



Synthesis of SFMR and Airborne Doppler Radar Observations in Hurricanes Katrina and Rita at Landfall

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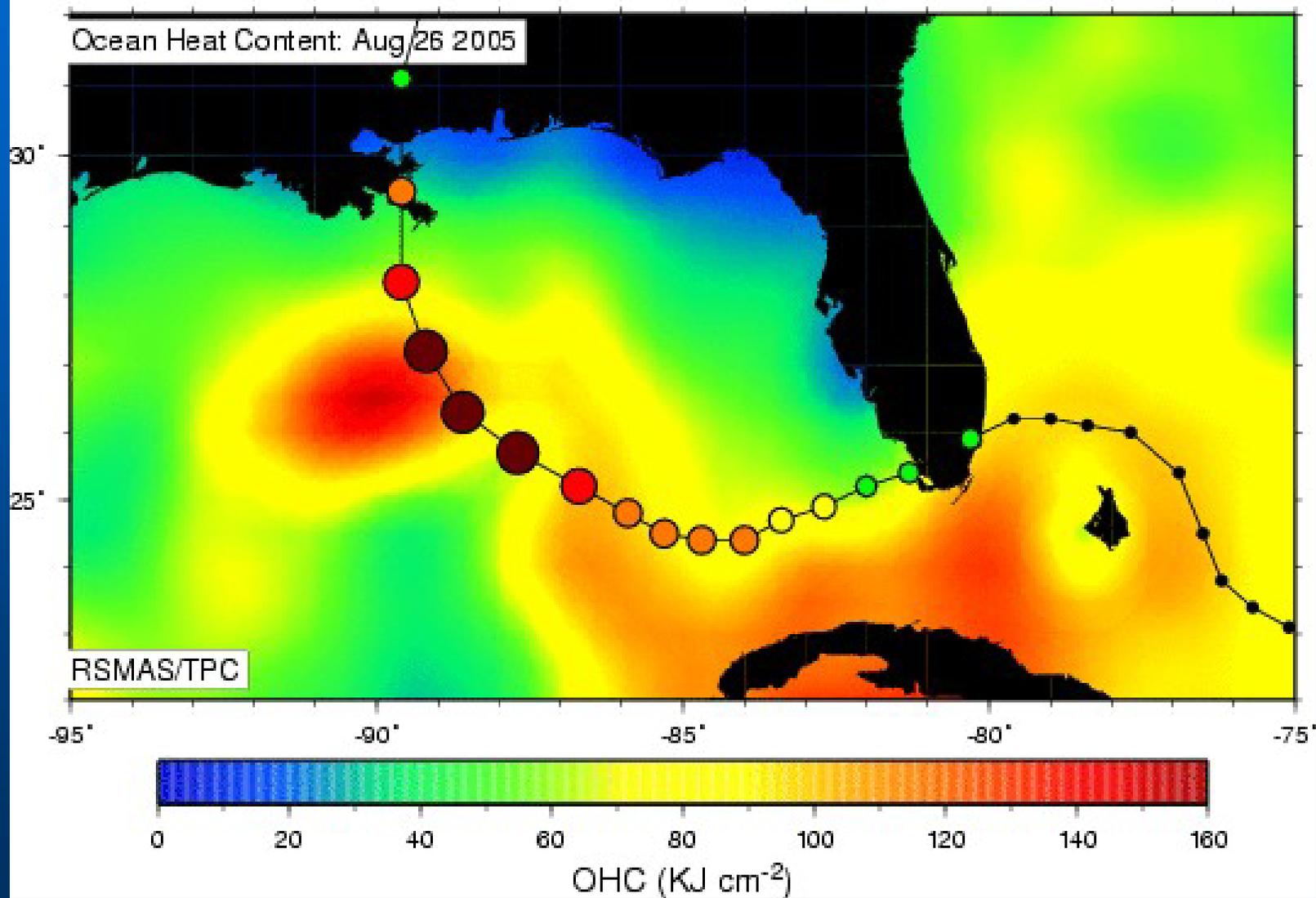
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ProSensing, Inc.



The Question of Katrina's Landfall Intensity & Structure

- Defining landfall intensity: was it CAT 3 or CAT 4?
- Was there substantial structure change just before landfall?
- Key to the answer: Define and Reduce Observational Uncertainty



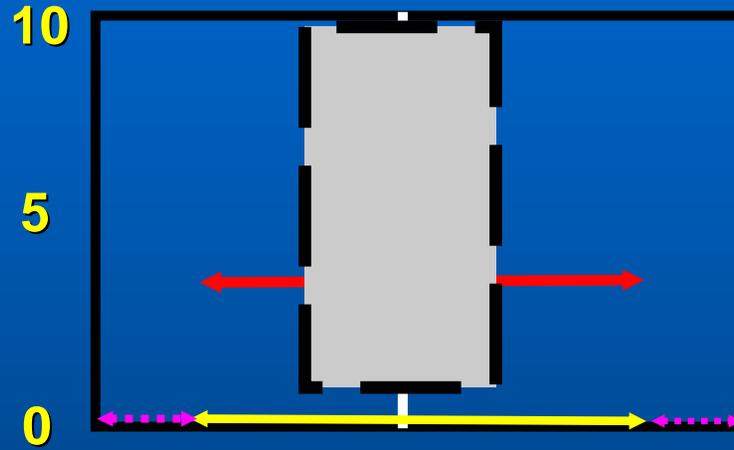
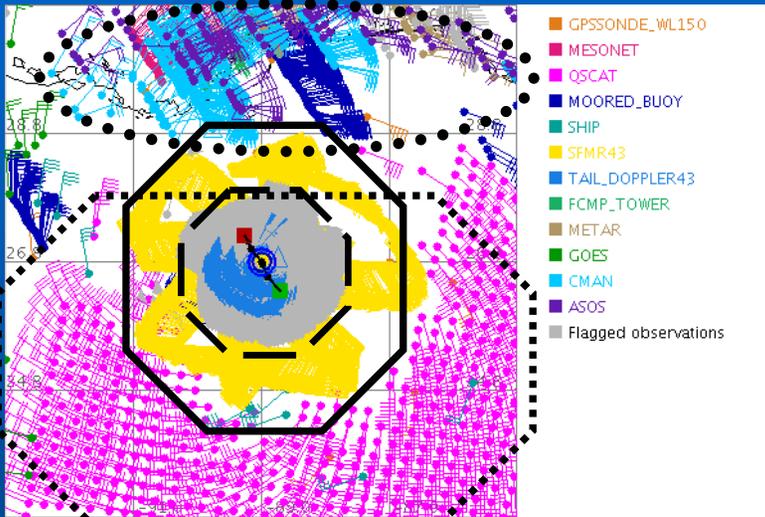


Reducing Surface Wind Uncertainty- Key Ingredients

- **New Airborne Technology Trifecta**
 - **Stepped Frequency Microwave Radiometer (SFMR)**
 - Surface Winds
 - **Airborne Tail Doppler radar**
 - 3D structure/fields
 - **GPS dropsondes**
 - Point vertical profile
- **Define Uncertainty**



What is observational uncertainty in hurricanes?



- **Horizontal domain relative to storm center varies according to satellite/aircraft platform availability.**
- **Vertical domain a function of platform type.**
- **Combination of platform type, domain coverage and measurement accuracy determines observational uncertainty.**



Reducing Surface Wind Uncertainty- Implementation

- **Real Time Synthesis Recipe: Template for improved intensity/structure**
 - Real time aircraft communication: ASDL, GLOBALSTAR, INMARSAT
 - Integration and comparison of 3 independent measures of surface wind
 - Direct forecaster interaction at NCEP/TPC National Hurricane Center

- **Key is SFMR**



2005 SFMR Performance

- Flown in 9 storms, 7 landfall situations
 - Arlene Cindy Dennis
 - Emily Irene Katrina
 - Ophelia Rita Wilma
- 34 total SFMR missions, 23 tasked
 - 16 total, 8 tasked for NOAA42
 - 18 total, 14 tasked for NOAA43



2005 SFMR Performance (cont'd)

- **SFMR used in 23 advisories, prompted 2 special advisories**
- **Every SFMR tasking lead to an important conclusion on current intensity or estimates of intensity change- only once per day**
- **Especially crucial for landfall intensity estimates for Dennis, Katrina, Rita and Wilma**
- **Mentioned prominently in Katrina, Rita and Ophelia NHC storm reports**



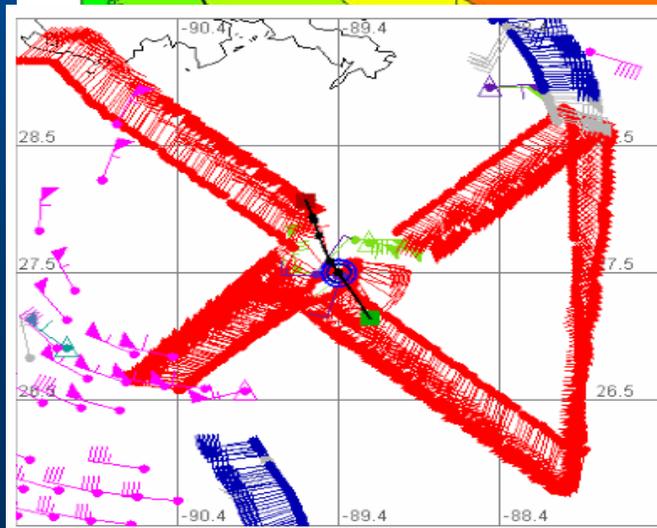
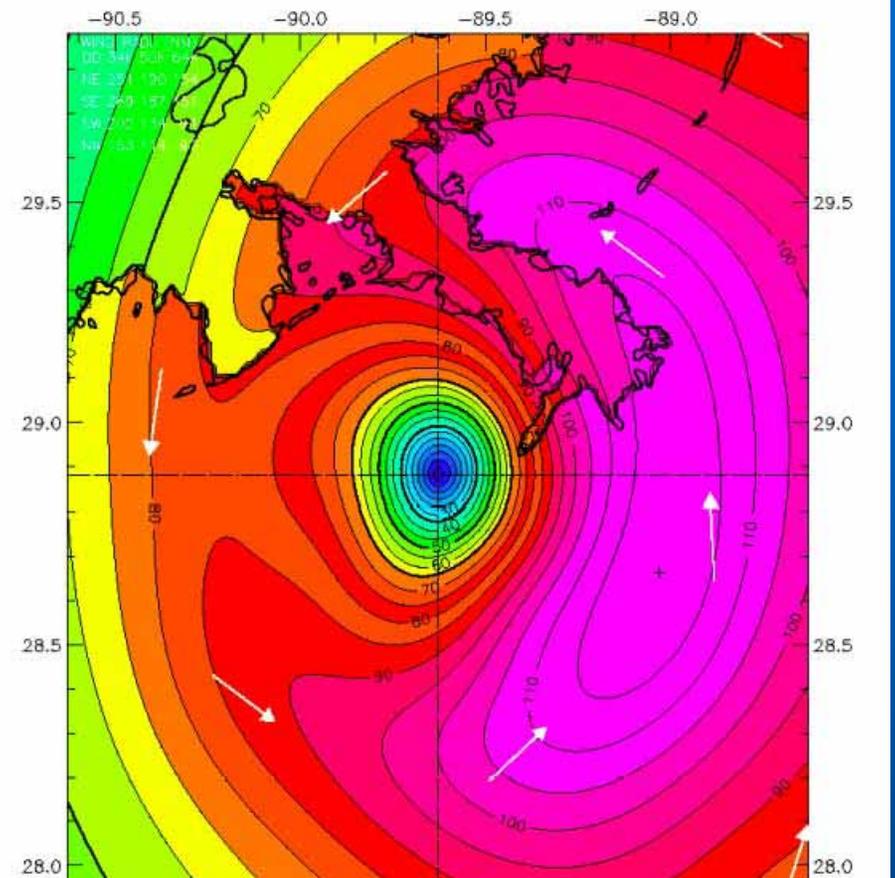
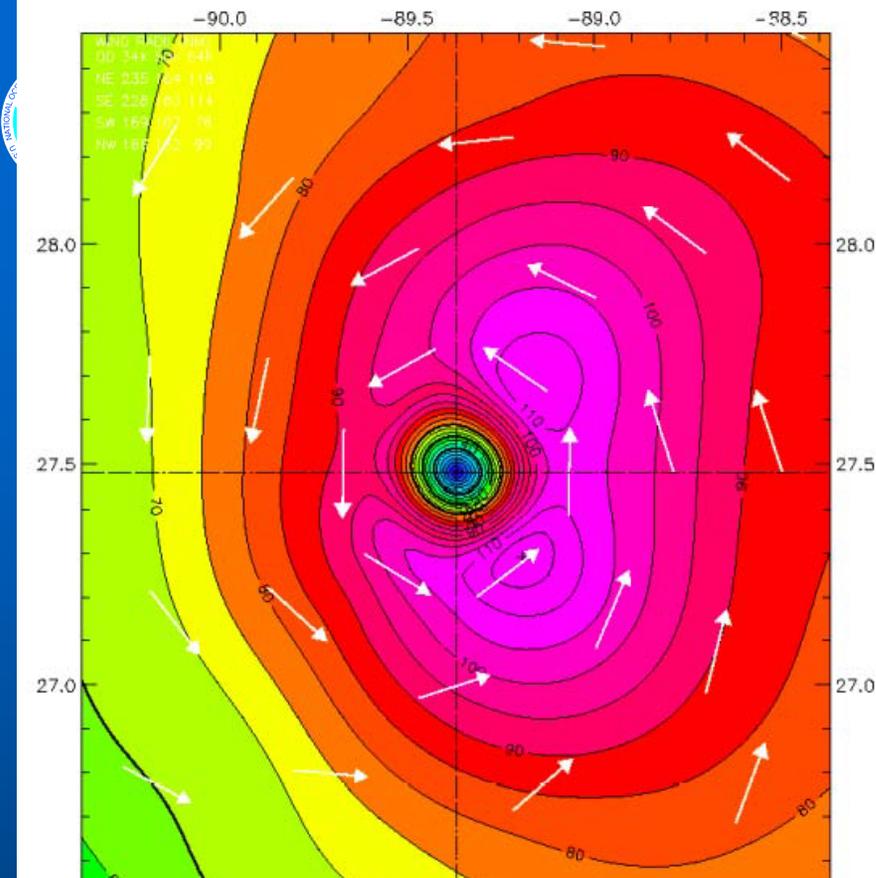
SFMR Use in 2005: A Key Deficit Highlighted

- **Difficult for forecasters to transition from routine AFRC flight level reco data to SFMR surface data, especially in landfall situations like Katrina**
- **Extensive use of SFMR in 2004-2005 illustrates the urgent need for SFMR installation on WC-130J aircraft as soon as possible- especially critical in current era of enhanced TC activity**



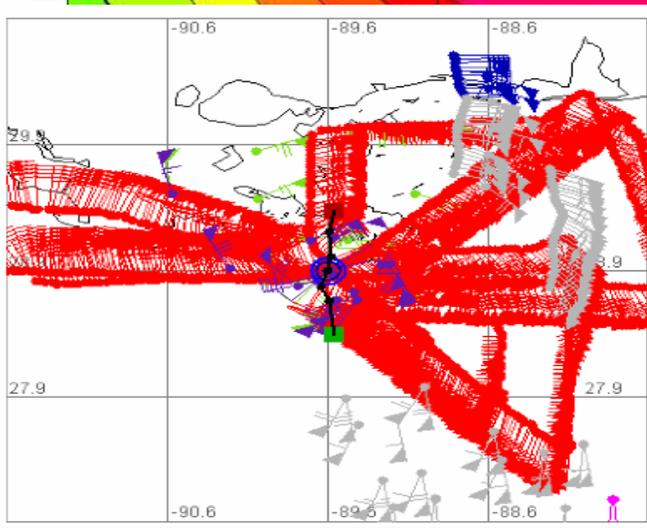
Hurricane Katrina

- **Flight-level estimates reduced to the surface suggested Katrina weakened slightly to a CAT4 at landfall**
- **SFMR and GPS dropsondes observed weakening from maximum peak surface winds of 142 kt to 100 kt in 8 h between 29 Aug, 0200 - 1000 GMT**
- **Airborne Doppler analysis showed that the change was near surface, but not at the flight-level of the AF WC-130 (John Gamache JHT presentation)**



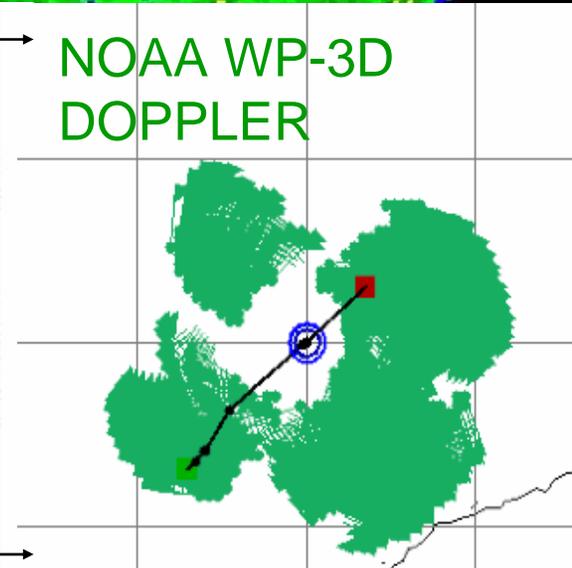
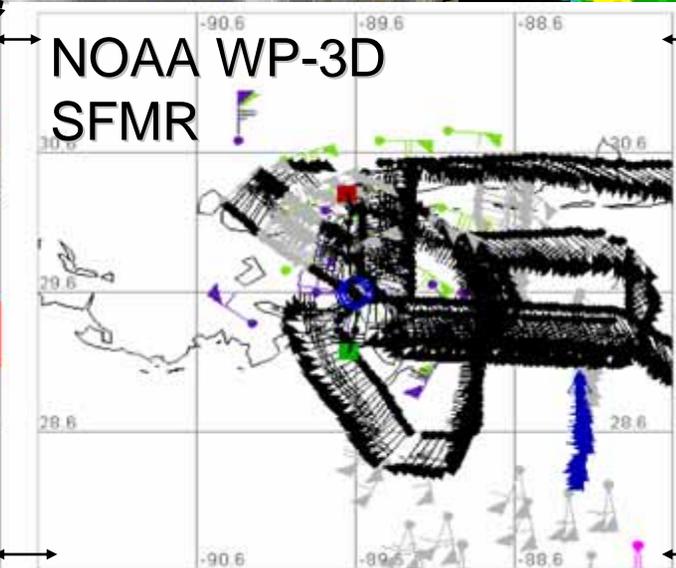
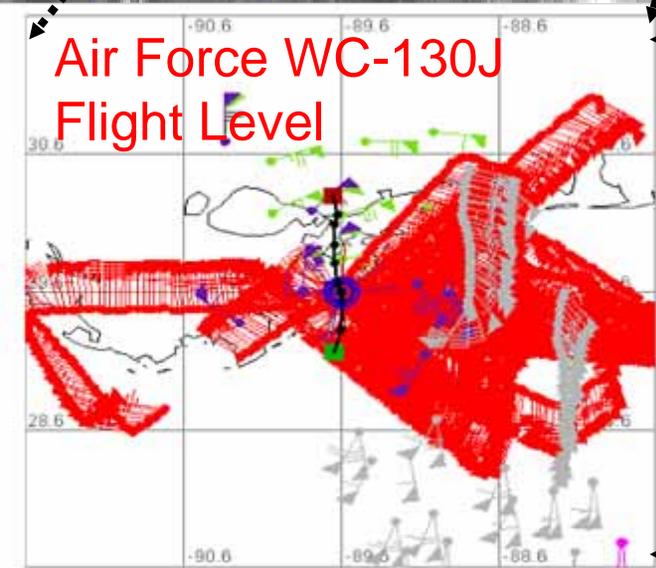
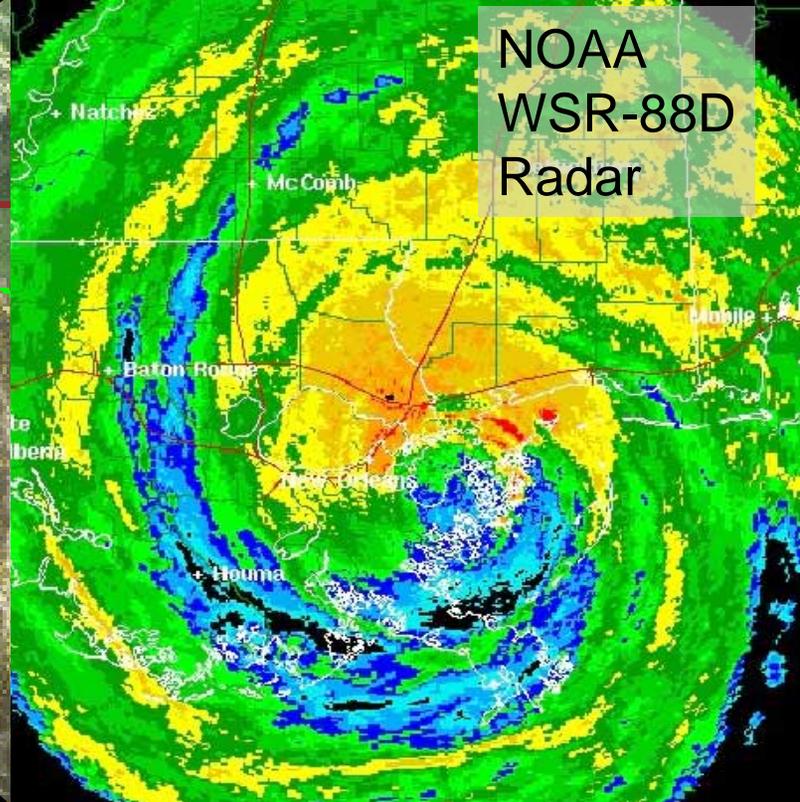
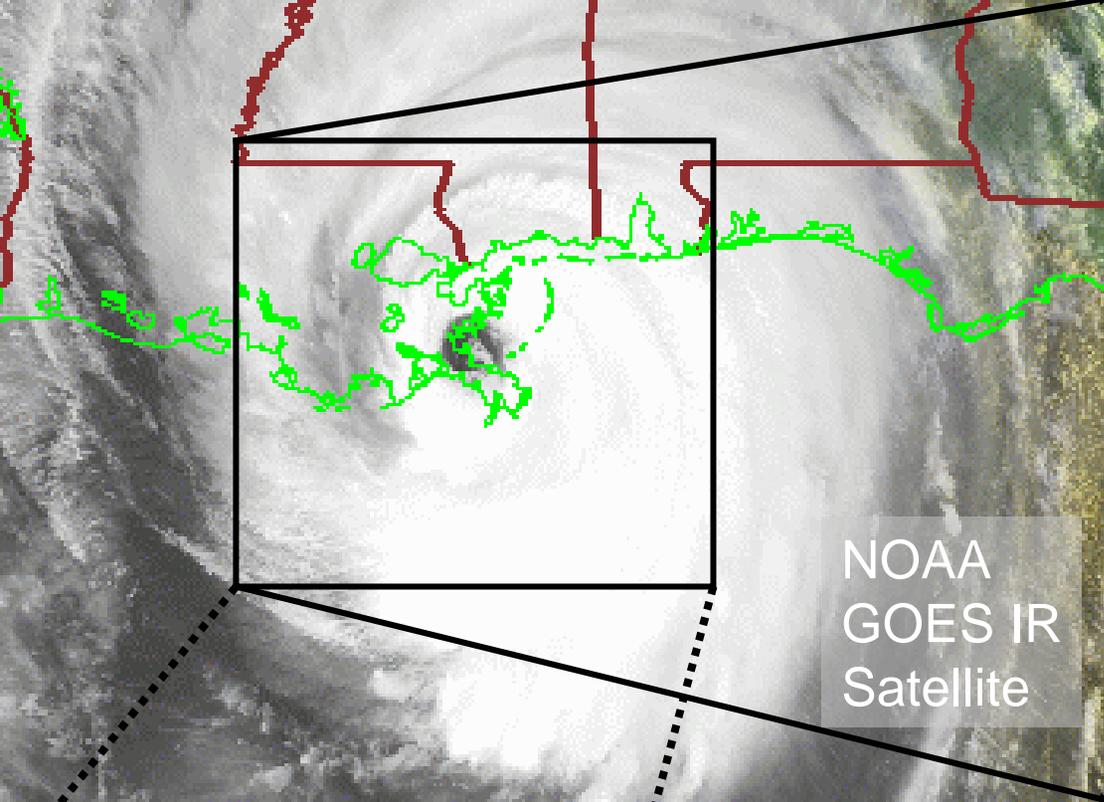
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- AFRES
- SHIP
- GPSSONDE_SFC
- MOORED_BUOY
- GOES_SWIR
- QSCAT
- Flagged observations

Air Force
29 Aug
0200 UTC



- GPSSONDE_WL151
- AFRES
- SHIP
- GPSSONDE_SFC
- MOORED_BUOY
- GOES_SWIR
- QSCAT
- Flagged observations

Air Force
29 Aug
0930 UTC





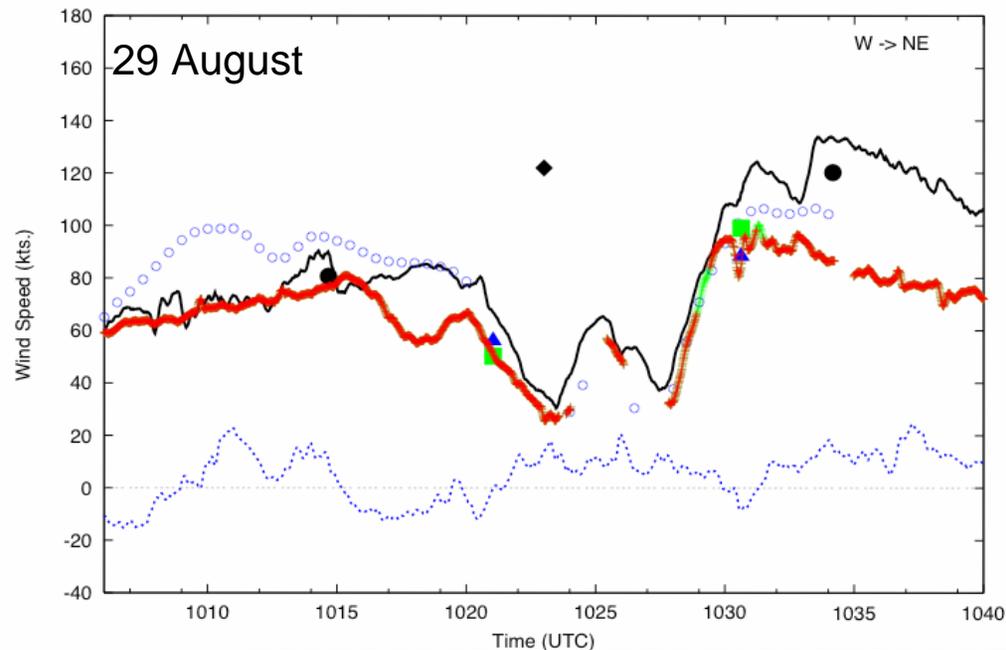
Hurricane Katrina- SFMR

28 Aug - Peaked profile

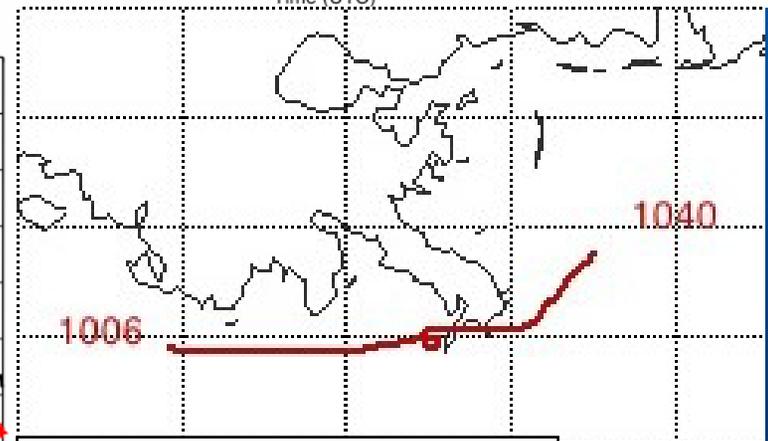
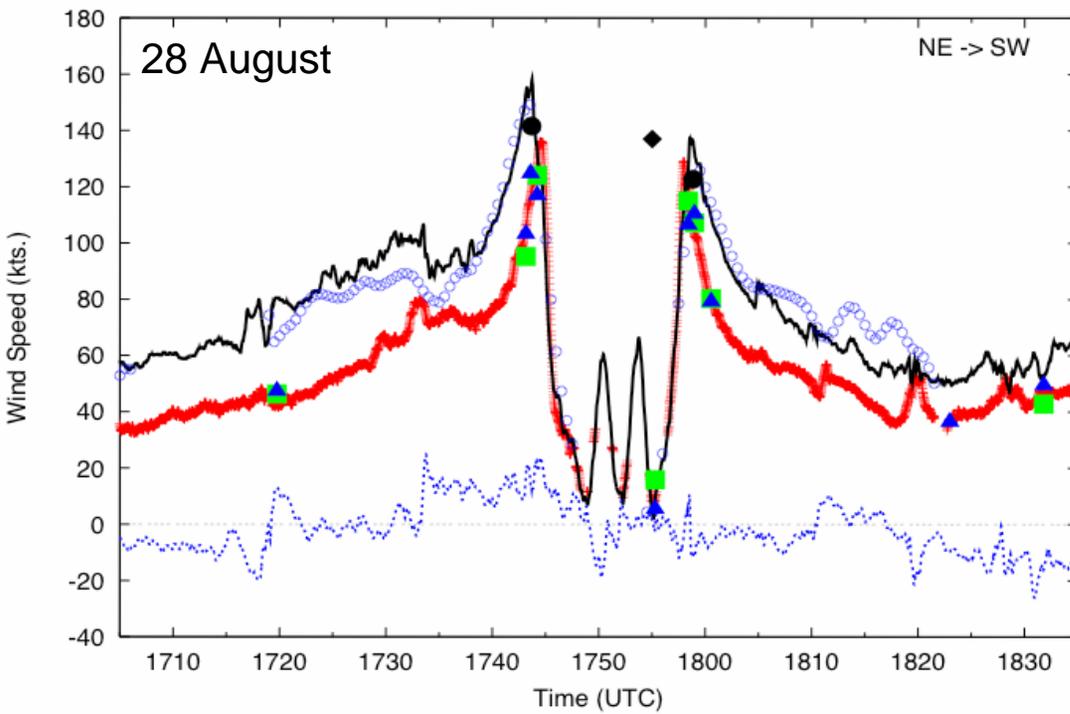
$V_{max} = 142$ kt

29 Aug - Flat profile

$V_{max} = 100$ kt



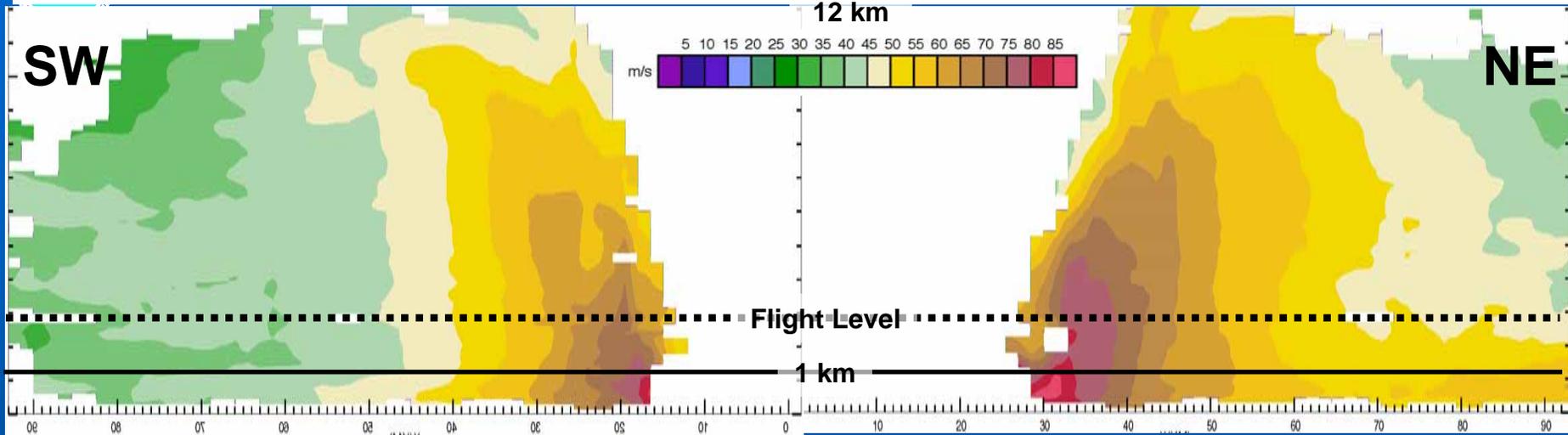
Hurricane Katrina 2005/08/28 NOAA43



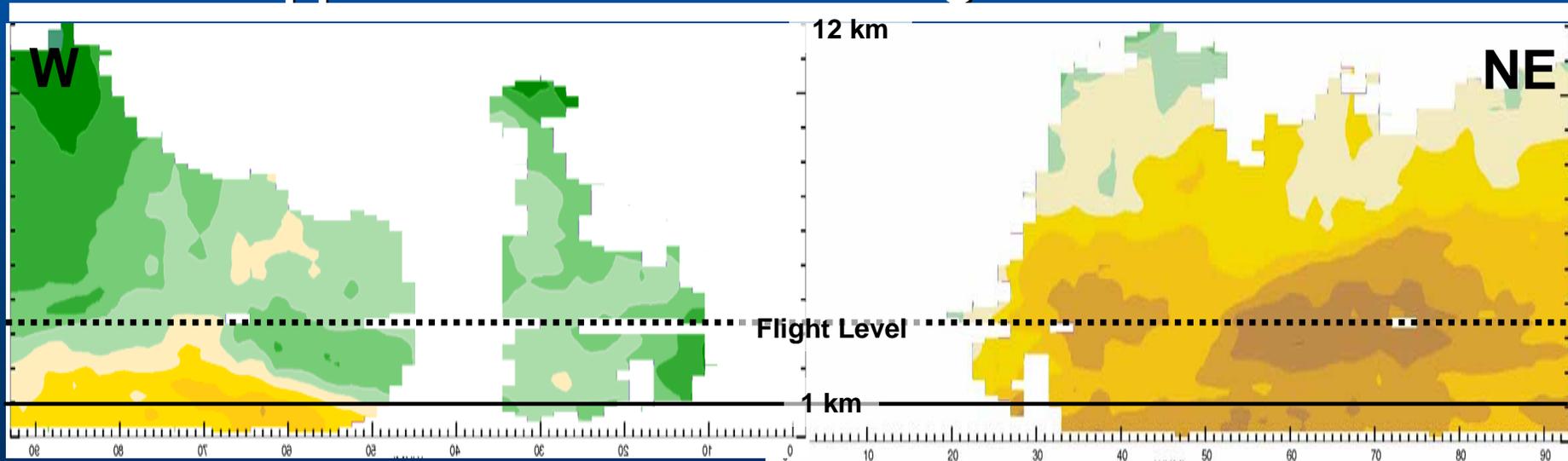
- * SFMR surface wind
- 700 mb flight-level wind
- 700 mb Gradient Wind
- - Radial wind
- - V_{max} NHC estimate
- Diamond - V_{max} Press/Wind
- Square - GPS 10-m estimate
- Triangle - GPS 10-m measurement



Doppler Wind Profile - 28 Aug 1725-1820 UTC



Doppler Wind Profile - 29 Aug 1000-1040 UTC



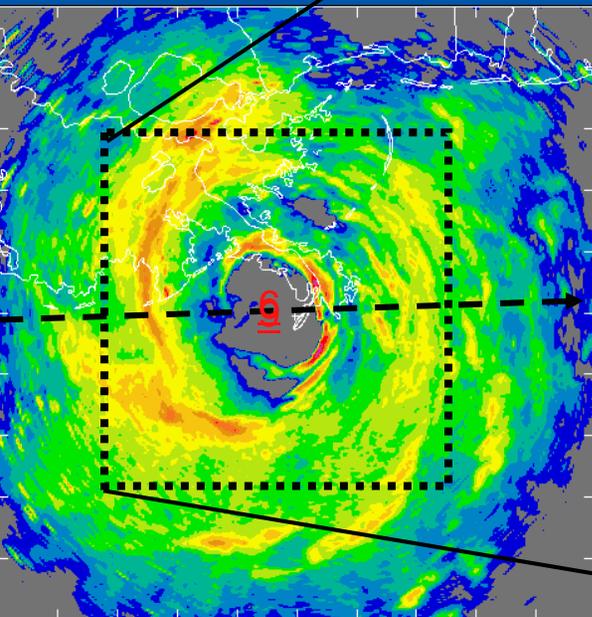
Dramatic 12-h change in Katrina Wind Profile: CAT5-CAT3



- Doppler analyses from 1st W-E leg during Katrina landfall showing asymmetry in horizontal and vertical wind distribution

Inflow and shallow wind max to West

Outflow and deep wind max to East

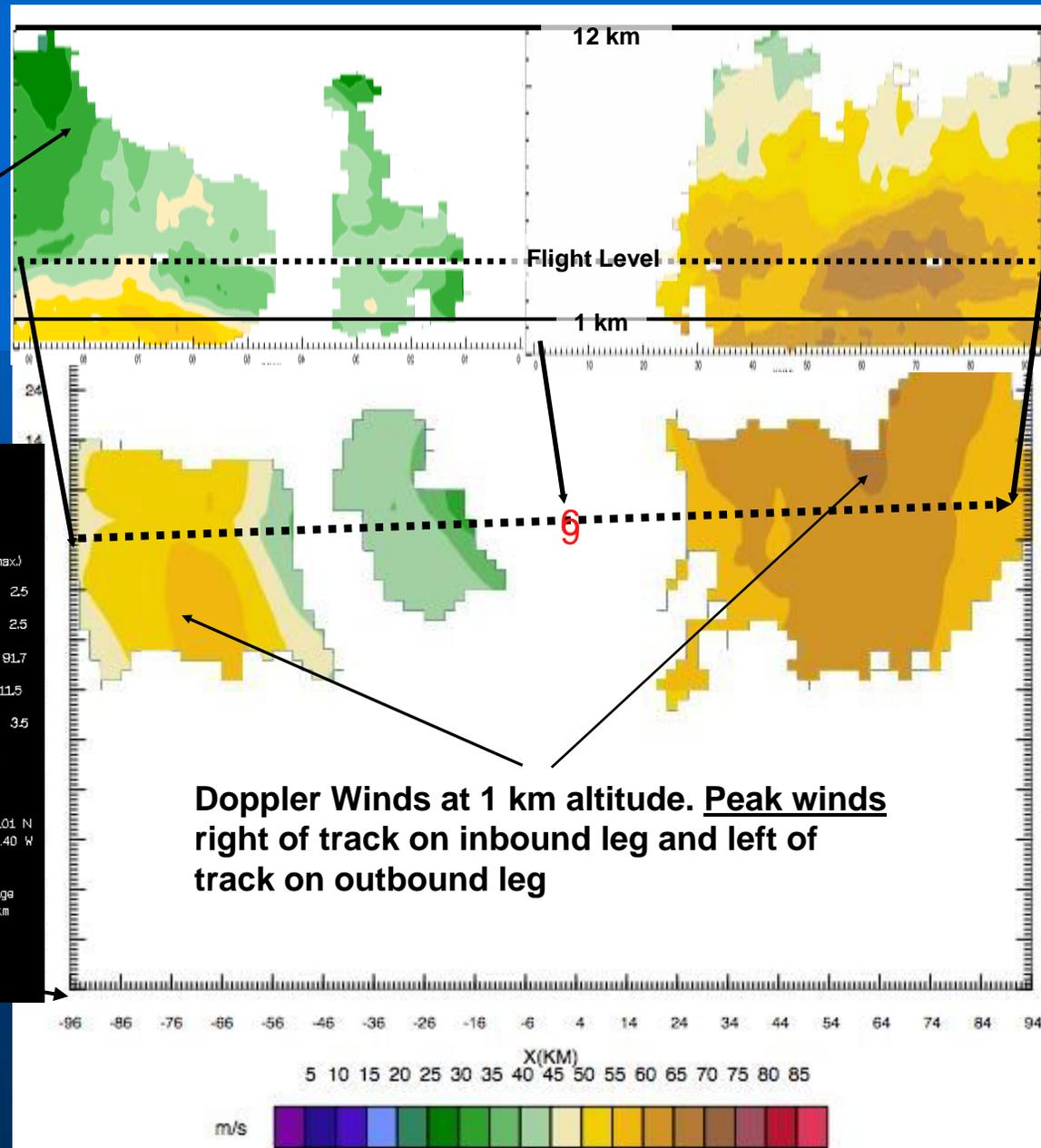


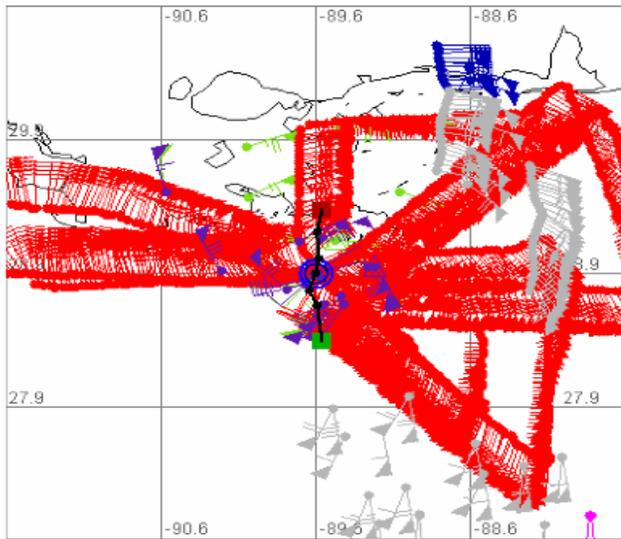
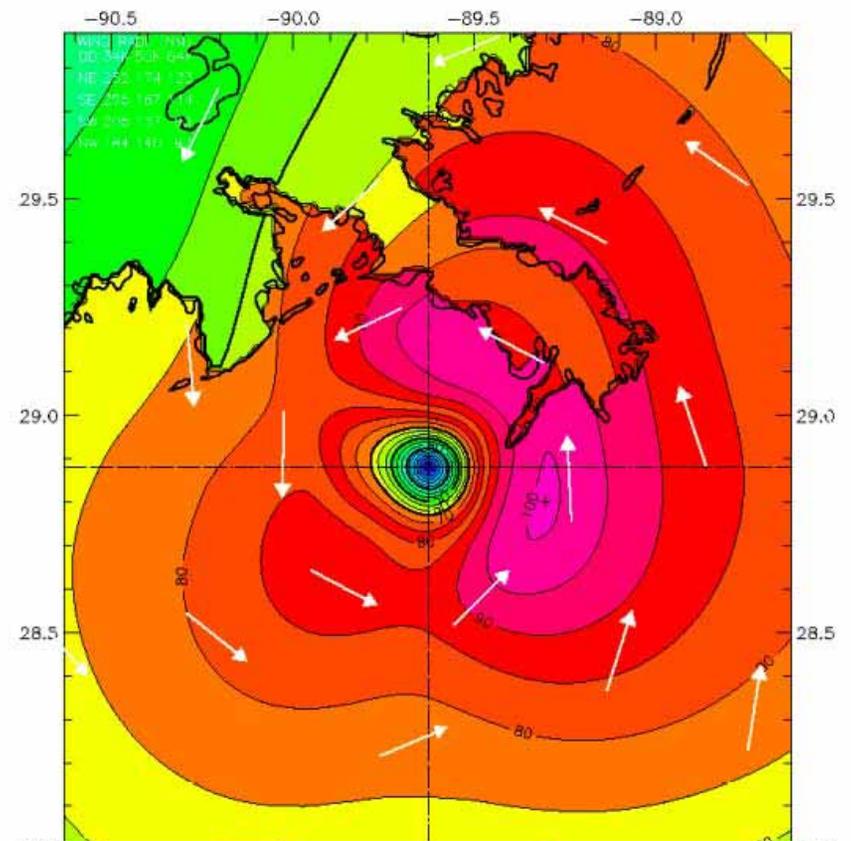
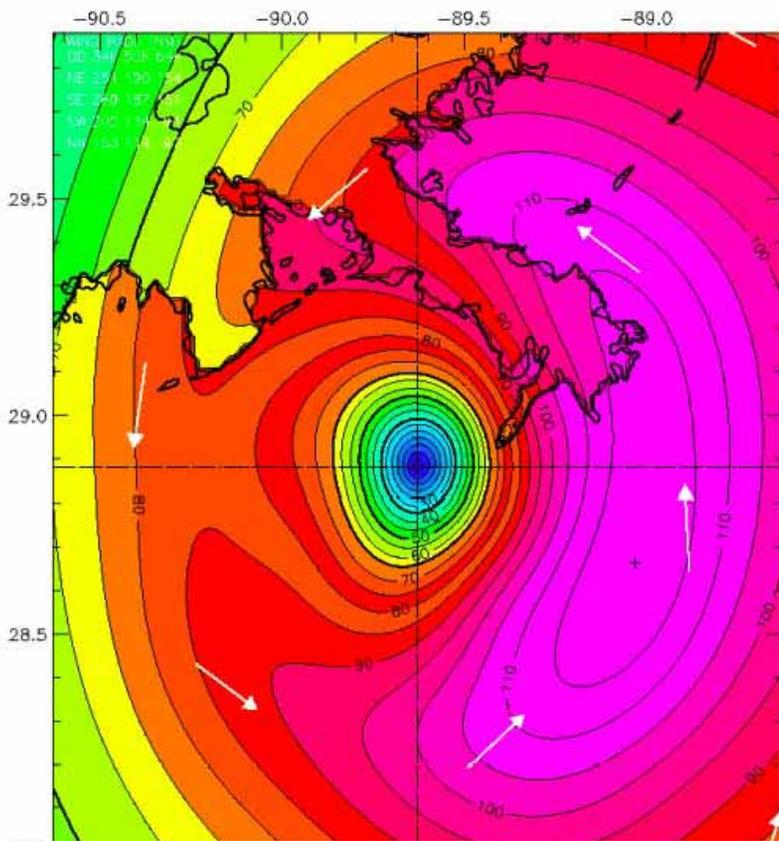
050829I1
KATRINA

(min) (max)

Pitch= 1.6; 2.5
Roll= -5.6; 2.5
Track= 90.3; 91.7
Drift=-14.7; -11.5
Tilt= 2.4; 3.5
Alt= 3145 m
HRD / AOHL
Rlat= 29.01 N
Rlon= 89.40 W
102841 Z
Lower Fuselage
360 X 360 km

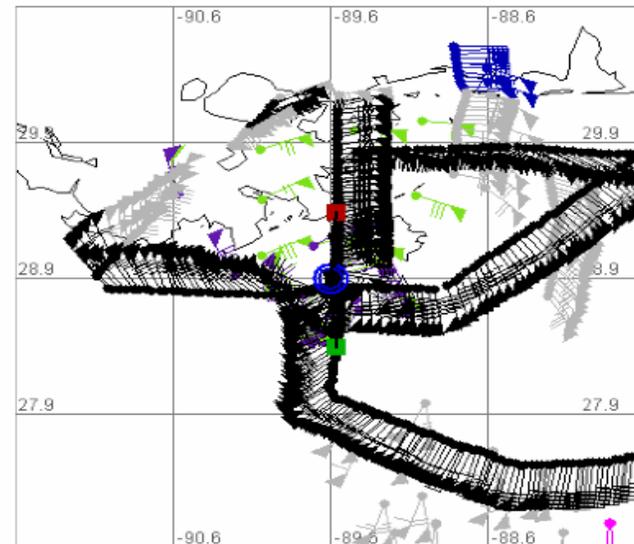
dBZ





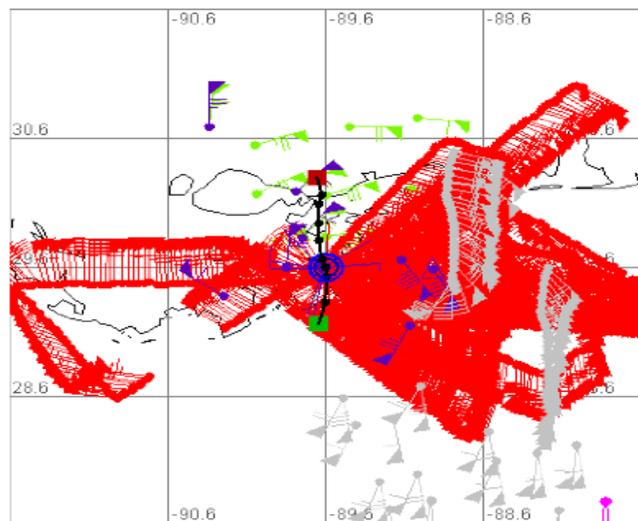
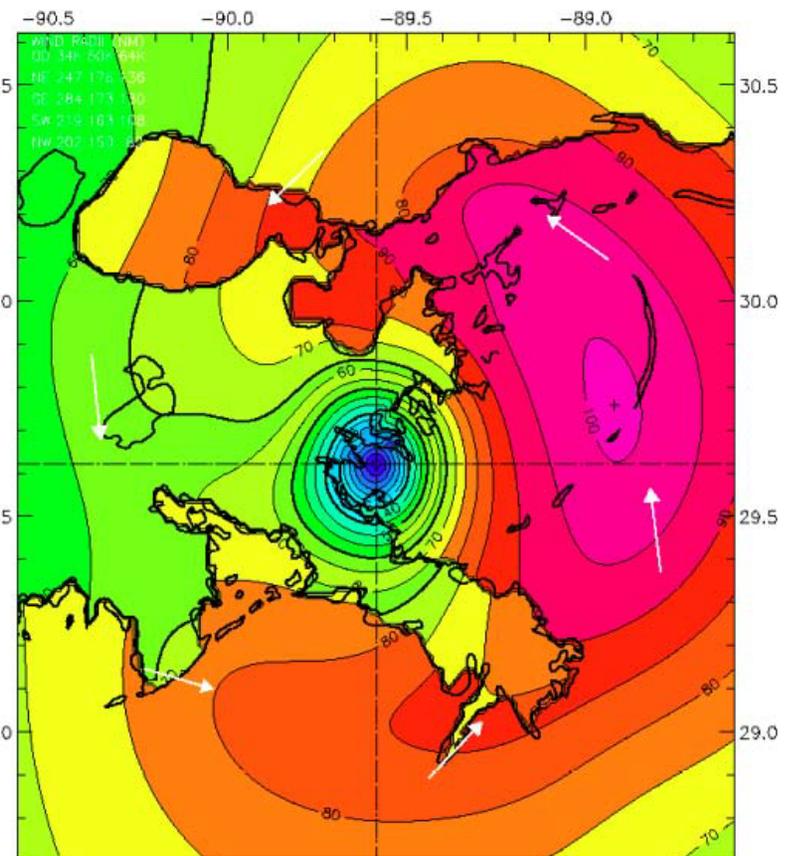
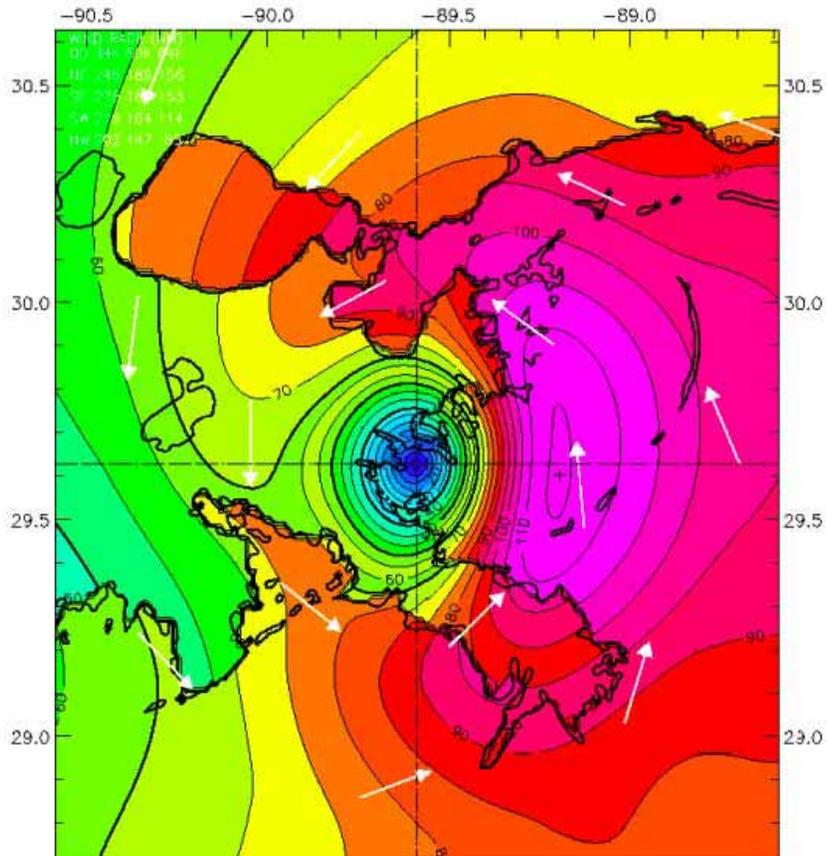
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- GOES_SWIR
- QSCAT
- Flagged observations:

Air Force
29 Aug
0930 UTC



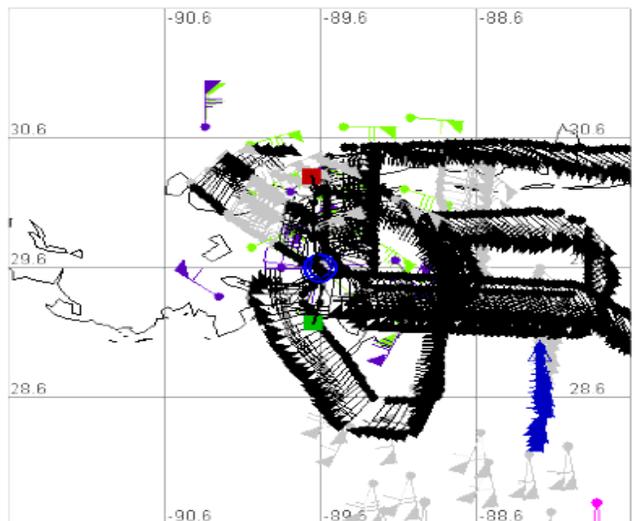
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- Flagged observations

NOAA
SFMR
29 Aug
0930 UTC



- GPSSONDE_WL150
- AFRES
- GPSSONDE_SFC
- MOORED_BUOY
- QSCAT
- GOES
- Flagged observations

Air Force
 29 Aug
 1230 UTC



- GPSSONDE_WL150
- GPSSONDE_SFC
- MOORED_BUOY
- QSCAT
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- Flagged observations

NOAA
 SFMR
 29 Aug
 1230 UTC

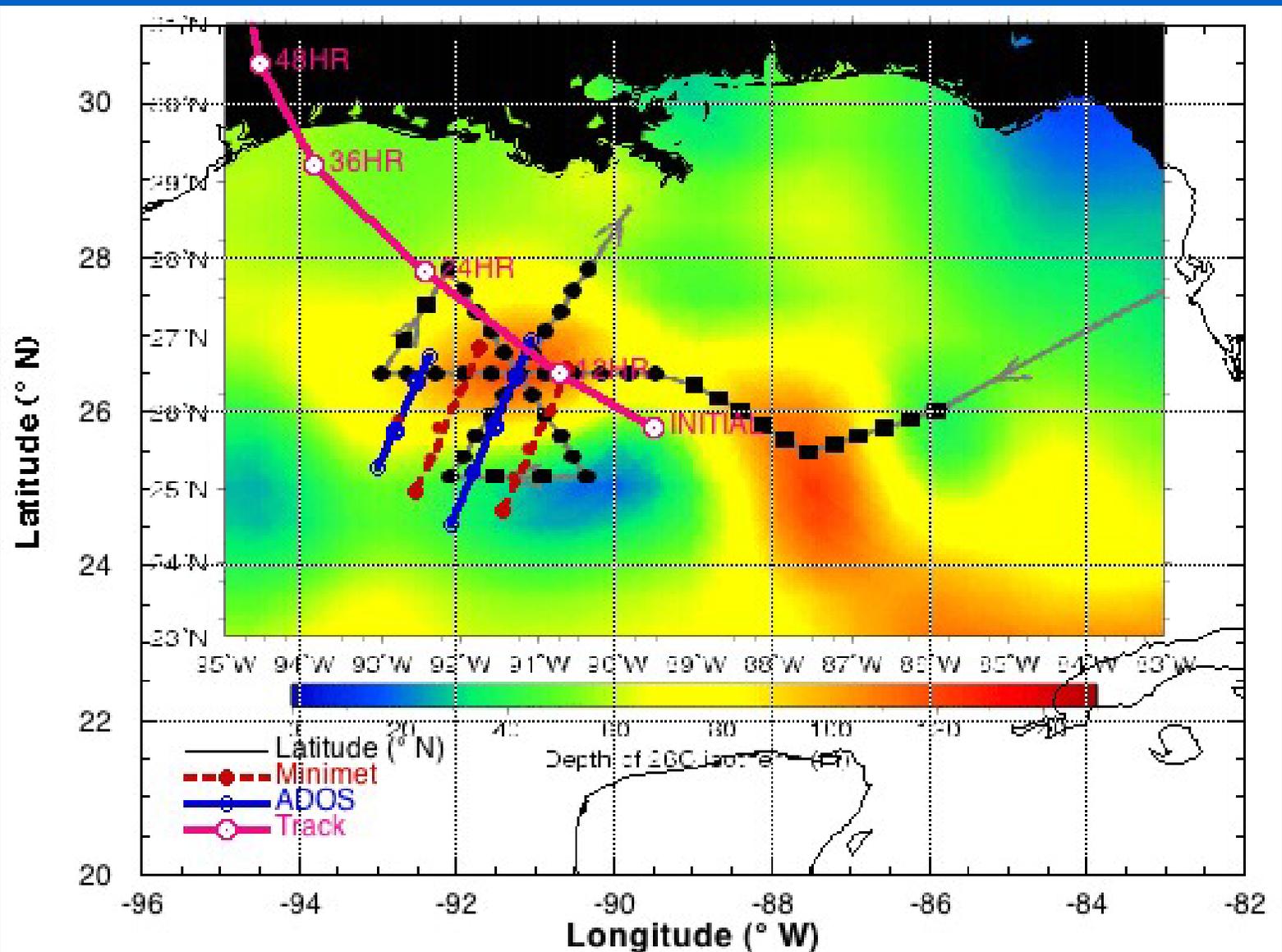


Katrina Summary

- **Dramatic change in structure and intensity prior to landfall (Weakened from CAT5 to CAT3 intensity in 8 h: 29 Aug, 0200 - 1000 GMT)**
- **Surface wind assessment changed from flight-level reduction to SFMR measurement.**
- **Surface Wind Uncertainty ~ 20% with flight-level data: reduced to ~10% with SFMR & further reduced by Doppler radar observations**
- **Result of real-time and post-storm synthesis: Initial CAT4 from flight level data downgraded to CAT3 in NHC Katrina Report using SFMR and Doppler radar (<http://www.nhc.noaa.gov/2005atlan.shtml>)**



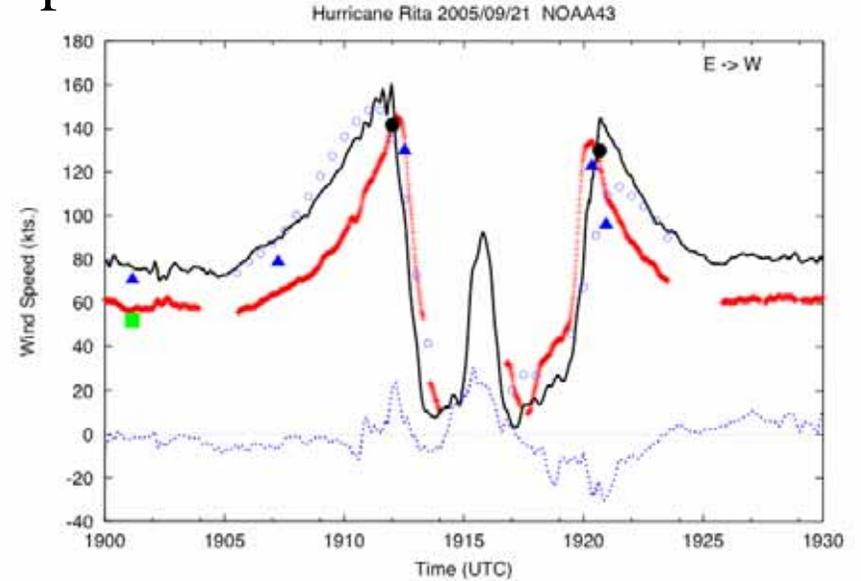
Hurricane Rita



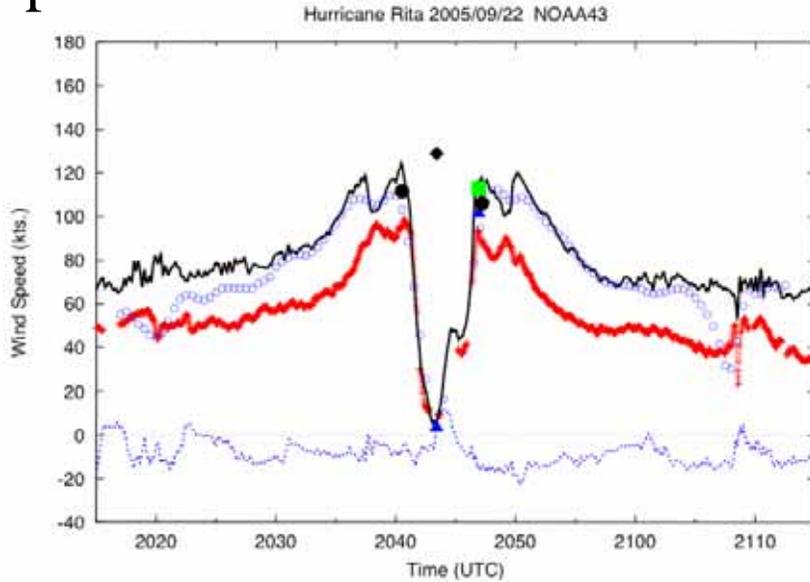


Hurricane Rita

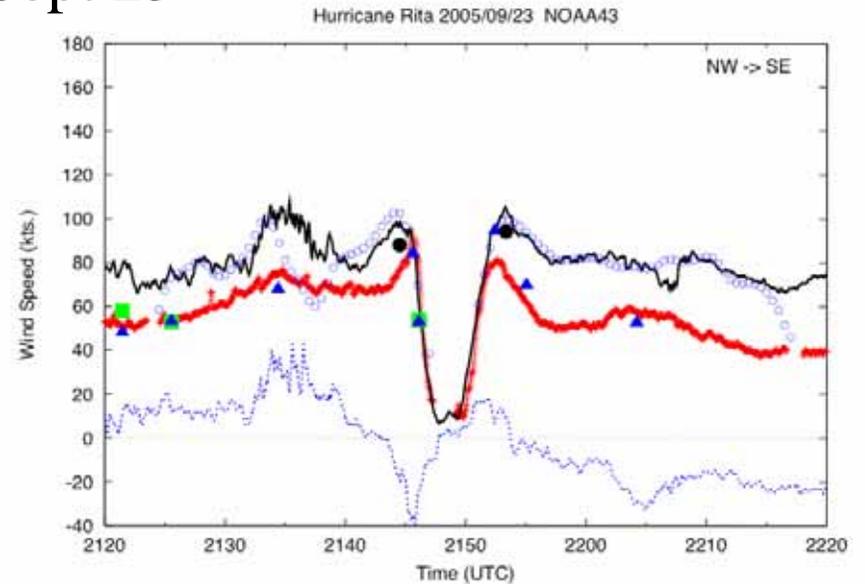
Sept 21



Sept 22



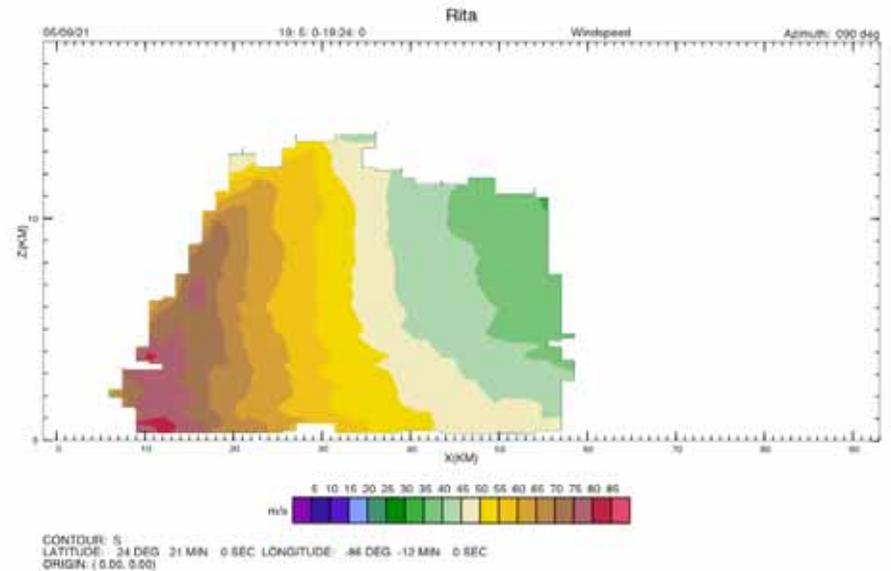
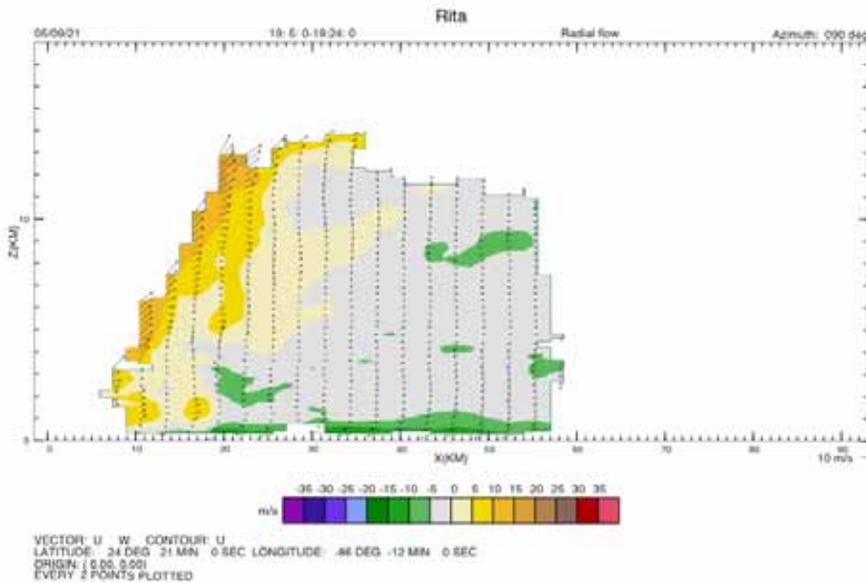
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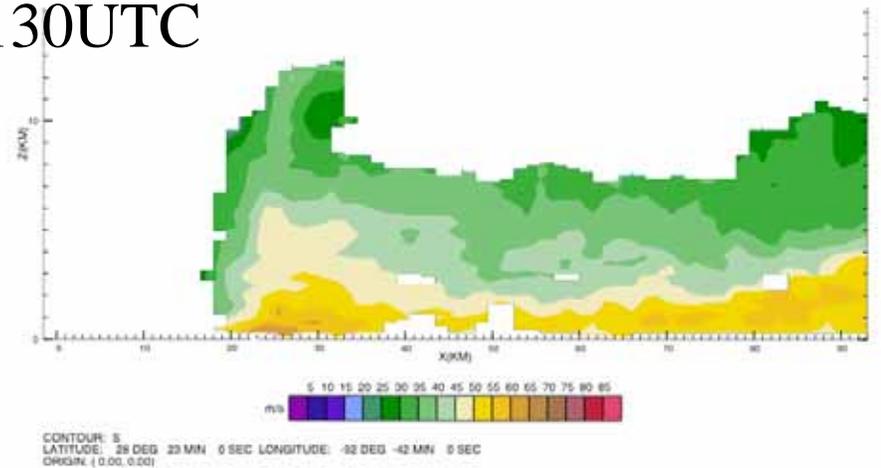
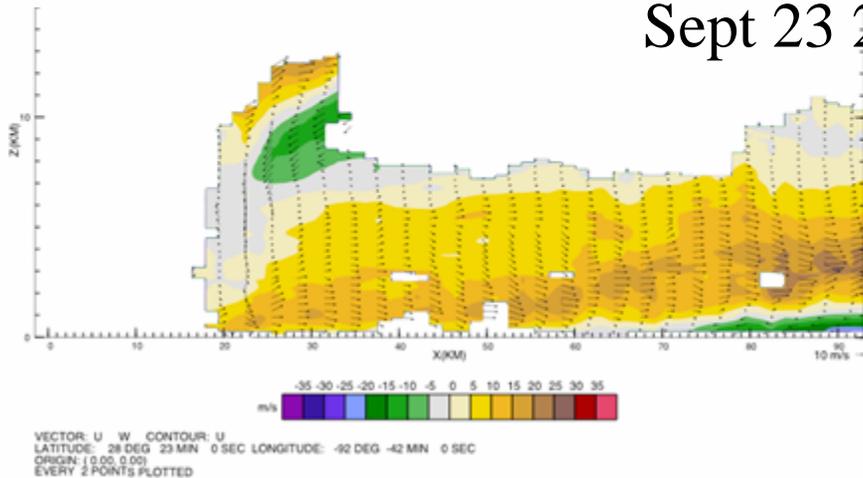


Hurricane Rita

Sept 21 1900UTC



Sept 23 2130UTC





Why rapid intensity change near landfall?

- Recent ongoing studies of north Gulf landfalling storms show 80% fill offshore prior to landfall (Rappaport)
- Mesoscale ocean features in the Gulf of Mexico, e.g. Loop Current and warm rings, may impact hurricane intensity change (see Shay presentation)



Conclusions

- **A template has been established for real-time storm intensity and structure change.**
- **Instrument trifecta of SFMR, airborne Doppler radar and GPS dropsonde is essential for real-time interpretation of rapidly changing events, especially near landfall**
- **Continued capability upgrade is essential**
 - **SFMR's on WC-130J aircraft to establish consistency in sampling**
 - **Improved airborne Doppler radar capability adding real time IWRAP to TA Doppler for improved boundary layer obs**
 - **Higher resolution 4 sample per second UBLOX dropsondes that consistently reach the surface**
 - **Improved true real time data transmission via high- speed coms such as AOC INMARSAT/ Globalstar links via efforts of NESDIS (Paul Chang) and Remote Sensing Systems (Jim Carswell)**