

NOAA Hurricane Forecast Improvement Project

Claudette

Ana

Bill

Frank Marks, Ed Rappaport, Fred Toepfer, Robert Gall
NOAA HFIP Leads, Project & Development Managers

25 May 2010



Current Capabilities



Track: reduced track error by ~50% since 1990 (current 48 h error ~100 nm)

Intensity: Little progress reducing intensity error (current 48 h error ~14 kt)

Storm Size: Progress is difficult to measure due to inadequate observations

Storm Surge: Accurate within $\pm 20\%$ when track, intensity, and size known

Lead Time: Lead time was extended from 3 to 5 days in 2001

Precipitation: Modest annual improvements; forecast patterns match observations when track error is low

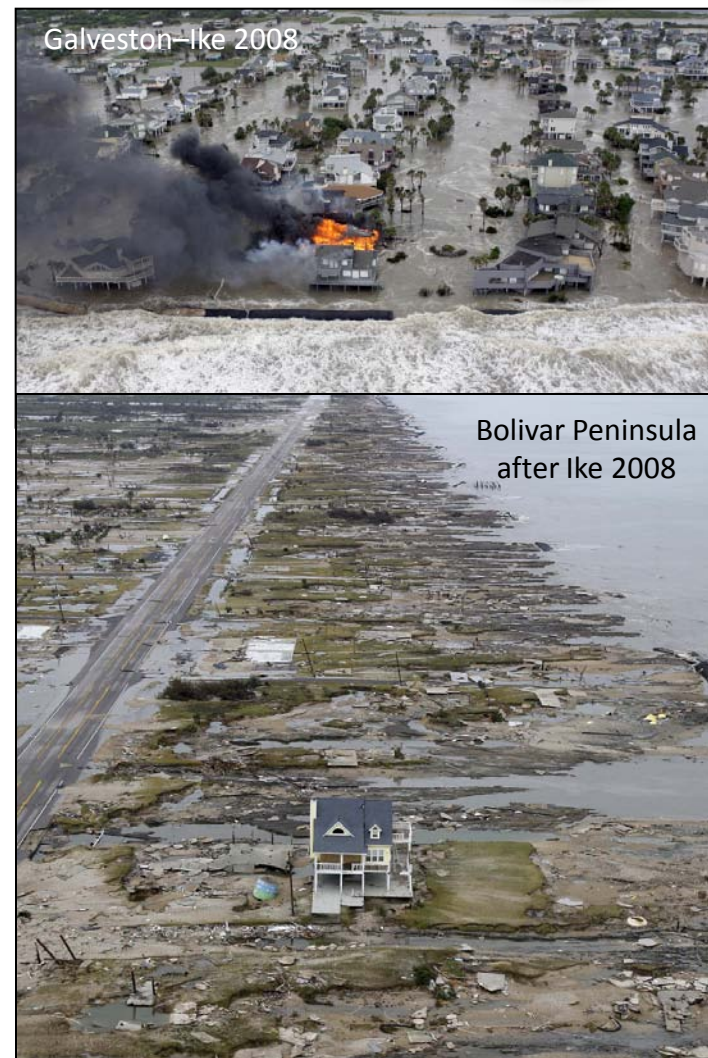
New/Improved Products: Refined cone graphic, wind speed probabilities, graphical tropical weather outlook, and probabilistic storm surge

Social/Behavioral Science: In its infancy

Improvements still needed!



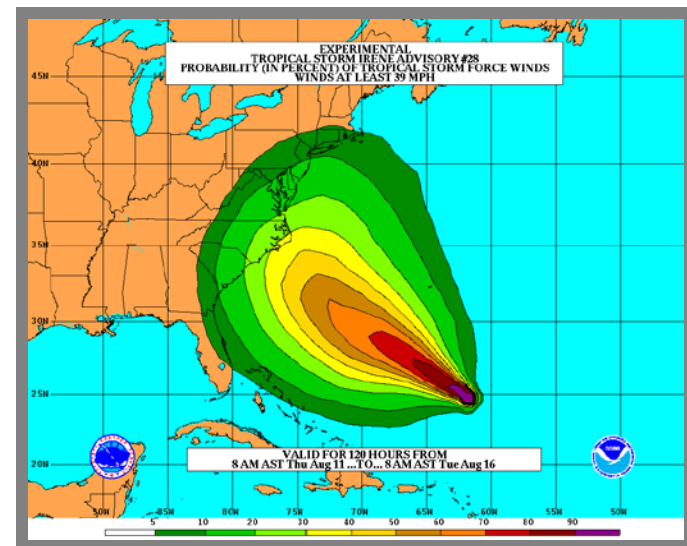
- Risk to life and property continues to escalate in coastal regions
 - Population continues to increase – 50% of US population now live within 50 miles of coast.
 - Value of coastal infrastructure and economic activity continues to rise – estimated at over **\$3 Trillion**
- More accurate hurricane forecasts and warnings can reduce response and recovery costs
 - More accurate forecast ➔ fewer false alarms, reduced warning footprint





Goals

- **Improve** Forecast Accuracy
 - Hurricane impact areas (track) – 50% in 10 years
 - Severity (intensity) – 50% in 10 years
 - Emphasis on Rapid Intensity Change
- **Extend** forecast reliability out to 7 days
- **Quantify, bound and reduce** forecast uncertainty to enable risk management decisions



How to get there?



➤ Science ([8 Teams](#))

- Improved understanding from combination of observations & models
- Higher resolution coupled models – critical to storm evolution forecasts – especially intensity changes
- Forecast techniques to understand, reduce & communicate uncertainty

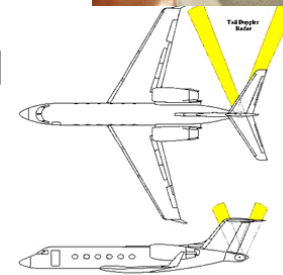
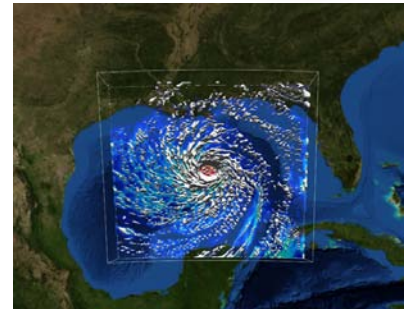
➤ Information Technology

- [Increased computing power](#) - run advanced hurricane/global models and reduce uncertainty
- IT infrastructure for inter-agency data exchange

➤ Observing Strategy

- Improved use of existing and planned systems

➤ Improved Products for Forecasters

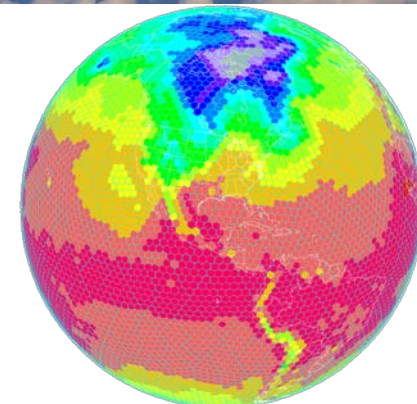


HFIP Activities



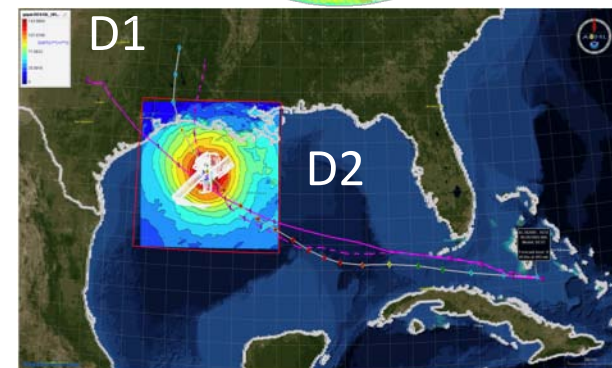
Traditional Hurricane Research Activities:

- Observations, analysis, database, & instrument R&D (IFEX)
- Statistical-dynamical model development
- Advances in operational models ([Stream 1](#))



New HFIP Research Thrusts:

- Experimental global and regional hurricane model development (Stream 2)
- Data assimilation techniques and observing system strategy analysis development (Stream 1 & 2)
- Model evaluation tool development
- Socioeconomic research and development



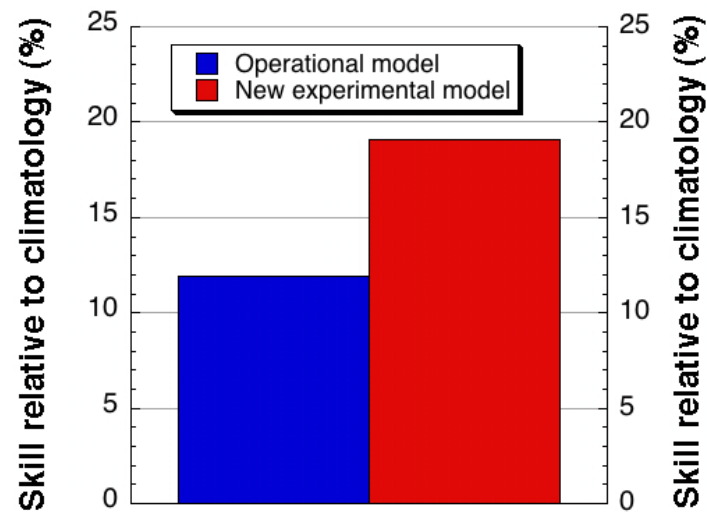
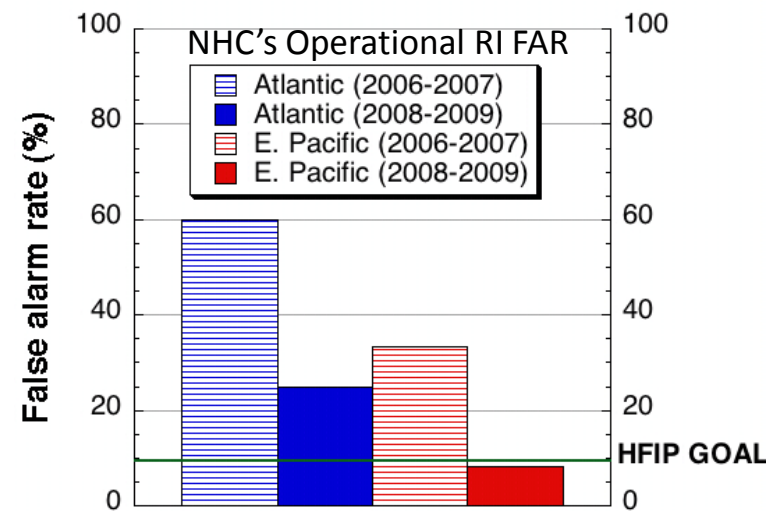
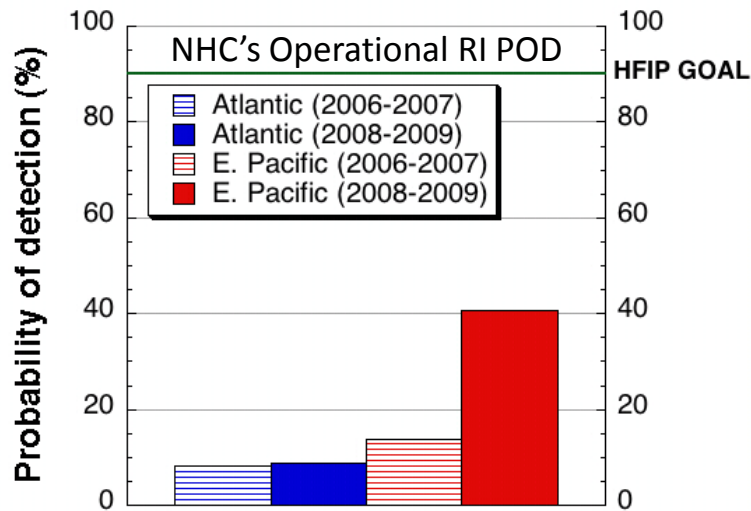
Partnership: NCEP, AOC, AOML, ESRL, GFDL, DTC, USWRP, NESDIS/STAR

National Hurricane Forecast Improvement Project

Meeting the Nation's Needs



Improved Models: Statistical-dynamical models-RI



Recent Improvements to
NOAA's Atlantic Basin
Statistical RI Prediction
Scheme

A satellite image of the Eastern Hemisphere of Earth, showing Asia, Australia, and the Indian Ocean. The image is labeled with 'Asia' over the Asian continent, 'Australia' over the Australian continent, and 'Indian Ocean' over the Indian Ocean. The image is set against a blue background.



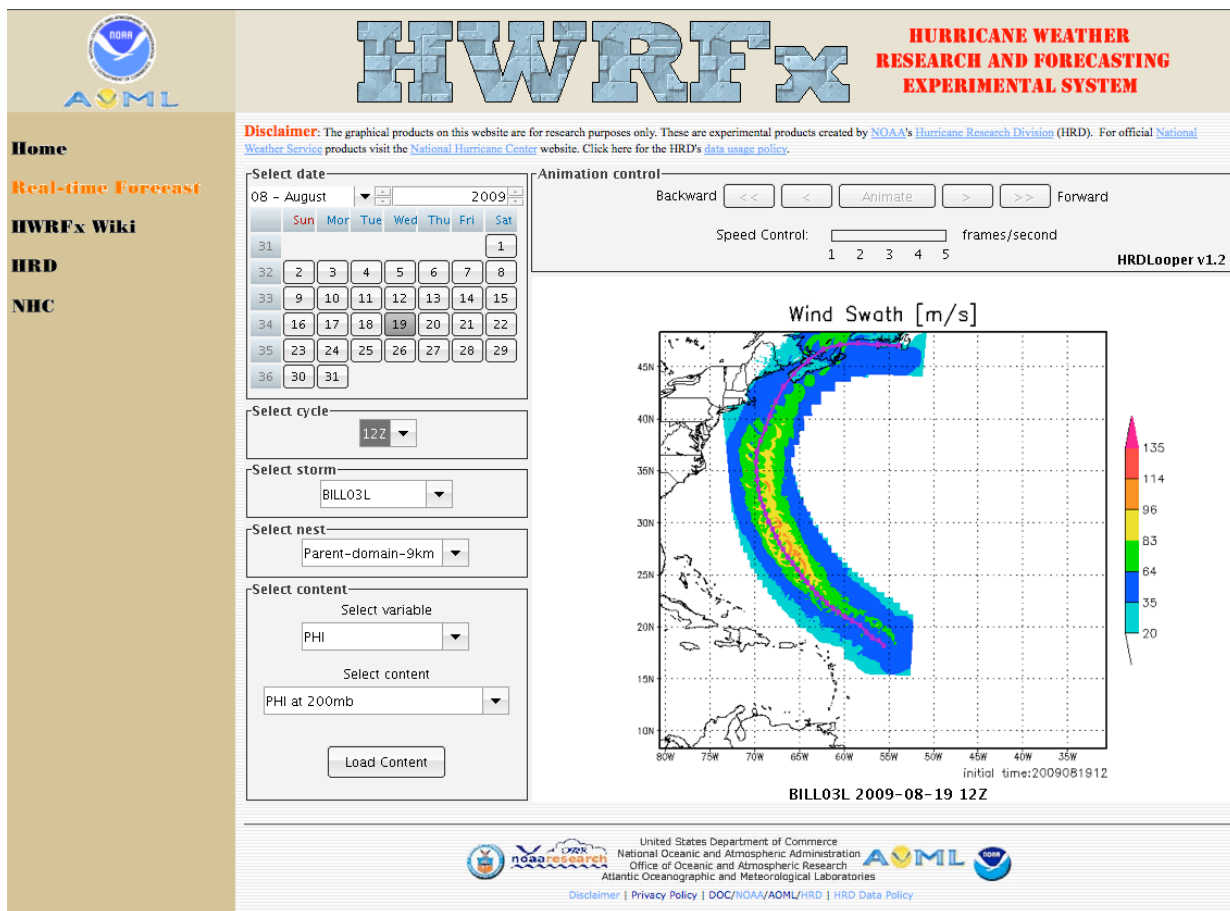
Regional Model Development – HWRFx (HWRF-3 km)



2009 hurricane season:

HWRF real-time demo simulations
(<https://storm.aoml.noaa.gov/hwrfx/>)

- Resolution (9/3km),
~HWRF physics, no
ocean (HWRF IC/BC)
- Real-time twice a day
(00Z, 12Z) – >70 cases
126 h forecasts
- Provided ATCF file to
DTC & multi-model
regional ensemble



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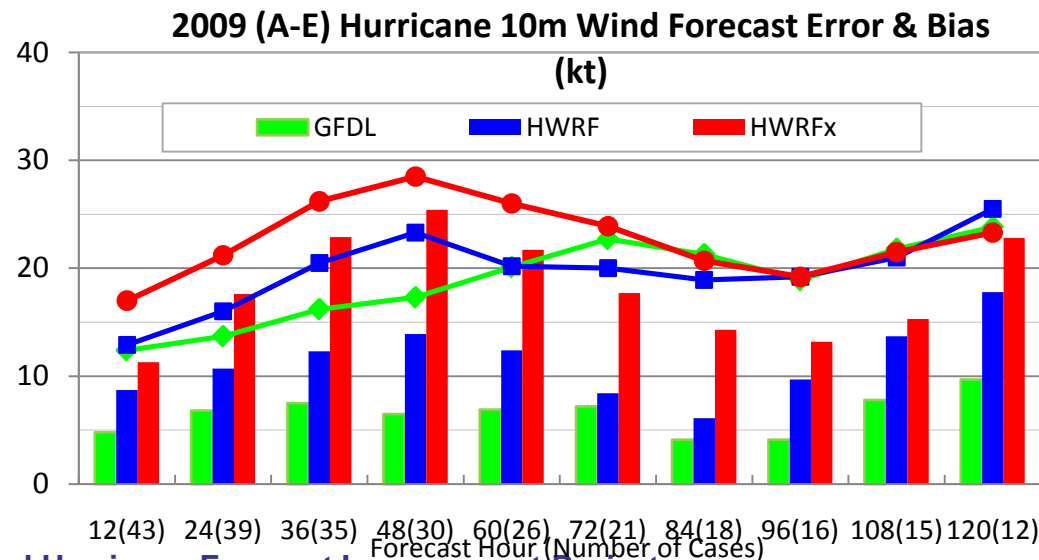
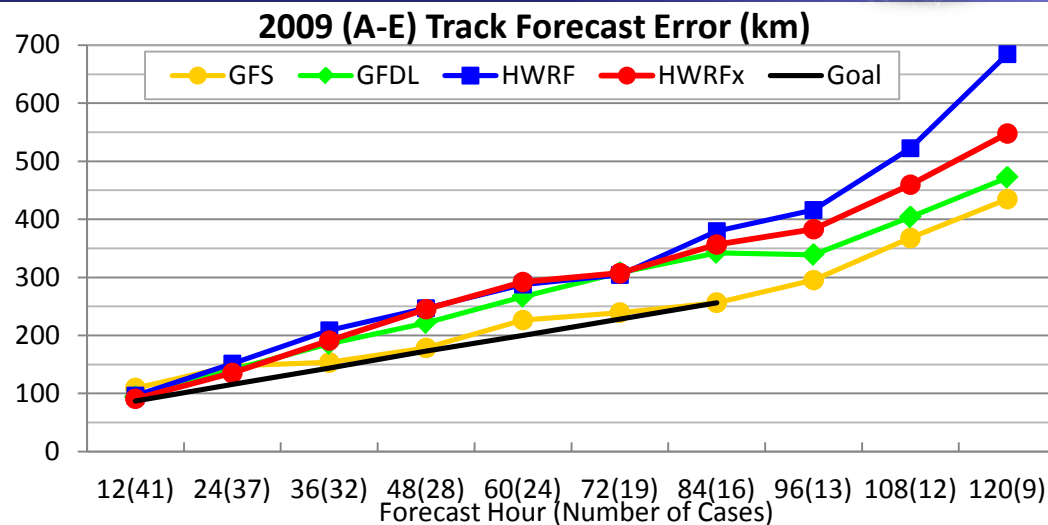
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Courtesy of Gopal & Thiago Quirino (AOML/HRD)

2009 Hurricane Season Demo



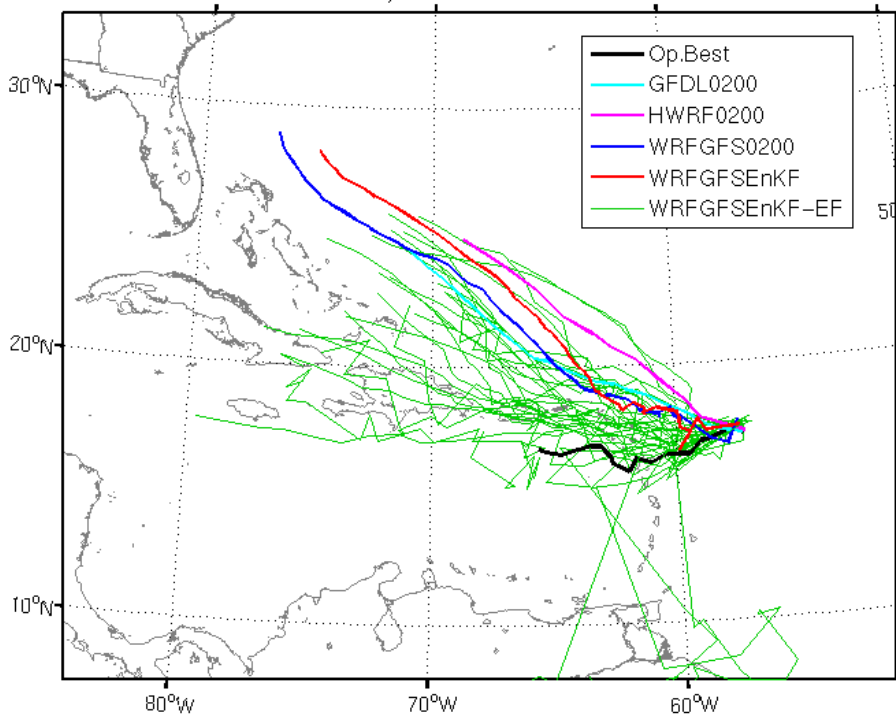
- Track performance is comparable to other regional models
- HWRFx intensity bias at 9/3 km with HWRF IC and physics indicates strong need for evaluation of physics and IC



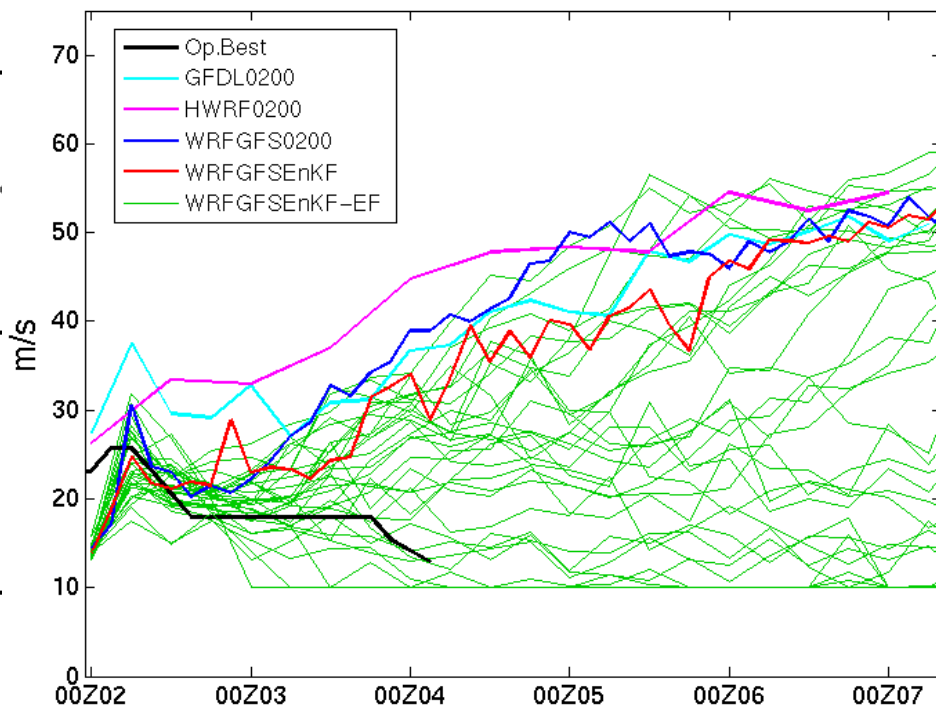
Single Model Ensembles: Erika



Erika 09090200 Track and EnKF DF wind swath
IC:00Z02; PureEF from GFSEnKF



Erika 09090200 max 10m WSP
IC:00Z02; PureEF from GFSEnKF



Courtesy Fuqing Zhang (PSU)

ICs: GFS-EnKF
analysis

BCs: GFS forecast

ARW

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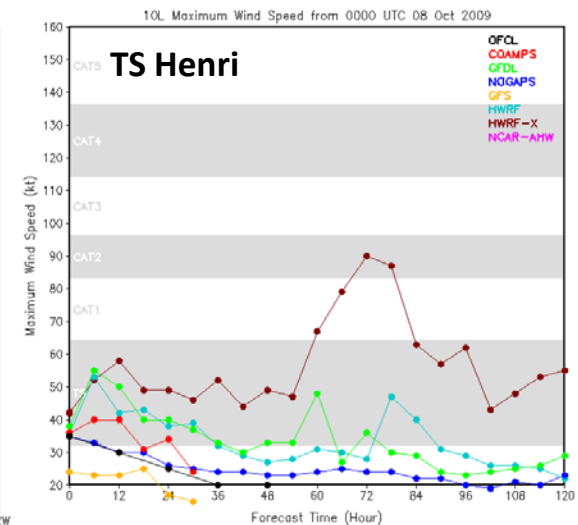
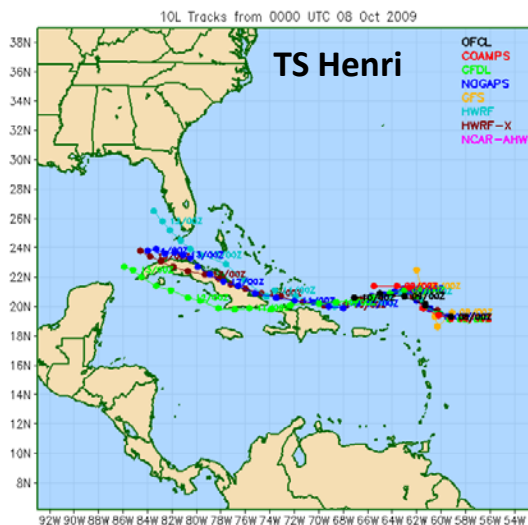
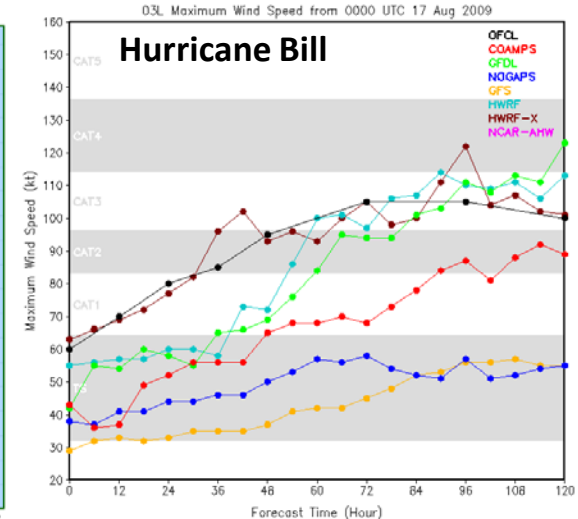
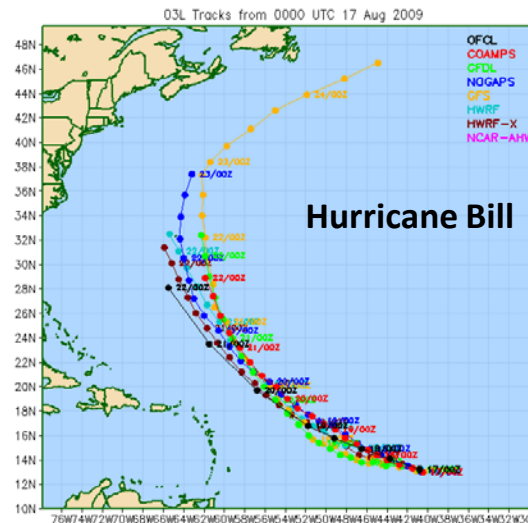
Multi-model Ensembles



2009 hurricane season:

- Multi-model (3 ARW, MM5, HWRF(9), HWRF(4), HWRFx, COAMPS) regional ensemble
- Initialization of regional models problematic, particularly with highly sheared storms in 2009 season (Ana, Danny, Erika, AL08, & Henri)
- Need to better convey value and use of ensemble information to forecast community.

Courtesy of DTC, FSU, & NRL Monterey



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Improved Use of Observations: Intensity Forecast experiment (IFEX)



In-situ

- Wind, press., temp.



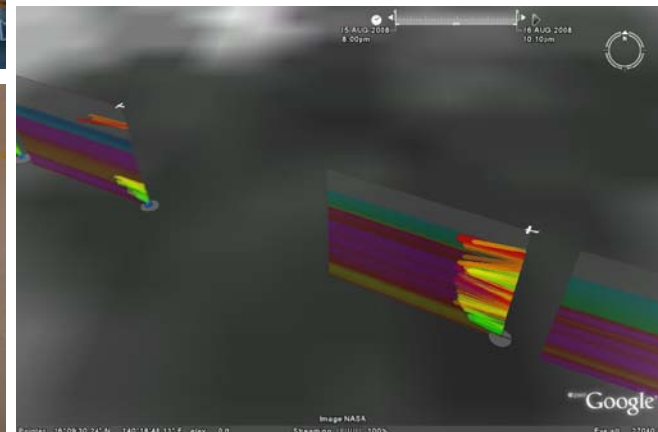
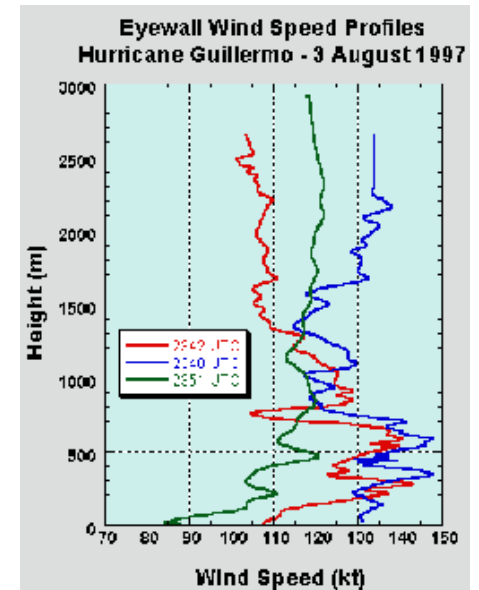
Expendables

- Dropsondes
- AXBT, AXCP, buoy



Remote Sensors

- Doppler Radar
- SFMR
- DWL (ONR)
- WSRA
- Scatterometer/ profiler
- UAS

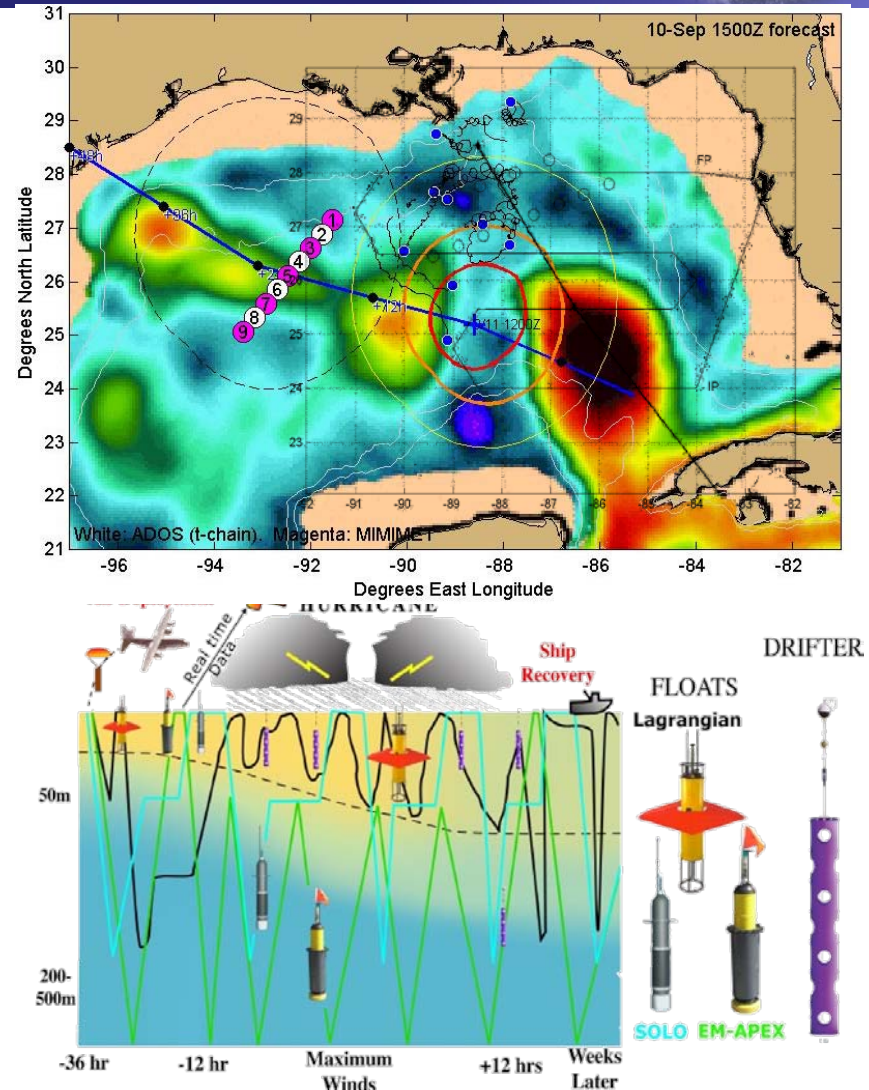


Improved Use of Observations: Air-sea interaction



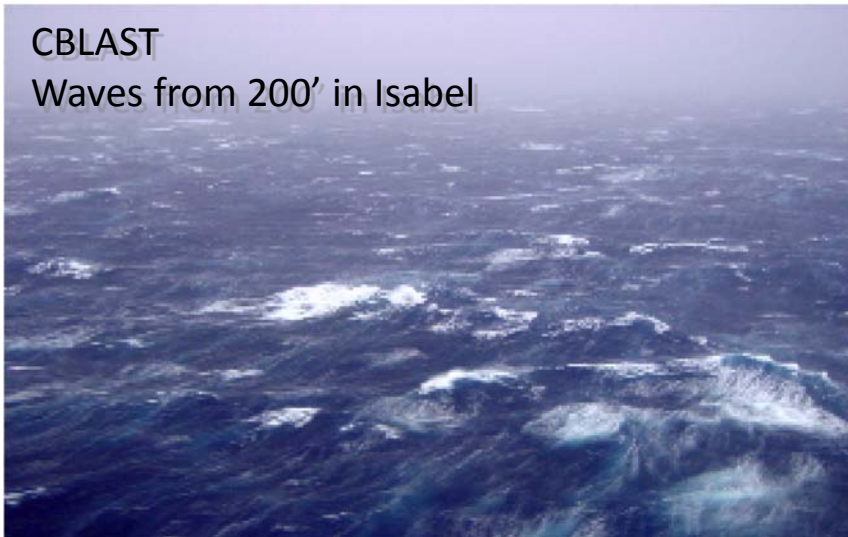
Targeted upper ocean observations

TC impact on upper ocean
effect of Hurricanes Gustav
and Ike (2008)



CBLAST

Waves from 200' in Isabel



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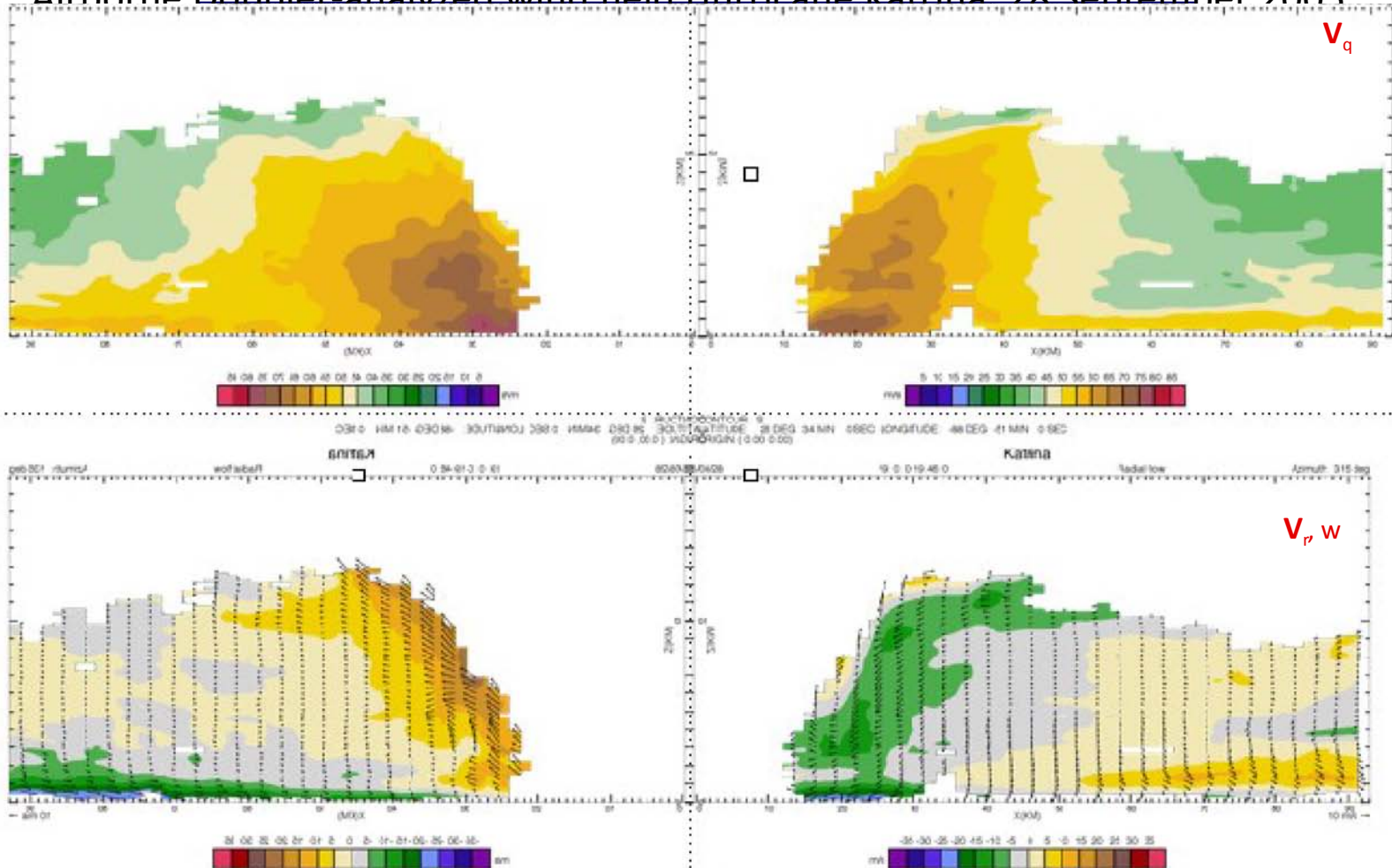
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E. Uhlhorn, AOML/HRD, R. Lumpkin AOML/PhOD

Improved Use of Observations: Airborne Doppler Radar



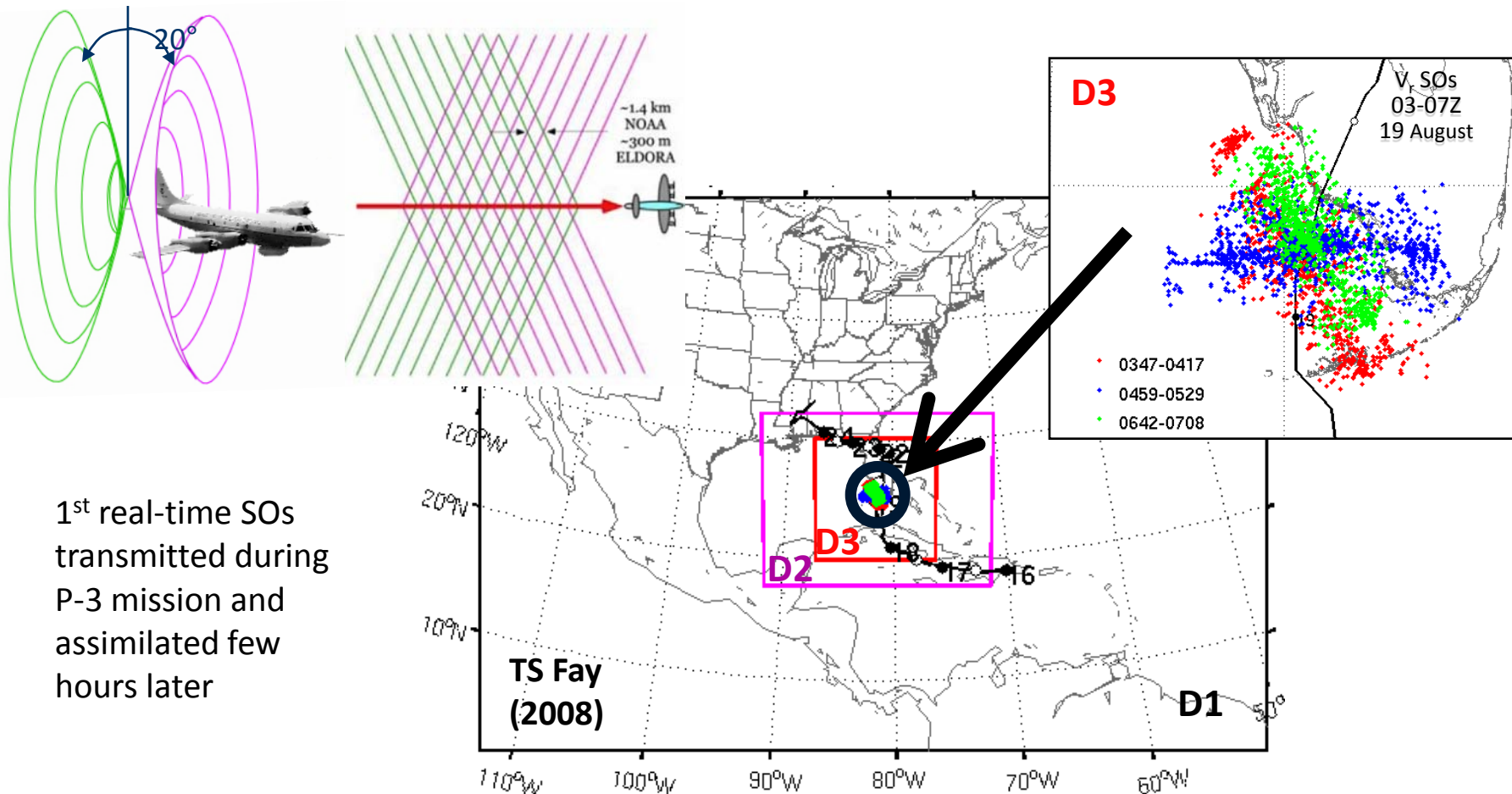
Airborne Doppler-analyzed wind field Hurricane Katrina 28 September 2005



Improved Models & Data: Doppler Radar Data Assimilation



EnKF data assimilation of inner core observations



Improved Models & Data:

Assessing Doppler radar assimilation



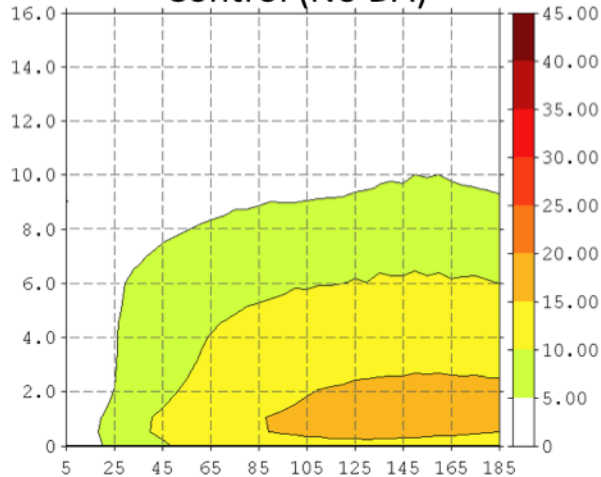
- **Ensemble**

- Initialization
- analysis
- Observ
- interval
- 07 17Z
- Only v
- inner (
- Only D
- assimilation

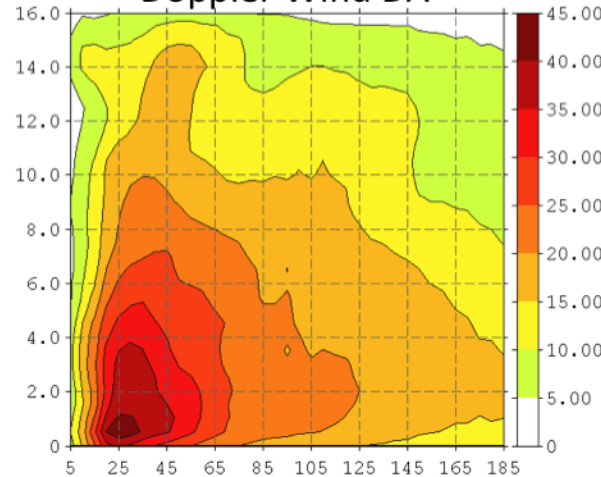
- **Observation**

Type
DROP
FL
SFMR
Radial wind

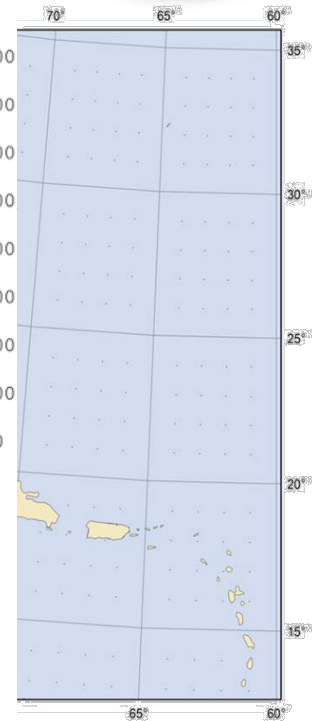
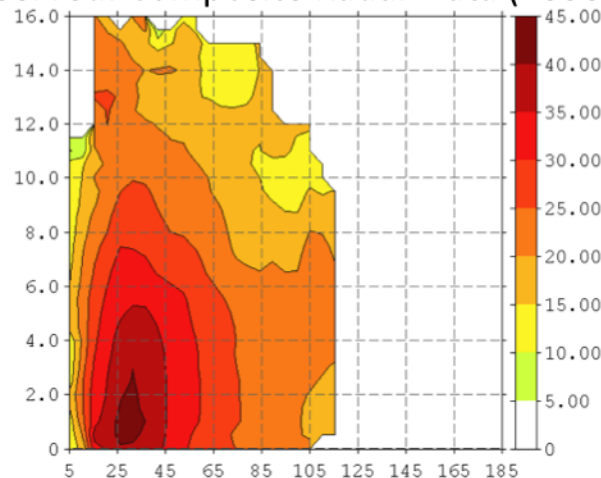
Control (No DA)



Doppler Wind DA



Observed: Composite Radar Data (1838Z)



Min. SLP (mb)

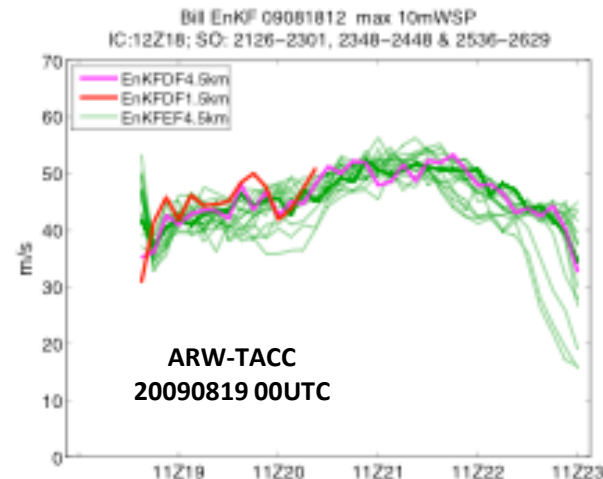
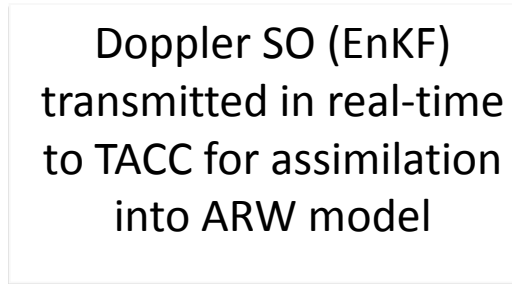
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Altug Aksoy & Sylvie Lorsolo (AOML/HRD)

A satellite image of the Eastern Hemisphere of Earth, showing Asia, Australia, and the Indian Ocean. The image is labeled with 'Asia' over the Asian continent, 'Australia' over the Australian continent, and 'Indian Ocean' over the Indian Ocean. The image is set against a blue background.



Improved Models & Data: Model evaluation



- Critical to HFIP success: Massive amounts of simulation output:
 - High-resolution hurricane (HRH) test: 69 cases (2005 & 2007) for 6 model teams - >50 Tb
 - 2008 & 2009 HFIP Real-time test – >70 cases plus multi-model regional ensembles - >70 Tb
- Need diagnostic tools to evaluate more than track and peak wind (e.g., large-scale, vortex-scale, convective scale, probability)

Improved Models & Data:

HRH cases (Bill): Surface winds

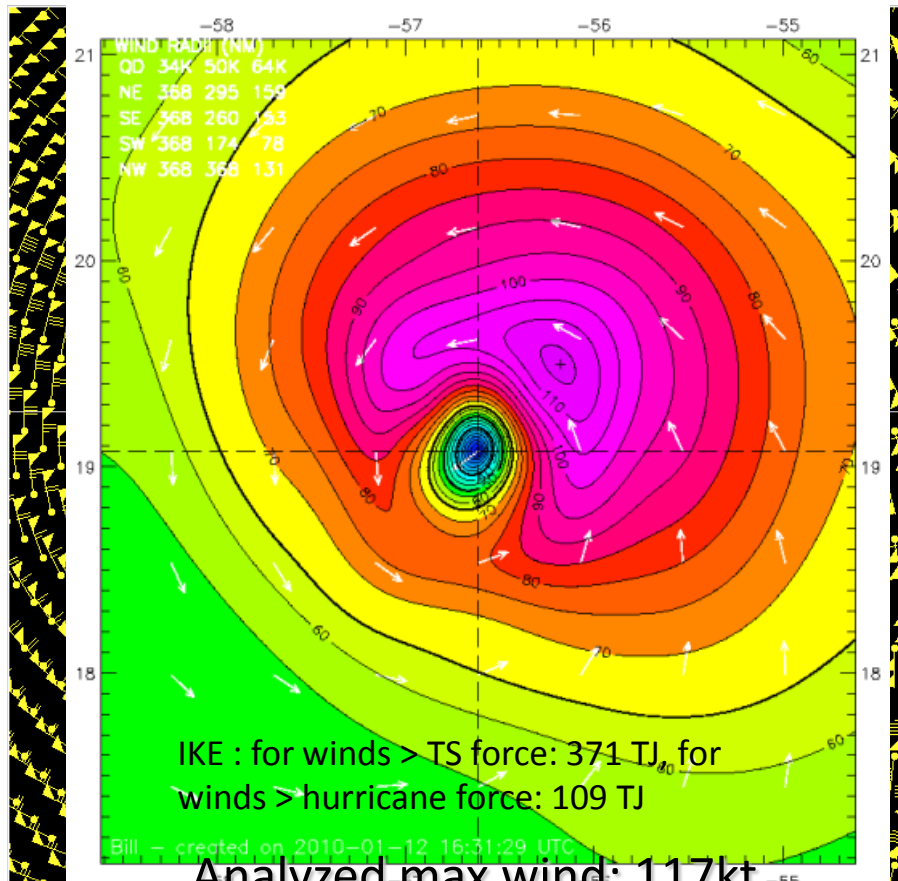


Hurricane Bill Aug. 19, 2009 1600 UTC

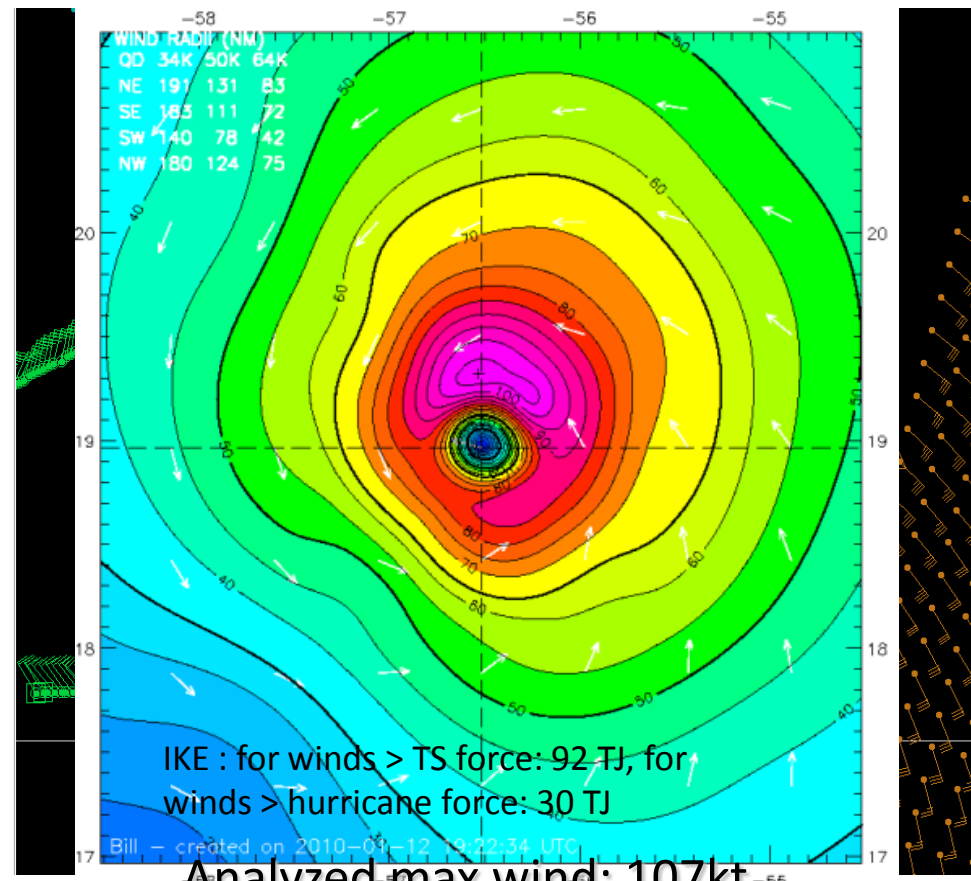
HWRFX 10m winds

Data Coverage

H*Wind 10m winds



Analyzed max wind: 117kt
from HWRFX, 37 nmi



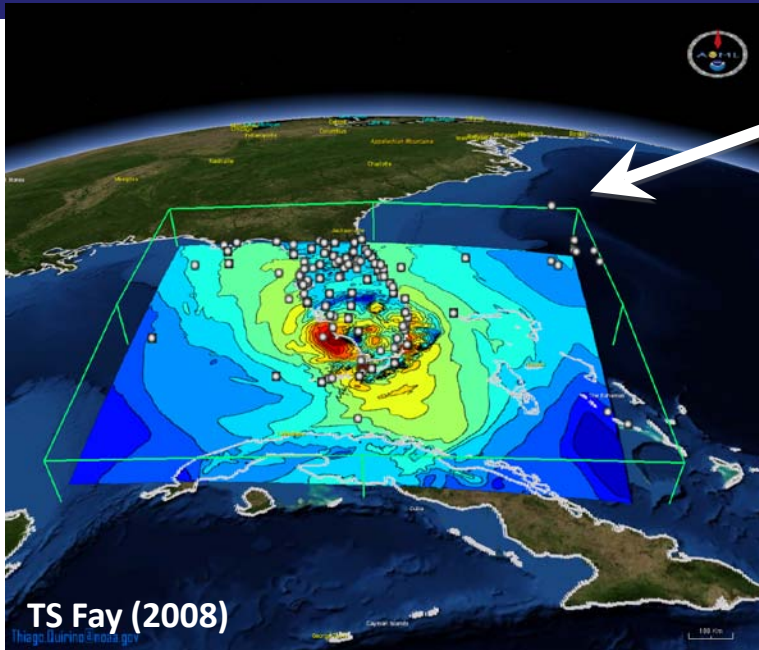
Analyzed max wind: 107kt
from Tail Doppler, 23 nmi

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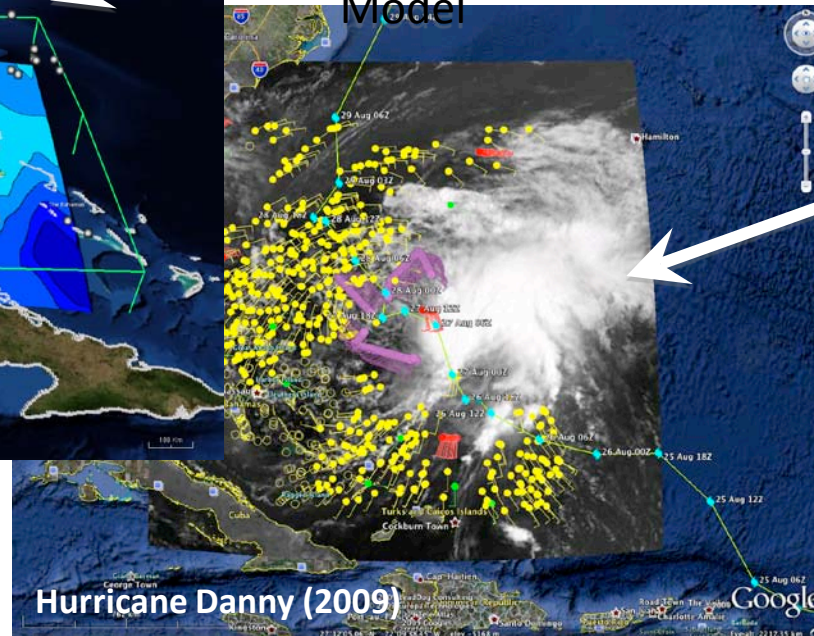
S. Murillo (AOML/HRD)

Improved Models & Data: Visualization of Model and Observations



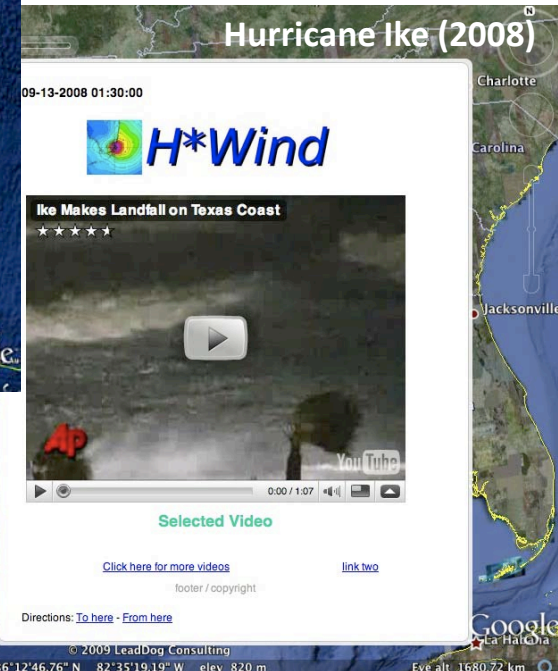
- Integration of H*Wind database & Model

- Integration of H*Wind database & NRL satellite imagery



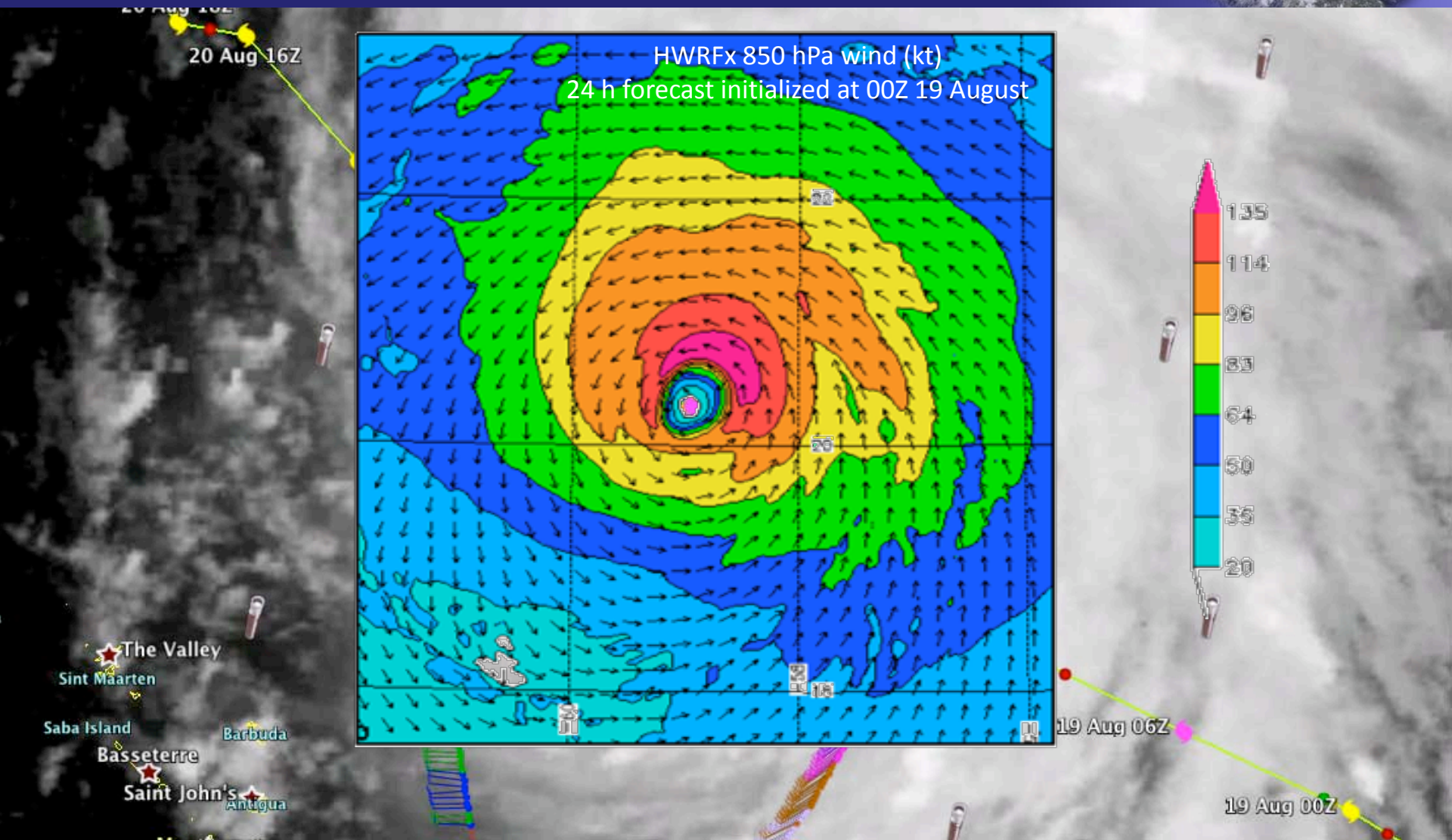
- Exploring AWIPS-II integration through use of common standards

- Integration of H*Wind database & YouTube



Improved Models & Data:

Visualization of Model and Observations



Improved Observations: IFEX 2010



IFEX 2010

- 2 NOAA WP-3D, G-IV – 700 flight hour (1 June-30 November)
- N42RF will be available by early June, N43RF available early August, N49RF (G-IV) available early June
- Crews available 2/day missions starting July (Tampa and deployments)
- Base from Tampa, FL; St. Croix, USVI; & Barbados

NASA Genesis and Rapid Intensity Processes (GRIP)

- [DC-8](#) and [Global Hawk \(GH\)](#) – 200 flight hour (15 August-30 September)
- Base Ft. Lauderdale, FL (DC-8); Edwards AFB (GH)

NSF Pre-Depression Investigation of Cloud-systems in the Tropics (PREDICT)

- [G-V \(HAIPER\)](#) – 200 flight hour (15 August-30 September)
- Base St. Croix, USVI

Keys to Success



- **Partnership:** AOML, ESRL, GFDL, DTC, USWRP, NESDIS/STAR working closely with Operations (EMC, NHC, AOC) and Federal & Academic Partners (NASA, NSF, ONR, NRL, NCAR, MMS)
- More integrated use & support of Testbeds: JHT, DTC, JCSDA
- Blend Traditional hurricane research activities and HFIP research activities
- **Manpower (diversity) to evaluate model performance with hurricane data sets is a critical need**





Claudette

Questions?

Ana

Bill

HFIP FY10 Teams



<u>FY2010 Teams</u>	<u>Team Leads and Member's Organization</u>
1. Global Model/Physics Development Team	Benjamin (ESRL), Brown (ESRL), AOML, NRL, GFDL, EMC, NRL
2. Regional Model/Physics Development Team	Bender (GFDL), Kwon (EMC), AOML, NRL, ESRL URI, Old Dominion Univ, NESL
3. Ensemble Development Team	Toth (ESRL), Reynolds (NRL), HRD, PSU, EMC, NHC, FSU
4. Data Assimilation/Vortex Initialization Team	Lapenta (EMC), Whitaker (ESRL), NRL, AOML, CIRA, PSU
5. Verification Team	Marchok (GFDL), Brown (RAL), NRL, NESDIS/STAR, AOML, NHC, EMC, ESRL
6. Applications Development and Diagnostics Team	Rappaport (NHC), DeMaria (NESDIS/STAR), EMC, NRL, HRD, RAL, ESRL, OUU, AOML, FSU
7. Hurricane Observations Team	Aberson (AOML), Shay (RSMAS), NHC, EMC, NESDIS/STAR, ESRL, URI, NRL, AOC, RAL
8. Ocean/Wave Model Team	Tolman (EMC), Halliwell (AOML), URI, ESRL, NRL, RSMAS

Operational System (Stream 1) Upgrades



Global Forecast System (GFS) upgrades (**Dec 2009**)

- Added tropical storm pseudo sea-level pressure observations
- Additional observations (NOAA19 HIRS/4, AMSU-A, & MHS brightness temperature, EUMETSAT-9 atmospheric motion vectors)

GFS upgrades (**May 2010**)

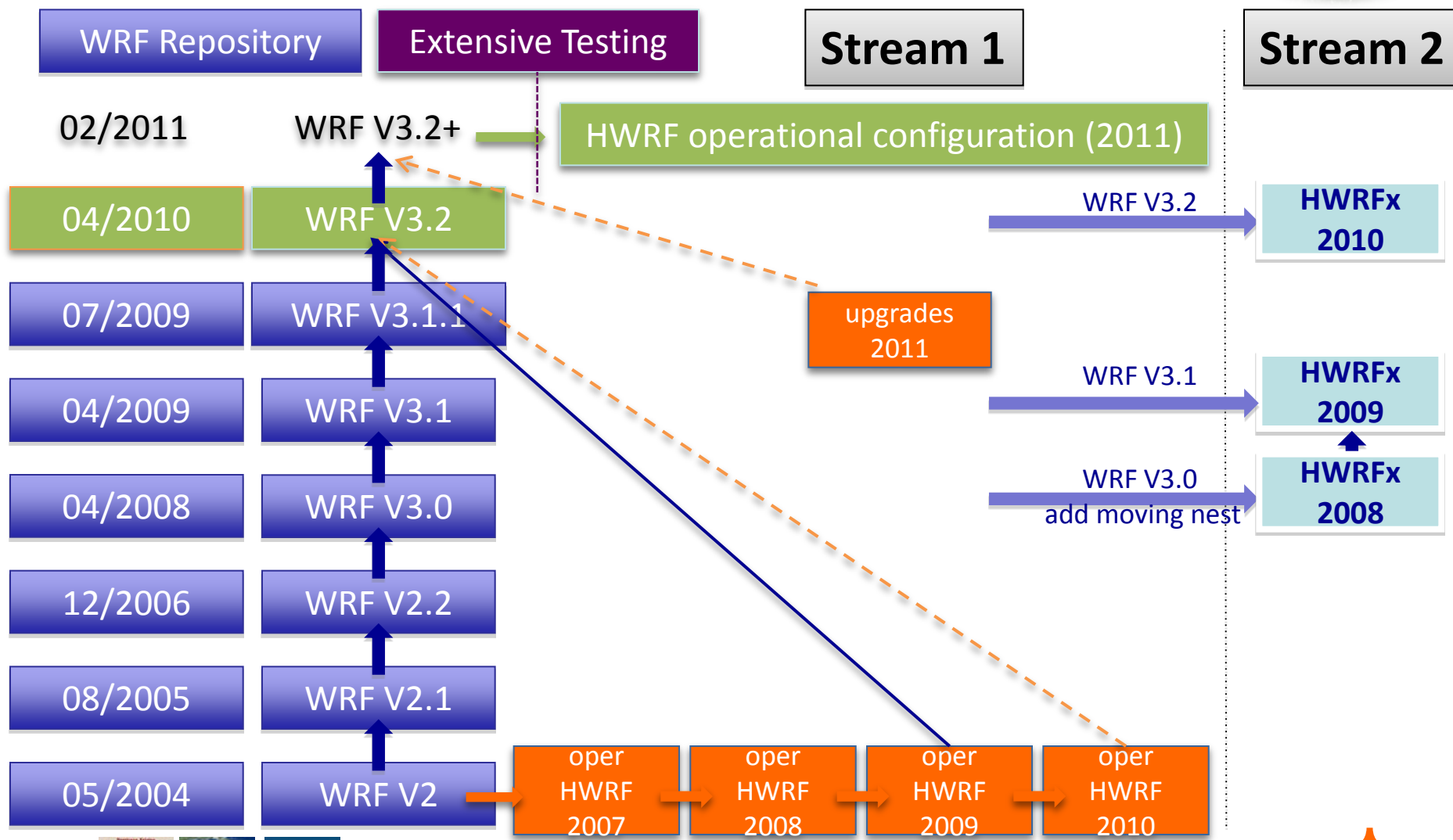
- Resolution increase (27 km from 38 km)
- Improved Physics (radiation, gravity wave drag, mountain blocking, shallow convection, PBL, deep convection with overshooting cloud tops)
- Removal of computational artifacts e.g.: negative water vapor

HWRF upgrades (**May 2010**)

- Upgrade surface exchange coefficients
- Coupling with HyCOM ocean model

HWRF code management:

facilitate research & operations collaboration



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Ligia Bernardet – DTC

High Performance Computing Augmentations



2008

- 15M Hours – NSF-supported Texas Area Computing Center (TACC)

2009

- NJET Boulder ~2MHours/month starting 9/2009
- TACC – HFIP 20M Hours 7/1 – 12/31
- TACC PSU 13M Hours for High Resolution ARW Ensembles and DA
- 115K Hours/month on NOAA R&D Computer in Gaithersburg
- NCEP backup computer (Cirrus) for HWRF testing

2010 - Planned

- NJET ~2M Hours/month
- DOE ORNL Jaguar - 20M hours
- TACC – 2.5M hours 1/1 – 6/30
- Add ~3000 Processors on NJET beginning 7/1/2010

Challenges for HFIP



- A vast majority of model forecasts will be initialized for storms with no aircraft data available.
- Development, testing, and evaluation of physics packages for global hurricane models at higher resolution is critical.
- Improved intensity prediction at higher resolutions requires additional physics development.
- High resolution global and regional ensemble systems are showing promise, but require further testing and evaluation.
- We need to develop better products to convey ensemble information to forecasters.
- We need to ensure future operational computer power is available for transfer to operations.

PREDICT HIAPER Payload

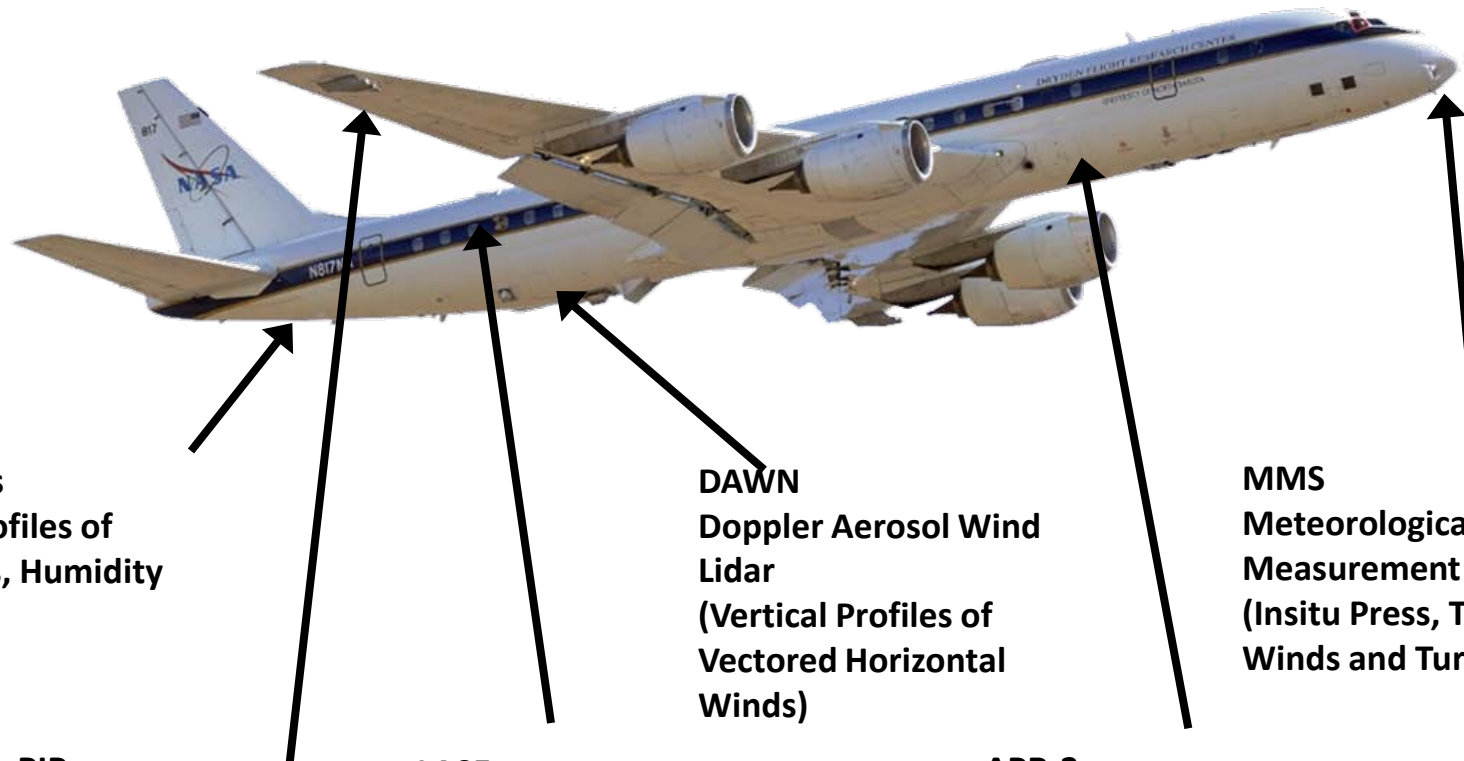


MTP
(Vertical Profiles of
Temp)

CVI, 3V-CPI,
(Cloud Particle Size
distributions, Precip
Rate, & Ice water
content)

Dropsondes
(Vertical Profiles of
Temp, Press,
Humidity and
Winds)

GRIP DC-8 Payload



Dropsondes
(Vertical Profiles of
Temp, Press, Humidity
and Winds)

CAPS, CVI, PIP
(Cloud Particle Size
distributions, Precip Rate,
Rain & Ice water content)

LASE
Lidar Atmospheric
Sensing Experiment
(H₂Ov, Aerosol
profiles and Cloud
distributions)

DAWN
Doppler Aerosol Wind
Lidar
(Vertical Profiles of
Vectored Horizontal
Winds)

APR-2
Airborne Precipitation
Radar Dual Frequency
(Vertical Structure Rain
Reflectivity and Cross
Winds)

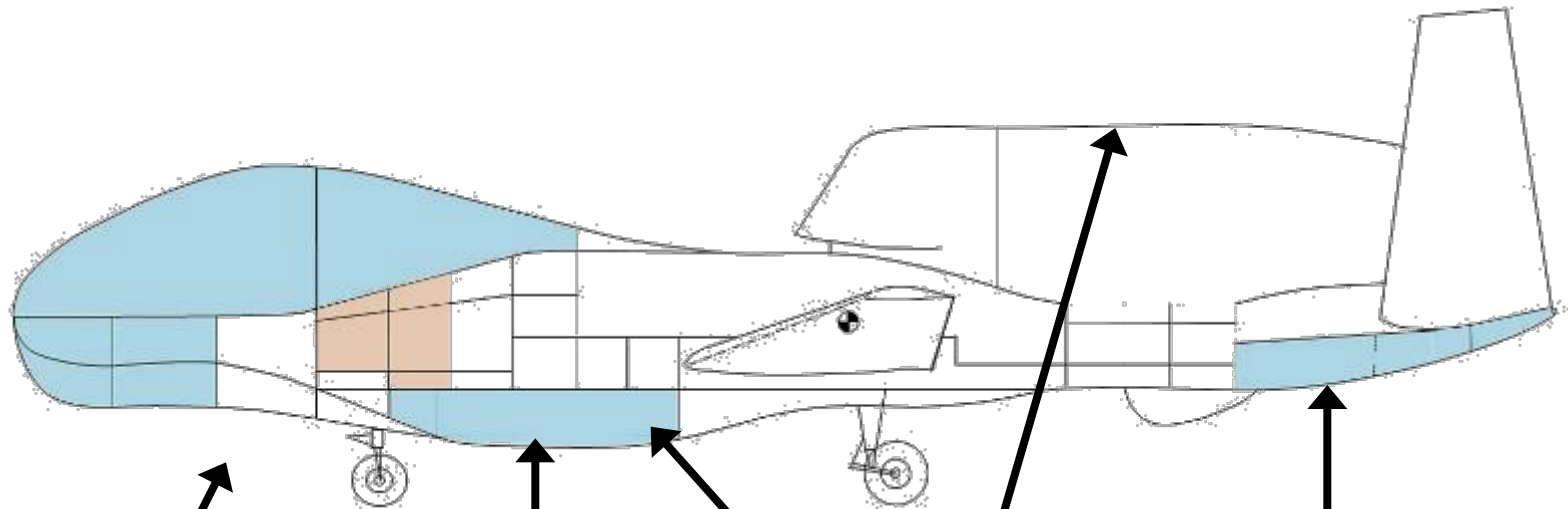
MMS
Meteorological
Measurement System
(Insitu Press, Temp, 3D
Winds and Turbulence)

National Hurricane Forecast Improvement Project

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GRIP GH Payload



HAMSR
High Altitude MMIC
Sounding Radiometer
(Temp, H₂O_v, Cloud
liquid & ice
distribution)

HIWRAP
High Altitude
Imaging Wind and
Rain Profiler
(Horizontal wind
vectors and ocean
surface winds)

LIP
Lightning
Instrument Package
(Lightning and
Electrical Storm
observation)

Driftsondes
High Altitude
Lightweight Dropsonde
(Vertical profiles of
temp, humidity,
pressure & winds)