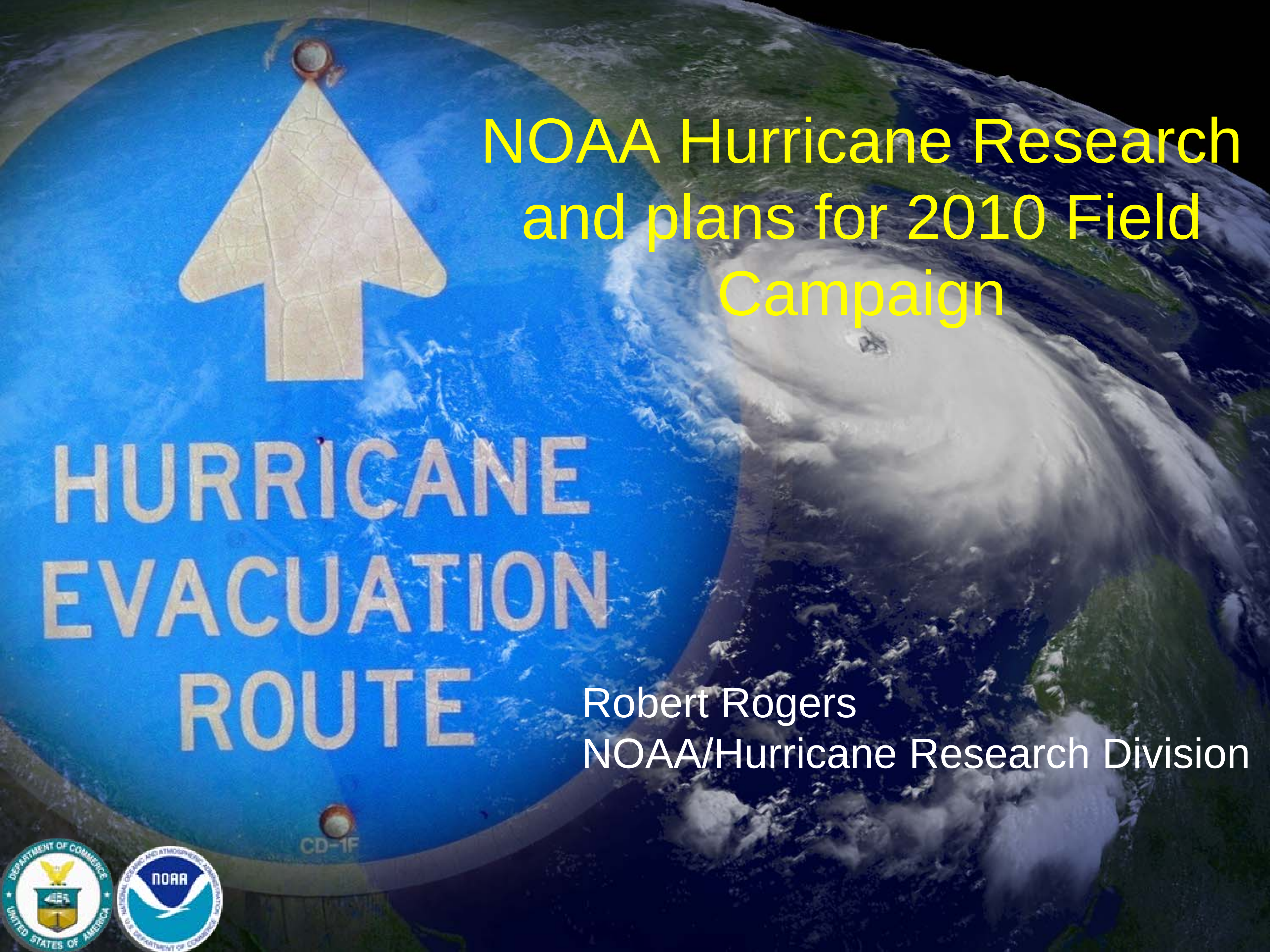
NOAA Hurricane Research and plans for 2010 Field Campaign



Robert Rogers
NOAA/Hurricane Research Division

Current state of forecasting capabilities

Track: NOAA 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 ±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

Given recent events,

- Katrina and Wilma causing catastrophic damage in 2005

- Large number of US landfalls (Hurricanes Dolly, Gustav, Ike, and TS Edouard, Fay) in 2008

- Rapid intensifiers just prior to landfall – Charley (2004) and Humberto (2007)

Time is now for NOAA to lead aggressive effort to improve hurricane forecasting

- **Unified NOAA approach** to **guide and accelerate improvements in forecasts**, with **emphasis on rapid intensity change**, and **reduction in uncertainty**

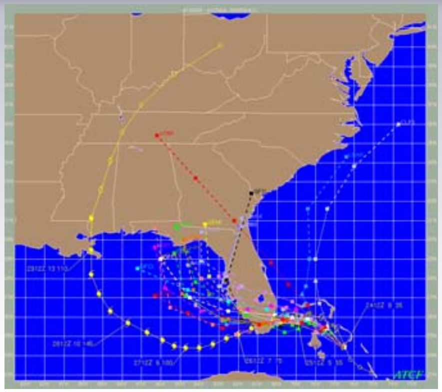
- **Embraces strong collaboration with non-NOAA partners** with **ultimate objective to transition research into operations**

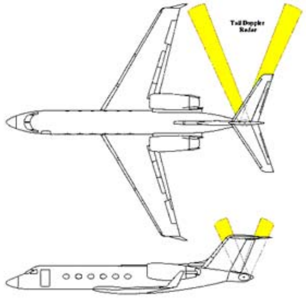
HFIP metrics for success

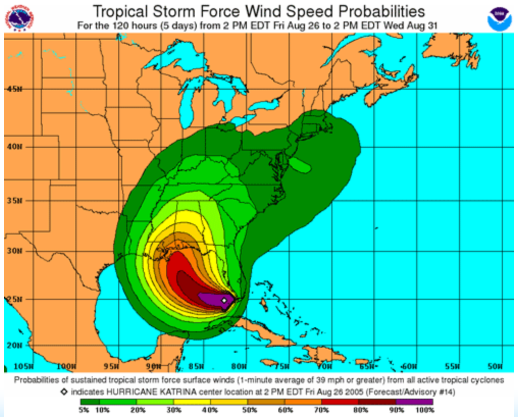
- Reduce track error by 50% at all lead times (100 nm to 50 nm at 48 h)
- Reduce intensity error by 50% at all lead times (14 kt to 7 kt at 48 h)
- Increase Probability of Detection and reduce False Alarm Ratio of rapid intensification (> 30 kt/24 h) events
- Extend the lead time to 7 days.

How to get there….

- **Improve understanding of physical processes**
- **Improve numerical model guidance**
- **Optimize use of new and existing observing systems**
- **Expand and improve forecaster tools and applications**

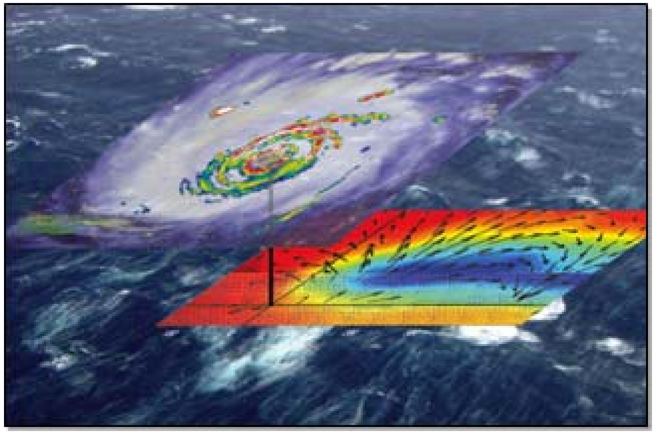


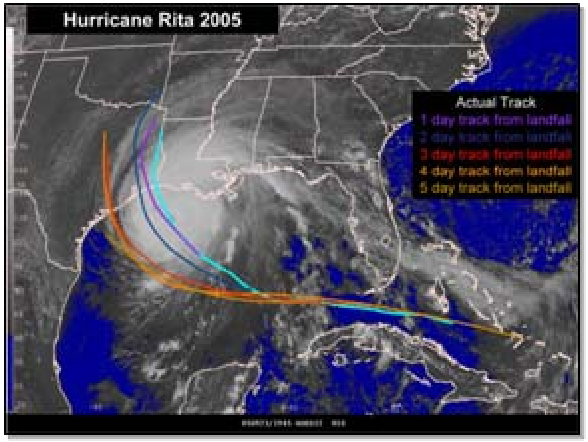


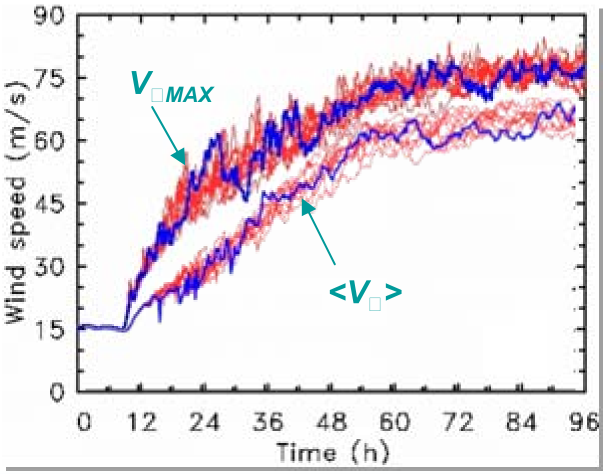


Research thrusts

- **Intensity and structure change, with emphasis on RI:** processes that modulate internal storm dynamics and storm interactions with atmosphere and ocean;
- **Track:** interactions between tropical cyclone and its environment through optimal use of observations;
- **Forecast Uncertainty**: global and regional model ensembles to bound uncertainty and test predictability







Improved understanding

Intensity change and rapid intensification

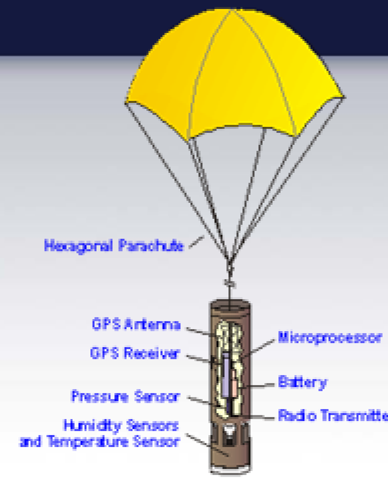
- Advances in forecasts of tropical cyclone (TC) intensity, structure, and rainfall lag advances in TC track forecasts
- Multiscale nature of these processes major reason for this
  - Environmental - O(1000 km) - troughs, shear
  - Vortex - O(1-100 km) - symmetric/asymmetric dynamics
  - Convective - O(1 km) – convection, vortical plumes
  - Turbulent - O(1-100 m) - surface fluxes, entrainment/detrainment
  - Microscale - O(1 mm) – hydrometeor/aerosol, latent heat release

Some motivating questions

- What is relative importance of various scales in governing genesis and intensity change?
- SAL impacts on genesis and intensification?
- Role of precipitation structure and convective bursts in TC genesis and intensification?
- What are predictability limits for various scales?

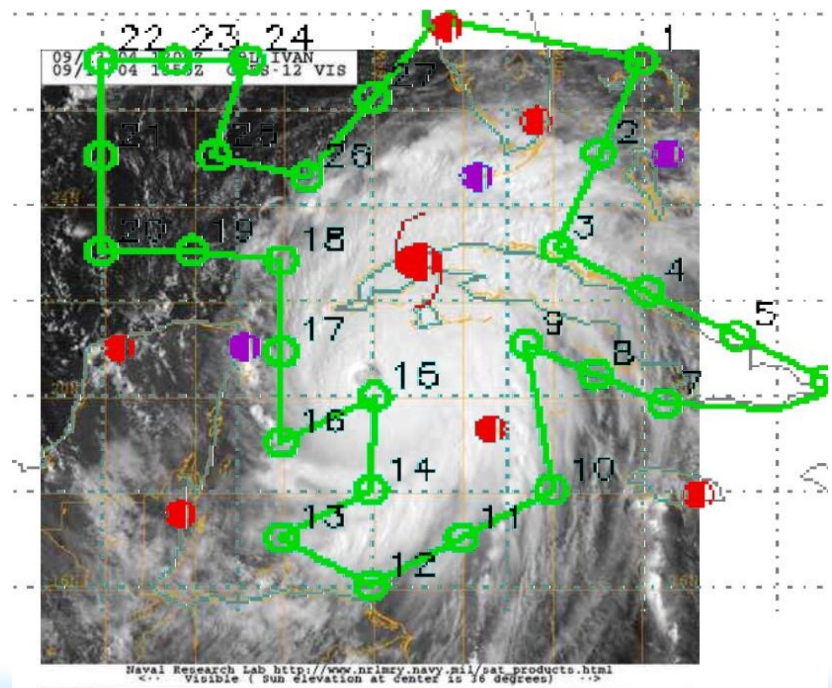
Environmental scale

Synoptic-surveillance using dropsondes.



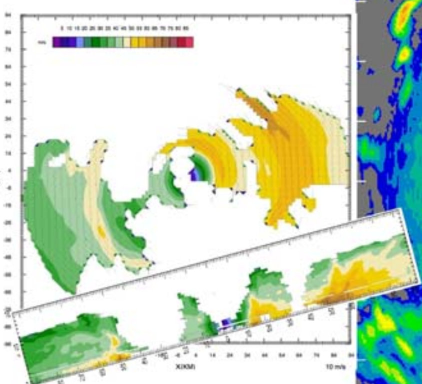
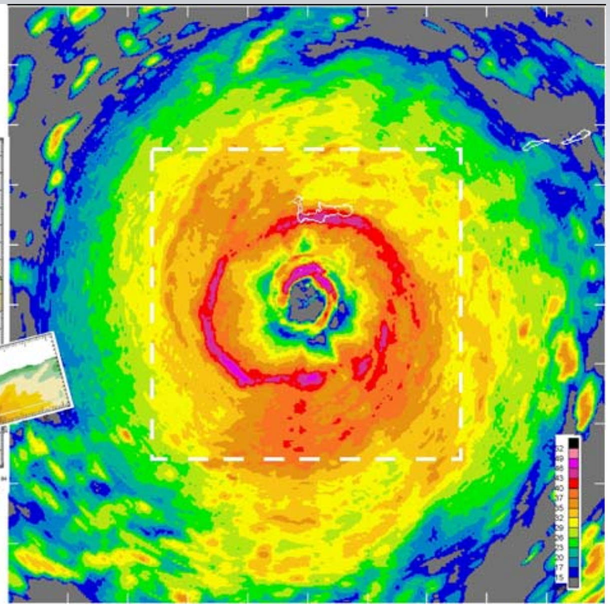
Analytical & numerical studies.

Ensemble track forecasting & targeted observations.



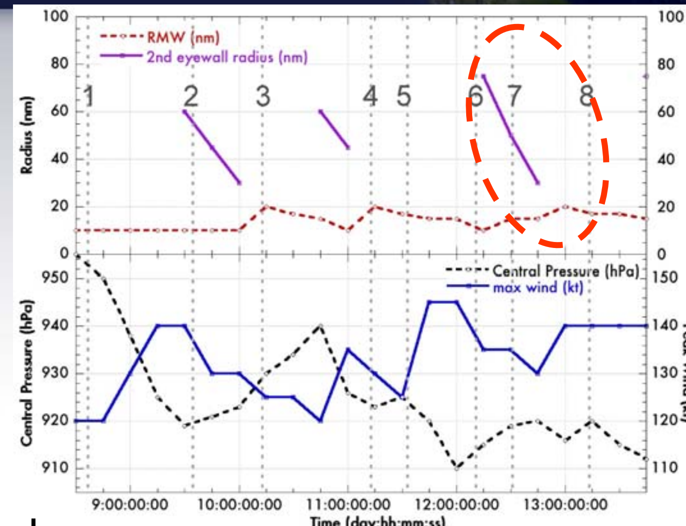
Vortex scale

Eyewall Replacement: Hurricane Ivan

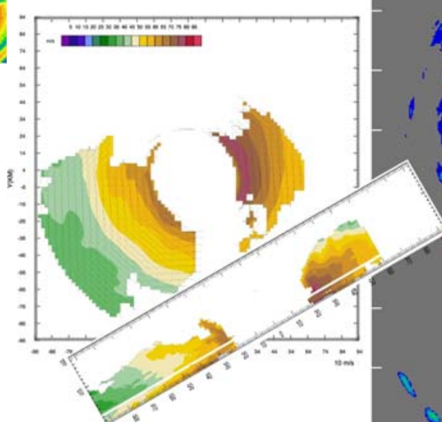
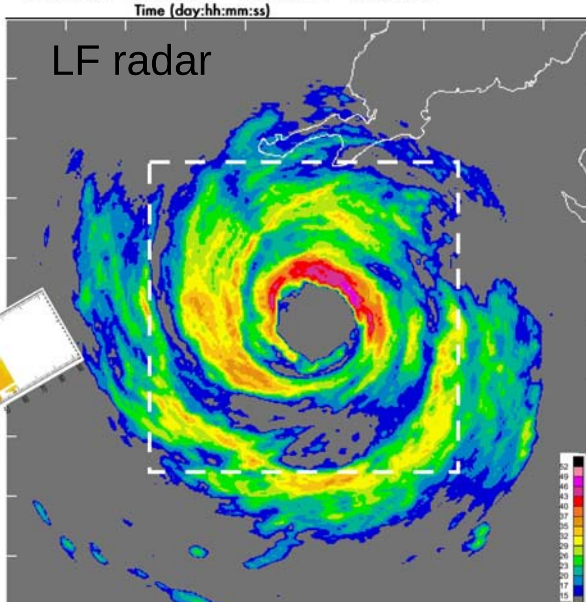



Doppler analysis

LF radar

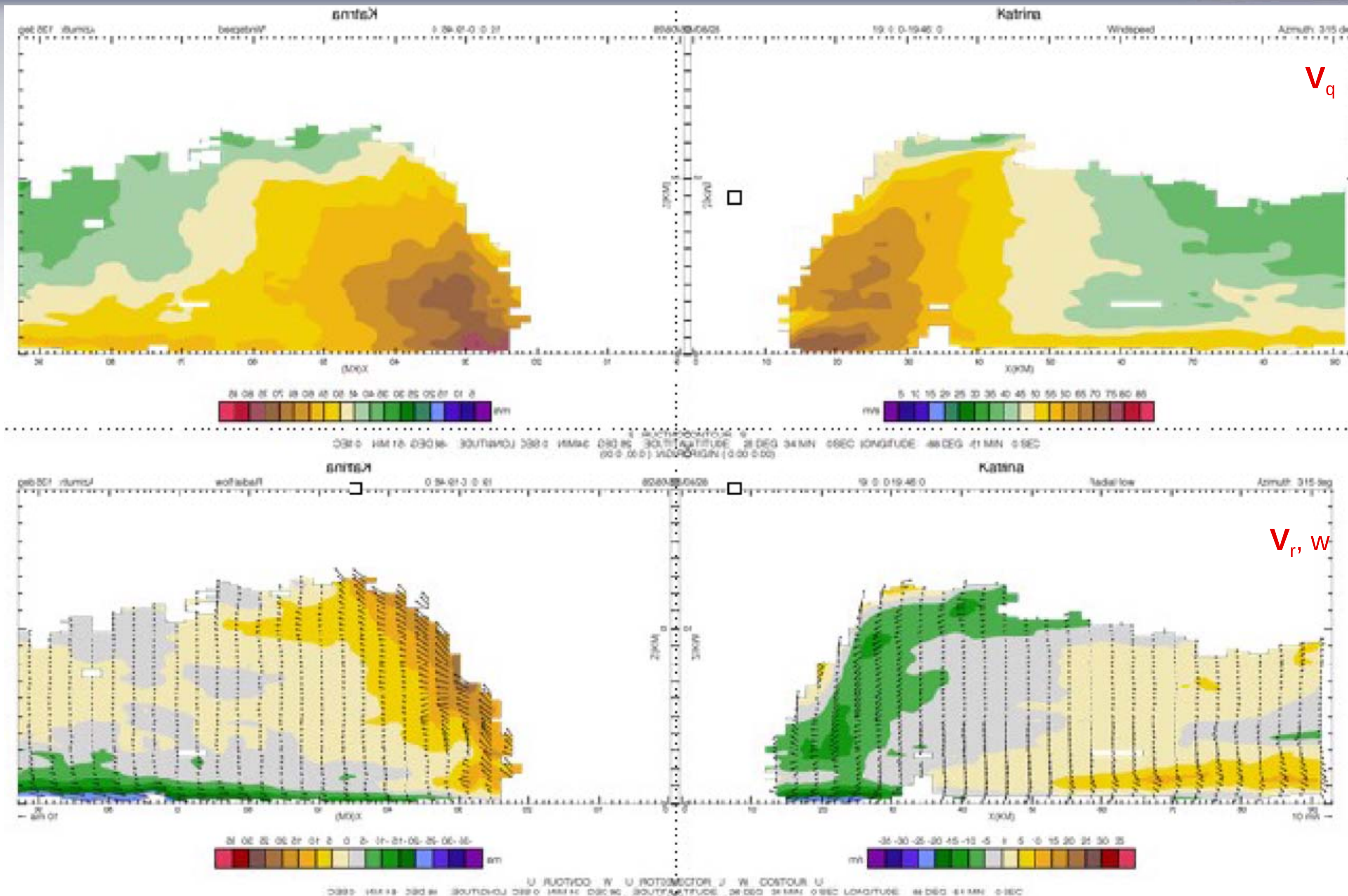


Doppler analysis

Horizontal radar reflectivity (dBZ), horizontal and vertical cross-sections of wind speed (m s^{-1}) for 12 (top, **7**) and 13 (right, **8**) September showing transition from double eyewall to larger single eyewall over 18 h period

Vortex/Convective scale

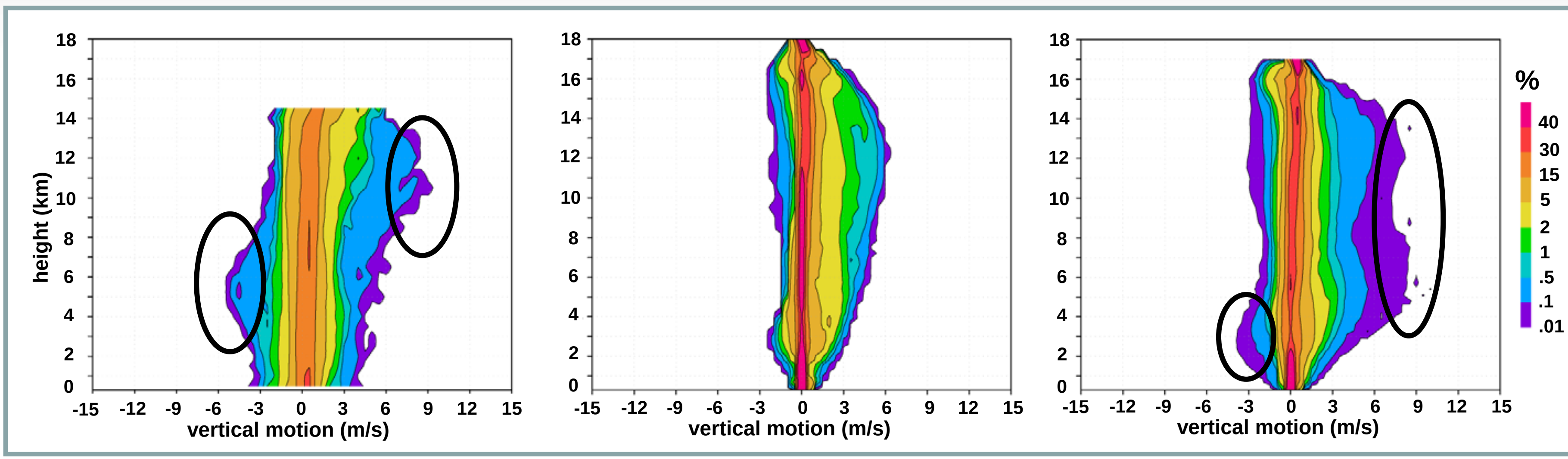


Airborne Doppler-analyzed wind field Hurricane Katrina, 28 September 2005

Convective scale

Contoured frequency by altitude diagrams (CFADs) of vertical motion
For observations and simulation of Hurricane Katrina

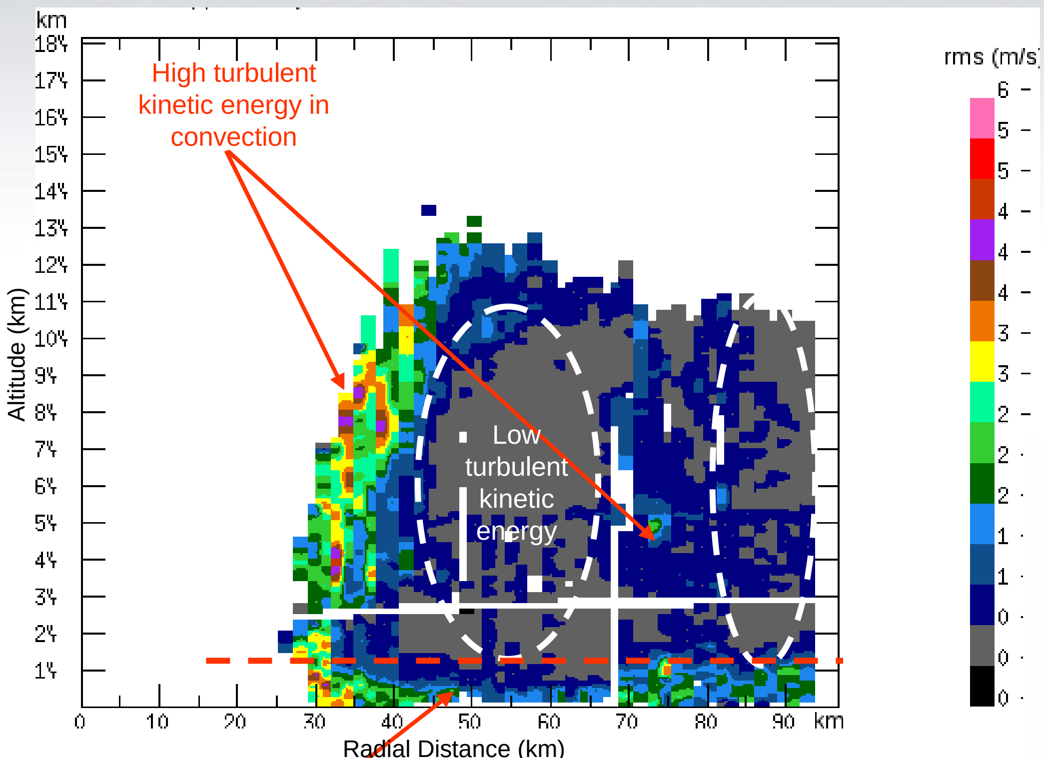
Doppler | **27-9 km HWRF-x** | **9-3 km HWRF-x**

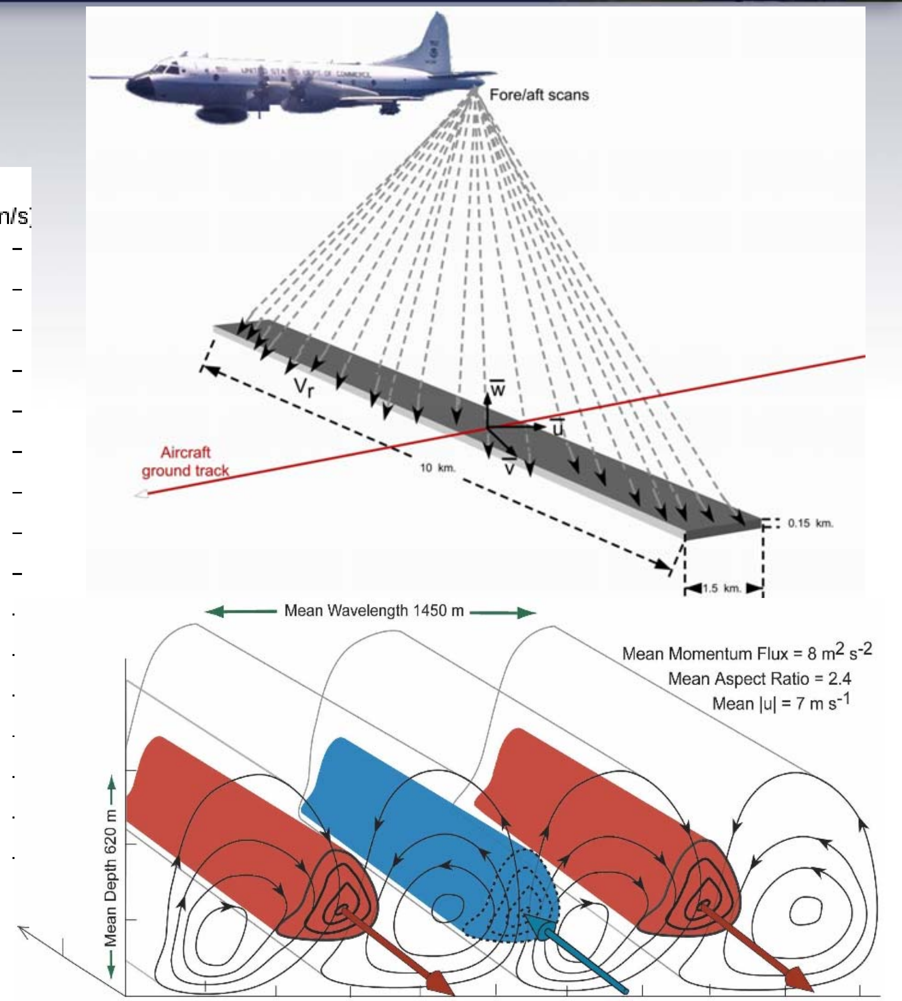


2038-2231 UTC 8/28 | **0900Z 29 Aug** | **0900Z 29 Aug**

Turbulent scale

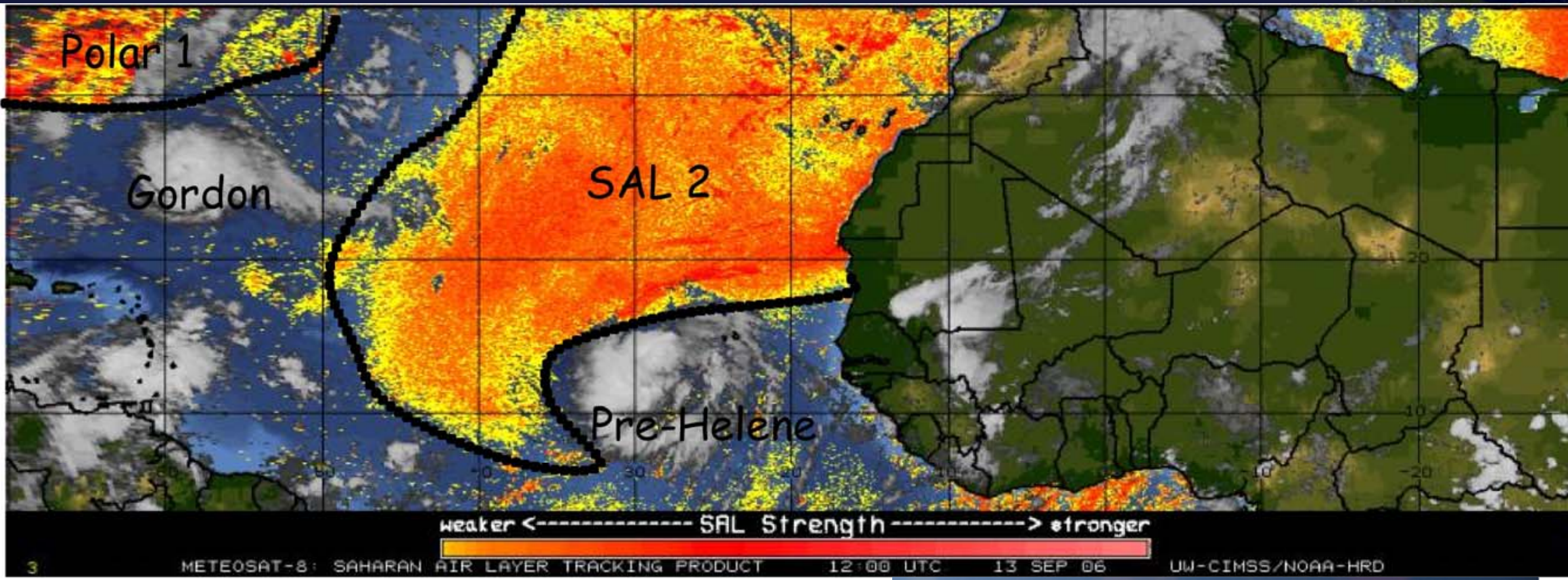
Sub-grid Scale Turbulent Kinetic Energy





Turbulent structure / Convection and Boundary Layer Rolls

Microphysical scale

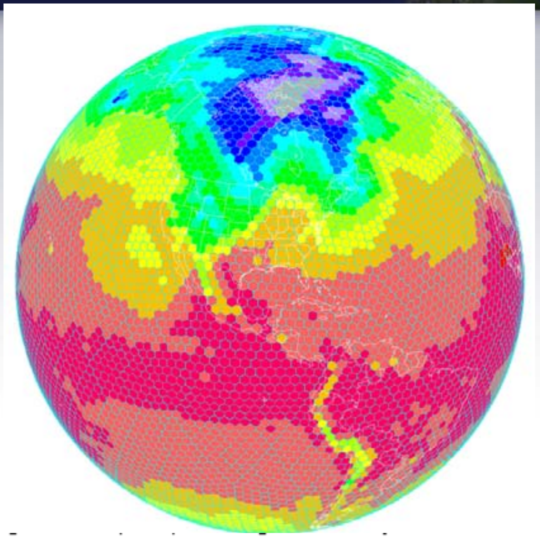


Saharan Air Layer (SAL)
Impact on intensity and rain

Improved models

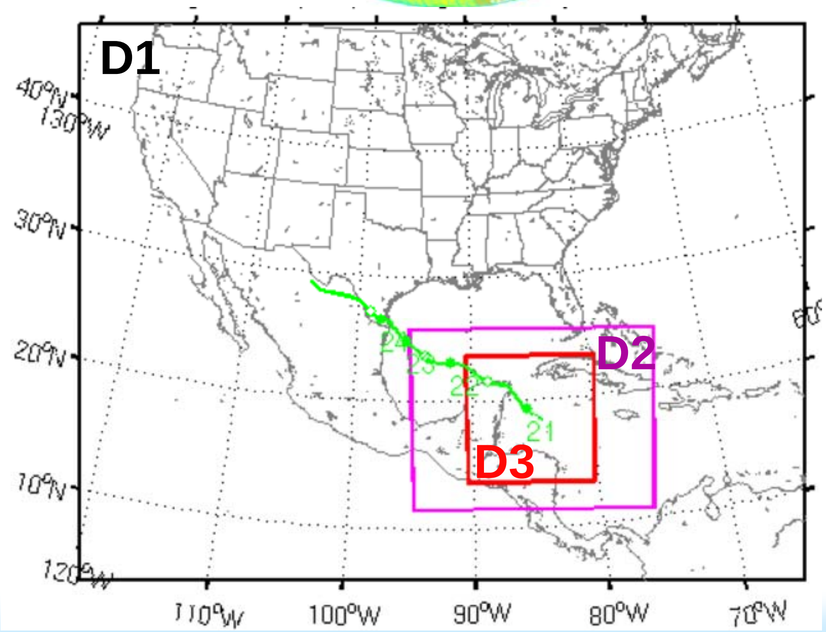
Global:

- FIM global model developed at ESRL with help from NCEP
- Uses unique global grid (soccer-ball-like horizontal, adaptive vertical coordinate)



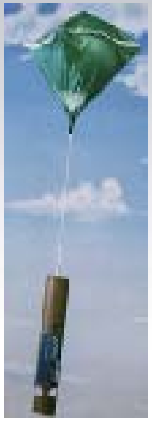
Regional:

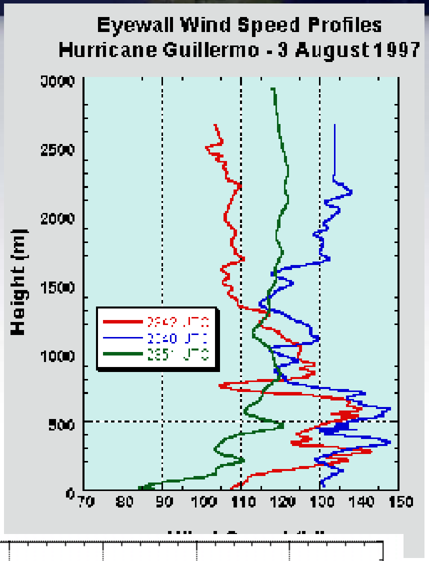
- Experimental HWRF developed at AOML & ESRL based on NCEP HWRF
- Triply-nested regional model down to 1-km horizontal resolution



Improved observations

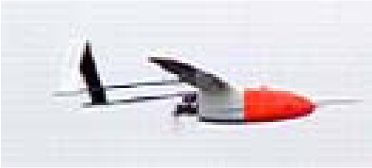
Airborne platforms
- P-3’s
- G-IV
- UAS





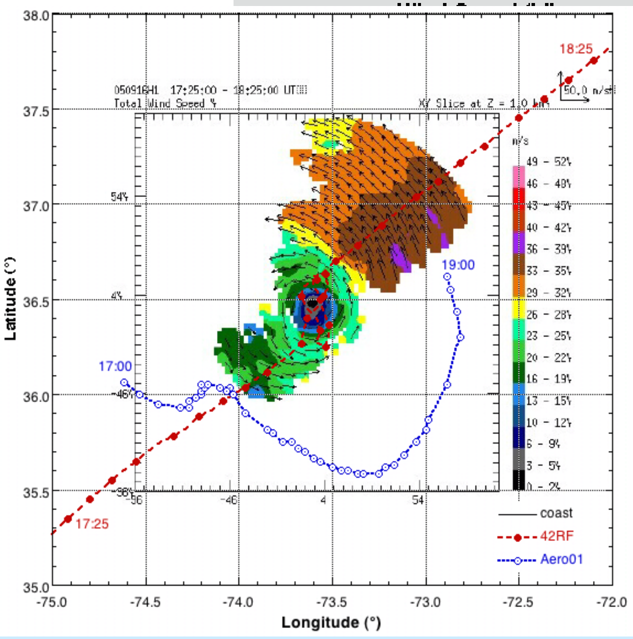
In-situ
- Wind, pressure, temperature

Expendables
- Dropsondes
- AXBT, AXCP, buoy



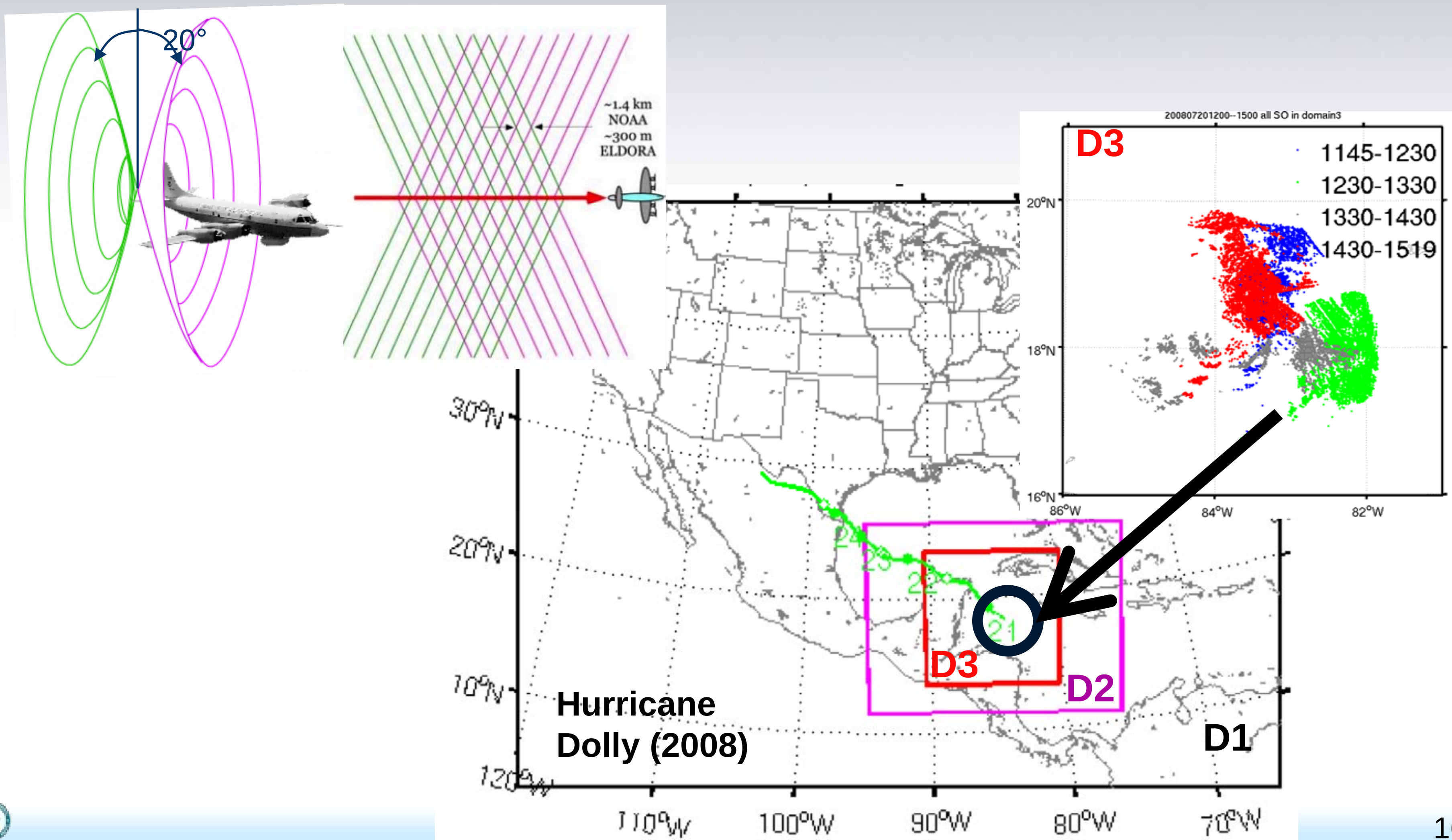
Remote sensors
- Doppler radar
- SFMR
- Scatterometer/profiler
- UAS

Doppler radar analysis overlaid by Aerosonde and coincident WP-3D track in TS Ophelia 16 Sept 2005



Improved use of observations

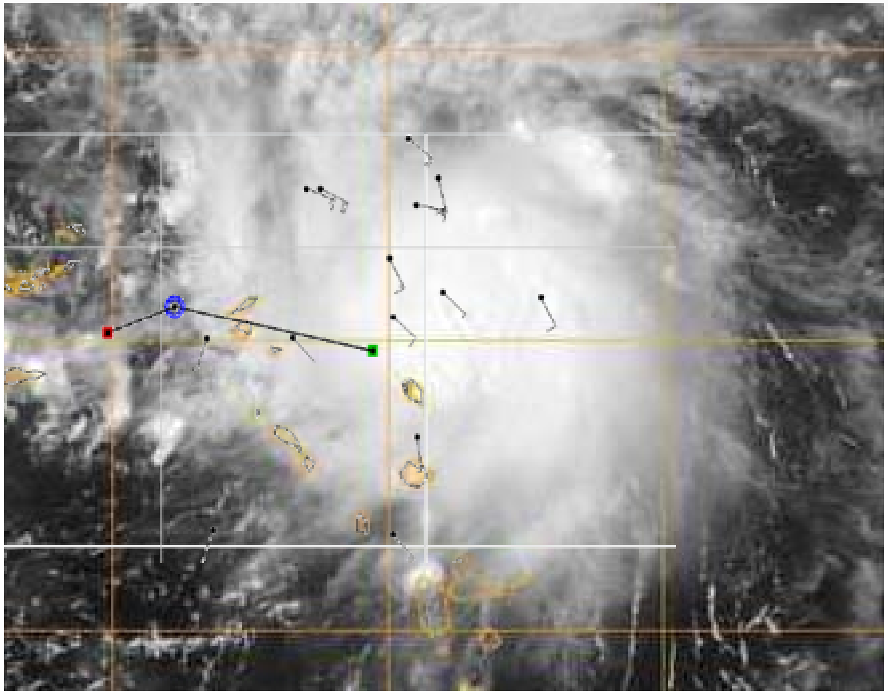
EnKF data assimilation of inner core observations



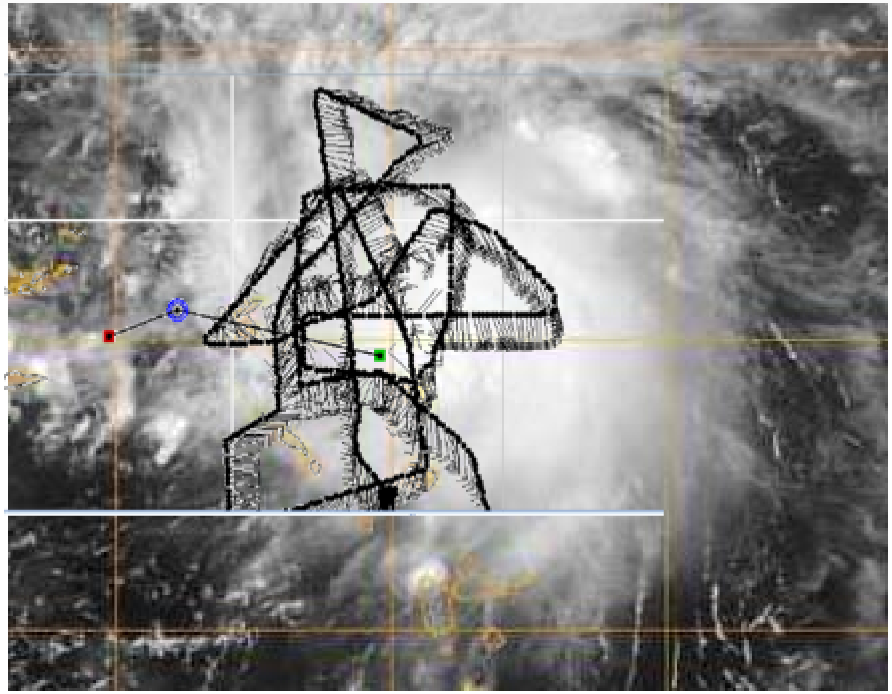
Recent genesis and RI cases sampled

T.S. Fay genesis case

Winds in lowest 150 m on
Aug. 14 2008

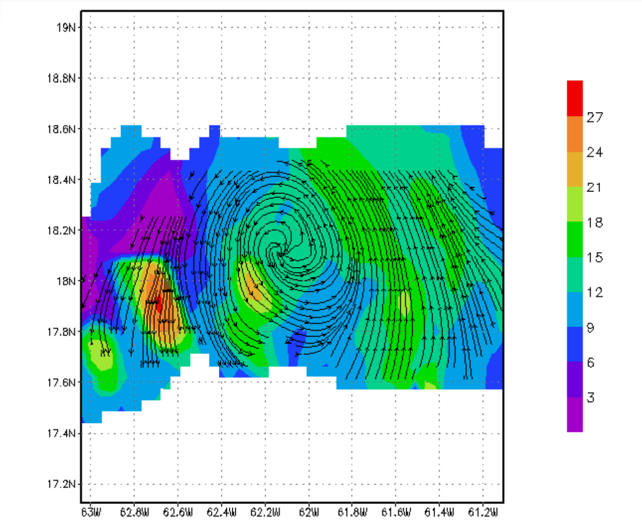


Flight-level winds on
Aug. 14 2008

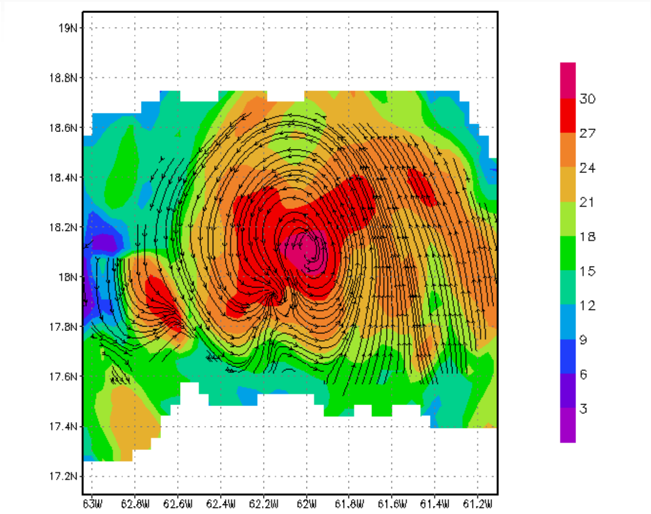


T.S. Fay genesis case

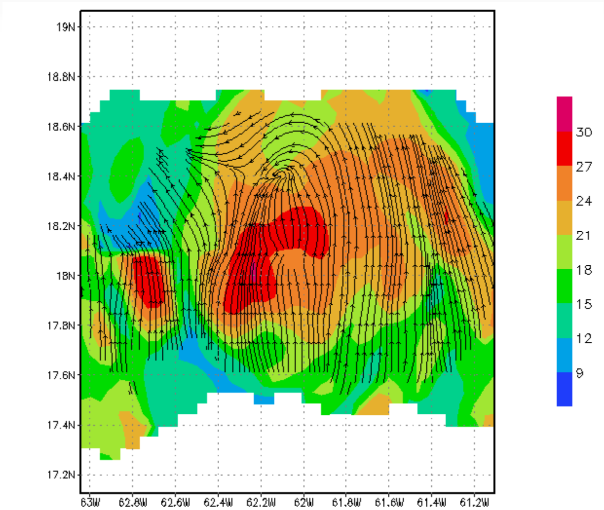
Doppler reflectivity (shaded) and winds (streamlines) at various levels
on Aug. 14 2008



7 km

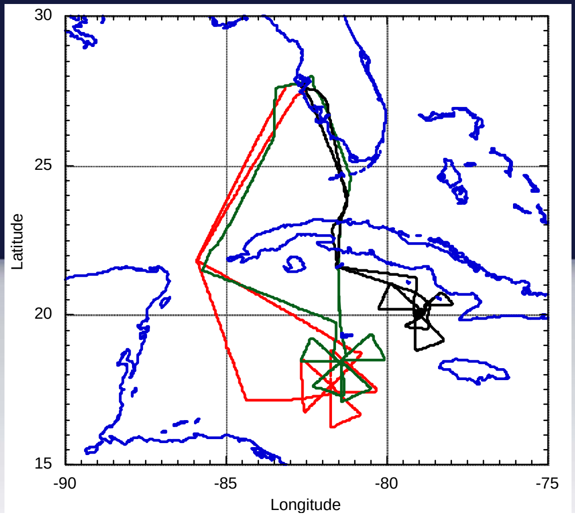


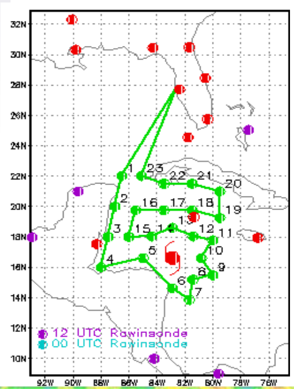
4 km

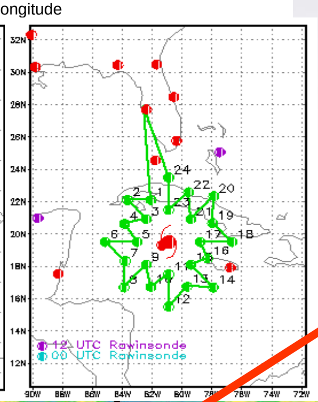


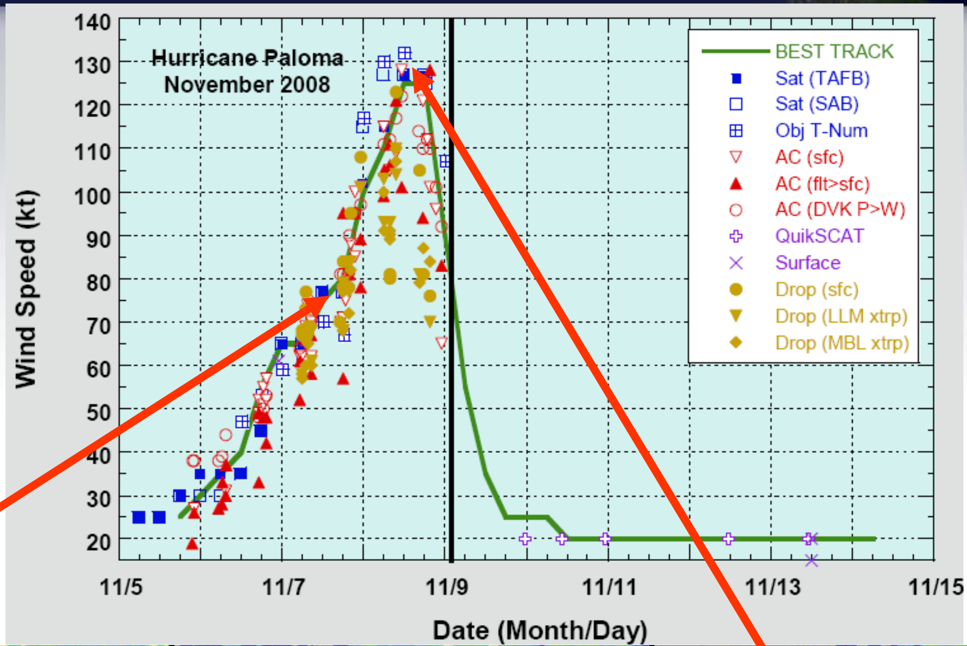
1.5 km

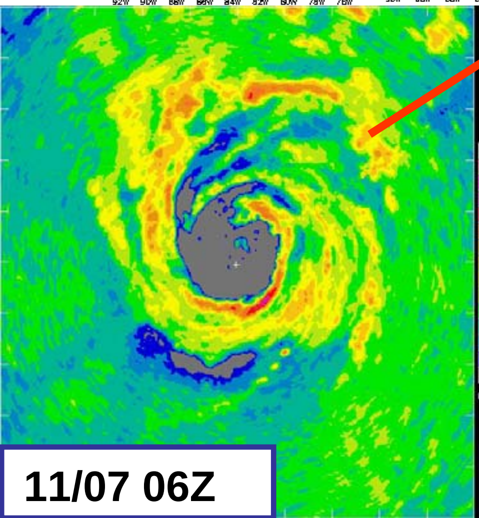
Paloma RI – 3 P-3, 2 G-IV 11/05 to 11/08

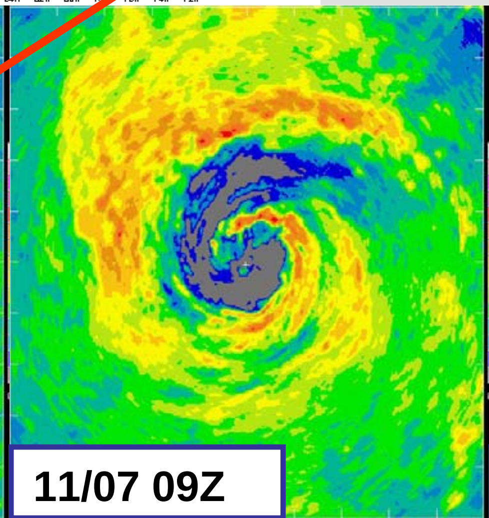


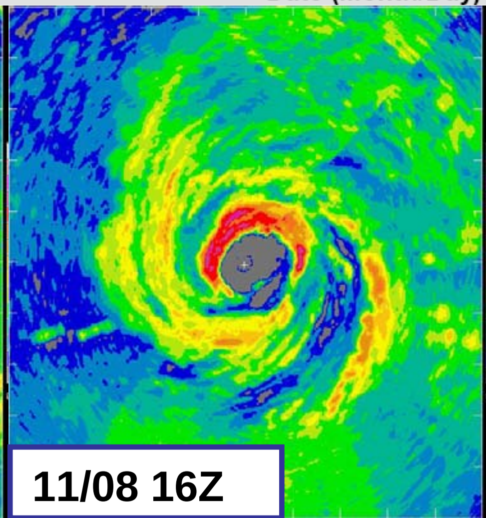


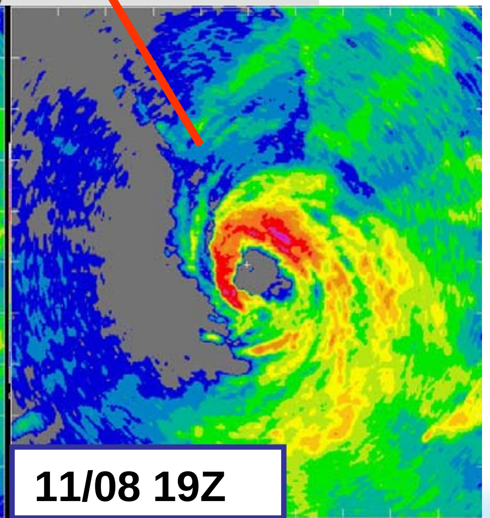






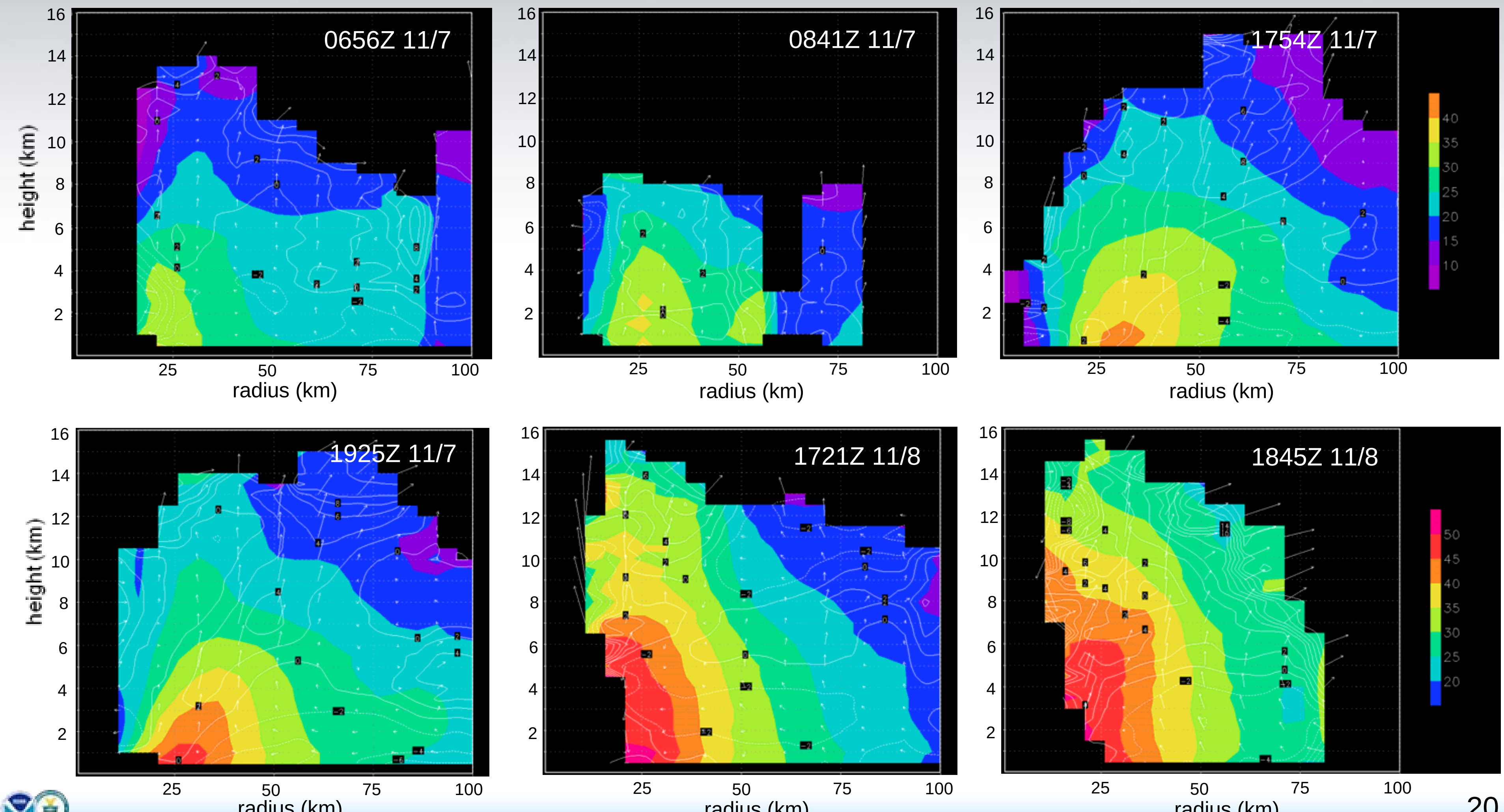






Recent genesis and RI cases sampled

Paloma axisymmetric tangential (shaded, m/s) and radial winds (contour, m/s)



Plans for 2010

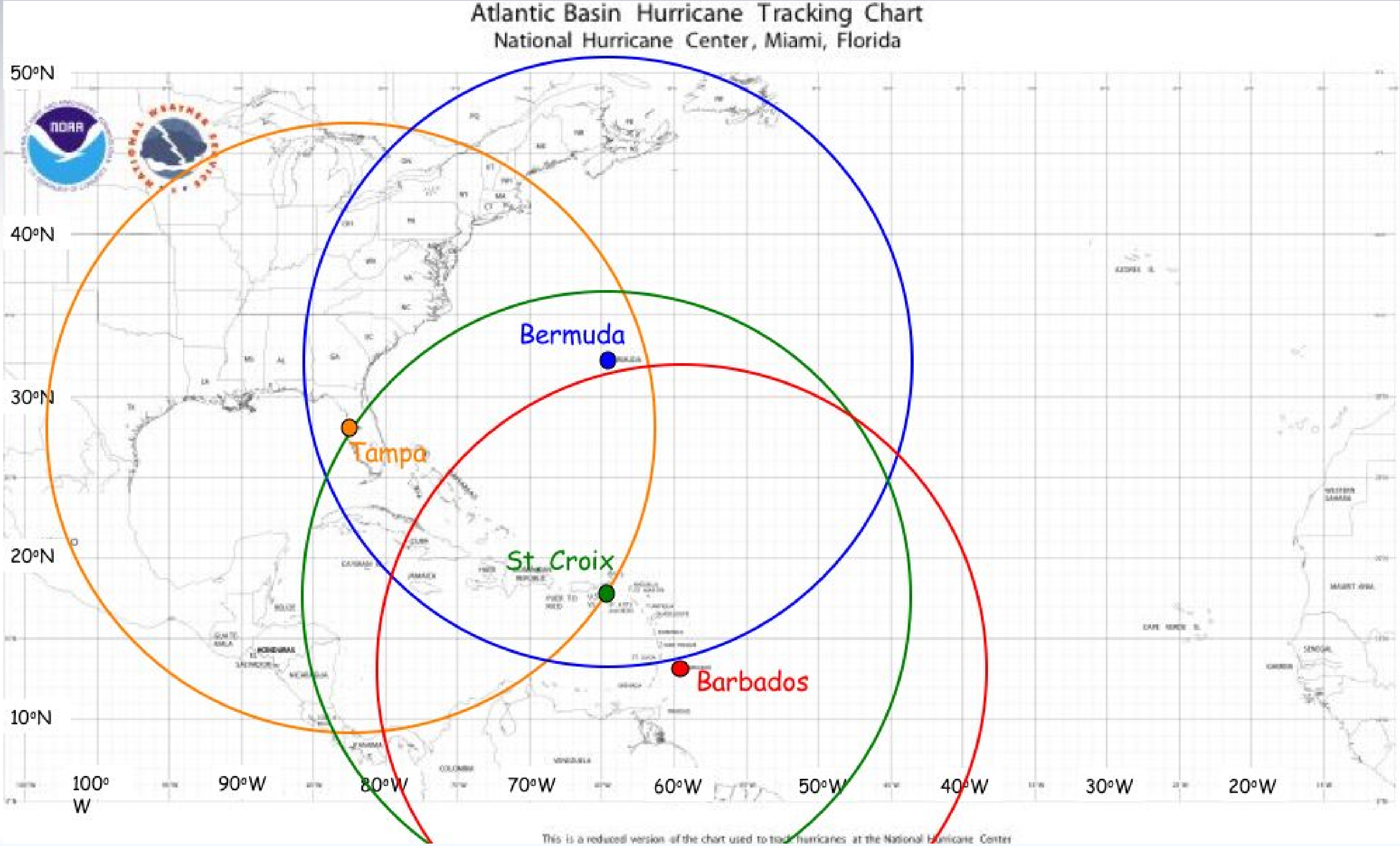
- IFEX 2010, Intensity Forecasting EXperiment
  - field phase of HFIP
  - partnering with NOAA interests (NHC, EMC, NESDIS)

- Research focus – genesis and rapid intensification

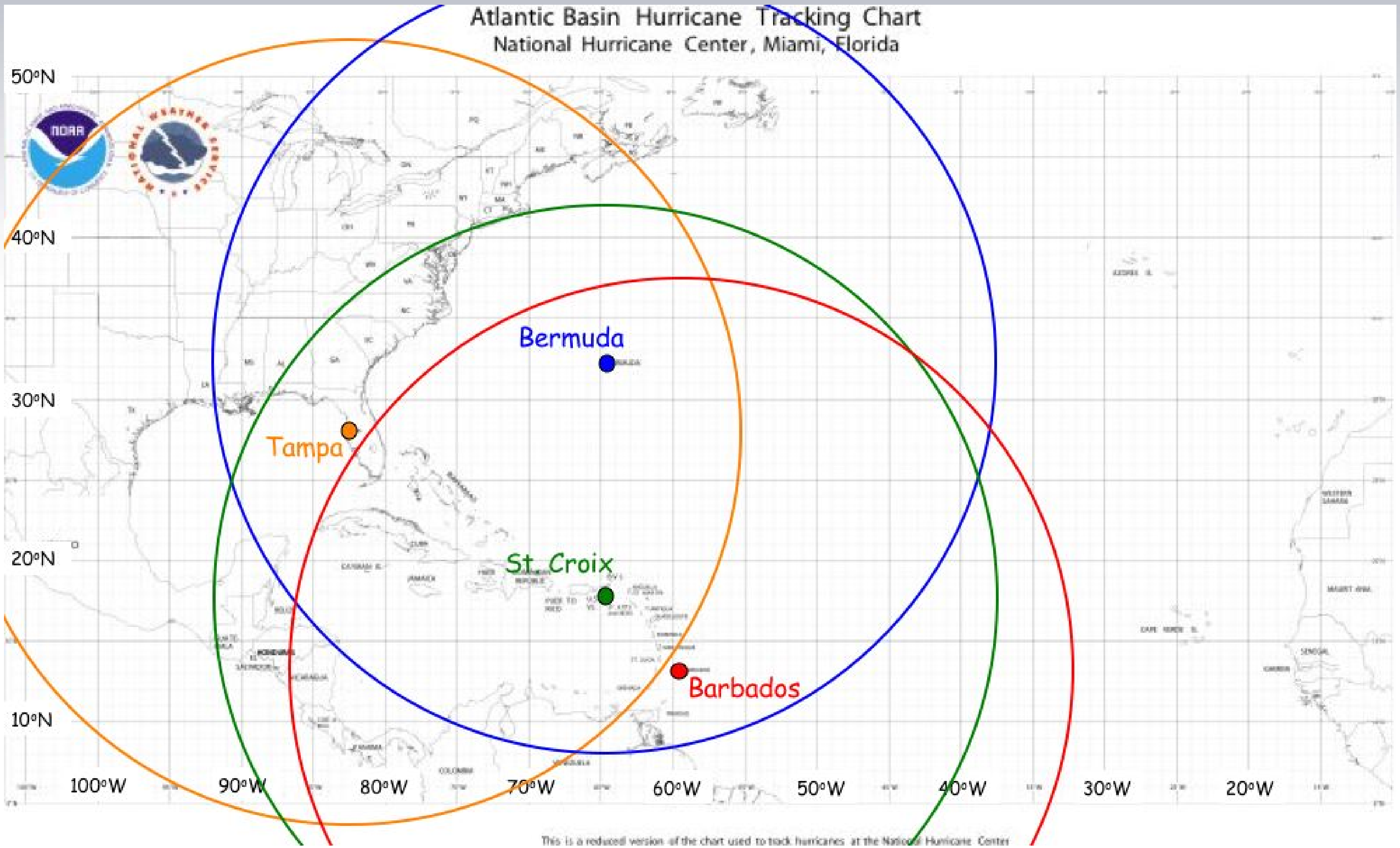
- Platforms
  - 2 P-3's
  - 1 G-IV (w/Doppler radar and SFMR)
  - High-altitude UAS (Global Hawk)
  - Possible low-altitude UAS (e.g., Aerosonde)

- Planned collaborations
  - NASA GRIP
  - NSF PREDICT

P-3 aircraft maximum range of operations

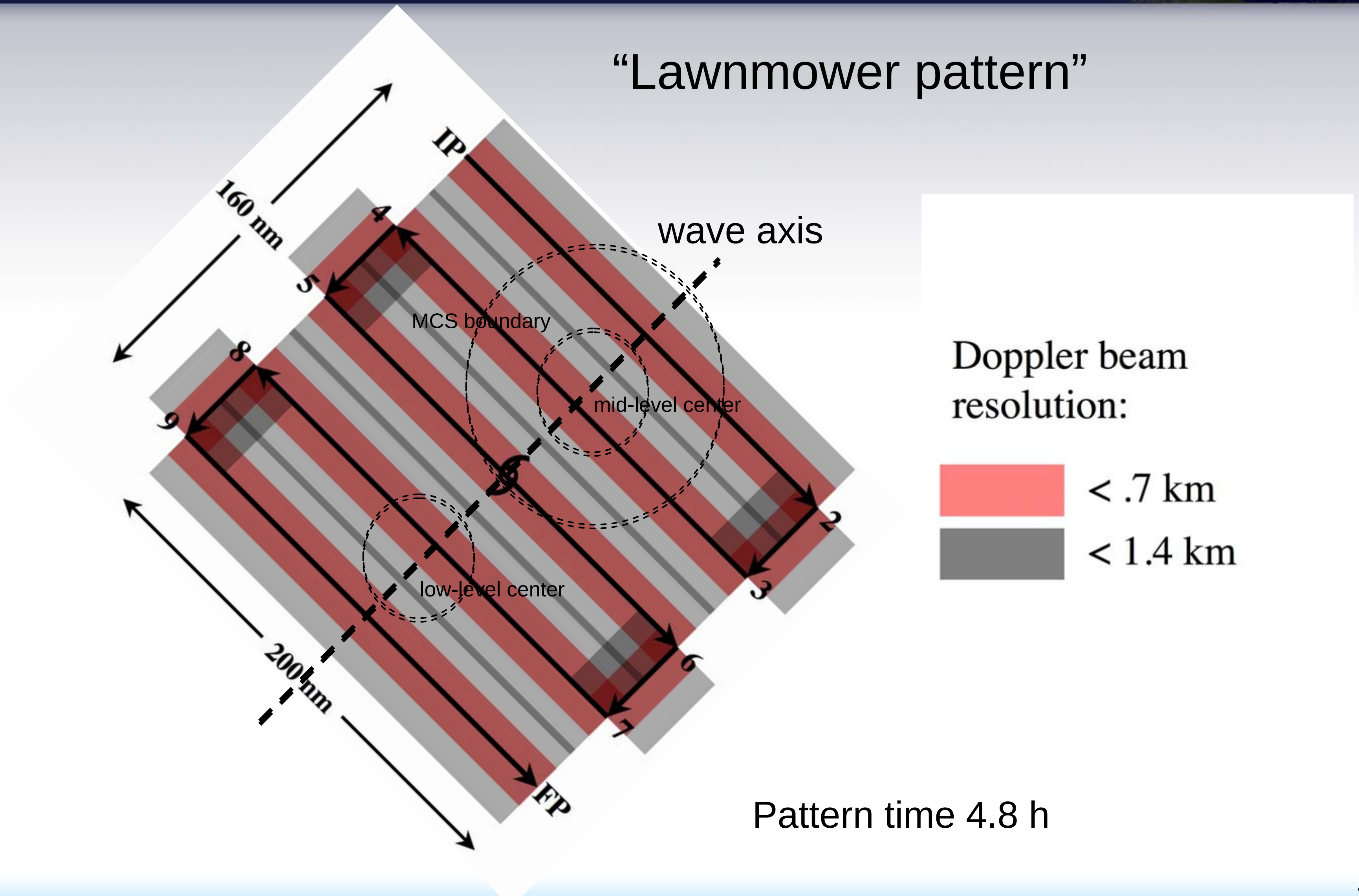


G-IV aircraft maximum range of operations



P-3 Flight pattern: Early genesis

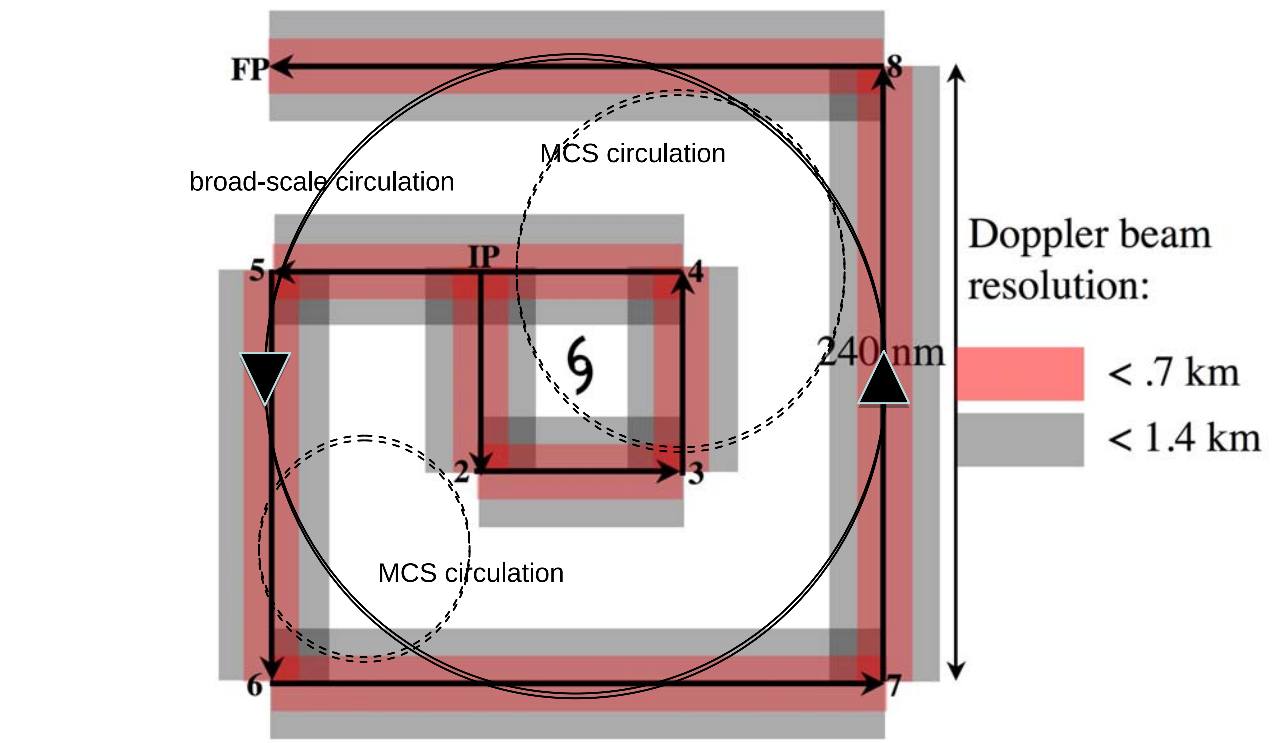
“Lawnmower pattern”



Pattern time 4.8 h

P-3 Flight pattern: Late genesis

"Box-spiral pattern"

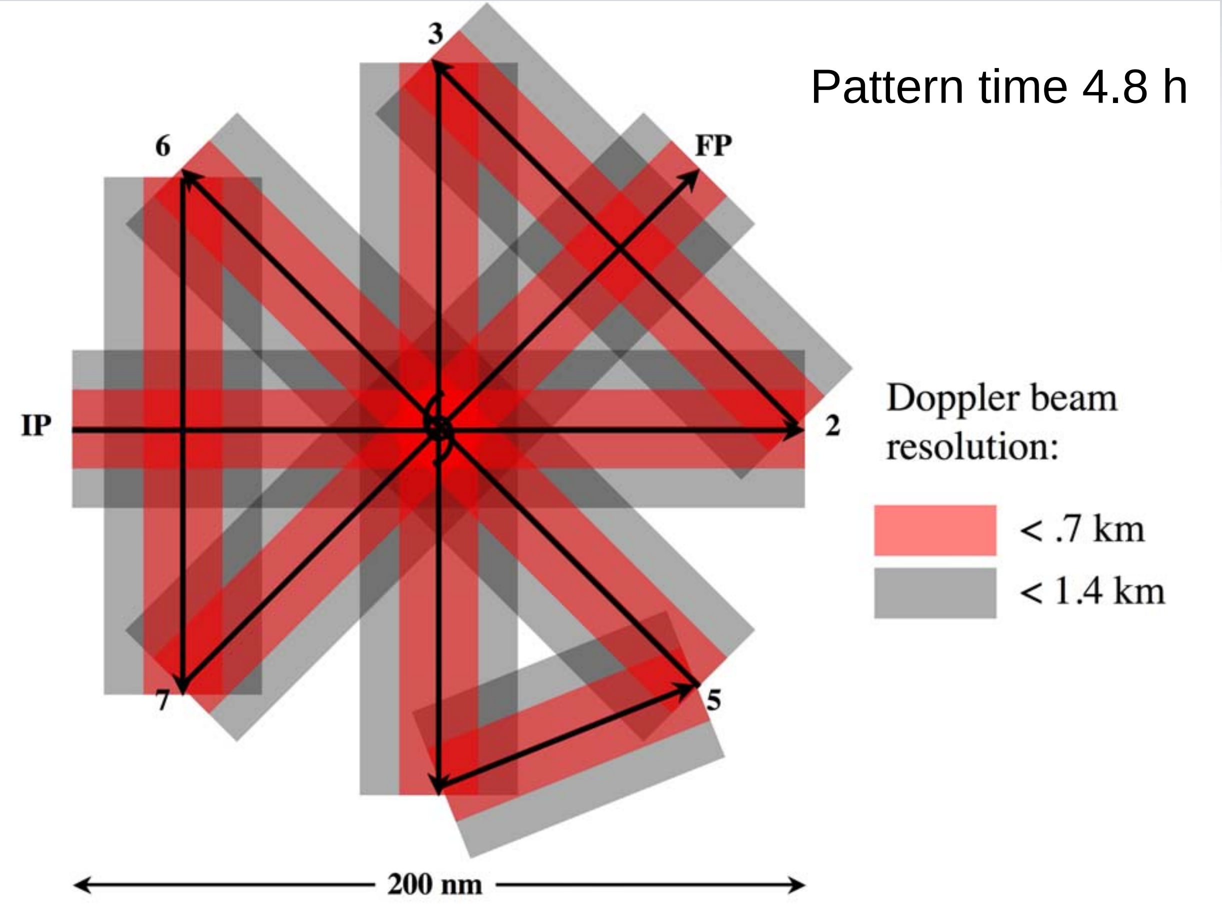


Pattern time 5.33 h

P-3 Flight pattern: post-genesis/intensification

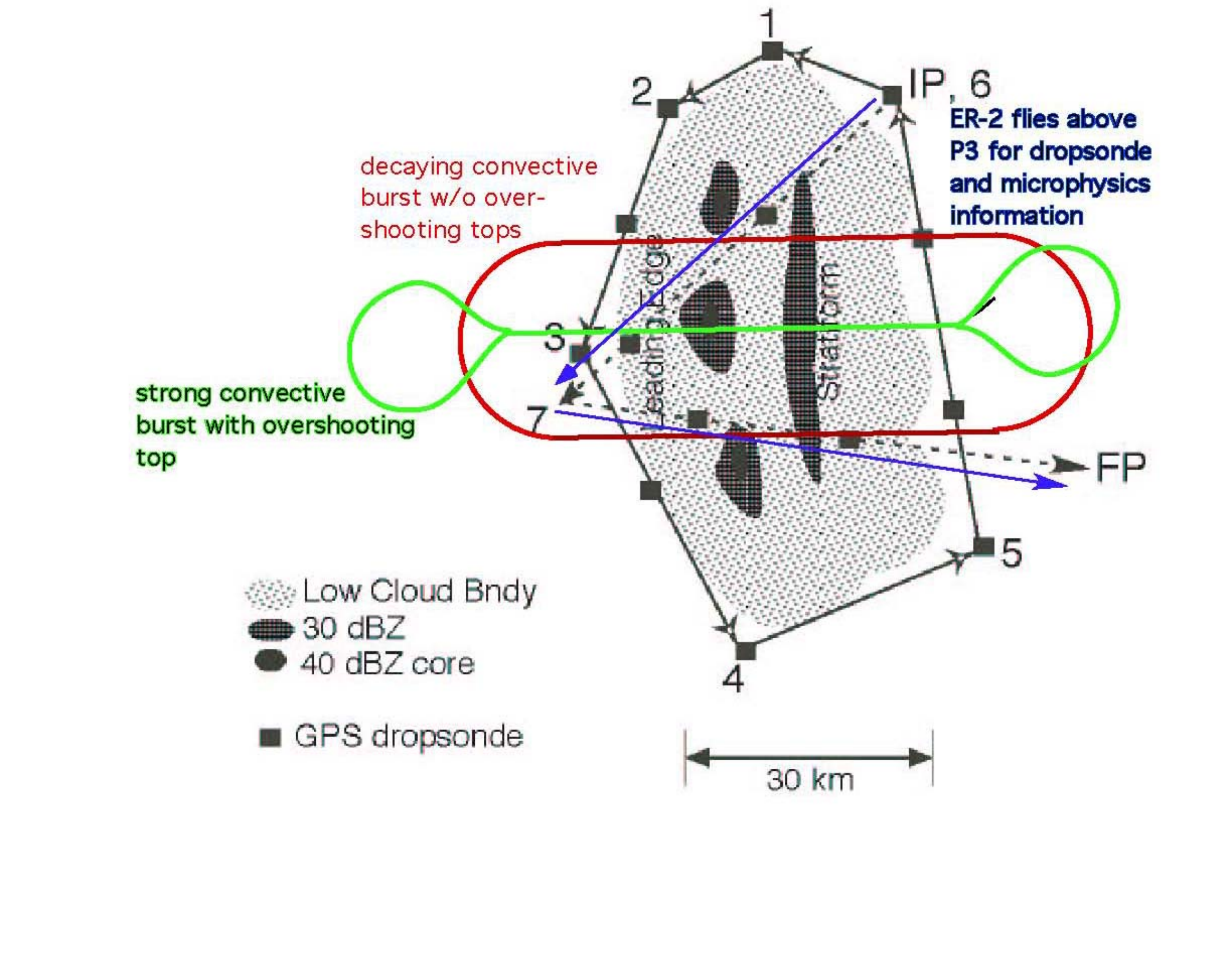
"Rotated Figure-4 pattern"

Pattern time 4.8 h



P-3 Flight pattern: modules

"Convective burst module"



G-IV Flight pattern: SAL experiment