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# NASA Airborne Hurricane Research

- Recent Experiences – TCSP
- Future Platform Assessments

# Overview

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- Tropical Cloud Systems & Processes (TCSP) Campaign Overview
- ER2: high-altitude platform for TCSP
- TCSP Highlights
- Hurricane Over-flights - ER2 Pilot Observations
- Aerosonde UAV – Ophelia penetration
- Future Platforms

# Tropical Cloud Systems & Processes (TCSP): Mission Overview

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An Earth Science field research investigation sponsored by the Science Mission Directorate of the National Aeronautics and Space Administration (NASA).

Field phase: conducted during the period July 1-27, 2005 out of the Juan Santamaria Airfield in San Jose , Costa Rica

## Research Objectives:

- Tropical cyclone structure, genesis, intensity change, moisture fields and rainfall
- Satellite and aircraft remote sensor data assimilation and validation studies pertaining to development of tropical cyclones
- The role of upper tropospheric/lower stratospheric processes governing tropical cyclone outflow, the response of wave disturbances to deep convection and the evolution of the upper level warm core.

## Airborne Platforms:

- 12 NASA ER-2 science flights, including missions to Hurricanes Dennis and Emily, Tropical Storm Gert and an eastern Pacific mesoscale complex that may possibly have further developed into Tropical Storm Eugene.
- The P-3 aircraft from the NOAA Hurricane Research Division (HRD) flew 18 coordinated missions with the NASA research aircraft to investigate developing tropical disturbances.
- Aerosonde uninhabited aerial vehicle flew 8 surveillance missions.

# NASA ER-2

## Capabilities

Altitude	Above 70,000 Feet
Range	6000+ Nautical Miles
Duration	10+ hours
Speed	410 knots (467 mph)
Payload Capacity	2600 lbs
Payload Power	36Kw

## Special Modifications & Facilities



Q-bay instrumentation area & payload pallets (pressurized)

Wing-mounted instrumentation pods (pressurized)

Nose instrumentation area (pressurized)

Zenith and nadir viewing capability

Navigation data recording system

Nadir Video Camera system

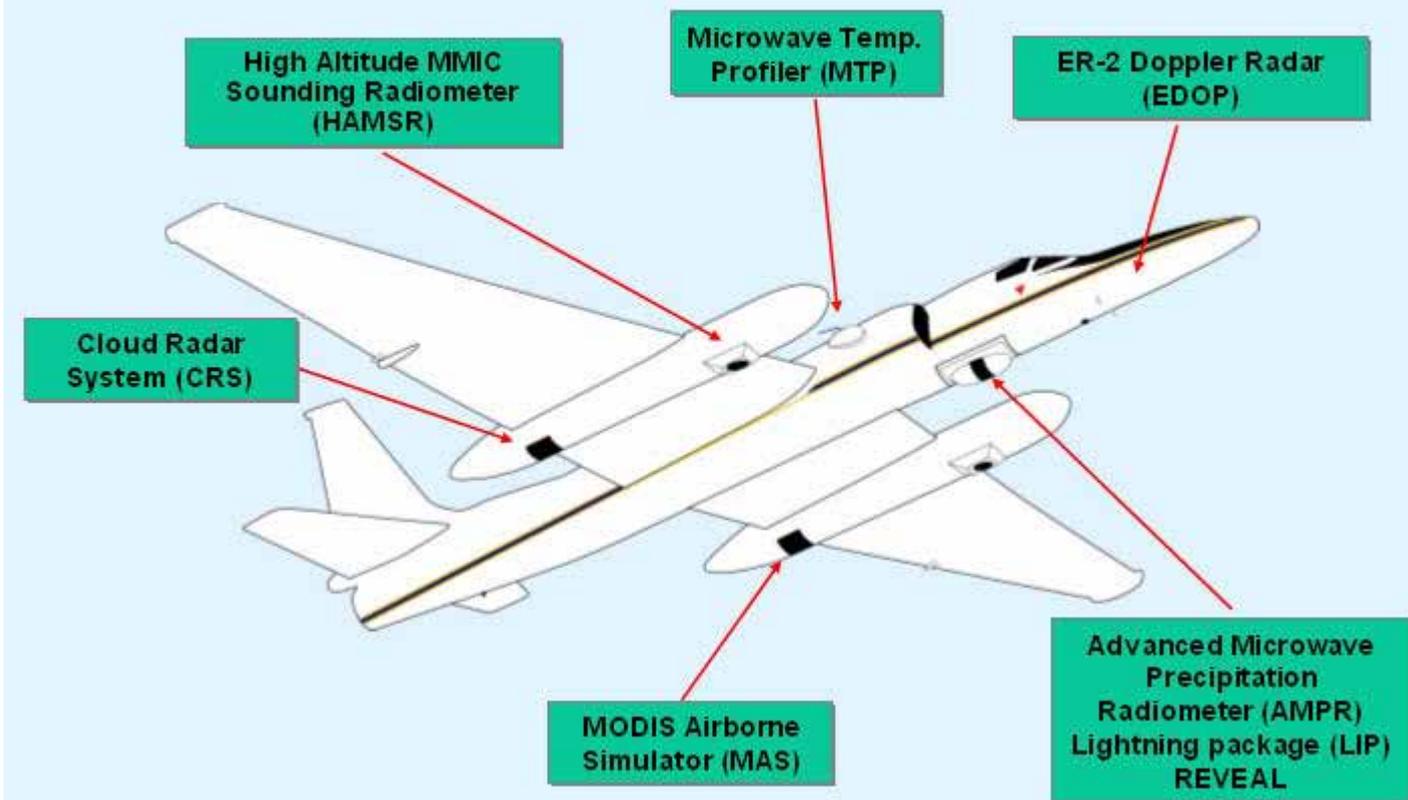
Facility Sensors (film-based cameras, multi/hyper spectral scanners)

Aerosol Particle Sampler Systems

Dropsonde delivery system

IRIDIUM Voice and Data Line; REVEAL

## TCSP ER-2 Instrument Payload



# TCSP: Noteworthy milestones of the 30-day mission:

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- Rapid genesis of Hurricane Dennis.
  - In a region of the Caribbean where such dramatic development is rare. The storm's pressure dropped 12 millibars in two hours. Researchers hope data from Dennis will help improve understanding of this "rapid deepening" phenomenon.
- Re-generation of Hurricane Dennis
  - As a powerful Category 4 -- passed over Cuba 's mountainous terrain, severely disrupting its well-defined eye and weakening it to a Category 2 hurricane. When it re-emerged over warm waters north of Cuba, the storm quickly regained its former strength and intensity.
- Birth of Tropical Storm Eugene.
  - Observed while monitoring a narrow Pacific region called the "Inter-Tropical Convergence Zone"
- Recording of the entire lifespan of Tropical Storm Gert
  - The ER-2 and P3 Orion flew five back-to-back missions enabling the team to monitor the entire lifespan of Gert, which developed from an elongated area of low-pressure or "trough" off the Yucatan coast. The ER-2 also investigated the impact of Mexican mountain ranges on Gert as the storm made landfall.
- Hurricane Emily overflight
  - ER-2 over-flew the most powerful hurricane of its "career" while studying the borderline Category 4-5 Hurricane Emily. Recorded frequent lightning, unusual in hurricanes, and captured startling Doppler radar imagery of Emily, including "eye wall" storms rising to rarely observed heights of above 60,000 feet.

# ER2 - Hurricane Emily (TCSP)



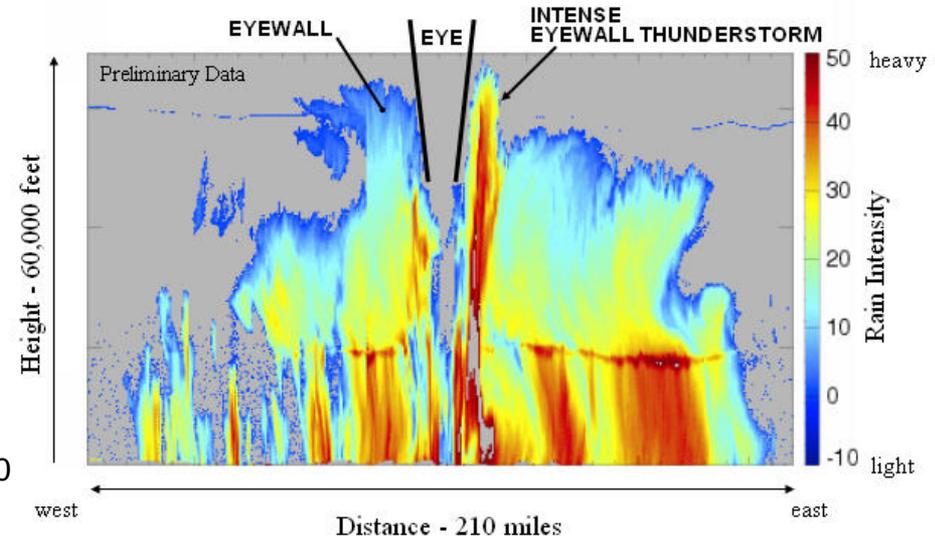
"EDOP measured *reflectivities nearly to the ER-2's level*, with very high reflectivity values in the upper troposphere (~40 dBZ to ~17 km altitude). LIP detected at least *10 flashes per minute*, likely more. AMPR and HAMSRS showed strong ice scattering, with even the lowest frequency channels scattered (indicative of very *large graupel or hail*)."

"Indeed, the electric fields above Emily were *among the strongest ever measured by the aircraft's sensors over any storm*."

"We observed steady fields in excess of 8 kilovolts per meter," says Blakeslee. "That is huge--comparable to the strongest fields we would expect to find over a large land-based 'mesoscale' thunderstorm."

## ER-2 Doppler Radar (EDOP) Views Detailed Super-Anatomy Of Intense Hurricane Emily During NASA's TCSP Experiment

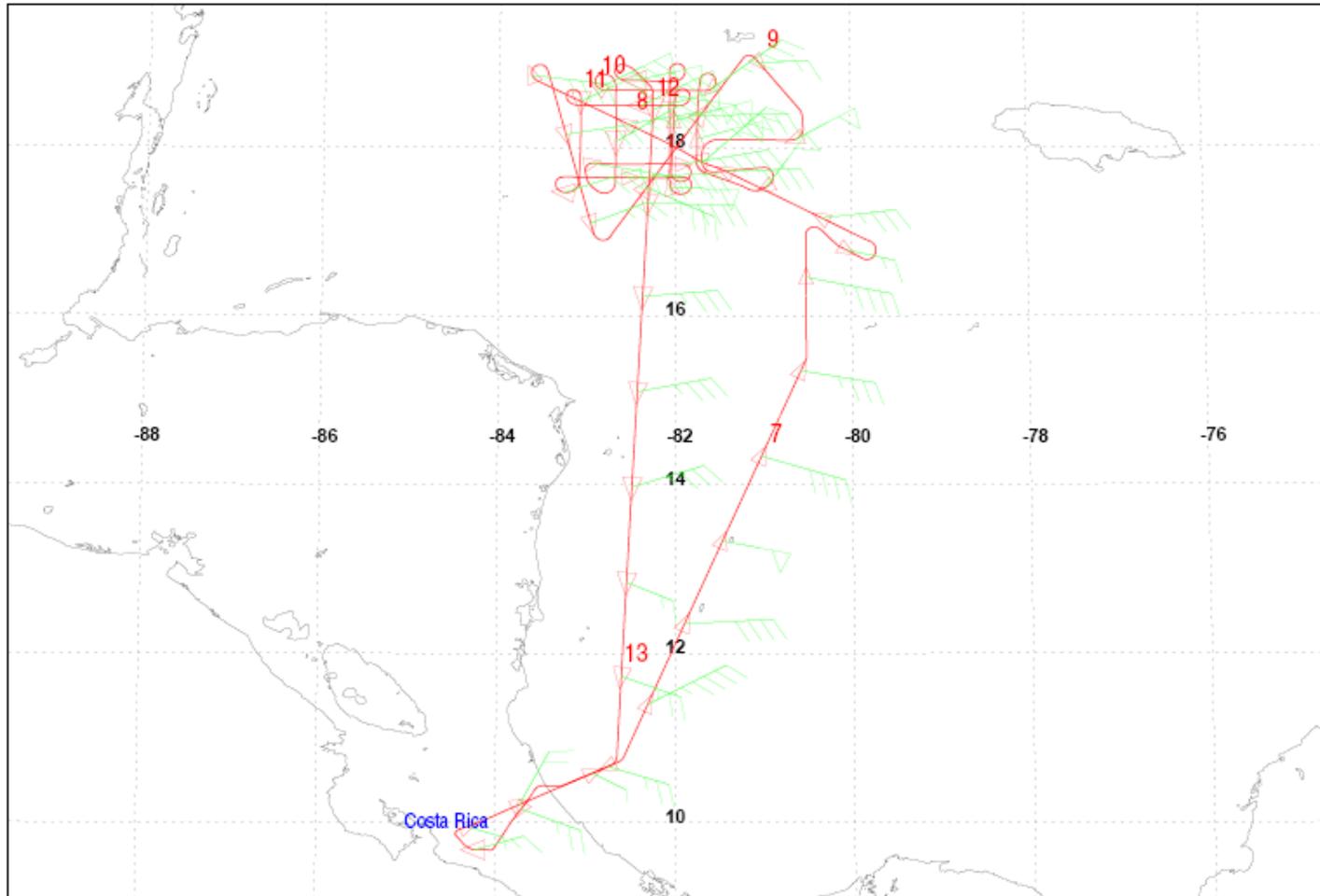
Principal Investigator: Dr. Gerald Heymsfield, NASA GSFC



**Vertical slice showing rain structure across the entire storm - 1:30 - 2:00 AM CST July 17, 2005**



# Hurricane Emily – ER2 Flight Track, 17 July 2005



# ER2 Pilot Observations

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- Hurricane Dennis (Cat 1):
  - Little or no turbulence; stable air mass at 65,000 feet.
  - Observed actual formation of the “eye”.
- Hurricane Emily (Cat 5):
  - Pronounced turbulence up to 68,000’.
  - Wild fluctuations in outside air temperature.
  - Winds in excess of 60 knots at 65,000’.
  - Eyewall cloud tops estimated between 62,000 & 63,000 feet.
    - Filled with severe lightning.
  - Lesson Learned: sacrifice endurance for altitude.

# Aerosonde Mark 3 Specifications

**Table 1. Specifications of Mark 3 Aerosonde UAV**

<b>Specifications</b>	
Weight, wing span	27-30 lb, 10 ft
Engine	24 cc, 1.2 kw, fuel injected using premium unleaded petrol
Navigation	GPS
<b>Operation</b>	
Staff for Launch and Recovery	3 people: Controller, Technician, Pilot/Maintenance
Staff for Flight Operations	1 Person for up to 3 aircraft
Ground Equipment	Proprietary Staging Box, personal computer (laptop), GPS antenna, aviation and local communications radios
Flight	Fully autonomous, under Base Command
Launch and Recovery	Launch from car roof rack (catapult option), land on belly, Autonomous or with pilot
Ground & air communications	UHF or Satcoms (Iridium) to Aerosonde, VHF to field staff and other aircraft, internet to command center and users.
<b>Performance</b>	
Speed, Climb	18 – >32 ms <sup>-1</sup> , Climb >2.5 ms <sup>-1</sup> at sea level
Range, Endurance with no additional payload	>1800 miles, >30 h
Altitude Range	Up to 20,000 ft (medium weight)
Payload	Maximum 5 lb with full fuel load
<b>Standard Instrumentation</b>	
Temperature, Pressure, Humidity, Wind	2 Vaisala RSS901 Sondes for temperature, pressure and humidity, and a proprietary wind system.



# Aerosonde – Ophelia Penetration

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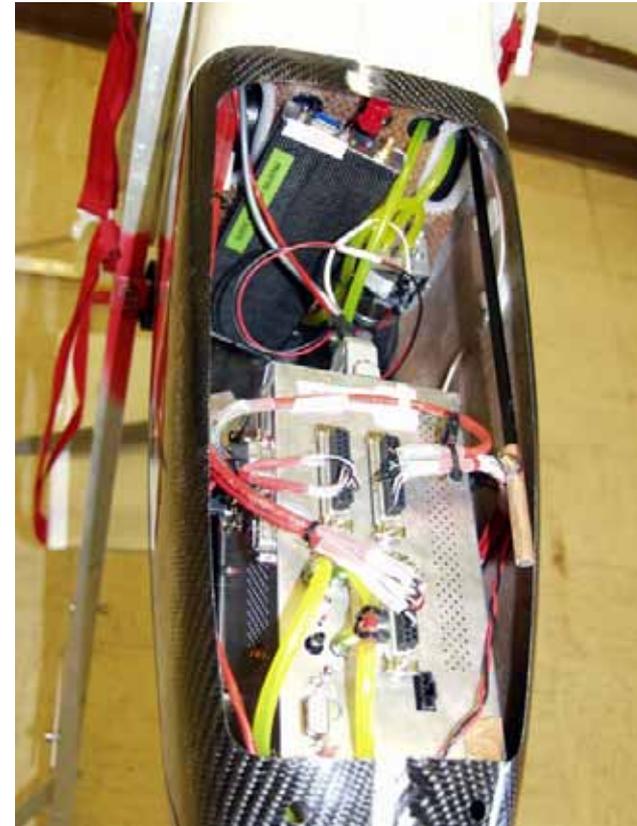
"Hurricane researchers at the NOAA Atlantic Oceanographic and Meteorological Laboratory in Miami, Fla., marked a new milestone in hurricane observation as the first unmanned aircraft touched down after a 10-hour mission into Tropical Storm Ophelia, which lost its hurricane strength Thursday night. The aircraft, known as an **Aerosonde**, provided the first-ever detailed observations of the near-surface, high wind hurricane environment, an area often too dangerous for NOAA and U.S. Air Force Reserve manned aircraft to observe directly."



# Payload

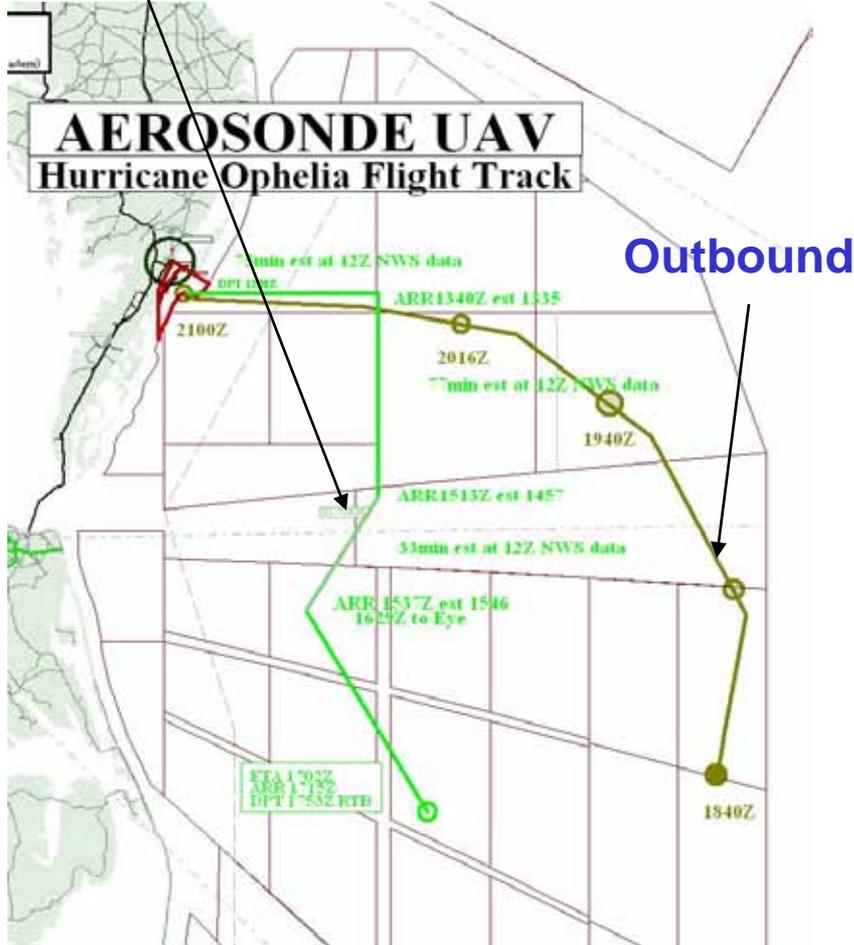
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- Two Vaisala RSS901 Sondes
  - Pressure
  - Temperature
  - Humidity
- KT11 Infrared Pyrometer
  - Sea Surface Temperature
- Winds Derived from Aerosonde  
Proprietary Algorithm

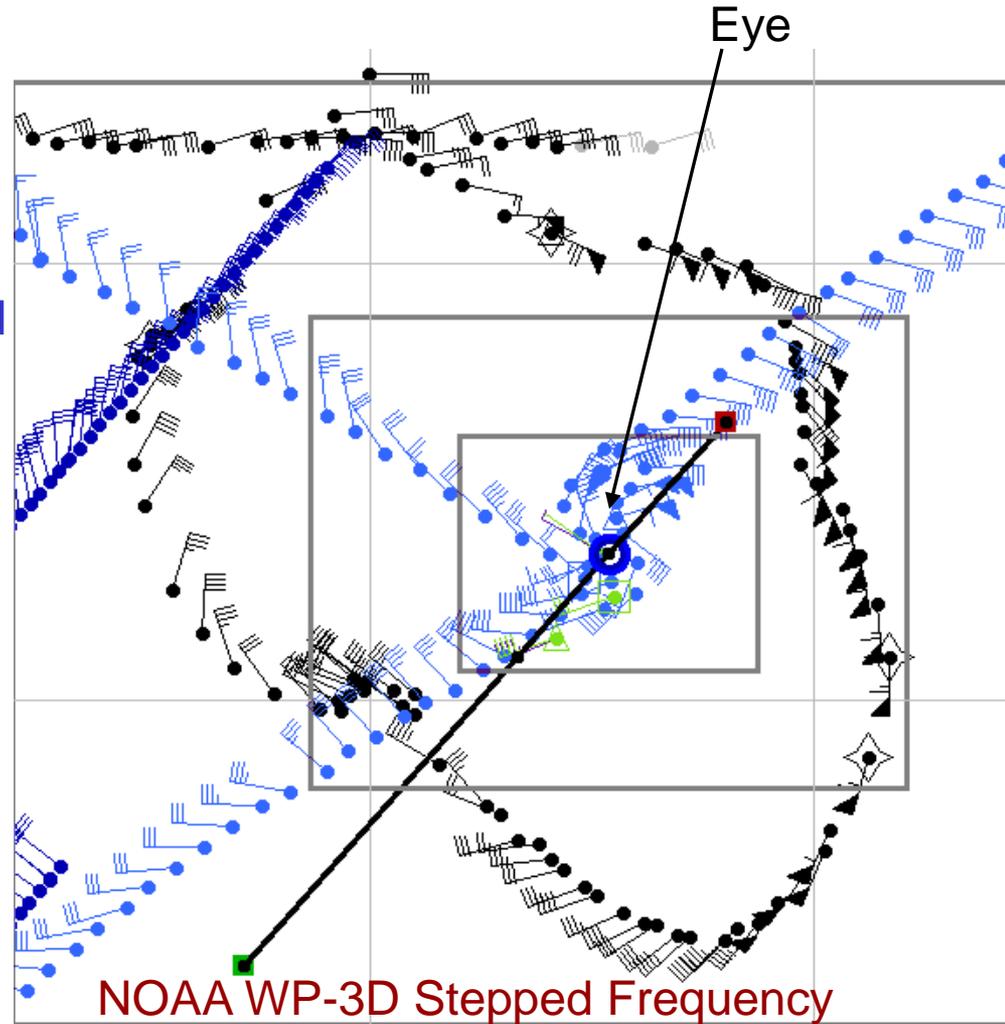


# Aerosonde Operations

Inbound



Outbound



NOAA WP-3D Stepped Frequency Microwave Radiometer (SFMR) Surface winds in light blue, Aerosonde winds in black, buoy winds in dark blue.

# Ophelia Flight Facts

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- 10.1 hours flight duration
- 2500 ft transit inbound to, and outbound from eye
- Over-flew buoy for SST comparison on Inbound leg at 2 altitudes
- Spiral down to 1200 ft conducted in the eye
- Measured 75 kt winds in NE quadrant

# Hurricane Research - Future Platforms

- Global Hawk:
  - Max Altitude: 65,000 feet
  - Ability to withstand conditions encountered over Emily still being assessed.
    - Climb profile not designed to maintain max altitude
    - Stability in such dynamic atmospheric conditions - uncharacterized
- ALTAIR:
  - Max design altitude: ~52,000 feet.
    - Max demonstrated: 45K on 18 hr mission
- Predator-B:
  - Max design altitude: ~50,000 feet
    - Max demonstrated: 40K on 24.5 hr mission



Penetration and over-flight capabilities still being assessed for ALTAIR and Predator-B.

Endurance of Global Hawk and Predator/ALTAIR make them ideal for Cyclogenesis studies.