL DATA' (e.g., Pressure Level, Forecast Time, GFS, Streamline Earth Relative, PG141L, PG143L, PG144L, PG145L, Relative Humidity, OW, Vorticity, Deep shear, Pouch shear, Sea Level Pressure, ECMWF, UKMET, NOGAPS). At the bottom, there are controls for 'Animation' (Observation Data, Model Data) and a time range selector (Start: 2010-09-13 15:00:00, End: 2010-09-14 15:00:00, Animation Step: 1 hour).

APR2

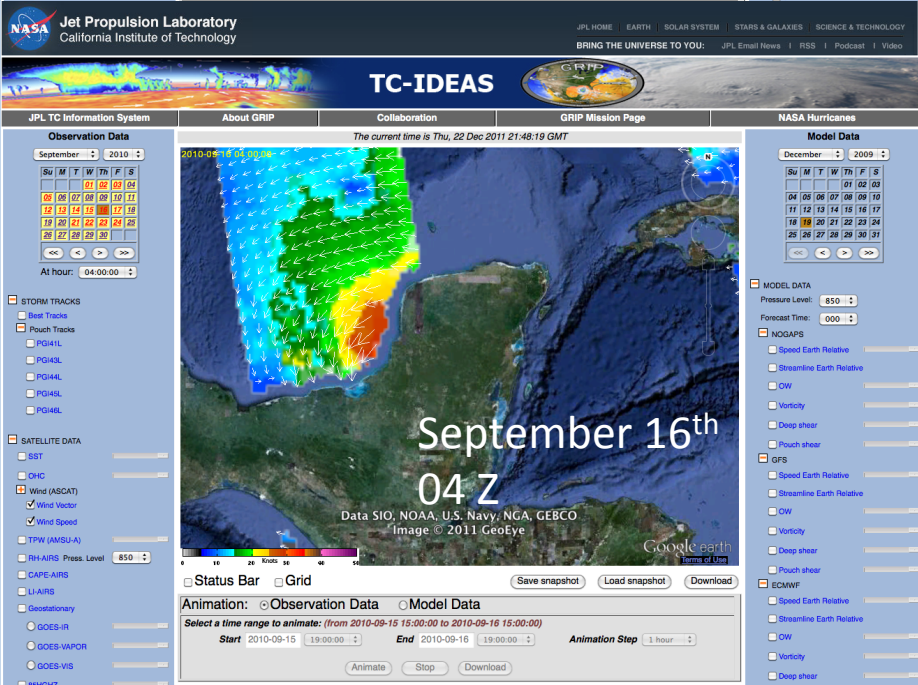
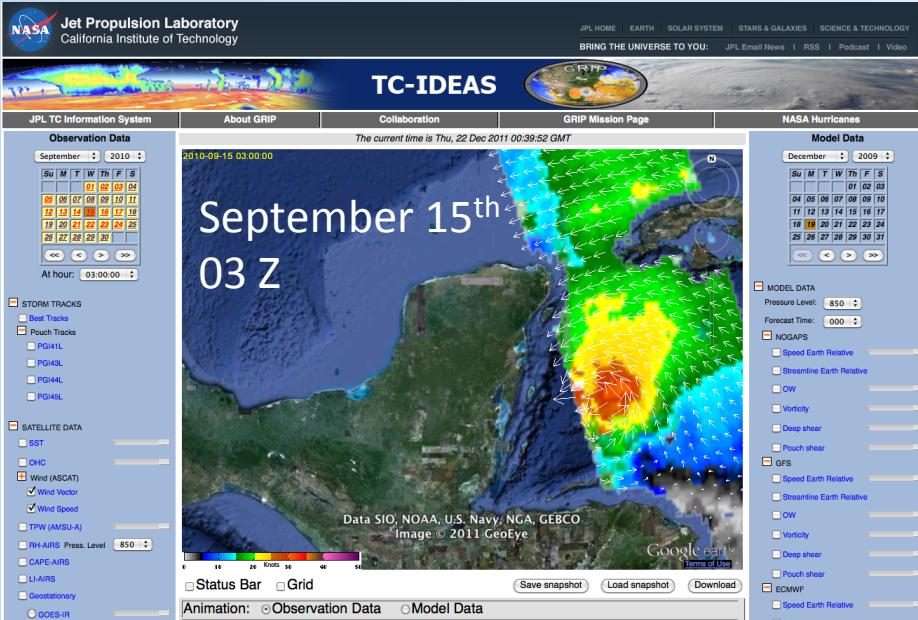
Reflectivity

Cross Wind



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



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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		

At hour: 22:00:00

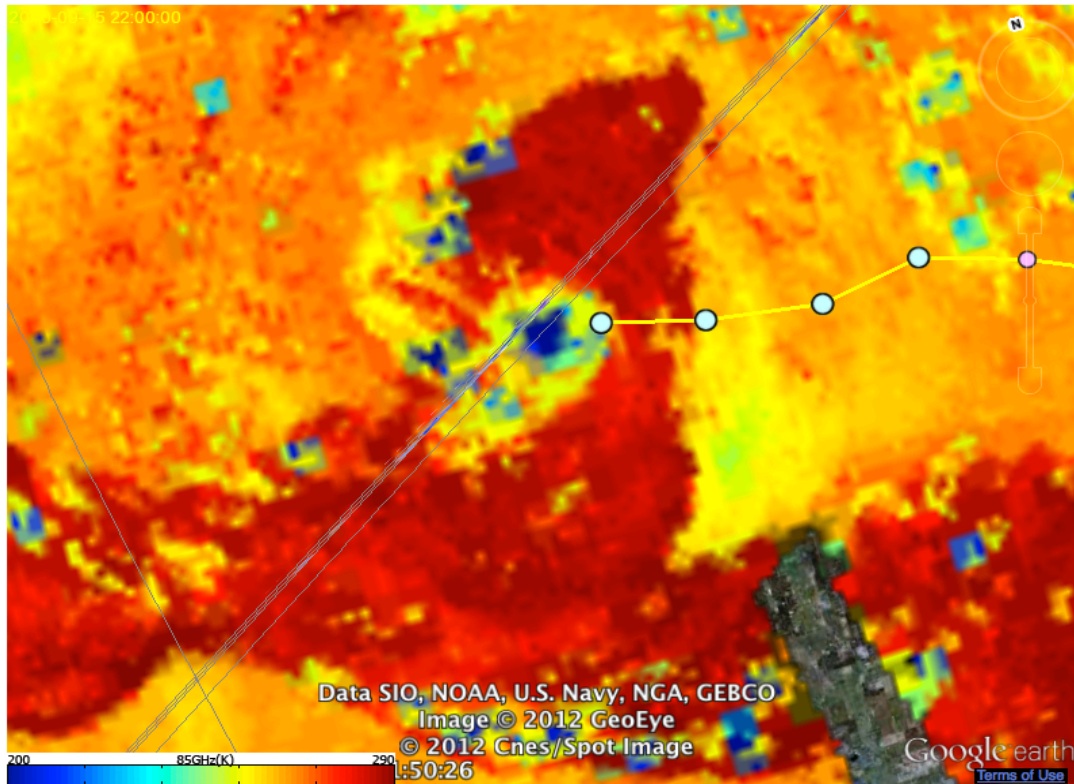
STORM TRACKS

- Best Tracks
- Pouch Tracks

SATELLITE DATA

- SST
- OHC
- Wind (ASCAT)
- TPW (AMSU-A)
- RH-AIRS Press. Level 850
- CAPE-AIRS
- LI-AIRS
- Geostationary
 - GOES-IR
 - GOES-VAPOR
 - GOES-VIS
- 85GHZ
- 37GHZ
- Rain
- TRMM PR Nadir
- CloudSat
- CALIPSO

The current time is Thu, 19 Jan 2012 02:44:29 GMT



Status Bar Grid

Save snapshot

Load snapshot

Download

Animation: Observation Data Model Data

Select a time range to animate: (from 2010-09-14 00:00:00 to 2010-09-15 00:00:00)

Start 2010-09-14 19:00:00

End 2010-09-15 19:00:00

Animation Step 1 hour

Animate

Stop

Download

Model Data

August 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	31				

MODEL DATA

Pressure Level: 850

Forecast Time: 036

GFS

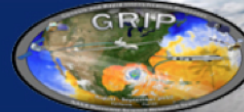
- Speed Earth Relative
- Streamline Earth Relative
- PGI31L
- PGI34L
- PGI36L
- PGI37L
- Relative Humidity
- OW
- Vorticity
- Deep shear
- Pouch shear
- Sea Level Pressure
- ECMWF
- UKMET
- NOGAPS



Untitled26



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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
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19	20	21	22	23	24	25
26	27	28	29	30		

At hour: 22:00:00

STORM TRACKS

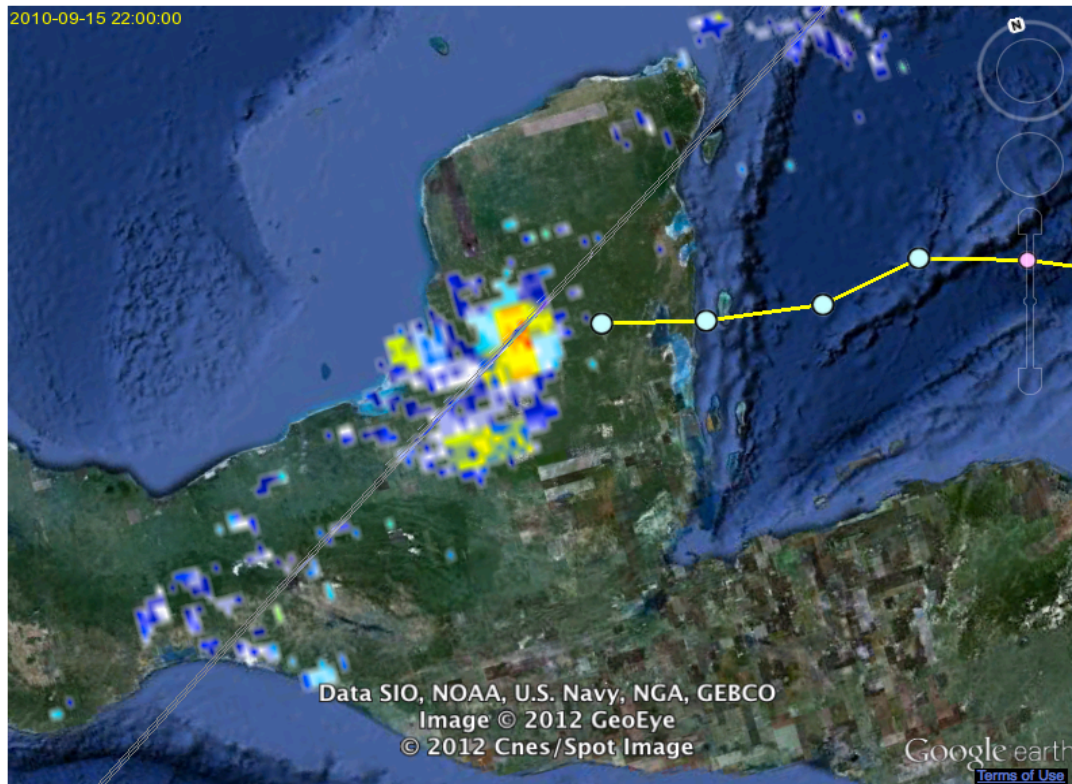
- Best Tracks
- Pouch Tracks

SATELLITE DATA

- SST
- OHC
- Wind (ASCAT)
- TPW (AMSU-A)
- RH-AIRS Press. Level: 850
- CAPE-AIRS
- LI-AIRS
- Geostationary
- GOES-IR
- GOES-VAPOR
- GOES-VIS
- 85GHZ
- 37GHZ
- Rain
- TRMM PR Nadir
- CloudSat
- CALIPSO

The current time is Thu, 19 Jan 2012 02:46:03 GMT

2010-09-15 22:00:00



Status Bar Grid

Save snapshot

Load snapshot

Download

Animation: Observation Data Model Data

Select a time range to animate: (from 2010-09-14 00:00:00 to 2010-09-15 00:00:00)

Start 2010-09-14 19:00:00

End 2010-09-15 19:00:00

Animation Step 1 hour

Animate

Stop

Download

Model Data

August 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	31				

MODEL DATA

Pressure Level: 850

Forecast Time: 036

GFS

- Speed Earth Relative
- Streamline Earth Relative
- PGI31L
- PGI34L
- PGI36L
- PGI37L
- Relative Humidity
- OW
- Vorticity
- Deep shear
- Pouch shear
- Sea Level Pressure
- ECMWF
- UKMET
- NOGAPS



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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
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26	27	28	29	30		

At hour: 22:00:00

STORM TRACKS

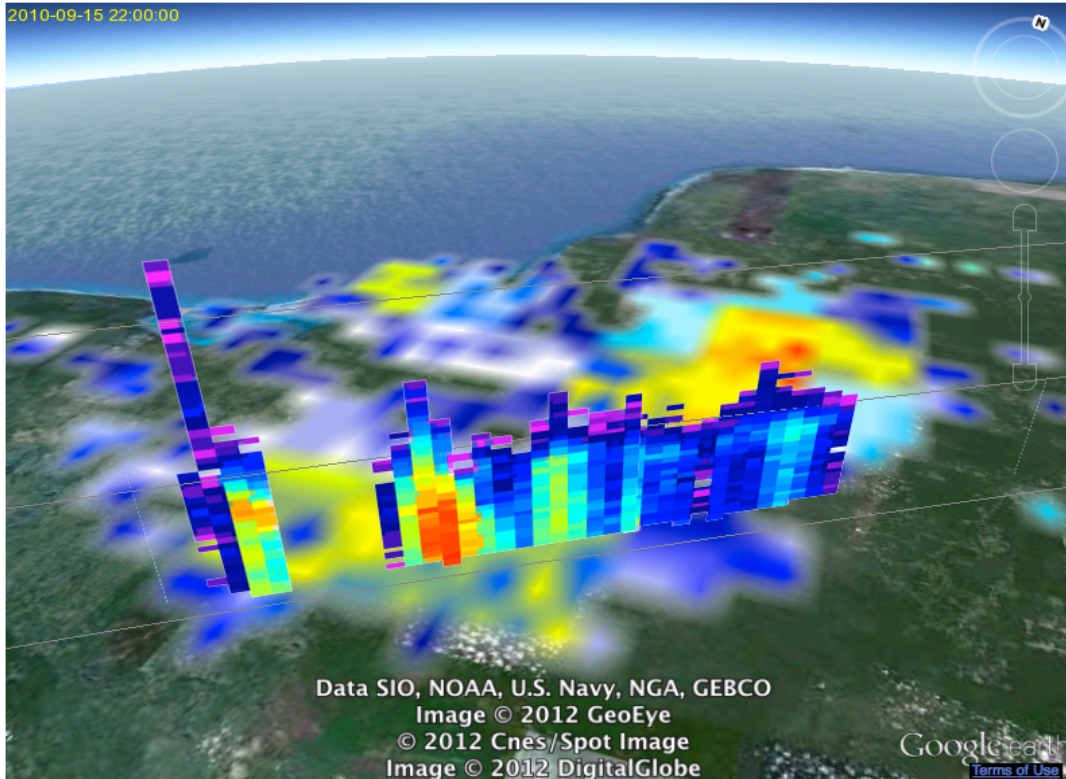
- Best Tracks
- Pouch Tracks

SATELLITE DATA

- SST
- OHC
- Wind (ASCAT)
- TPW (AMSU-A)
- RH-AIRS Press. Level: 850
- CAPE-AIRS
- LI-AIRS
- Geostationary
- GOES-IR
- GOES-VAPOR
- GOES-VIS
- 85GHZ
- 37GHZ
- Rain
- TRMM PR Curt2
- CloudSat
- CALIPSO

The current time is Thu, 19 Jan 2012 02:50:45 GMT

2010-09-15 22:00:00



Model Data

August 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	31				

MODEL DATA

- Pressure Level: 850
- Forecast Time: 036
- GFS
 - Speed Earth Relative
 - Streamline Earth Relative
 - PG131L
 - PG134L
 - PG136L
 - PG137L
 - Relative Humidity
 - OW
 - Vorticity
 - Deep shear
 - Pouch shear
 - Sea Level Pressure
- ECMWF
- UKMET
- NOGAPS

Status Bar Grid

Save snapshot

Load snapshot

Download

Animation: Observation Data Model Data

Select a time range to animate: (from 2010-09-14 00:00:00 to 2010-09-15 00:00:00)

Start 2010-09-14 19:00:00

End 2010-09-15 19:00:00

Animation Step 1 hour

Animate

Stop

Download



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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		

At hour: 22:00:00

STORM TRACKS

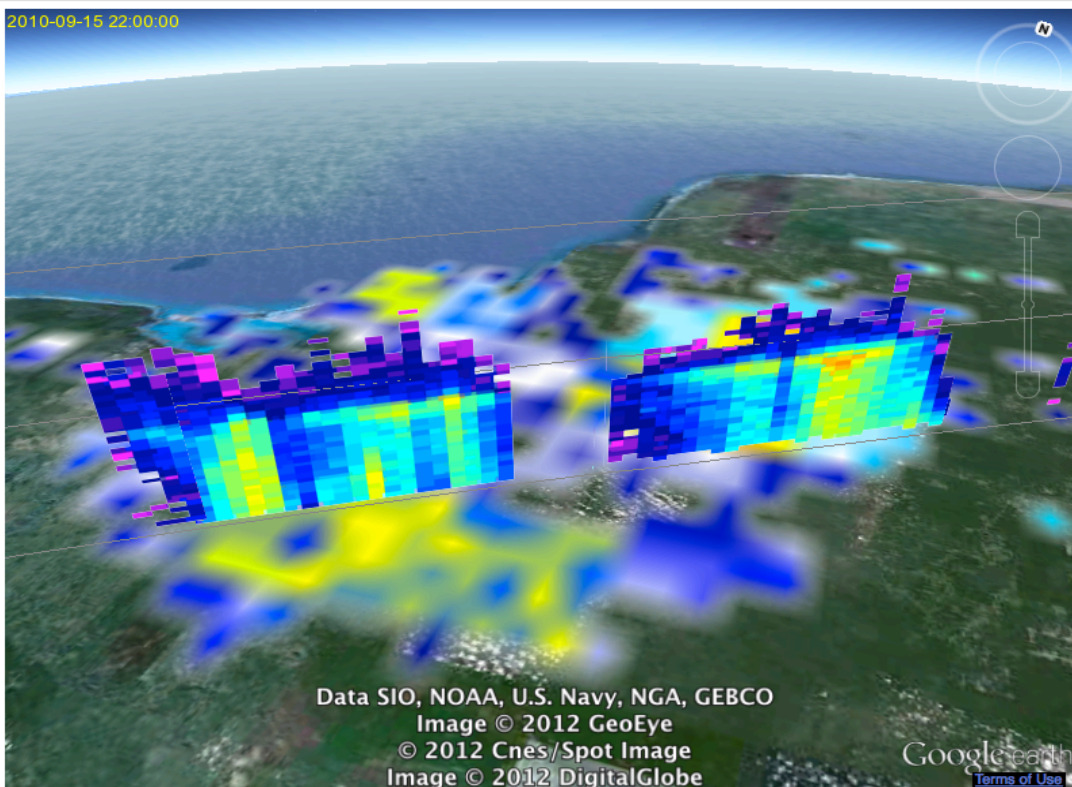
- Best Tracks
- Pouch Tracks

SATELLITE DATA

- SST
- OHC
- Wind (ASCAT)
- TPW (AMSU-A)
- RH-AIRS Press. Level 850
- CAPE-AIRS
- LI-AIRS
- Geostationary
 - GOES-IR
 - GOES-VAPOR
 - GOES-VIS
- 85GHZ
- 37GHZ
- Rain
- TRMM PR Curt3
- CloudSat
- CALIPSO

The current time is Thu, 19 Jan 2012 02:51:40 GMT

2010-09-15 22:00:00



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Status Bar Grid

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Animation: Observation Data Model Data

Select a time range to animate: (from 2010-09-14 00:00:00 to 2010-09-15 00:00:00)

Start 2010-09-14 19:00:00

End 2010-09-15 19:00:00

Animation Step 1 hour

Animate

Stop

Download

Model Data

August 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	31				

MODEL DATA

Pressure Level: 850

Forecast Time: 036

GFS

- Speed Earth Relative
- Streamline Earth Relative
- PGI31L
- PGI34L
- PGI36L
- PGI37L
- Relative Humidity
- OW
- Vorticity
- Deep shear
- Pouch shear
- Sea Level Pressure
- ECMWF
- UKMET
- NOGAPS



TC-IDEAS



JPL TC Information System

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NASA Hurricanes

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		

At hour: 22:00:00

STORM TRACKS

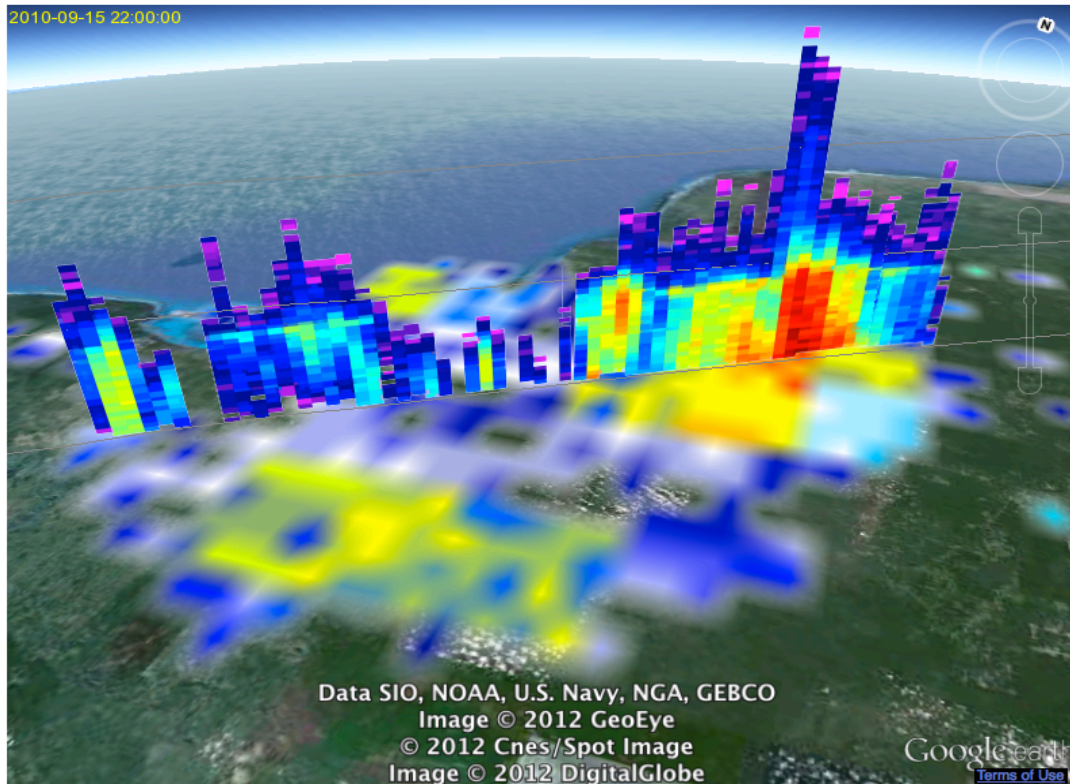
- Best Tracks
- Pouch Tracks

SATELLITE DATA

- SST
- OHC
- Wind (ASCAT)
- TPW (AMSU-A)
- RH-AIRS Press. Level: 850
- CAPE-AIRS
- LI-AIRS
- Geostationary
 - GOES-IR
 - GOES-VAPOR
 - GOES-VIS
- 85GHZ
- 37GHZ
- Rain
- TRMM PR Nadir
- CloudSat
- CALIPSO

The current time is Thu, 19 Jan 2012 02:52:26 GMT

2010-09-15 22:00:00



Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2012 GeoEye
© 2012 Cnes/Spot Image
Image © 2012 DigitalGlobe

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Status Bar Grid

Save snapshot

Load snapshot

Download

Animation: Observation Data Model Data

Select a time range to animate: (from 2010-09-14 00:00:00 to 2010-09-15 00:00:00)

Start 2010-09-14 19:00:00

End 2010-09-15 19:00:00

Animation Step 1 hour

Animate

Stop

Download

Model Data

August 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	31				

At hour: 03:30:00

MODEL DATA

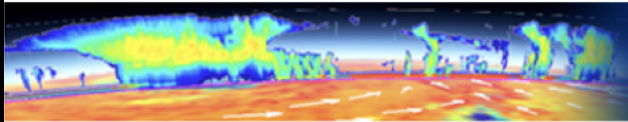
Pressure Level: 850

Forecast Time: 03:30

GFS

- Speed Earth Relative
- Streamline Earth Relative
- PGI31L
- PGI34L
- PGI36L
- PGI37L
- Relative Humidity
- OW
- Vorticity
- Deep shear
- Pouch shear
- Sea Level Pressure

- ECMWF
- UKMET
- NOGAPS



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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		

At hour: 22:00:00

STORM TRACKS

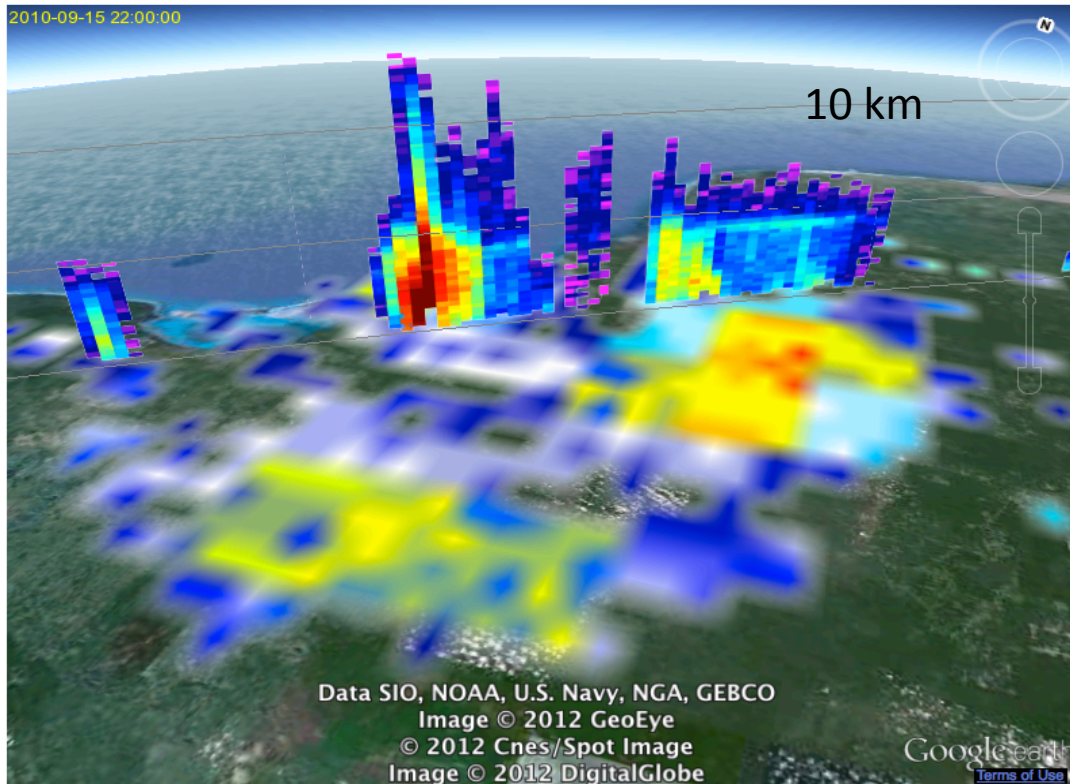
- Best Tracks
- Pouch Tracks

SATELLITE DATA

- SST
- OHC
- Wind (ASCAT)
- TPW (AMSU-A)
- RH-AIRS Press. Level: 850
- CAPE-AIRS
- LI-AIRS
- Geostationary
- GOES-IR
- GOES-VAPOR
- GOES-VIS
- 85GHZ
- 37GHZ
- Rain
- TRMM PR Curt5
- CloudSat
- CALIPSO

The current time is Thu, 19 Jan 2012 02:53:14 GMT

2010-09-15 22:00:00



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Load snapshot

Download

Animation: Observation Data Model Data

Select a time range to animate: (from 2010-09-14 00:00:00 to 2010-09-15 00:00:00)

Start 2010-09-14 19:00:00

End 2010-09-15 19:00:00

Animation Step 1 hour

Animate

Stop

Download

Model Data

August 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	31				

At hour: 22:00:00

MODEL DATA

Pressure Level: 850

Forecast Time: 036

GFS

- Speed Earth Relative
- Streamline Earth Relative
- PGI31L
- PGI34L
- PGI36L
- PGI37L
- Relative Humidity
- OW
- Vorticity
- Deep shear
- Pouch shear
- Sea Level Pressure

- ECMWF
- UKMET
- NOGAPS

The convection - 16th September 2010, 07Z

Rain Indicator – a multi-channel passive microwave index

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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		

At hour: 08:00:00

Model Data

December 2009

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	31

Model Data

Pressure Level: 850
Forecast Time: 000

NOGAPS

- Speed Earth Relative
- Streamline Earth Relative
- OW
- Vorticity
- Deep shear
- Pouch shear

GFS

- Speed Earth Relative
- Streamline Earth Relative
- OW
- Vorticity
- Deep shear
- Pouch shear

ECMWF

- Speed Earth Relative
- Streamline Earth Relative
- OW
- Vorticity
- Deep shear
- Pouch shear

Image © 2011 GeoEye
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2011 TerraMetrics
© 2011 Cnes/Spot Image

0 Rain Indicator 4

Status Bar Grid

Animation: Observation Data Model Data

Select a time range to animate: (from 2010-09-15 08:00:00 to 2010-09-16 08:00:00)

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

At hour: 07:00:00

- GOES-IR
- GOES-VAPOR
- GOES-VIS
- 8SHGHZ

TRMM PR Curt1

- CloudSat
- CALIPSO
- MLS
- AOT (MODIS)
- Satellite Winds (CIMSS)

AIRBORNE DATA

- HAMS Channel 01
- HAMS Reflectivity
- APR2 Zku
- Dropsonde
- NOAA N42R
- Lase
- Daily DCS-Flight track

85 GHz Brightness temperatures

Visualization Portal

The current time is Thu, 19 Jan 2012 03:01:24 GMT

Model Data

August 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	31				

Model Data

Pressure Level: 850
Forecast Time: 036

GFS

- Speed Earth Relative
- Streamline Earth Relative
- PG131L
- PG134L
- PG136L
- PG137L
- Relative Humidity
- OW
- Vorticity
- Deep shear
- Pouch shear
- Sea Level Pressure

ECMWF

- UNMET
- NOGAPS

Image © 2012 DigitalGlobe
Image © 2012 GeoEye
Image © 2012 TerraMetrics

200 85GHz(K) 220

Status Bar Grid

Animation: Observation Data Model Data

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

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

Note the ring of convection



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Visualization Portal

The current time is Thu, 19 Jan 2012 03:07:22 GMT

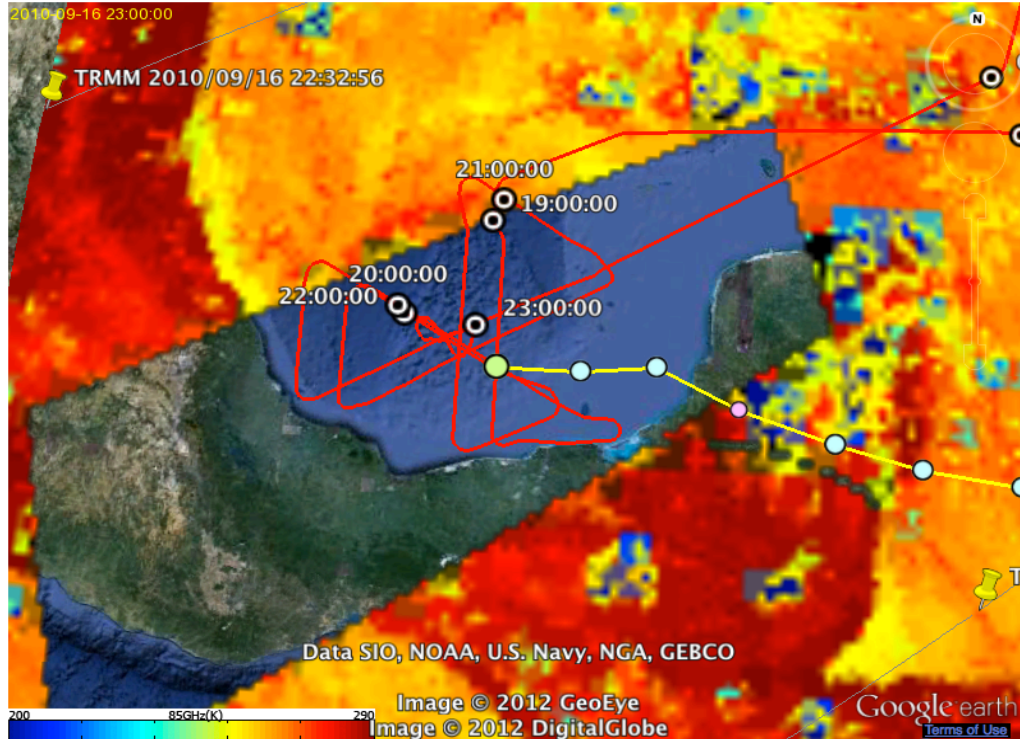
Observation Data

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		

At hour: 23:00:00

- GOES-IR
- GOES-VAPOR
- GOES-VIS
- 85GHZ
- 37GHZ
- Rain
- TRMM PR Curt1
- CloudSat
- CALIPSO
- MLS
- AOT (MODIS)
- Satellite Winds (CIMSS)
- AIRBORNE DATA
 - HAMS Channel 01
 - HAMS Reflectivity
 - APR2 Zku
 - Dropsonde
 - NOAA N42RF
 - Lase
 - Daily DC8-Flight track
 - Daily Global Hawk track
 - Hourly Global Hawk track



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

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Image © 2012 DigitalGlobe

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Status Bar Grid

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Animation: Observation Data Model Data

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

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

Animate Stop Download

Model Data

August 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	31				

- MODEL DATA
 - Pressure Level: 850
 - Forecast Time: 036
- GFS
 - Speed Earth Relative
 - Streamline Earth Relative
 - PGI31L
 - PGI34L
 - PGI36L
 - PGI37L
 - Relative Humidity
 - OW
 - Vorticity
 - Deep shear
 - Pouch shear
 - Sea Level Pressure
- ECMWF
- UKMET
- NOGAPS

Hurricane Karl, September 16th

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



TC-IDEAS

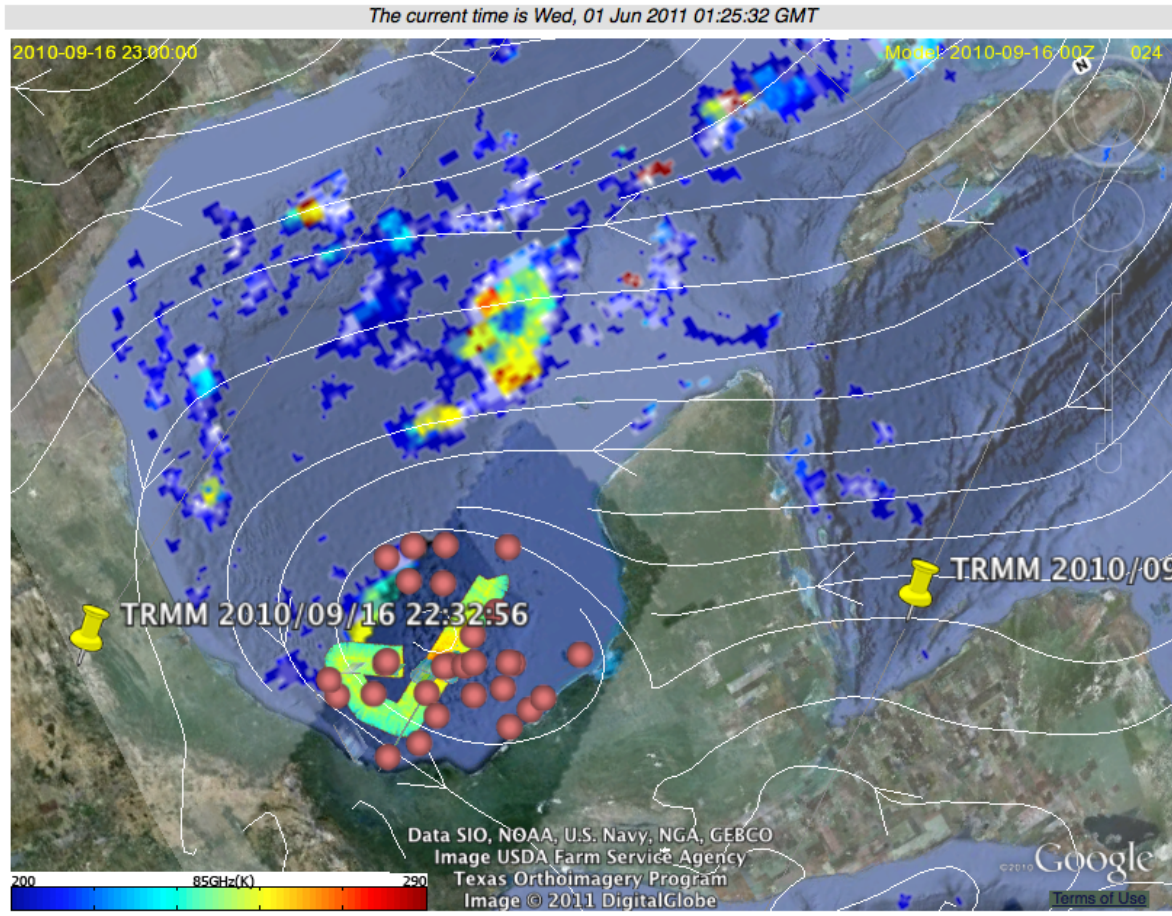
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- About GRIP
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- GRIP Mission Page
- NASA Hurricanes

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		

At hour: 23:00:00



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		

- STORM TRACKS
- SATELLITE DATA
 - SST
 - OHC
 - Wind (ASCAT)
 - TPW (AMSU-A)
 - RH-AIRS Press. Level: 850
 - CAPE-AIRS
 - LI-AIRS
 - Geostationary
 - GOES-IR
 - GOES-VAPOR
 - GOES-VIS
 - 85GHZ
 - 37GHZ
 - Rain
 - TRMM PR Nadir

- MODEL DATA
 - Pressure Level: 850
 - Forecast Time: 024
 - GFS
 - ECMWF
 - Speed Earth Relative
 - Streamline Earth Relative
 - PG41L
 - PG43L
 - PG44L
 - PG45L
 - PG46L
 - Relative Humidity
 - OW
 - Vorticity
 - Deep shear
 - Pouch shear
 - Sea Level Pressure
 - UKMET
 - NOGAPS

Status Bar Grid

Animation: Observation Data Model Data

Hurricane Karl, September 16th

Rain Index (satellite PMW), DC8 dropsondes, HAMSr (ch. 6 – 55GHz)

TC-IDEAS



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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		

At hour: 23:00:00

STORM TRACKS

SATELLITE DATA

AIRBORNE DATA

HAMSr Channel 01

HAMSr Reflectivity

APR2 Zku

Dropsonde

Daily DC8-Flight track

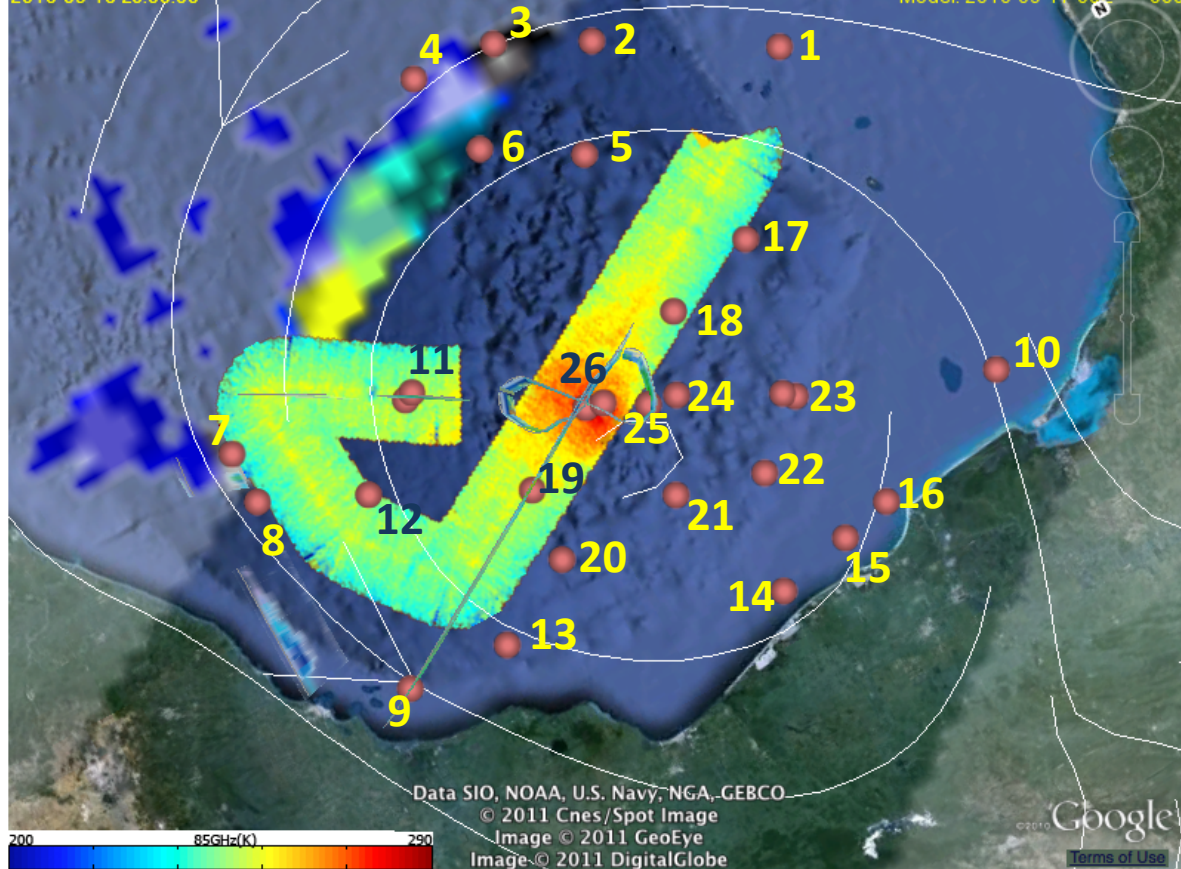
Daily Global Hawk track

Hourly Global Hawk track

The current time is Wed, 01 Jun 2011 01:32:07 GMT

2010-09-16 23:00:00

Model: 2010-09-17 00Z 000



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Status Bar Grid

Animation: Observation Data Model Data

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		

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

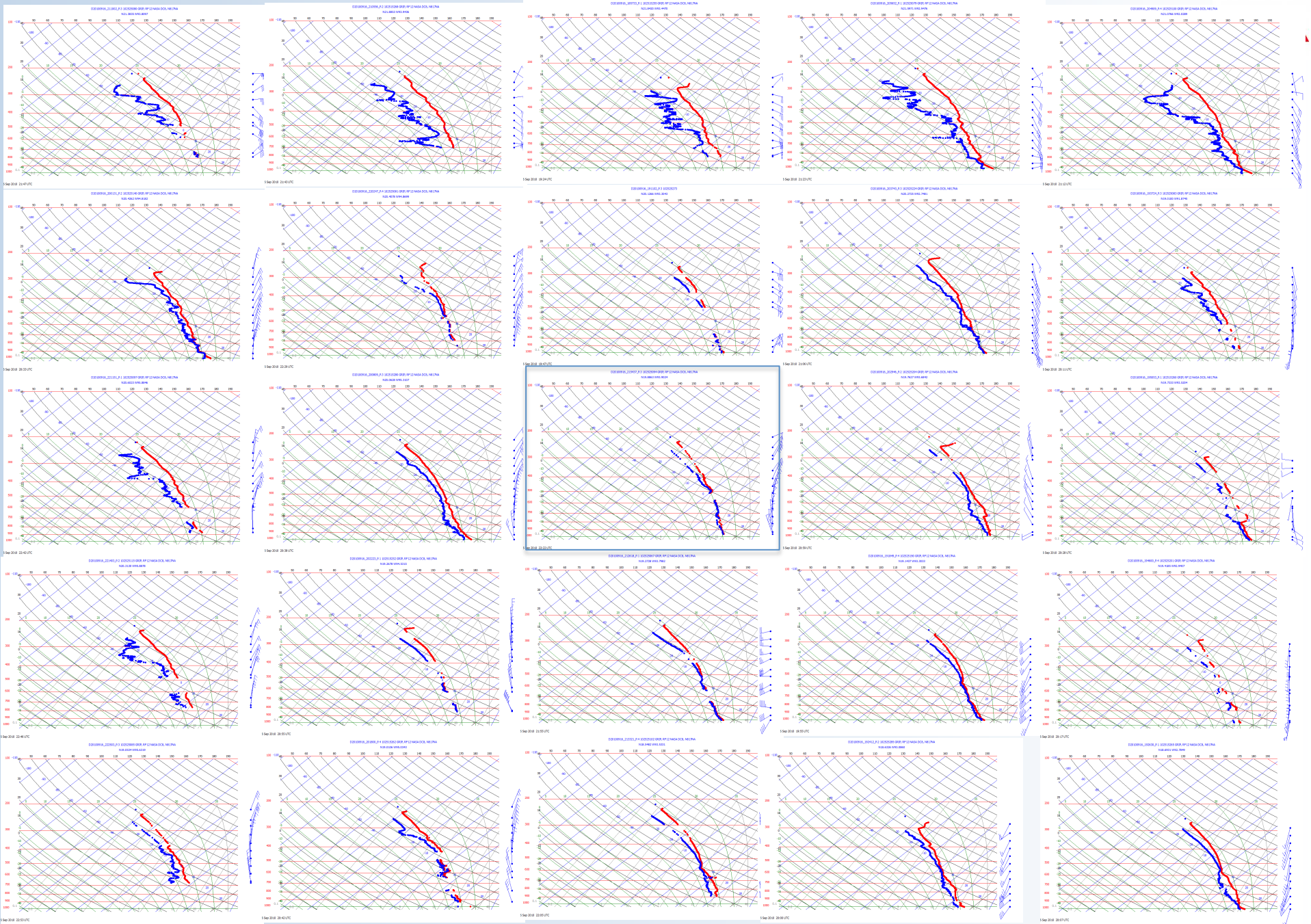
Speed Earth Relative

Streamline Earth Relative

PGI41L

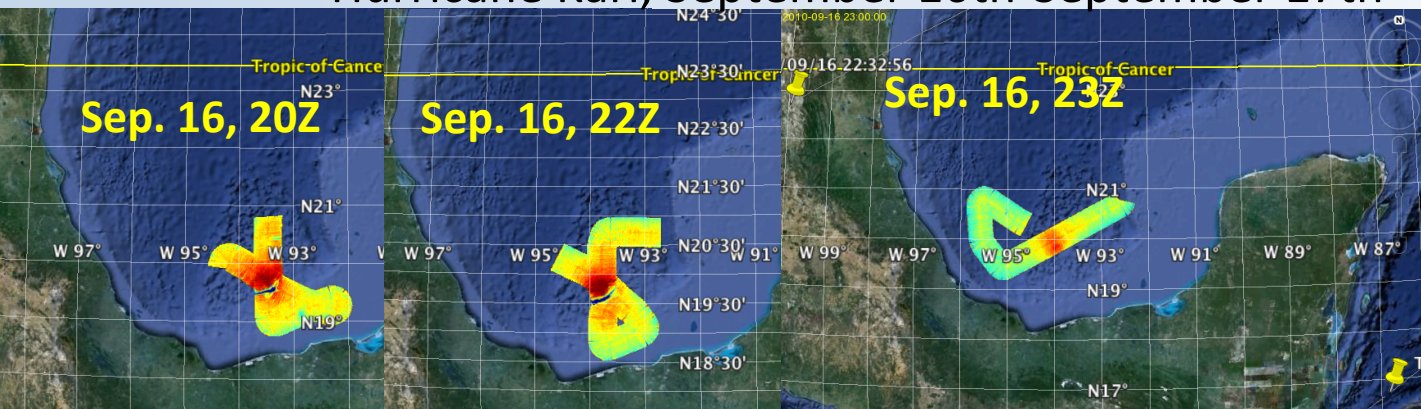
Layout of the soundings on the next slide,
using the dropsonde numbers from the previous slide

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

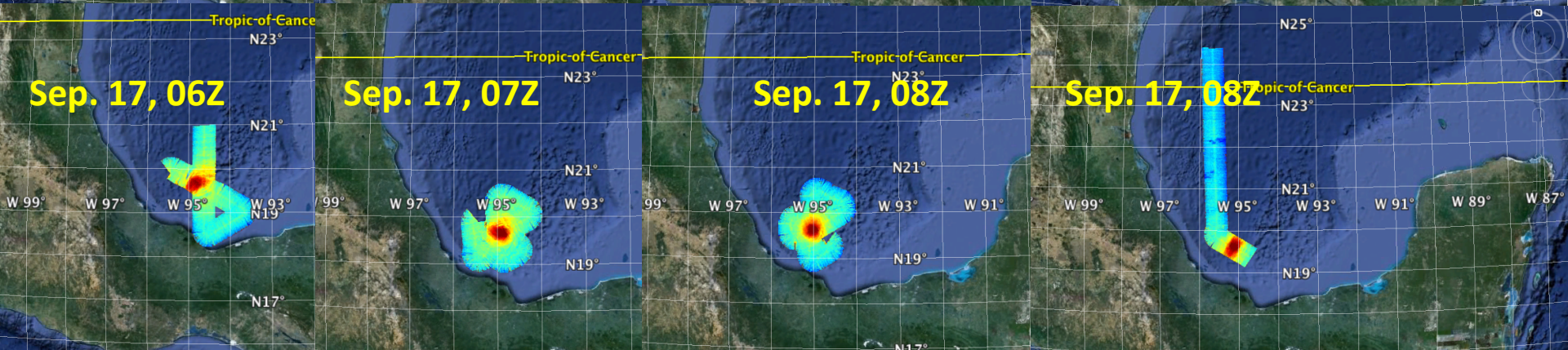
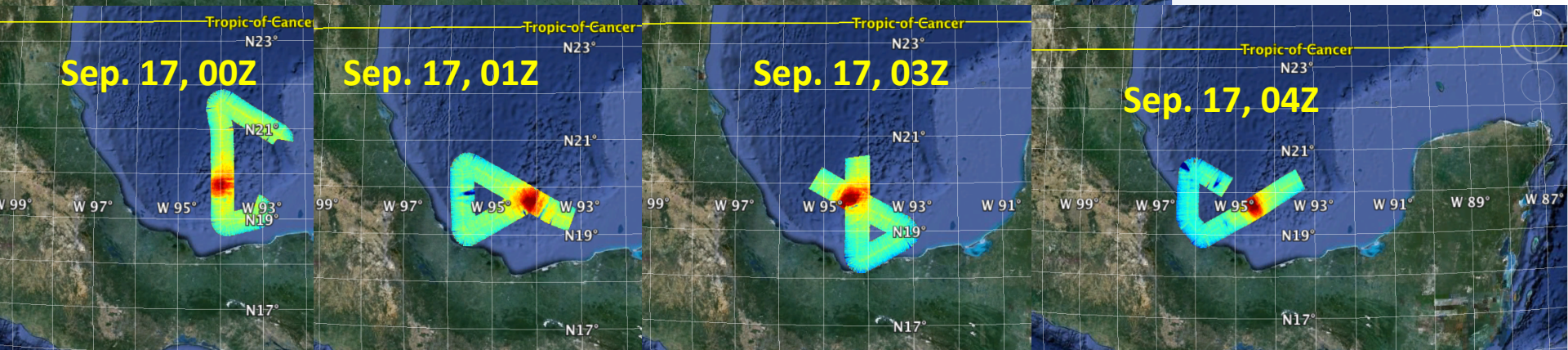


The Warm Core

Hurricane Karl, September 16th-September 17th

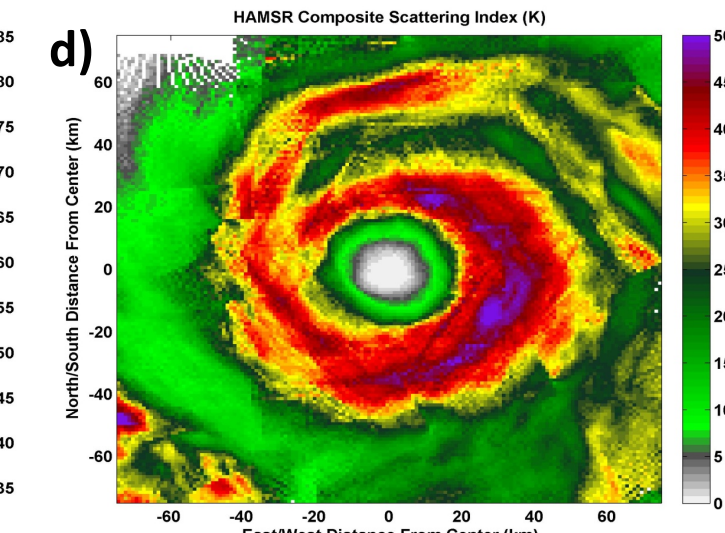
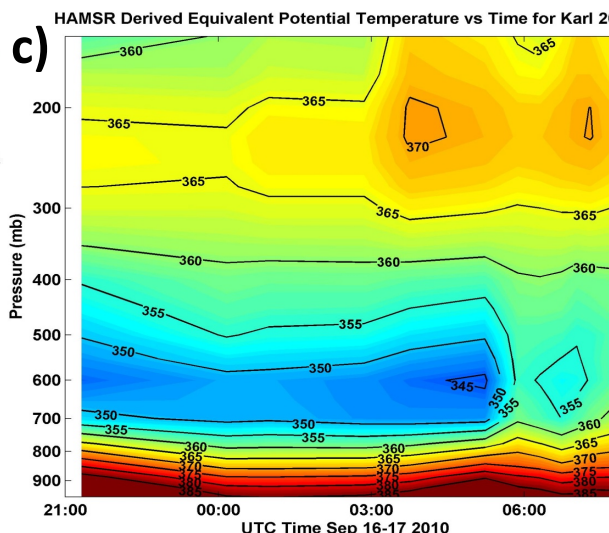
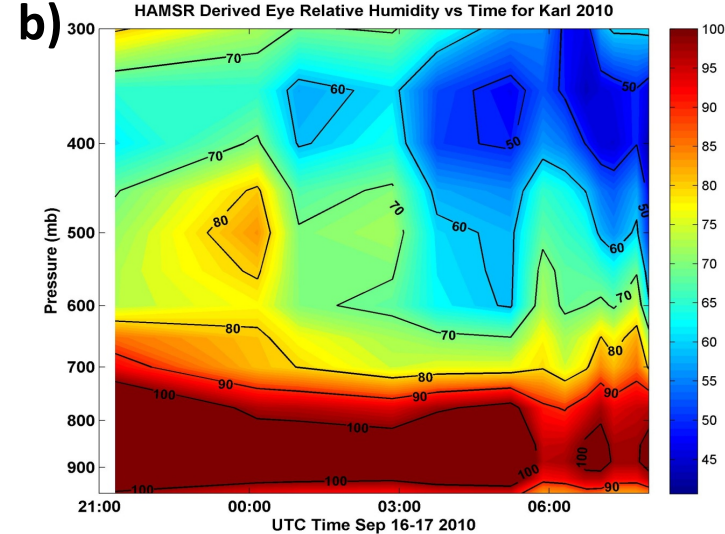
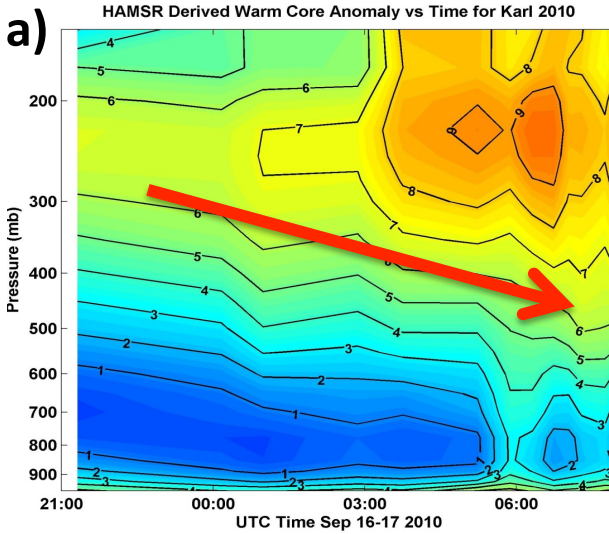
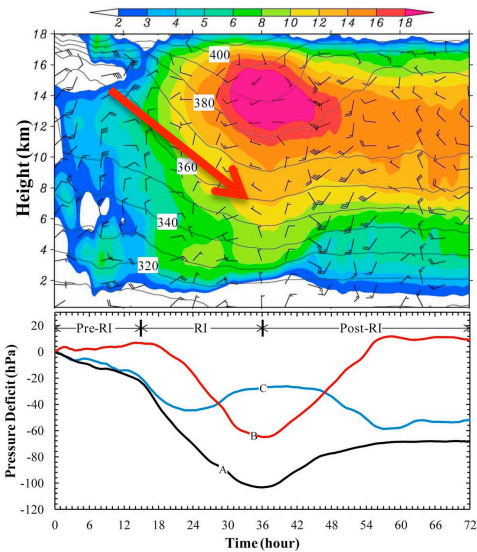


**Warm core evolution
as seen by
HAMSR**
(brightness temperatures
Channel 6)



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 →



TC-IDEAS



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

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		

<< < > >>

At hour: 23:00:00

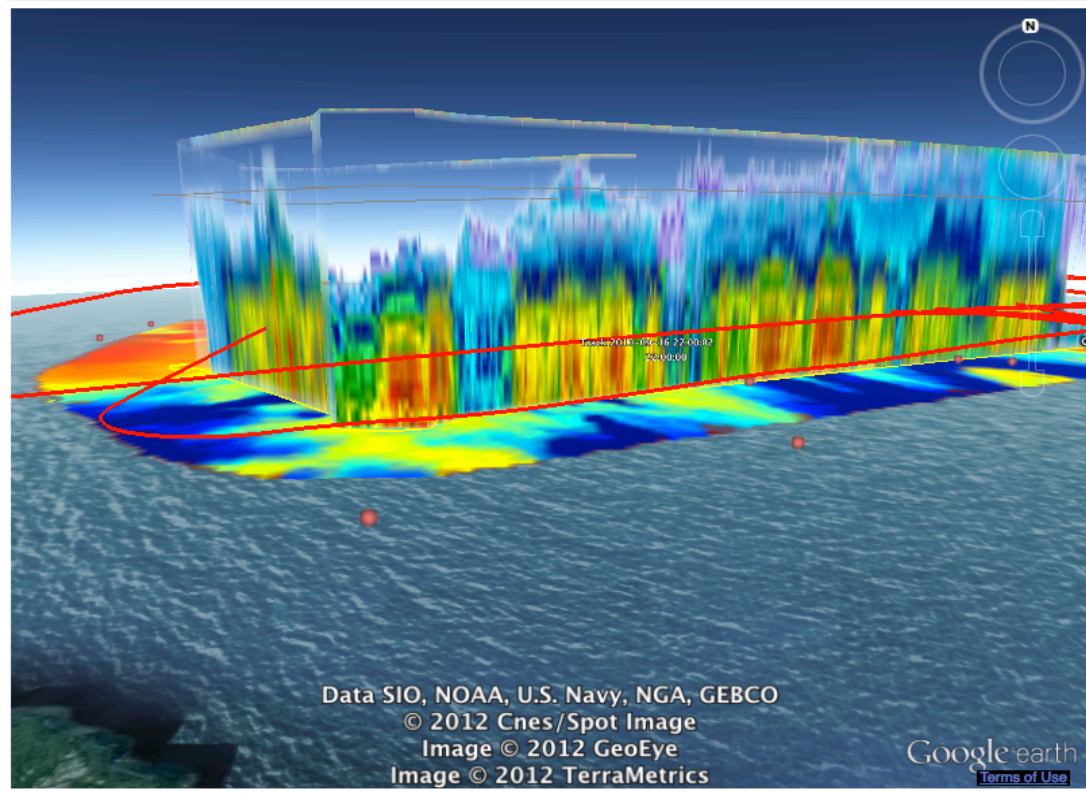
STORM TRACKS

- Best Tracks
- Pouch Tracks

SATELLITE DATA

AIRBORNE DATA

- HAMS Channel 09
- HAMS Reflectivity
- APR2 Zku
- Dropsonde
- NOAA N42RF
- Lase
- Daily DC8-Flight track
- Daily Global Hawk track
- Hourly Global Hawk track



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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		

<< < > >>

MODEL DATA

Pressure Level: 850

Forecast Time: 000

GFS

- Speed Earth Relative
- Streamline Earth Relative
- PG141L
- PG143L
- PG144L
- PG145L
- PG146L
- Relative Humidity
- OW
- Vorticity
- Deep shear
- Pouch shear
- Sea Level Pressure

- ECMWF
- UKMET
- NOGAPS

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



TC-IDEAS



The current time is Thu, 19 Jan 2012 03:17:53 GMT

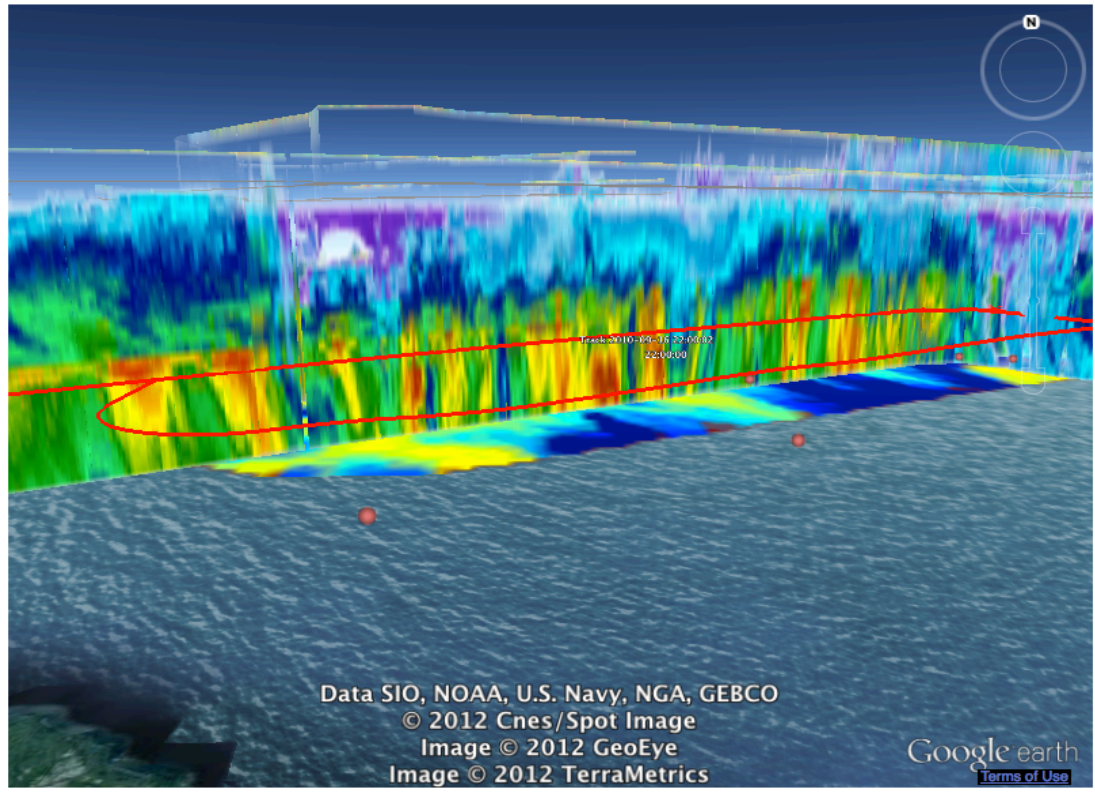
Observation Data

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		

At hour: 23:00:00

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



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Image © 2012 TerraMetrics



Status Bar Grid

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

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		

- MODEL DATA
 - Pressure Level: 850
 - Forecast Time: 000
- GFS
 - Speed Earth Relative
 - Streamline Earth Relative
 - PG141L
 - PG143L
 - PG144L
 - PG145L
 - PG146L
 - Relative Humidity
 - OW
 - Vorticity
 - Deep shear
 - Pouch shear
 - Sea Level Pressure
- ECMWF
- UKMET
- NOGAPS



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The current time is Thu, 19 Jan 2012 03:21:40 GMT

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		

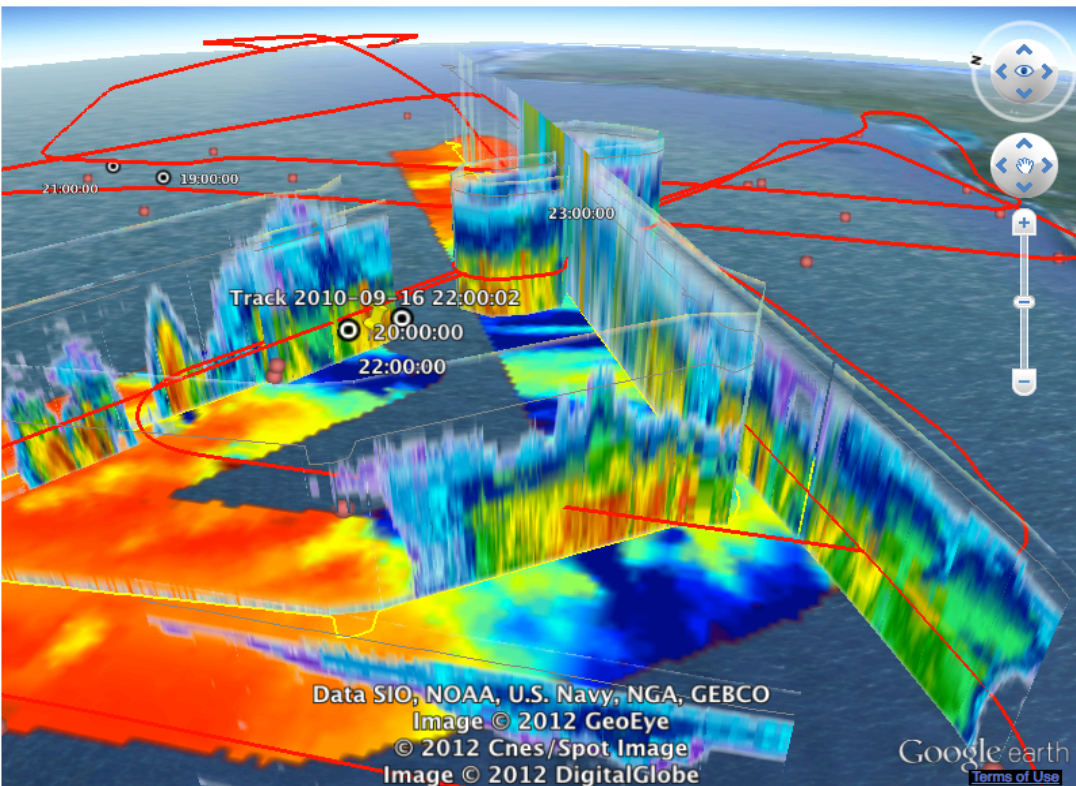
At hour: 23:00:00

- STORM TRACKS
 - Best Tracks
 - Pouch Tracks

SATELLITE DATA

AIRBORNE DATA

- HAMS Channel: 09
- HAMS Reflectivity
- APR2: Zku
- Dropsonde
- NOAA: N42RF
- Lase
- Daily DC8-Flight track
- Daily Global Hawk track
- Hourly Global Hawk track



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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		

- MODEL DATA
 - Pressure Level: 850
 - Forecast Time: 000
- GFS
 - Speed Earth Relative
 - Streamline Earth Relative
 - PG141L
 - PG143L
 - PG144L
 - PG145L
 - PG146L
 - Relative Humidity
 - OW
 - Vorticity
 - Deep shear
 - Pouch shear
 - Sea Level Pressure
- ECMWF
- UKMET
- NOGAPS

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

The Convection - 17th September 2010, 07Z

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The ring

Observation Data

The current time is Thu, 22 Dec 2011 01:09:22 GMT

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					

At hour: 07:00:00

Model Data

December 2009

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	31				

STORM TRACKS

- Best Tracks
- Pouch Tracks

SATELLITE DATA

- SST
- OHC
- Wind (ASCAT)
- TPW (AMSU-A)
- RH-AIRS Press. Level 850
- CAPE-AIRS
- LI-AIRS
- Geostationary
- GOES-IR
- GOES-VAPOR
- GOES-VIS
- 85GHZ
- 37GHZ
- Rain
- TRMM PR Curt1
- CloudSat
- CALIPSO
- MLS
- AOT (MODIS)

Animation: Observation Data Model Data

Select a time range to animate: (from 2010-09-16 08:00:00 to 2010-09-17 19:00:00)

Start 2010-09-16 19:00:00 End 2010-09-17 19:00:00

Animate Stop Download

NASA Jet Propulsion Laboratory
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TC-IDEAS

GRIP

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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					

At hour: 06:00:00

STORM TRACKS

- Best Tracks
- Pouch Tracks

SATELLITE DATA

- SST
- OHC
- Wind (ASCAT)
- Wind Vector
- Wind Speed
- TPW (AMSU-A)
- RH-AIRS Press. Level 850
- CAPE-AIRS
- LI-AIRS
- Geostationary
- GOES-IR
- GOES-VAPOR
- GOES-VIS
- 85GHZ
- 37GHZ
- Rain
- TRMM PR Curt1
- CloudSat
- CALIPSO
- MLS
- AOT (MODIS)

Animation: Observation Data Model Data

Select a time range to animate: (from 2010-09-16 08:00:00 to 2010-09-17 19:00:00)

Start 2010-09-16 19:00:00 End 2010-09-17 19:00:00

Animate Stop Download

The current time is Wed, 01 Jun 2011 00:43:28 GMT

2010-09-17 06:00:00

Track 2010-09-17 05:06:40

HAMSR 118 GHz

STORM TRACKS

- Best Tracks
- Pouch Tracks

SATELLITE DATA

- SST
- OHC
- Wind (ASCAT)
- Wind Vector
- Wind Speed
- TPW (AMSU-A)
- RH-AIRS Press. Level 850
- CAPE-AIRS
- LI-AIRS
- Geostationary
- GOES-IR
- GOES-VAPOR
- GOES-VIS
- 85GHZ
- 37GHZ
- Rain
- TRMM PR Curt1
- CloudSat
- CALIPSO
- MLS
- AOT (MODIS)

Animation: Observation Data Model Data

Select a time range to animate: (from 2010-09-16 19:00:00 to 2010-09-17 19:00:00)

Start 2010-09-16 19:00:00 End 2010-09-17 19:00:00 Animation Step 1 hour

Animation: Observation Data Model Data

Select a time range to animate: (from 2010-09-16 19:00:00 to 2010-09-17 19:00:00)

Start 2010-09-16 19:00:00 End 2010-09-17 19:00:00 Animation Step 1 hour



TC-IDEAS



The current time is Thu, 19 Jan 2012 07:14:51 GMT

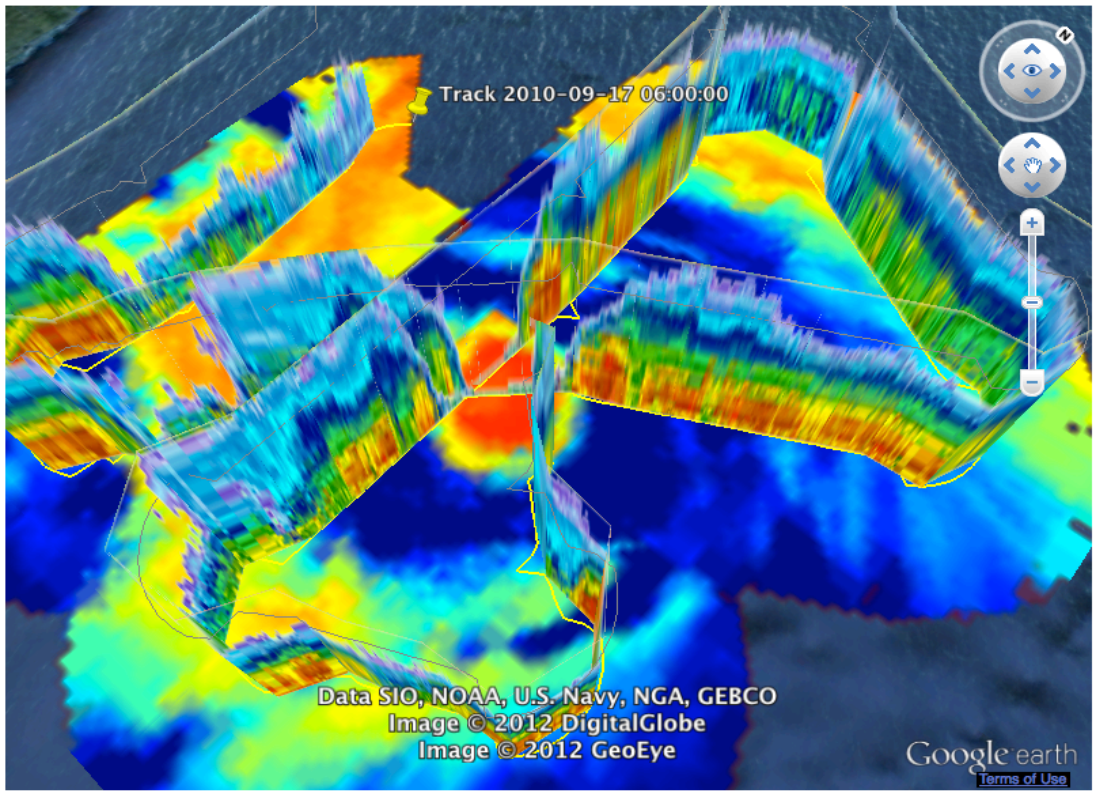
Observation Data

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		

At hour: 07:00:00

- GOES-IR
 - GOES-VAPOR
 - GOES-VIS
 - 85HGZ
 - 37HGZ
 - Rain
 - TRMM PR Nadir
 - CloudSat
 - CALIPSO
 - MLS
 - AOT (MODIS)
 - Satellite Winds (CIMSS)
- AIRBORNE DATA**
- HAMS Channel 09
 - HAMS Reflectivity
 - APR2 Zku
 - Dropsonde
 - NOAA N42RF
 - Lase
 - Daily DC8-Flight track
 - Daily Global Hawk track
 - Hourly Global Hawk track



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		

- 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

Status Bar Grid

Save snapshot | Load snapshot | Download

Animation: Observation Data Model Data

Select a time range to animate: (from 2010-09-16 00:00:00 to 2010-09-17 00:00:00)

Start 2010-09-16 19:00:00 End 2010-09-17 19:00:00 Animation Step 1 hour

Animate | Stop | Download



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NASA Hurricanes

September 2010

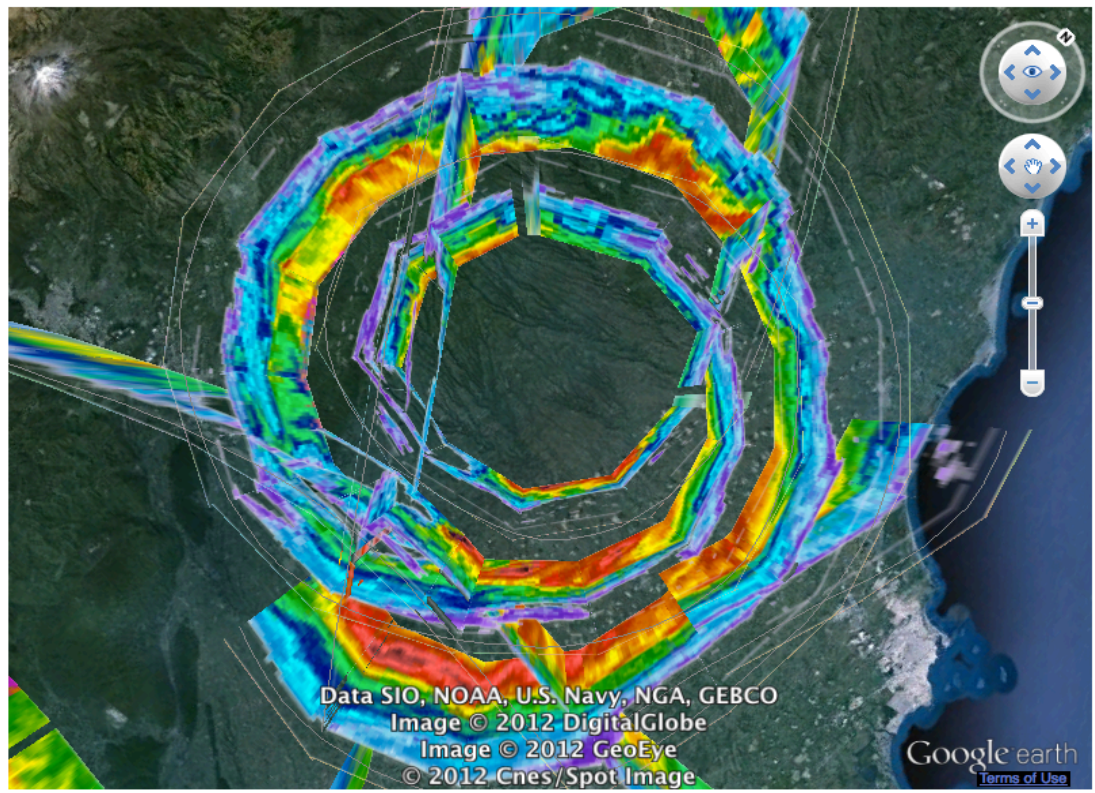
Su	M	T	W	Th	F	S
			01	02	03	04
05	06	07	08	09	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

At hour: 21:00:00

- GOES-IR
- GOES-VAPOR
- GOES-VIS
- 85GHZ
- 37GHZ
- Rain
- TRMM PR Nadir
- CloudSat
- CALIPSO
- MLS
- AOT (MODIS)
- Satellite Winds (CIMSS)

AIRBORNE DATA

- HAMS Channel 09
- HAMS Reflectivity
- APR2 Zku
- Dropsonde
- NOAA N42RF
- Lase
- Daily DC8-Flight track
- Daily Global Hawk track
- Hourly Global Hawk track



Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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Image © 2012 GeoEye
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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		

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

Status Bar Grid

Save snapshot Load snapshot Download

Animation: Observation Data Model Data

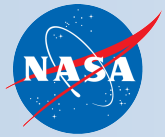
Select a time range to animate: (from 2010-09-16 00:00:00 to 2010-09-17 00:00:00)

Start 2010-09-16 19:00:00 End 2010-09-17 19:00:00 Animation Step 1 hour

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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 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

The screenshot displays the TC-IDEAS (Tropical Cyclone Information Data and Analysis System) web interface. At the top, it features the NASA Jet Propulsion Laboratory logo and navigation links for JPL HOME, EARTH, SOLAR SYSTEM, STARS & GALAXIES, and SCIENCE & TECHNOLOGY. The main header includes the text 'BRING THE UNIVERSE TO YOU:' followed by links for JPL Email News, RSS, Podcast, and Video. Below this is a navigation bar with tabs for 'JPL TC Information System', 'About GRIP', 'Collaboration', 'GRIP Portals', 'RTMM', and 'Waypoint Tool'. The central panel shows a 3D visualization of a hurricane over the Atlantic Ocean, with a color-coded intensity scale from 200 to 250. The current time is displayed as 'Wed, 01 Sep 2010 18:01:27 GMT'. To the left, there is an 'Observation Data' panel with a calendar for August 2010 and a 'Time of Day' selector set to 14:00:00. Below this are checkboxes for 'STORM TRACKS' (Best Tracks, Pouch Tracks) and 'SATELLITE DATA' (SST, OHC, Wind (ASCAT), TPW (AMSU-A), RH-AIRS Press. Level, CAPE-AIRS, LI-AIRS, Geostationary, GOES-IR, GOES-VAPOR, GOES-VIS, 85GHZ). To the right, the 'Model Data' panel shows a calendar for September 2010, a 'Pressure Level' selector set to 850, and a 'Forecast Time' selector set to 000. Below these are checkboxes for 'MODEL DATA' (Speed Earth Relative, Streamline Earth Relative, PG136L, PG138L, PG139L, PG140L, Relative Humidity, OW, Vorticity, Deep shear, Pouch shear, Sea Level Pressure) and 'ECMWF' (UKMET, NOGAPS). At the bottom, there are checkboxes for 'Status Bar' and 'Grid'.

In collaboration with:

R. Rogers, S. Gopalakrishnan,
F. Marks, T. Vukicevic - HRD/AOML
V. Tallapragada - NOAA/EMC