Overview of the NASA Fourth Convection And Moisture Experiment

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Main Research Issues Supporting the NASA Earth Science Enterprise

- **Is the global water cycle through the atmosphere accelerating?**
- **How are variations in local weather, precipitation and water resources related to global climate change?**
- **How well can weather forecasting be improved by new global observations and advances in satellite data assimilation?**

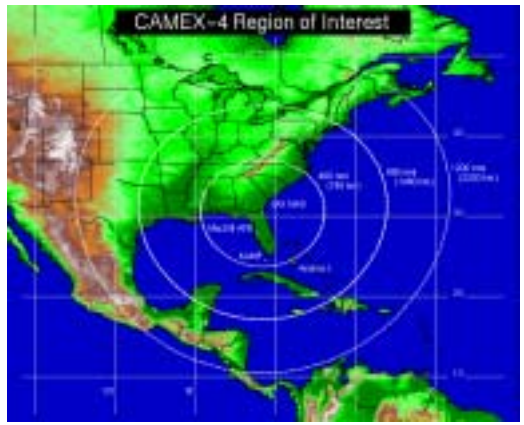
Specific Tropical Cyclone Research Topics

- Observation and modeling of processes related to rapid intensification of tropical cyclones
- Observation and modeling of storm movement
- Improving remote sensing techniques to observe wind, temperature, and moisture in tropical cyclones and their environment
- Enhanced understanding of tropical convective system structure and dynamics
- Improved understanding of scale interactions between intense convection and mesoscale systems

The Fourth Convection And Moisture EXperiment

- *Science Team*
  - 29 Principal Investigators from 5 NASA Centers, 10 universities, and 2 other governmental agencies
  - Collaborative partners with NOAA, United States Weather Research Program, and Air Force Reserve 53rd Weather Reconnaissance Squadron

- *Field Operations*
  - Conducted during 16 August – 24 September, 2001
  - Measurement platforms include high and medium aircraft, Unpiloted Aerial Vehicle, weather balloons, ground-based radars, and EOS satellites
  - NASA field command center located at Jacksonville Naval Air Station, Florida



Mobile Profiler in Key West

NASA ER-2

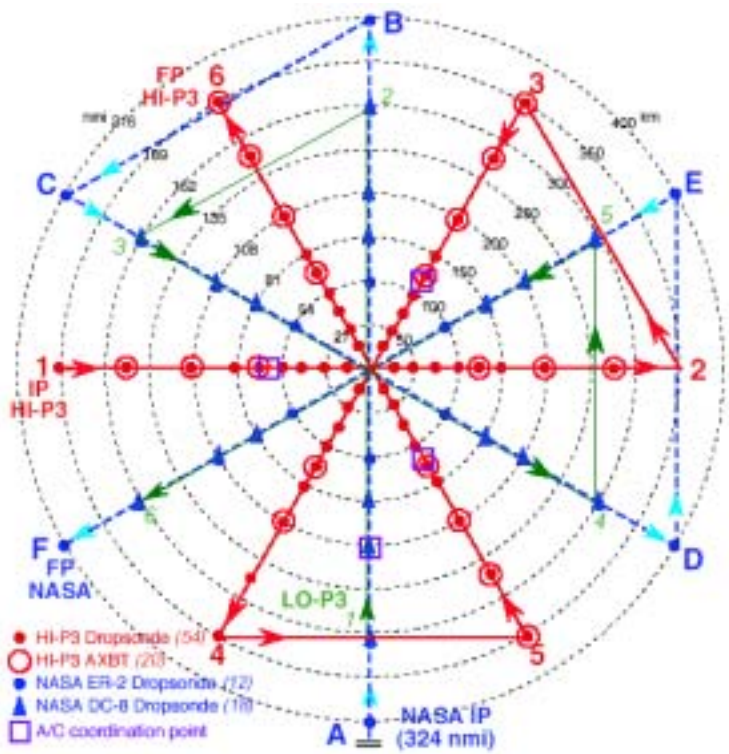
NASA DC-8

AEROSONDE

Weather Balloon at Andros Island, Bahamas

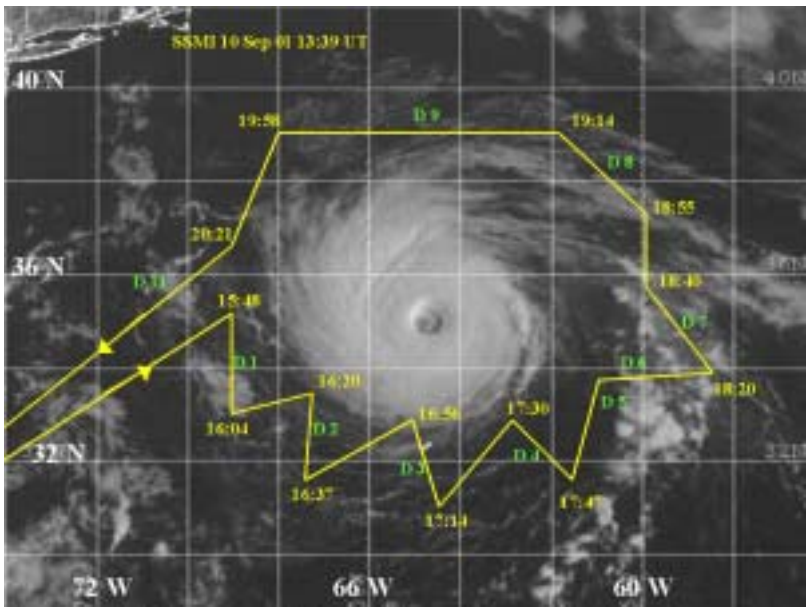
The CAMEX-4 Team and its Partners

Recommended Aircraft Missions



- **Coordinated Observations of Vortex Evolution and Structure (COVES)**
  - Extensive multi-aircraft sampling of mature hurricane over a two day period
  - Study of processes related to rapid intensification (or weakening)
  - Requires high density network of dropsondes and AXBTs

Recommended Aircraft Missions



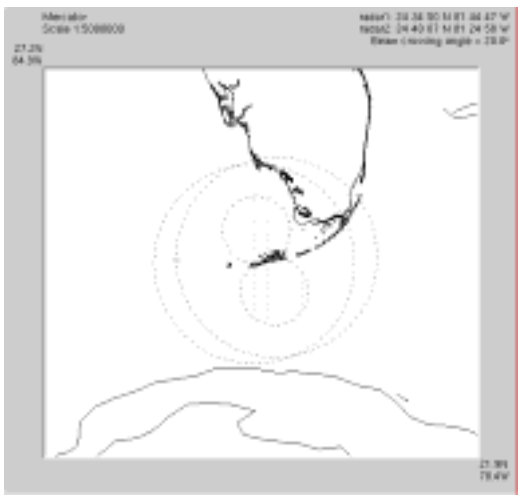
- **Optimal Data Assimilation (ODA)**
  - Assessment of the impact of high resolution water vapor and wind measurements on forecasts of hurricane intensity and track
  - Collection of high resolution water vapor measurements to characterize water vapor inflow regions
  - Evaluation of upper troposphere humidity field and investigate troposphere-stratosphere exchange

Recommended Aircraft Missions

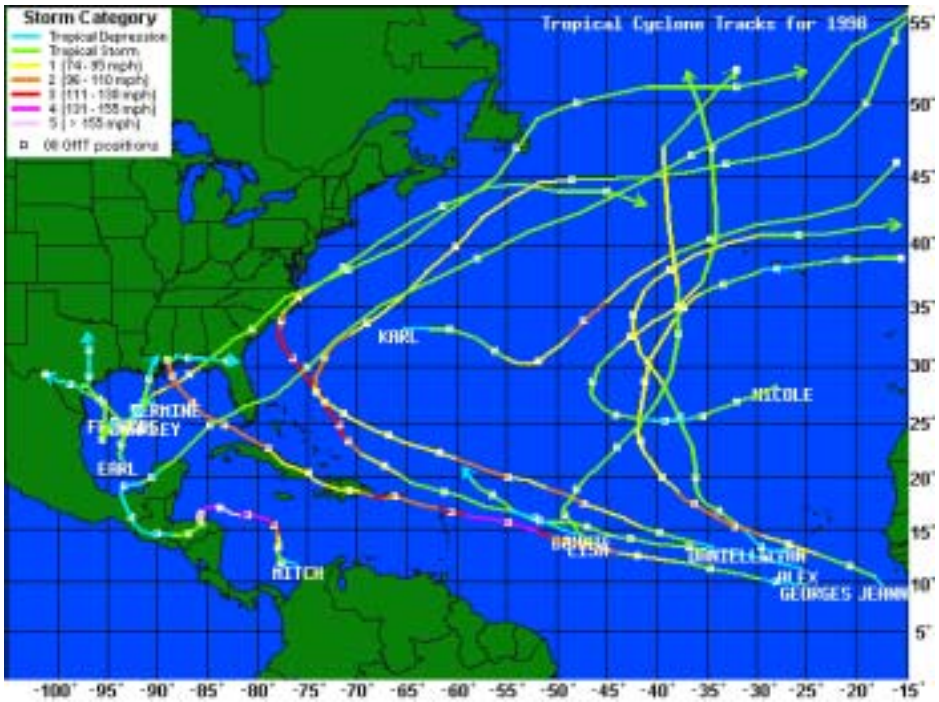
- **Eyewall and Rainband Convection (ERC)**
  - Study of eyewall rain and rainband vertical structure, horizontal extent, evolution, and quantification
  - Investigation of warm core dynamics, hot tower environment, and the relationship of convective bursts to intensity change
- **Landfalling Structure Changes (LSC)**
  - Study of vortex breakdown and resulting changes in wind and rainfall distributions
  - Evaluation of quantitative precipitation estimation techniques
- **Extra-tropical Transition (EXT)**
  - Study of interactions between a tropical cyclone and the mid-latitude baroclinic environment
  - Multi-agency, multi-aircraft mission if suitable storm exists within CAMEX region of interest

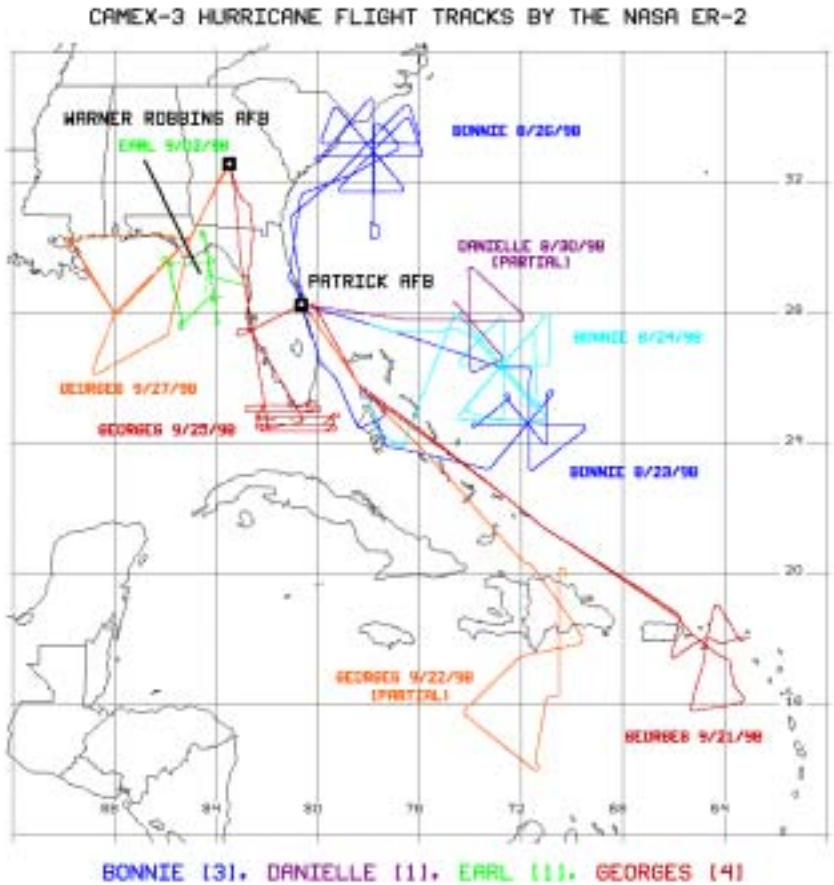
Recommended Aircraft Missions

- **Andros Island Calibration (AIC)**
  - Short cross-calibration mission of radiosonde, Aerosonde, and aircraft remote sensors and dropsonde measurement capabilities
- **Key Area Microphysics Project (KAMP)**
  - Multi-aircraft, multi-radar study of tropical cloud storm dynamics and microphysics
  - Evaluation of quantitative precipitation estimation techniques



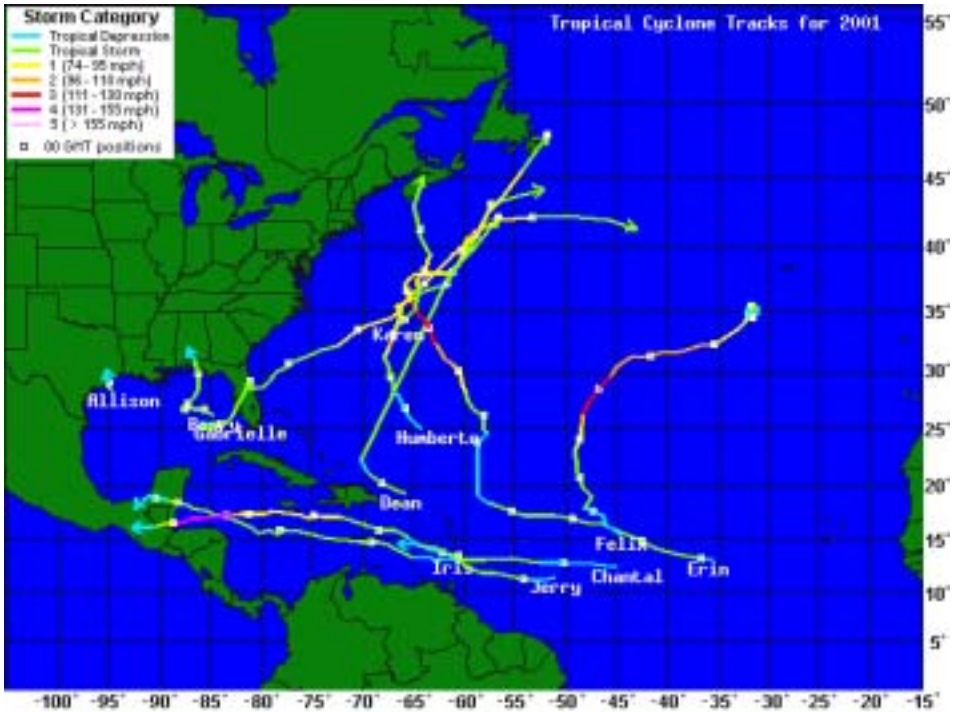
CAMEX-3 Tracks

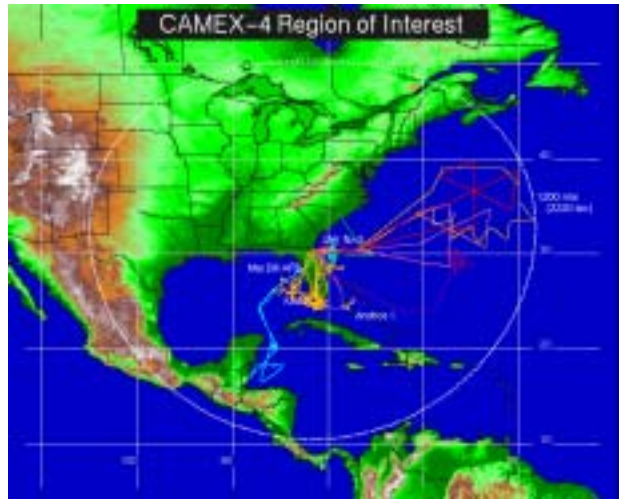


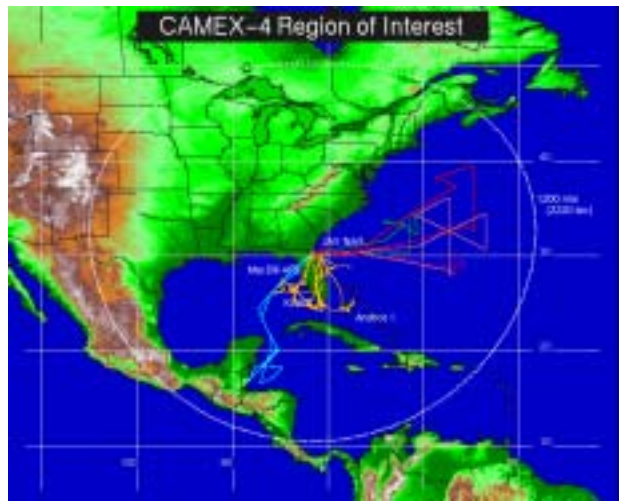


- Numerous hurricanes
- Long life cycles
- Relatively short aircraft transit times
- Several landfalls during experiment

CAMEX-4 Tracks

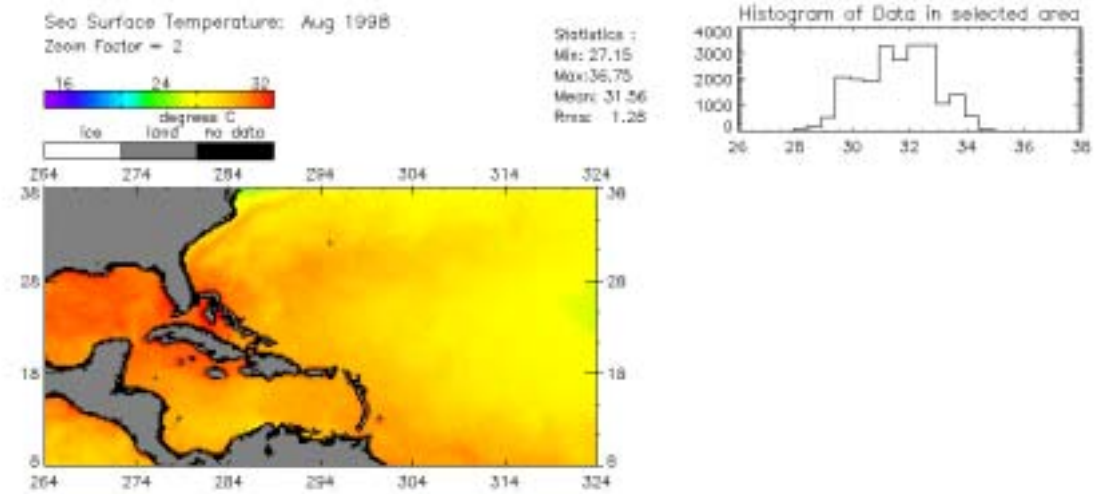




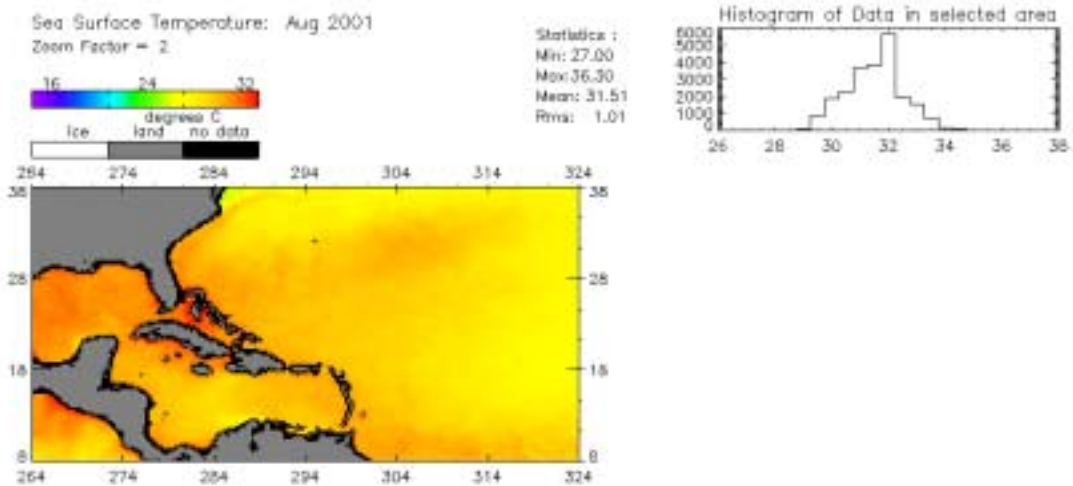


- Few hurricanes; Short life cycles
- Intensity difficult to forecast
- Long aircraft transit times
- Only one landfall during experiment

TRMM SST



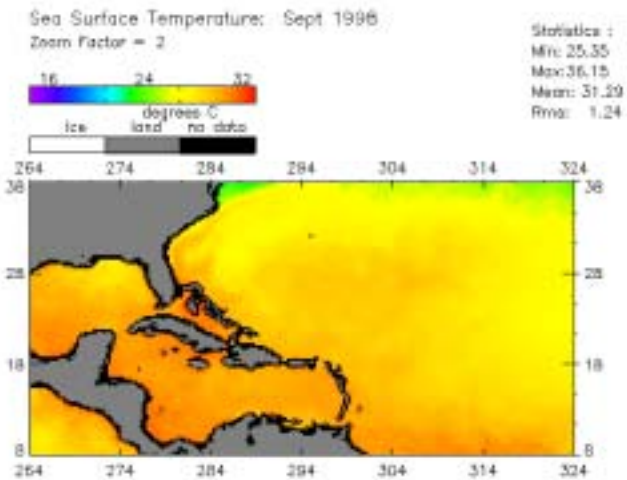
August, 1998

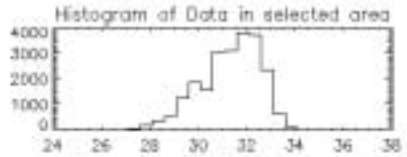


August, 2001

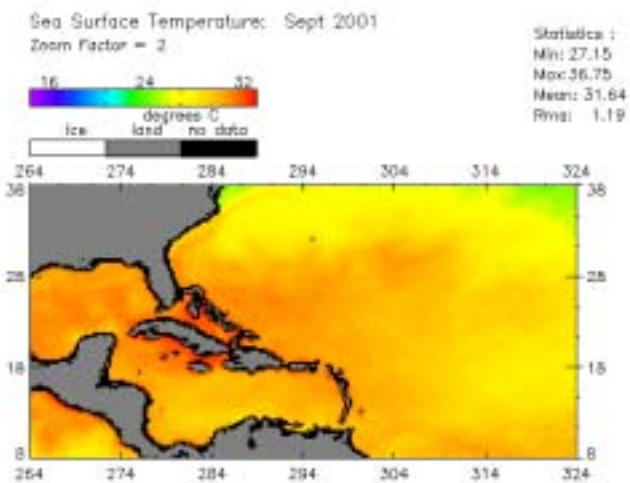
(During TRMM boost)

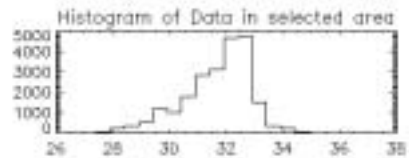
TRMM SST





September, 1998

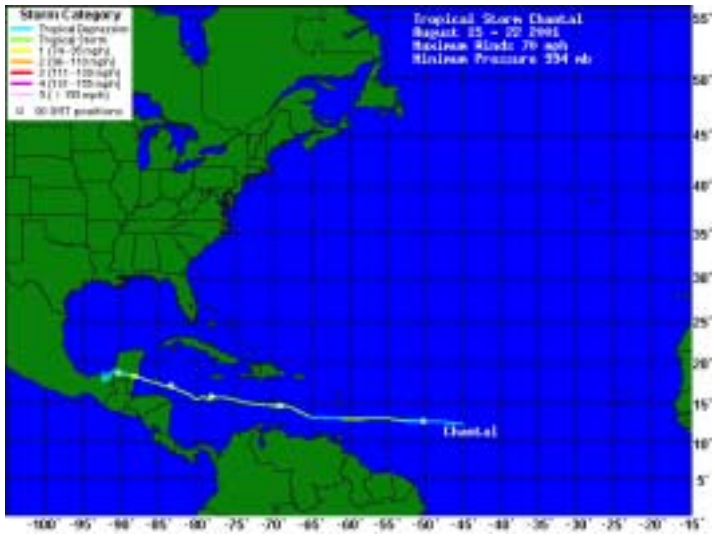


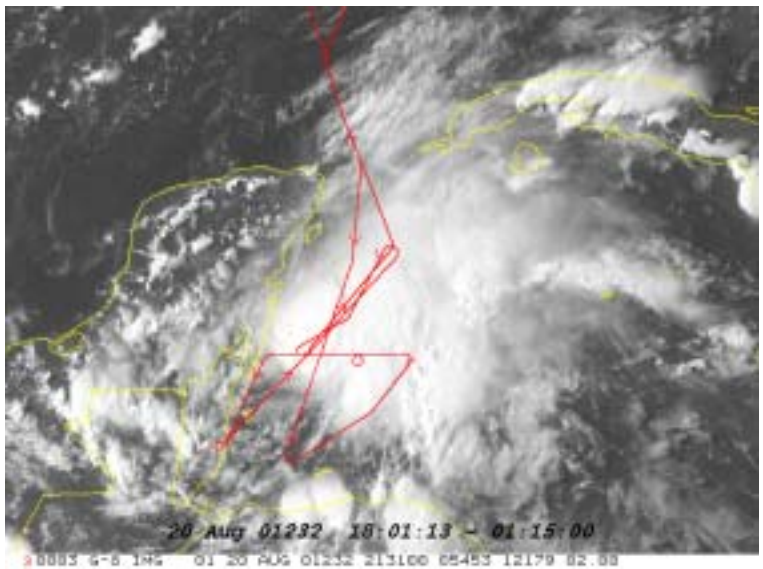


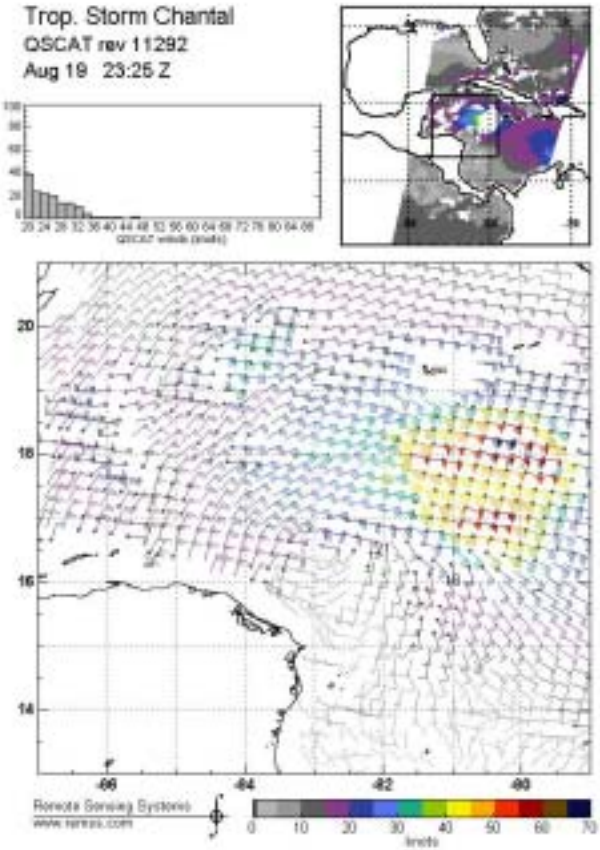
September, 2001

(After TRMM boost)

Tropical Storm Chantal

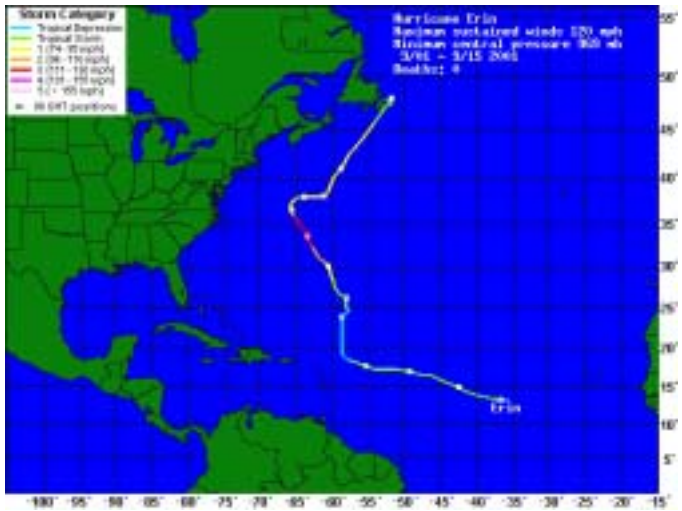


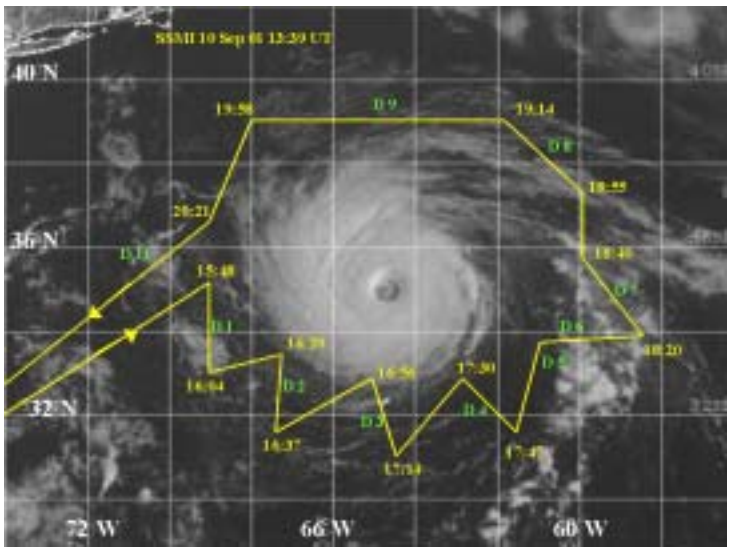


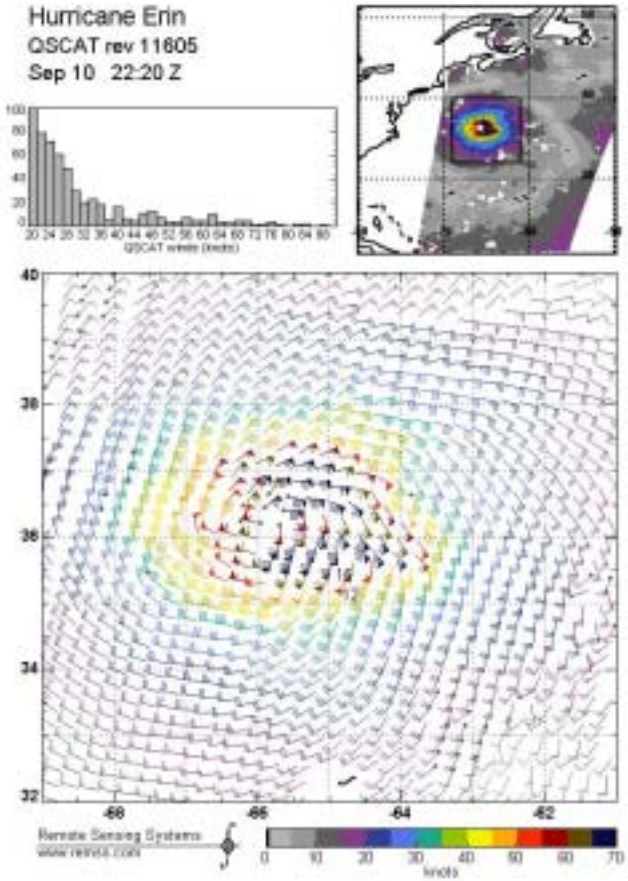


- 20 Aug. ERC Mission
- Poorly organized; no eyewall
- Large wind shears observed by dropsondes

Hurricane Erin



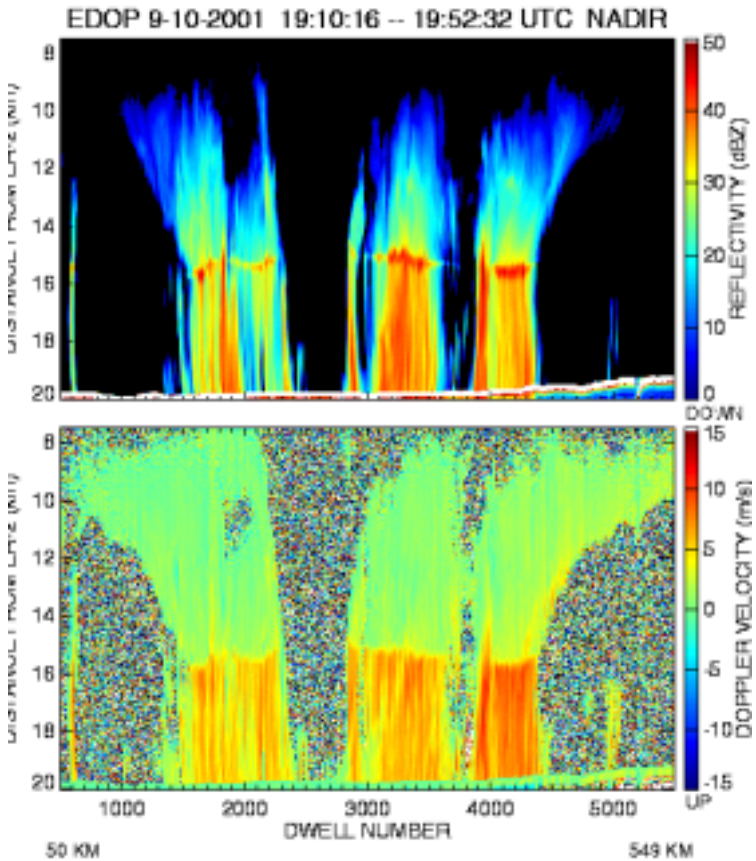




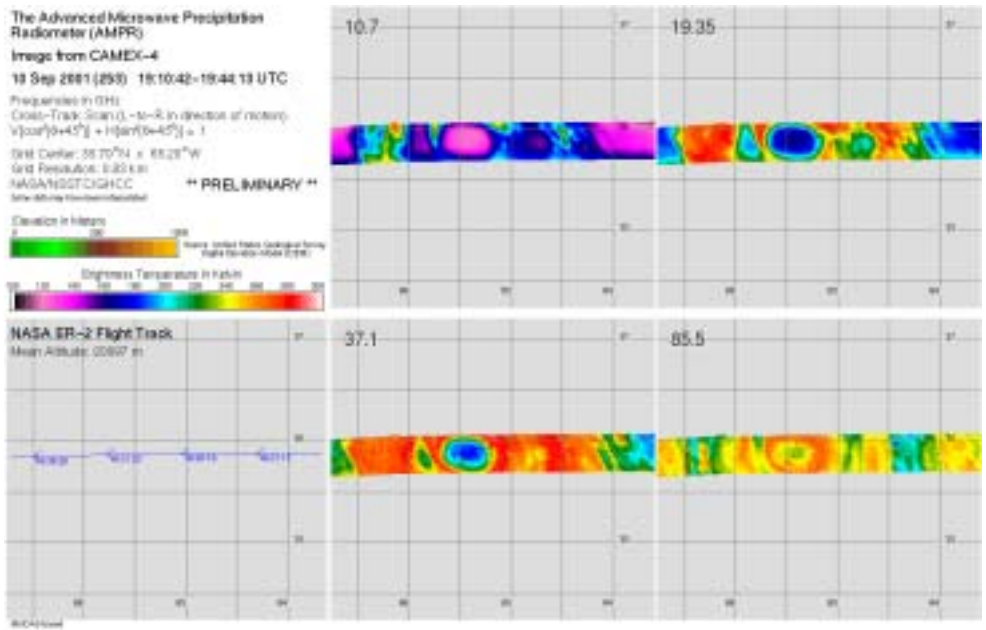
- 10 Sept ODA mission
- Historical release of dropsonde from stratosphere into hurricane eye

Hurricane Erin

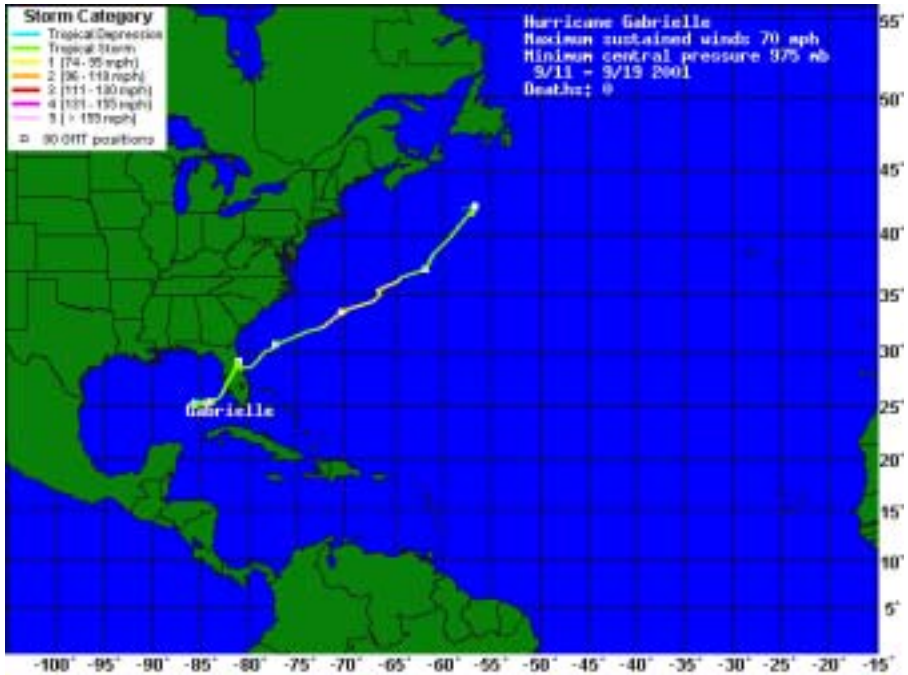
ER-2 Doppler Radar (EDOP)



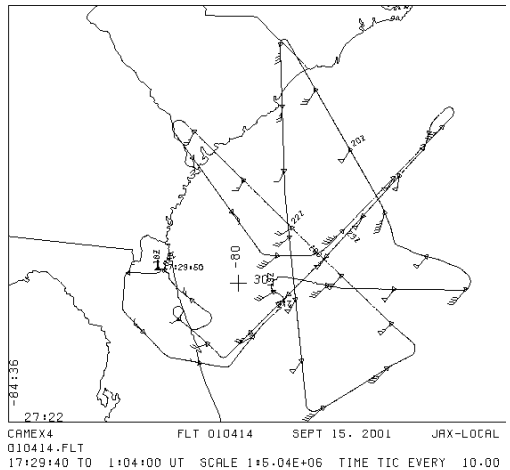
Advanced Microwave Precipitation Radiometer (AMPR)



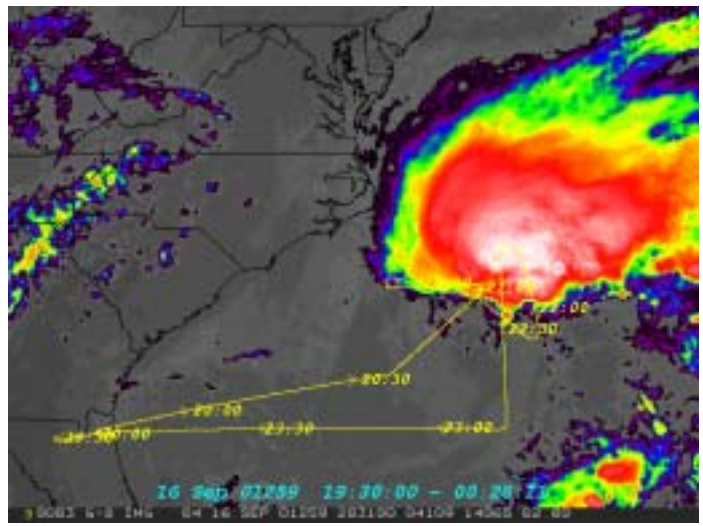
Tropical Storm Gabrielle



15 Sept. DC-8 flight

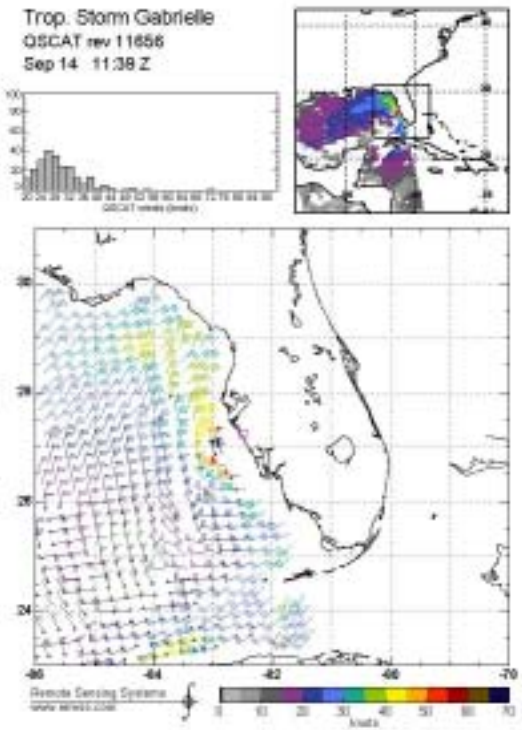


16 Sept. ER-2 flight

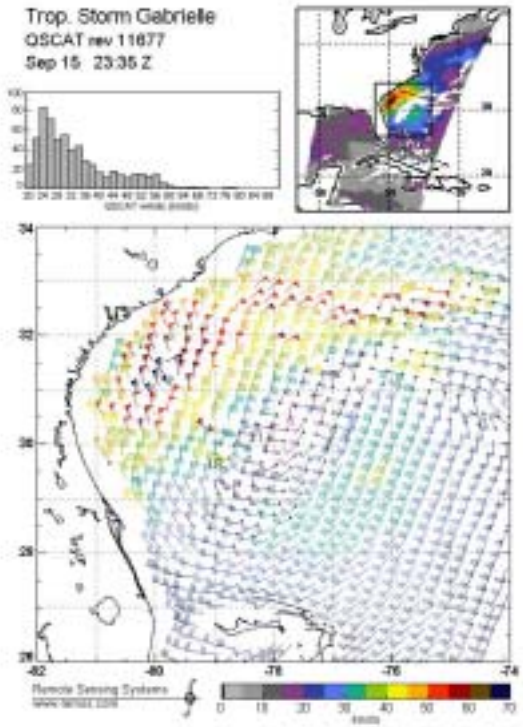


- Difficult to forecast intensity
- Early landfall on 14 Sept. (Ground-based LSC)
- Refused to intensify on 15 Sept. (EXT/ODA)
- Intensified unexpectedly on 16 Sept. (ODA/ERC)

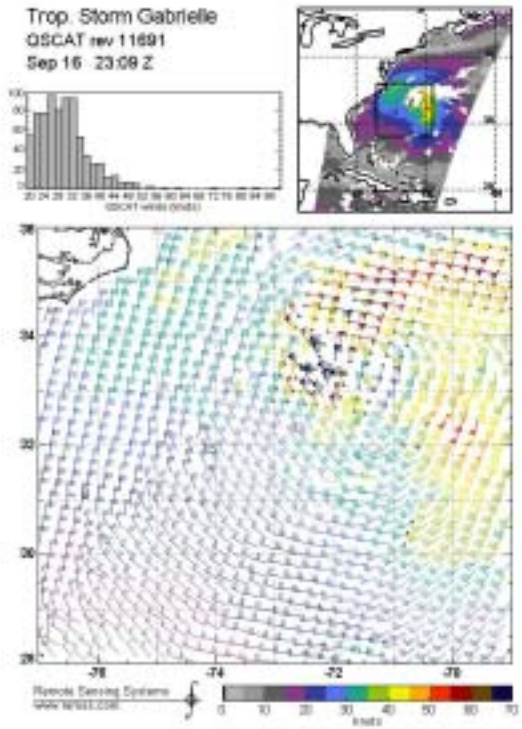
Tropical Storm Gabrielle



14 September

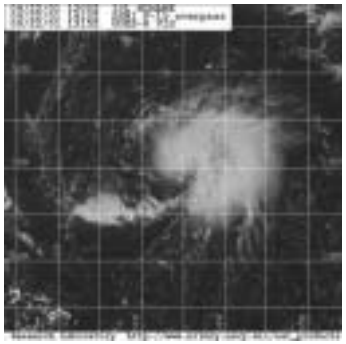


15 September



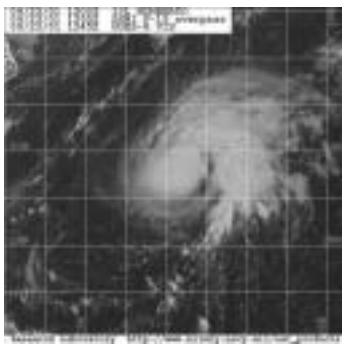
16 September

Hurricane Humberto



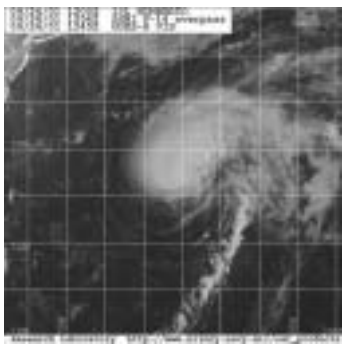
22 Sept

Gaining strength



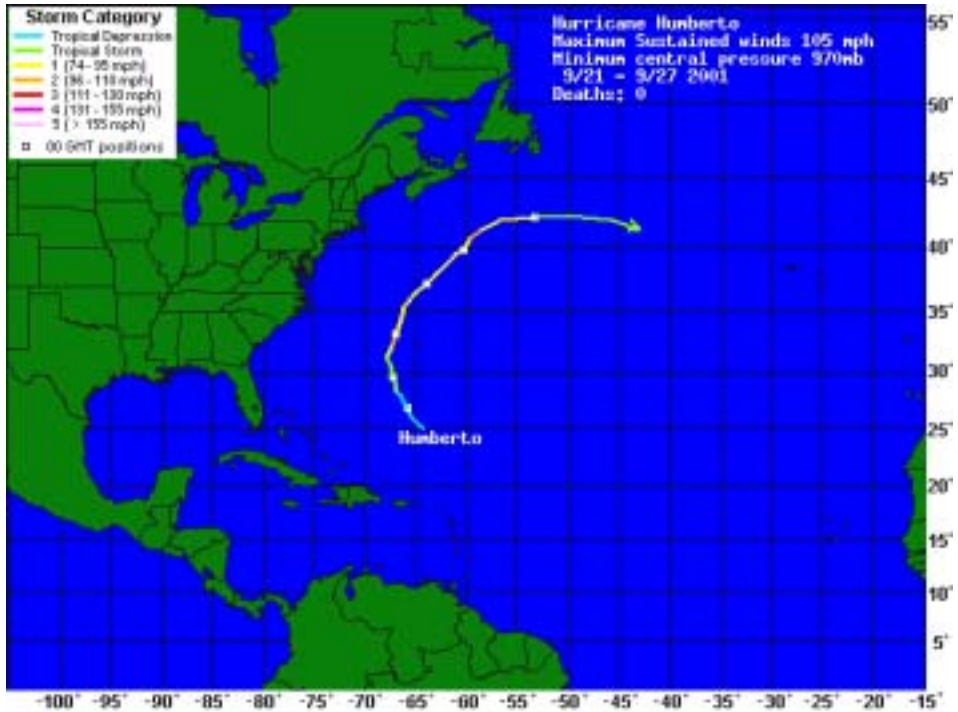
23 Sept

Maximum intensity



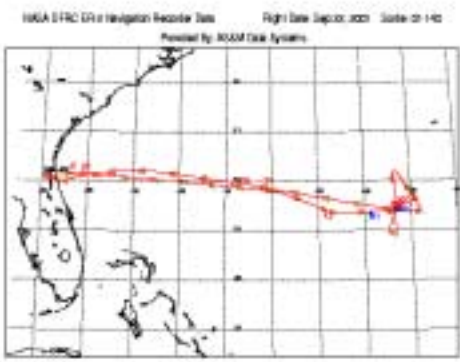
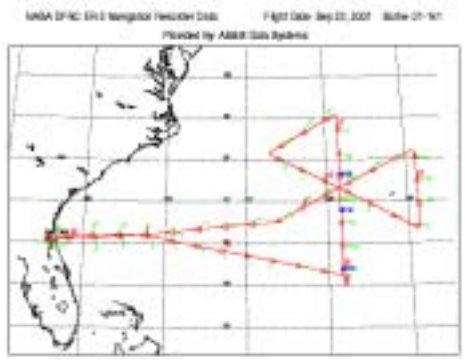
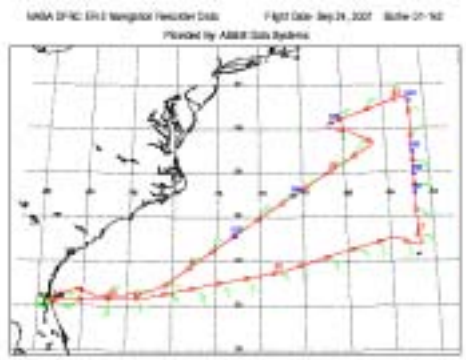
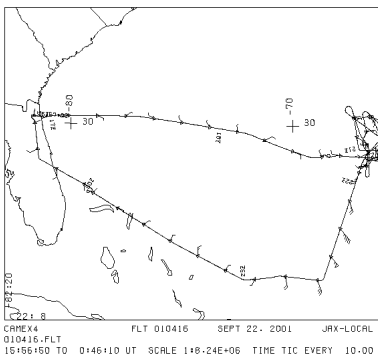
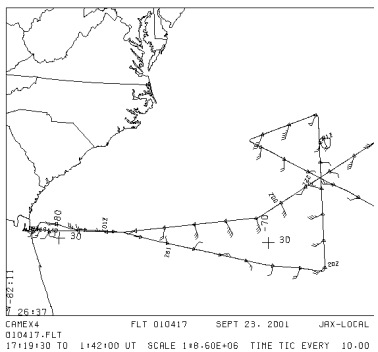
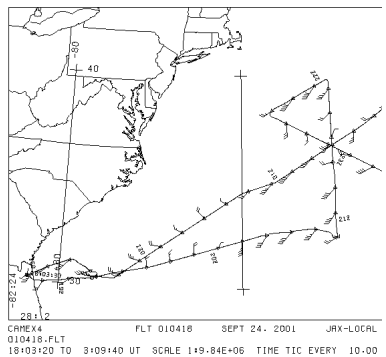
24 Sept

Weakening

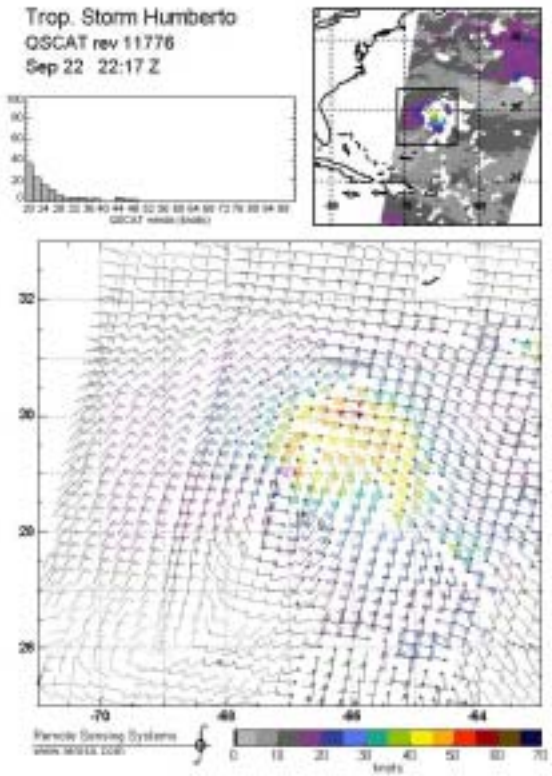


- Noticeable warm core
- Vigorous convection on north side
- Displaced upper and lower level centers

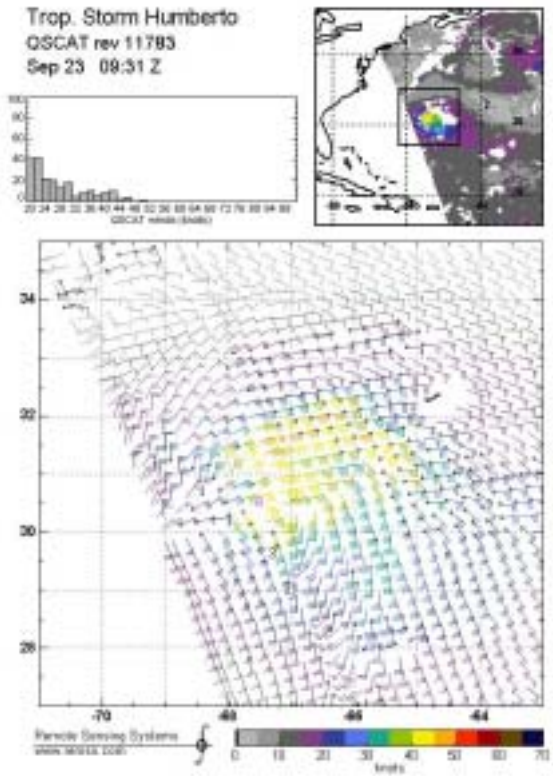
Hurricane Humberto Flight Tracks

	22 Sept. (ERC)	23 Sept. (COVES)	24 Sept. (COVES)
ER-2			
DC-8			

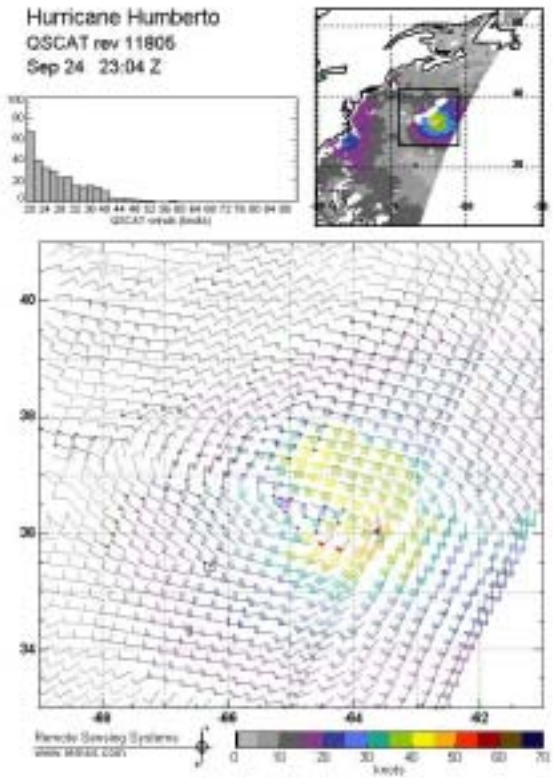
Hurricane Humberto



22 September



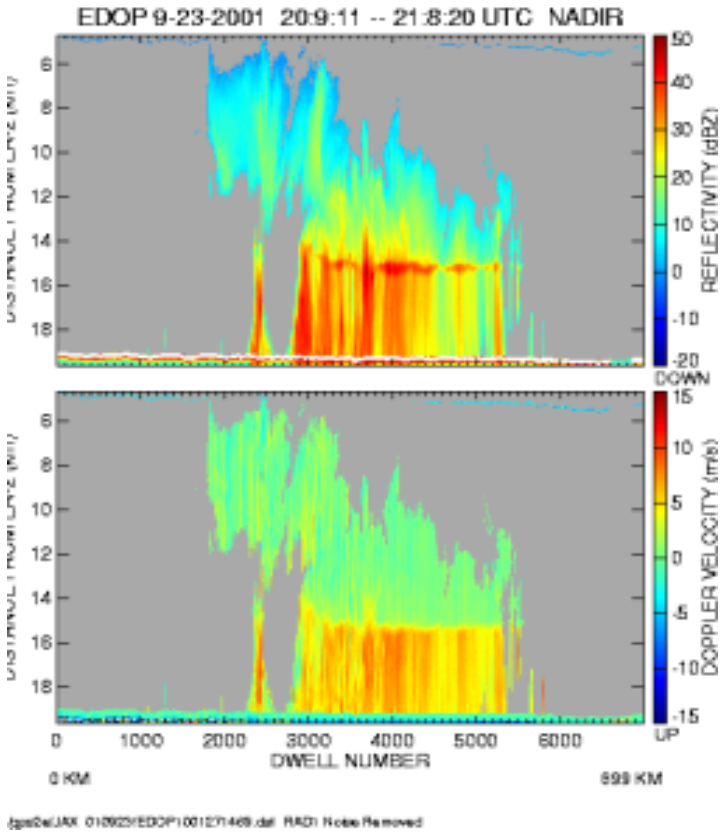
23 September



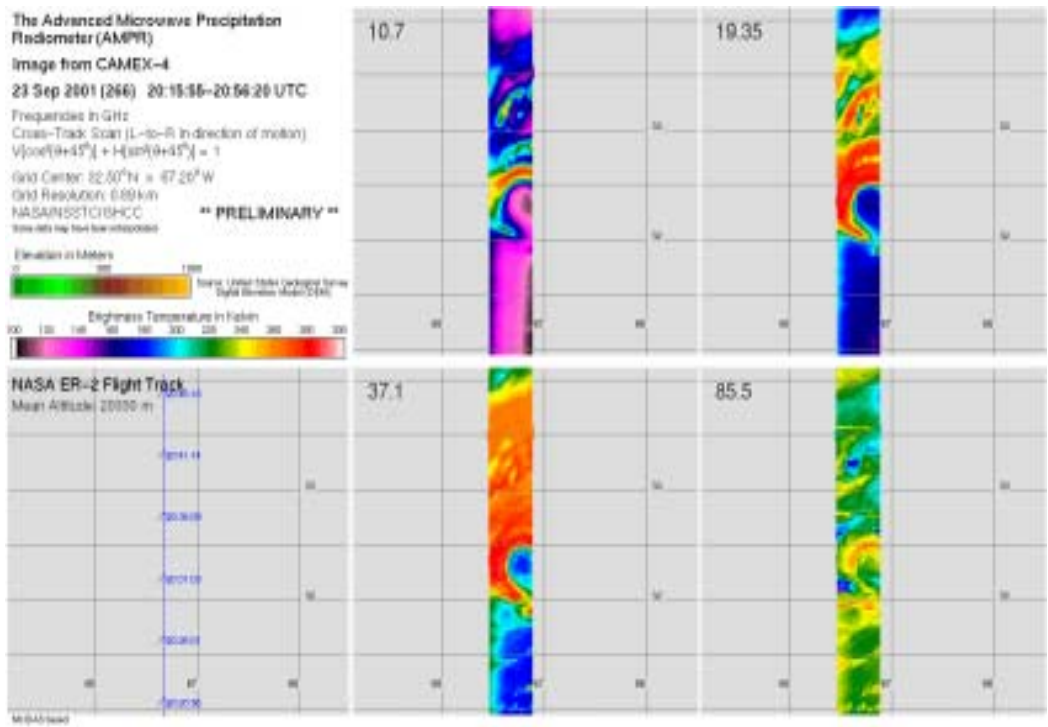
24 September

Hurricane Humberto

ER-2 Doppler Radar (EDOP)



Advanced Microwave Precipitation Radiometer (AMPR)



Success Criteria

- **Success guarantees:**
  - Science plan incorporating a combination of hurricane and KAMP rainfall missions to offset risk of non-conducive weather conditions
  - Designing multiple hurricane missions to accommodate several types of storms
  - Missions are not dependant on any one instrument or aircraft
  - Conducting field phase during the peak period of the hurricane season
  - Will return to DFRC to sample tropical cyclones along the western coast of Mexico if no Atlantic tropical cyclones are expected to form before the end of the experiment
- **Predicted milestones for success:**
  - Good / 2 hurricane flights and 2 KAMP flights
  - Great / 2 COVES, 2 ODA, 2 ERC, 1 LFS, and 3 KAMP
- Final Outcome – Great Success
  - **2 COVES, 1.5 ODA, 2.5 ERC, 1 LFS w/o aircraft, 0.5 EXT and 4 KAMP**

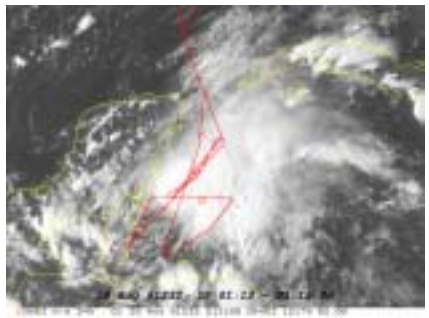
Key Accomplishments

- **Unprecedented joint NASA/NOAA aircraft sampling of tropical rain systems**
- **First stratospheric release of dropsondes into eye of hurricane**
- **Successful sampling of landfalling T.S. Gabrielle with ground-based instrumentation**
-
- **Near real-time broadcast of NASA dropsonde and radiosonde information to NOAA Data Pipeline for input into operational weather forecast models**
- **First long-endurance environmental sampling of western Atlantic Ocean by Aerosonde, an Unpiloted Aerial Vehicle**
- **Close range observation of Jacksonville funnel cloud**

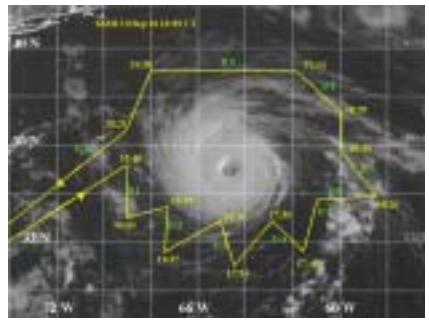
Key Accomplishments

- **Missions conducted into Tropical Storms Chantal and Gabrielle as well as Hurricanes Erin and Humberto**
- **Unprecedented sampling of tropical cyclones with joint NASA and NOAA aircraft missions**
- **First stratospheric release of dropsonde into eye of hurricane measuring temperature, humidity, and air pressure down to the ocean surface**
- **Successful sampling of landfalling Tropical Storm Gabrielle with mobile ground-based instrumentation**
- **First long-endurance sampling of western Atlantic Ocean by Unpiloted Aerial Vehicle**
- **Sampled rain structures in Key West area**
- **Conducted daily upper air soundings at Andros Island, Bahamas**
- **Contributed to development to climatic data base needed to study long-term hurricane trends**

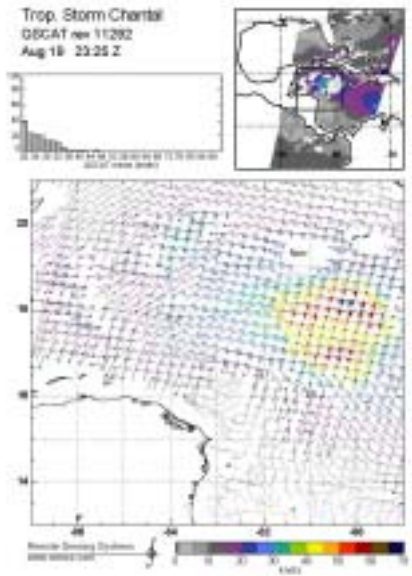
20 Aug. ER-2 Flight Track over Tropical Storm Chantal



10 Sept. DC-8 Flight Track over Hurricane Erin



19 Aug. QuikSCAT Observations of Tropical Storm Chantal



10 Sept. QuikSCAT Observations of Hurricane Erin