



# NASA Global Hawk Overview November 2014





# Outline



- **NASA Global Hawk**
  - **Project Overview**
  - **System Capability**
  - **Operations Overview**
  - **Ground Control Stations – Fixed-Base and Portable**
  - **Communications between Aircraft and Ground Control Stations**
  - **Payload Integration and Payload Accommodations**
  
- **Science Campaigns**
  - **Summary of Flights to Date**
  - **GloPac 2010**
  - **GRIP 2010**
  - **WISPAR 2011**
  - **HS3 2011, 2012, 2013, 2014**
  - **ATTREX 2011, 2013, 2014**
  - **IceHawk 2013**
  - **Future Missions**
  
- **Accomplishments of the NASA/NGC Team**



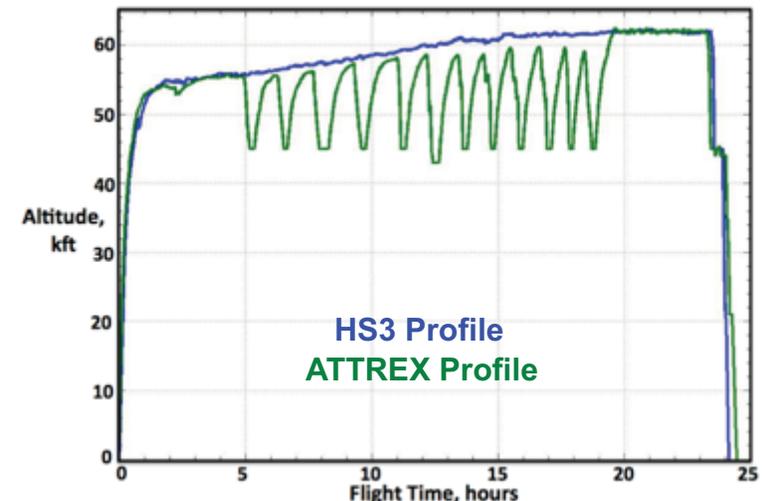


# NASA Global Hawk Summary and Capability



- NASA has been flying Global Hawk aircraft for airborne Earth science research since 2010. Ten science campaigns have been completed.
- The autonomous aircraft are remotely operated from either NASA Armstrong Flight Research Center, NASA Wallops Flight Facility, or a portable Flight Control Station.
- A NASA/Northrop Grumman team is maintaining, modifying, and operating these 2 aircraft through a partnership that was established in 2008 and renewed in 2013.
- A total of 133 missions have been flown, with a total of 1,644 flight hours.

Endurance	24-26 hours for Typical Missions 28.6 hours Demonstrated
Range	10,000 nmi
Service Ceiling	65,000 ft, < 50% available A/C payload power 62,500 ft, > 50% available A/C payload power
Airspeed (55,000+ ft)	335 KTAS
Payload	1,200 lb Demonstrated
Length	44 ft
Wingspan	116 ft



Typical Flight Profiles



# NASA Global Hawk Asset Overview



**Operational Aircraft**



**Global Hawk Operations Center – East (WFF)**



**Global Hawk Operations Center (AFRC)**



**Portable Ground Systems**



**Spares Aircraft**



# NASA Global Hawk Operations Overview at Edwards Air Force Base/NASA AFRC



**EAFB  
Runways**



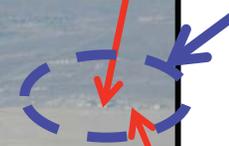
**Mission Staging  
Locations**



**Maintenance Hangar  
& Instrument Lab**



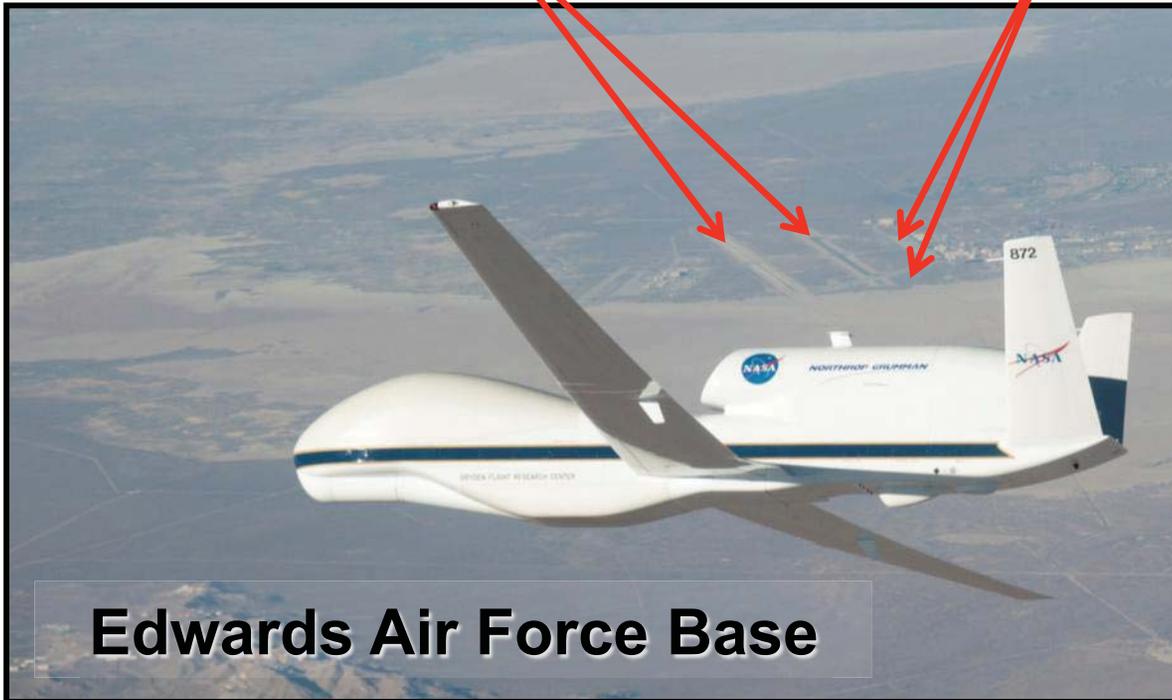
**NASA  
Armstrong  
Flight  
Research  
Center**



**Flight Operations Center**

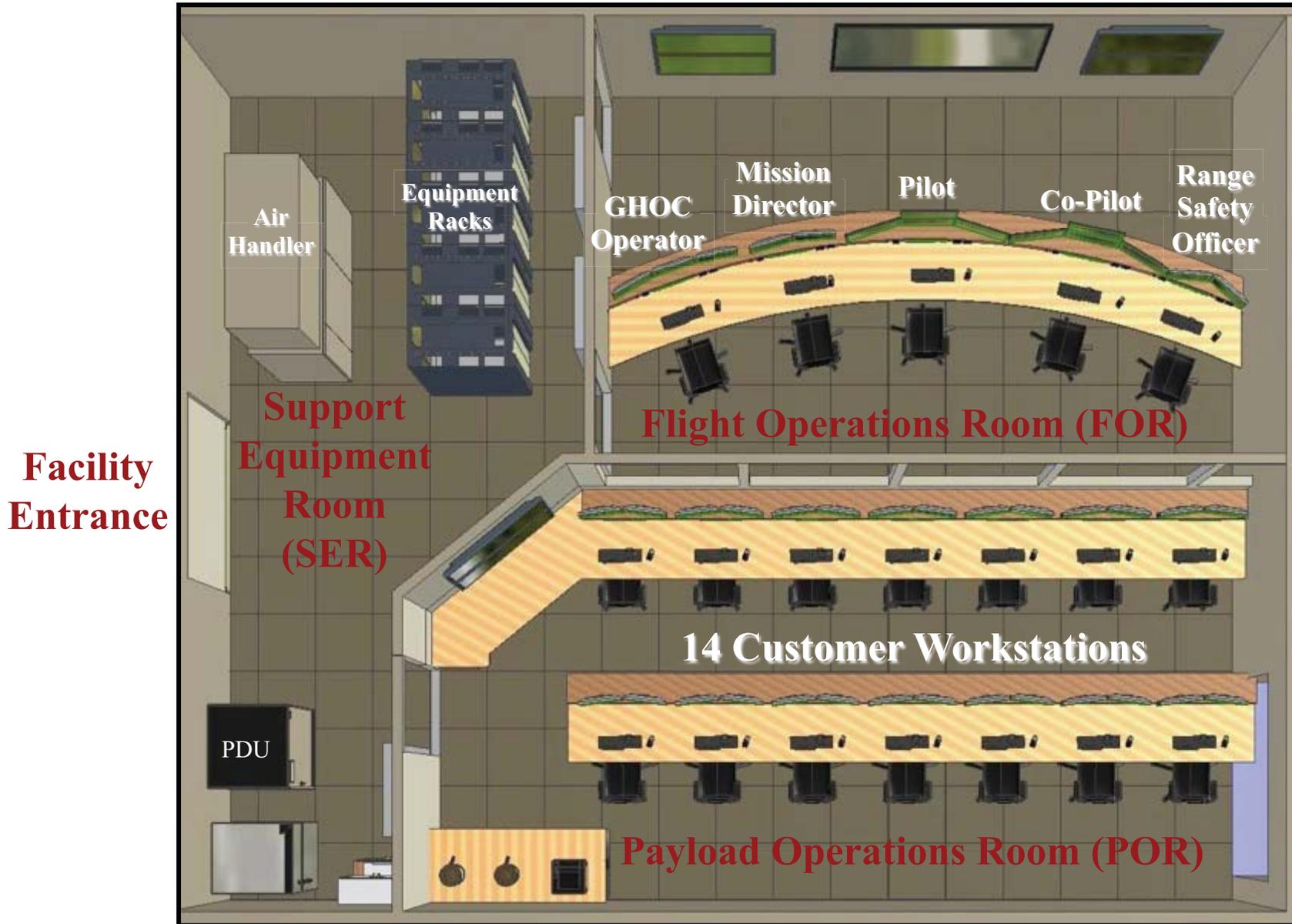


**Edwards Air Force Base**





# Global Hawk Operations Center (GHOC) Room Layout at NASA AFRC





# GHOC Fully Staffed During a Hurricane Overflight





# GHOC East at Wallops Flight Facility, Virginia





# Portable Ground Control Station Suite used for Deployed Operations



**Ku  
Satellite  
Ground  
Station**

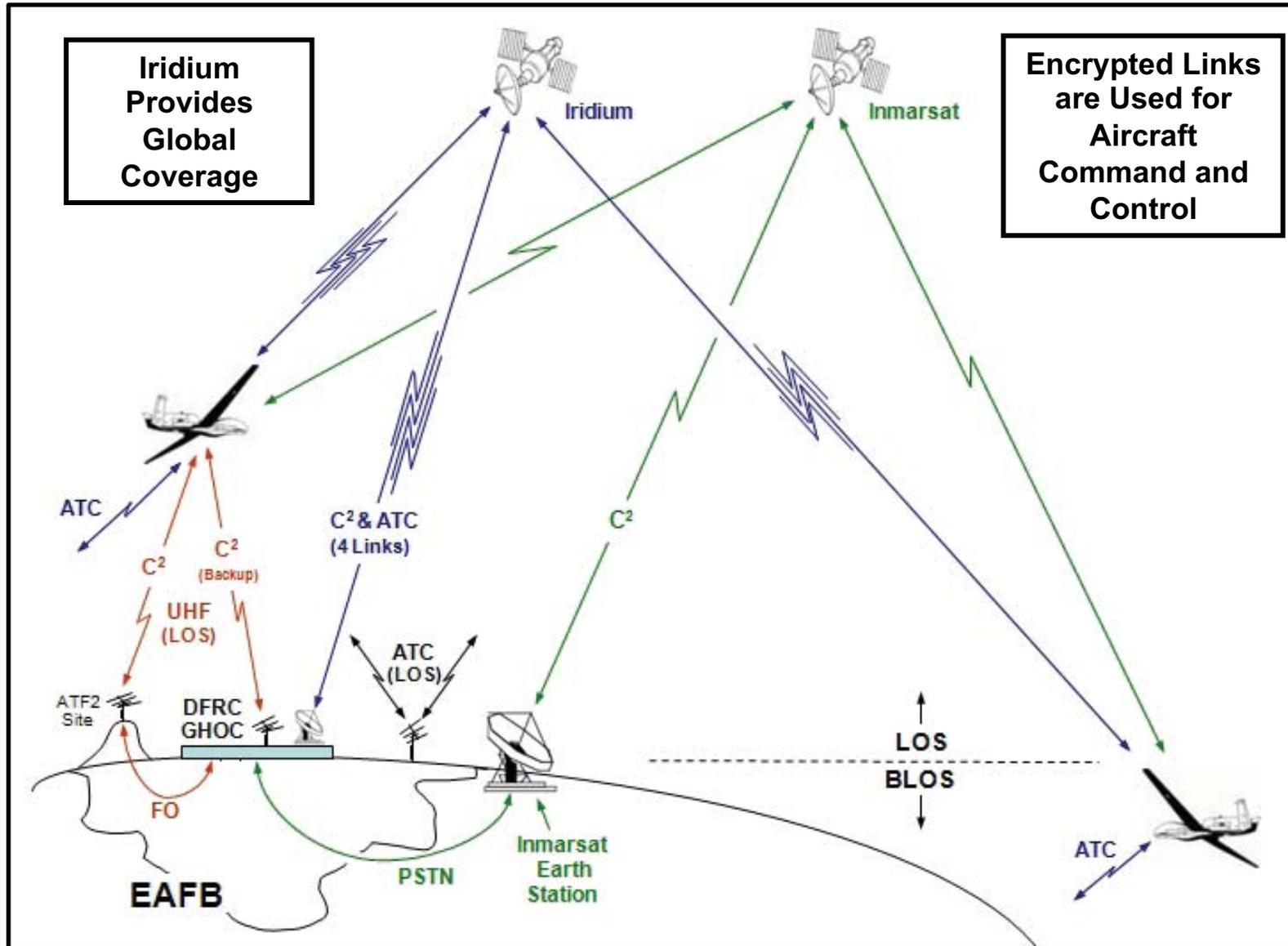
**Payload Mobile Operations Facility**

**Global Hawk Mobile Operations Facility**



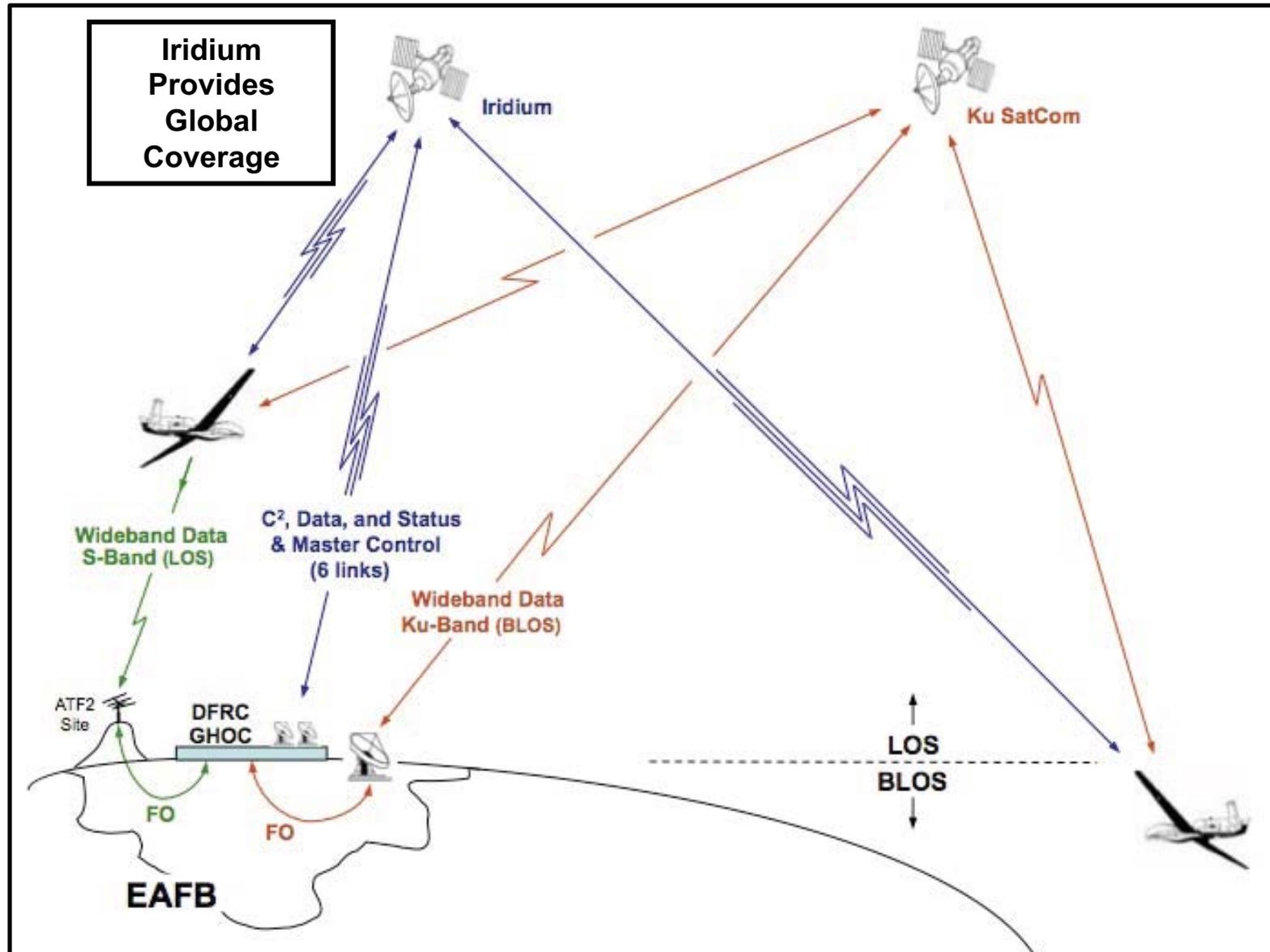


# Aircraft Flight Control and Air Traffic Control Communications Architecture





# Payload Communications Architecture





# Payload Integration and Accommodations



**Payload Power and Aircraft Data**

**Payload C<sup>2</sup> and Payload Data**



**Experiment Interface Panel & Ethernet Switch**  
(6 sets distributed on aircraft, each set supports up to 4 payloads)



**Payload Integration Test Bench**  
(Pre-Integration Checkout)



**Mounting Rails**



**Bay Under the Nose**



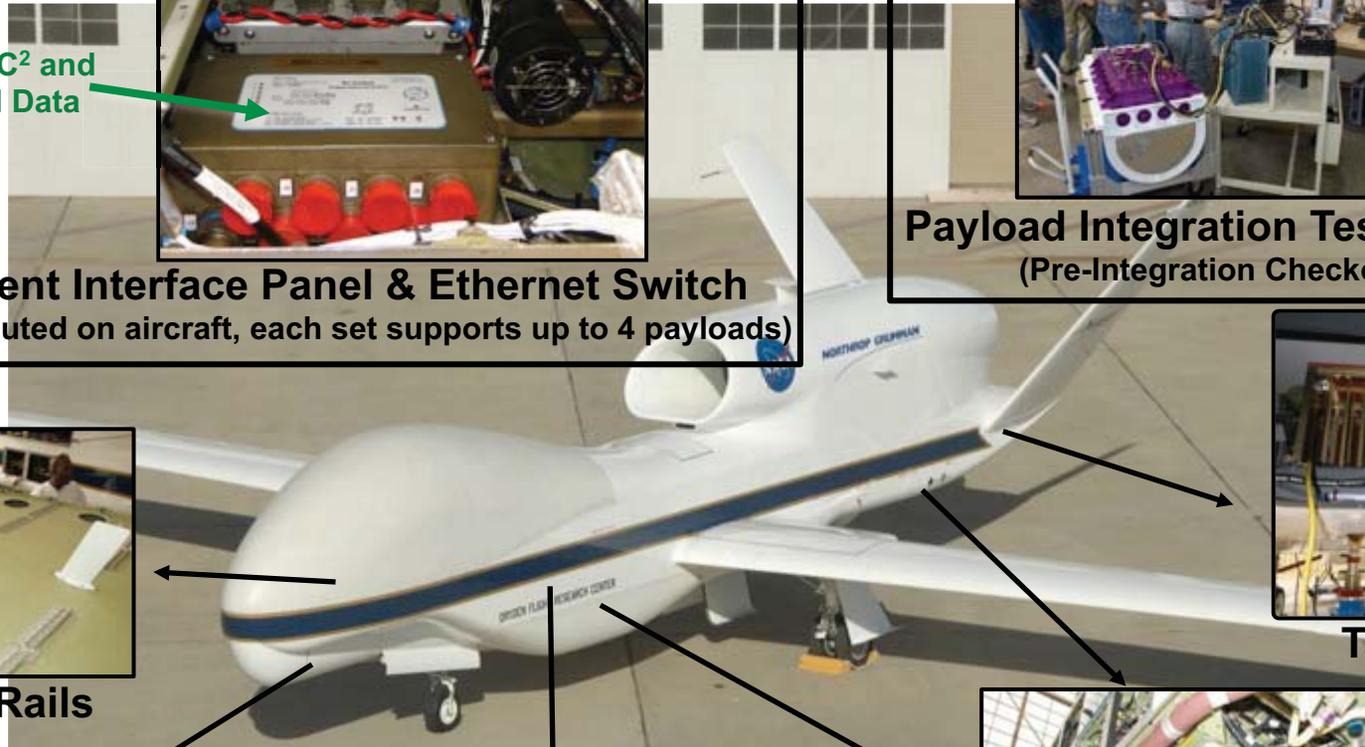
**Pallets and Specialized Hatches**



**Mounting Hard Points**



**Tail Zone**

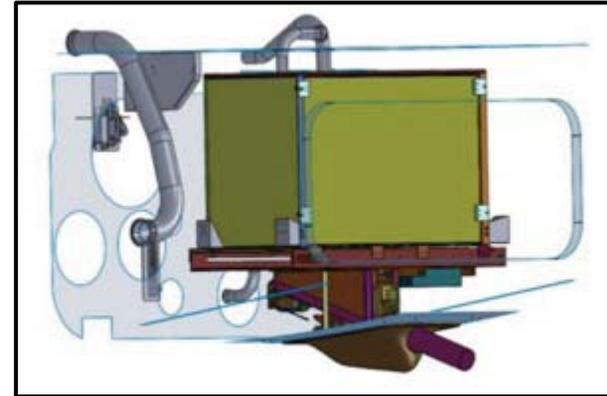




# Payload Integration Process (1 of 2)



- **Site visit at customer's location; initial discussion of payload and operational concept.**
- **Receipt of payload solid models and design/integration data from customer.**
- **Integration engineering (performed by AFRC and/or NGC).**
- **Avionics harness fabrication at AFRC.**
- **Fabrication and fit-check of payload mounting structure.**
- **Initial mechanical integration on aircraft.**





# Payload Integration Process (2 of 2)



- Environmental tests on payloads, as required.
- Electrical integration on payload test bench.
- Final integration on aircraft.
- Payload communications and payload data telemetry verification in the GHOC.
- Combined System Test with all aircraft and payload systems operating.
- Range check-out flight.
- Ready for operational flights.





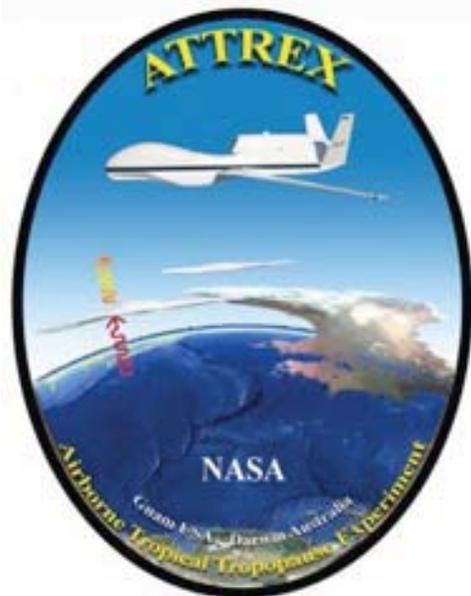
# Completed Science Campaigns



2010



2010



2011, 2013, 2014



2011



2011, 2012, 2013, 2014



# Global Hawk Science Flights (1 of 2)



**GloPac**  
2010

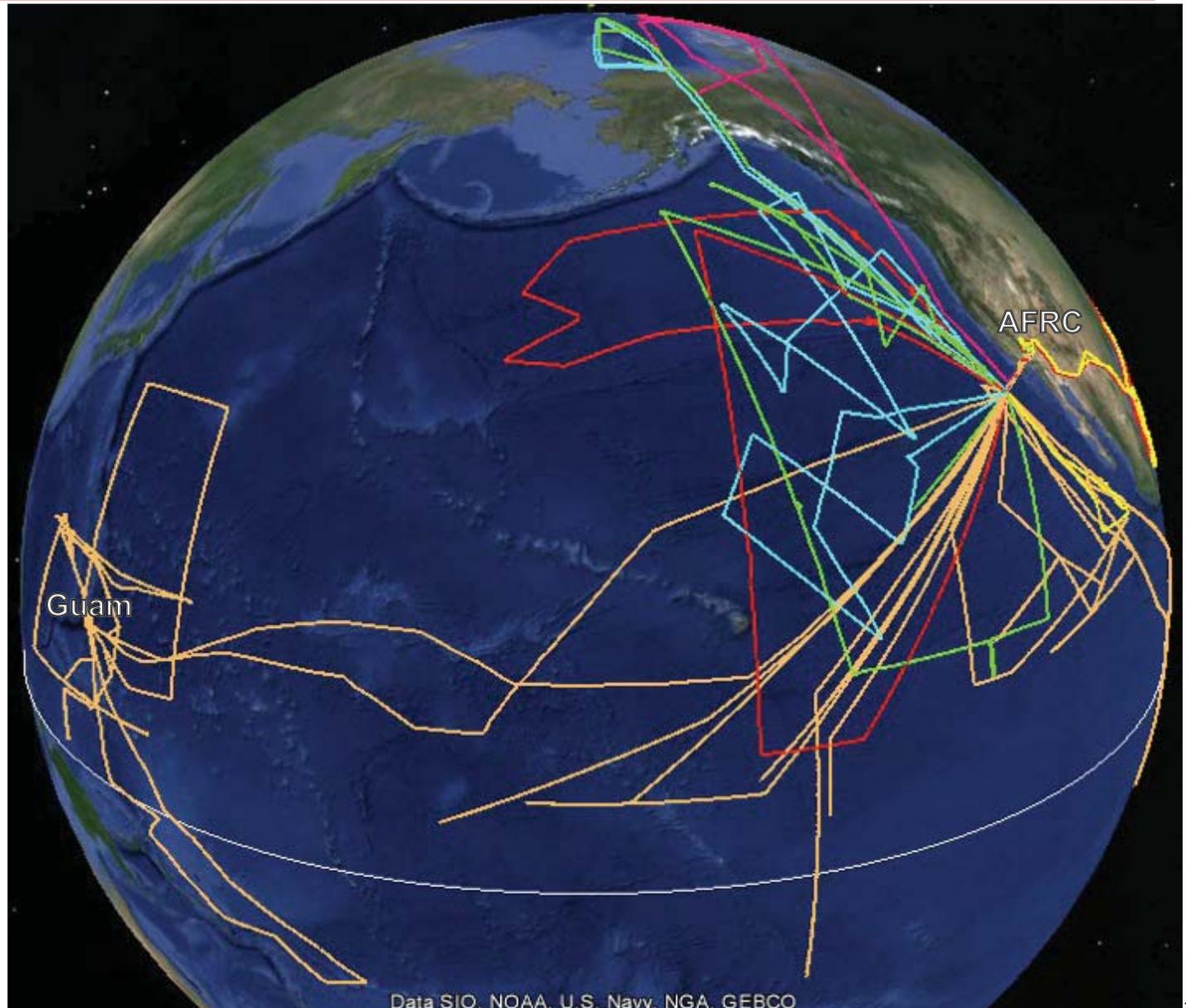
**GRIP**  
2010

**WISPAR**  
2011

**HS3**  
2011, 2012, 2013

**ATTREX**  
2011, 2013, 2014

**IceHawk**  
2013



Data SIO, NOAA, U.S. Navy, NGA, GEBCO



# Global Hawk Science Flights (2 of 2)



**GloPac**  
2010

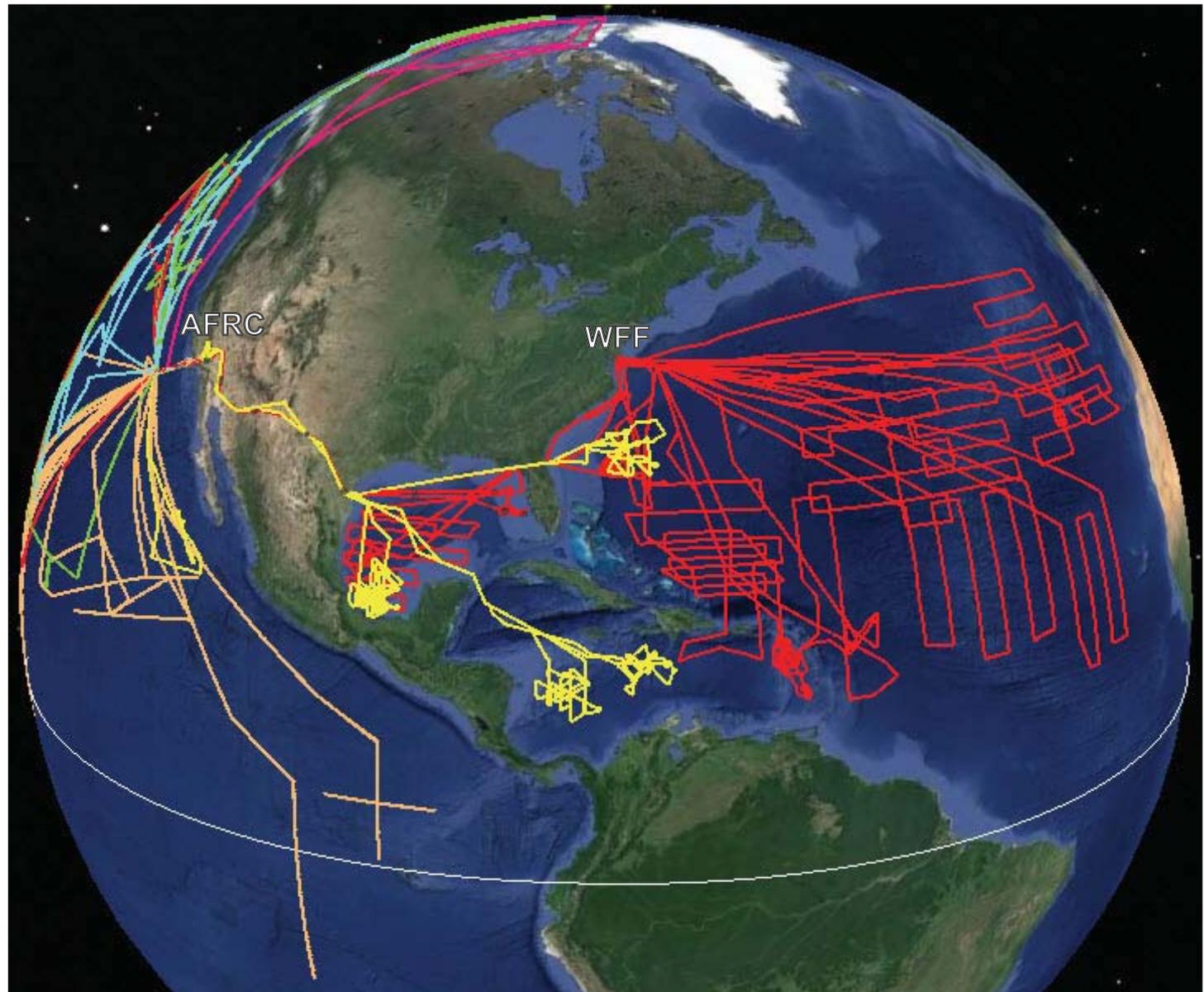
**GRIP**  
2010

**WISPAR**  
2011

**HS3**  
2011, 2012, 2013

**ATTREX**  
2011, 2013, 2014

**IceHawk**  
2013





# Global Hawk Pacific Overview

(March-April 2010)



- **First Science Mission conducted by any Global Hawk aircraft.**
- **Proved Global Hawk is a viable platform for Earth Science data collection.**
- **11 state-of-the-art instruments were installed on the aircraft for GloPac.**
- **4 science flights were flown over the Pacific Ocean and Arctic Region, totaling 76 hours.**
- **Flights spanned latitudes from 12-85 deg North.**





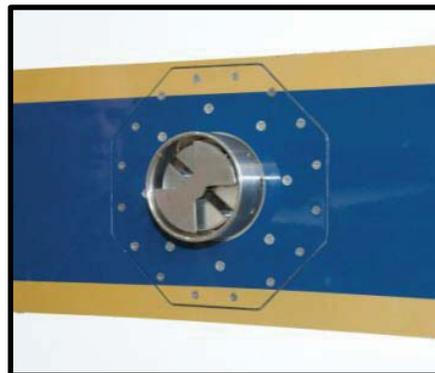
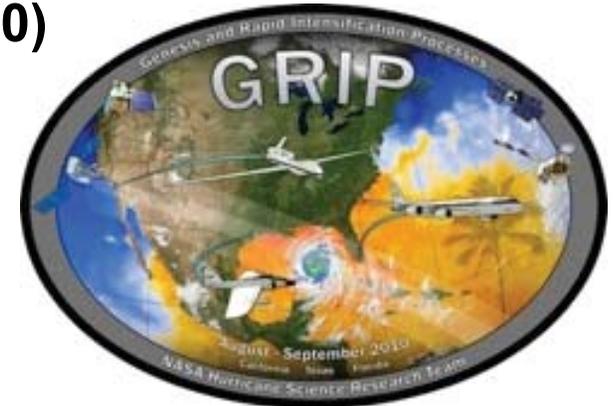


# Genesis and Rapid Intensification Processes Overview and Goals



(August-September 2010)

- 4 Instruments were integrated on the aircraft and 5 missions were flown totally 114 flight hours.
- First demonstration of Global Hawk Capabilities for Severe Storm Research
- Multi-agency, Multi-aircraft Research Campaign
- Improved Severe Storm Intensification Forecast Models
- Included the integration of new Global Hawk Payloads and new Aircraft Systems

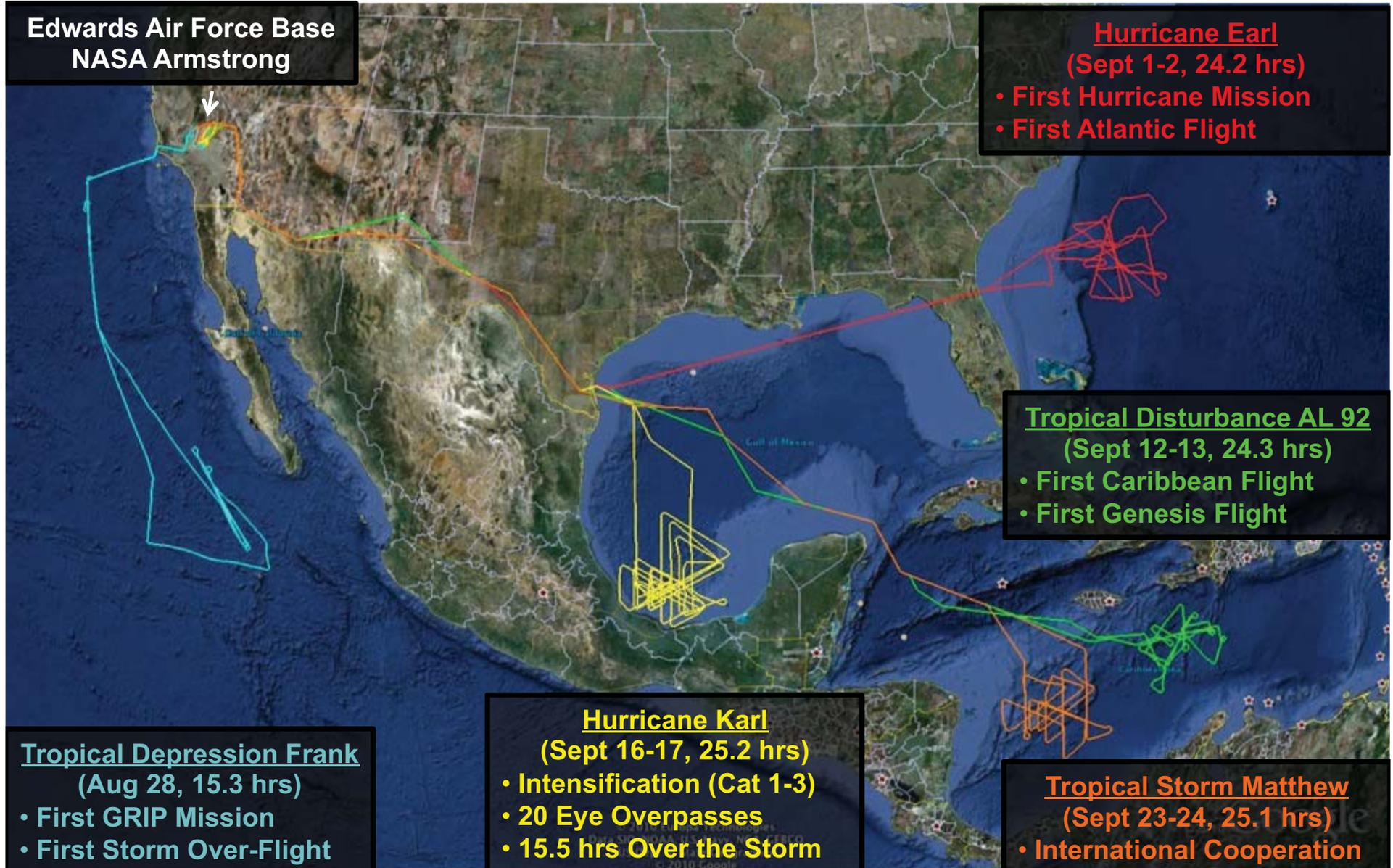




# GRIP 2010 Global Hawk Flights



Edwards Air Force Base  
NASA Armstrong



Hurricane Earl  
(Sept 1-2, 24.2 hrs)

- First Hurricane Mission
- First Atlantic Flight

Tropical Disturbance AL 92  
(Sept 12-13, 24.3 hrs)

- First Caribbean Flight
- First Genesis Flight

Hurricane Karl  
(Sept 16-17, 25.2 hrs)

- Intensification (Cat 1-3)
- 20 Eye Overpasses
- 15.5 hrs Over the Storm

Tropical Depression Frank  
(Aug 28, 15.3 hrs)

- First GRIP Mission
- First Storm Over-Flight

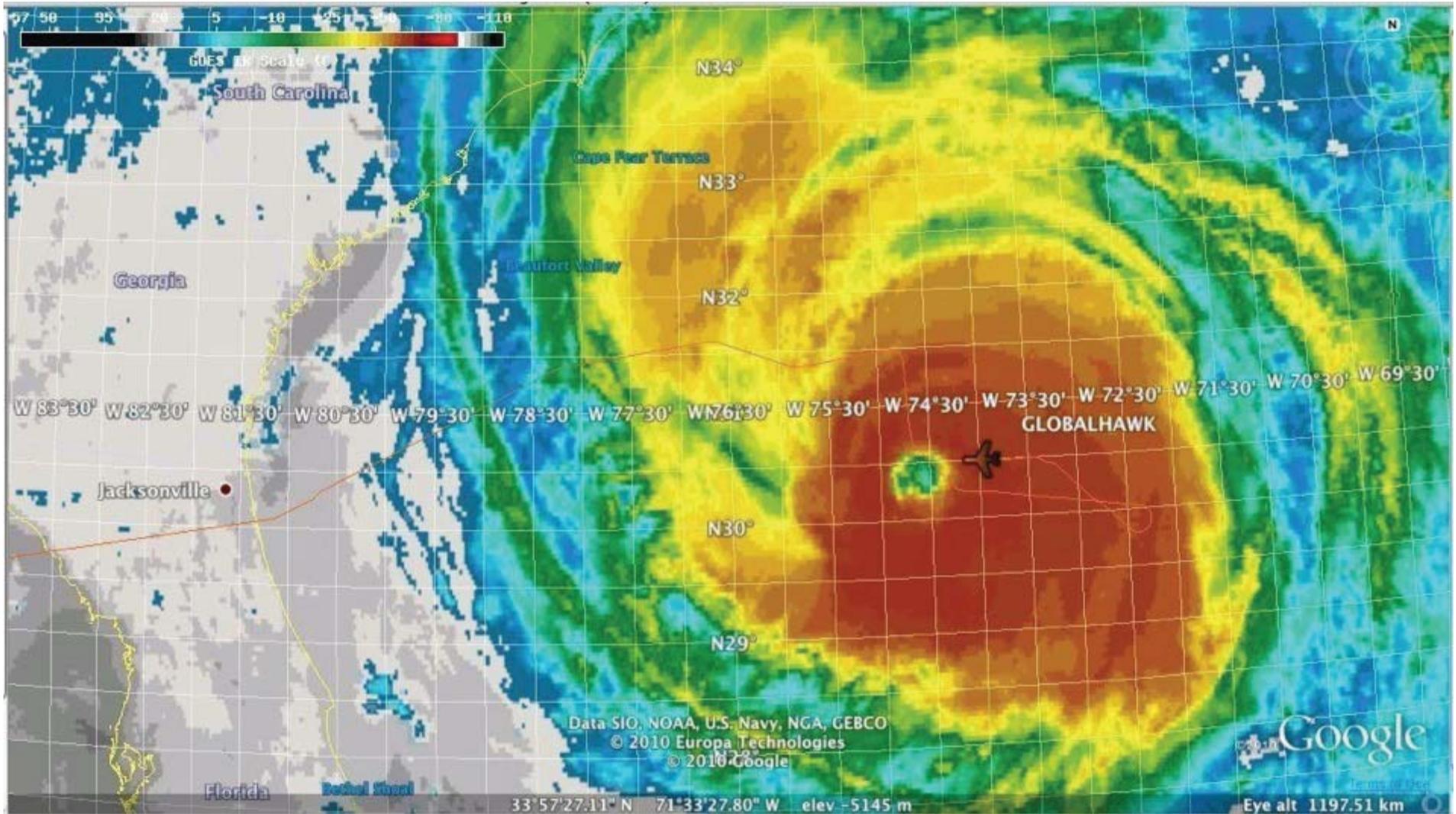
Tropical Storm Matthew  
(Sept 23-24, 25.1 hrs)

- International Cooperation



# GRIP – Hurricane Earl, Sept 2010

First Global Hawk Flight over the Eye of a Hurricane





# Winter Storm Pacific and Atmospheric Rivers Overview



(February-March 2011)

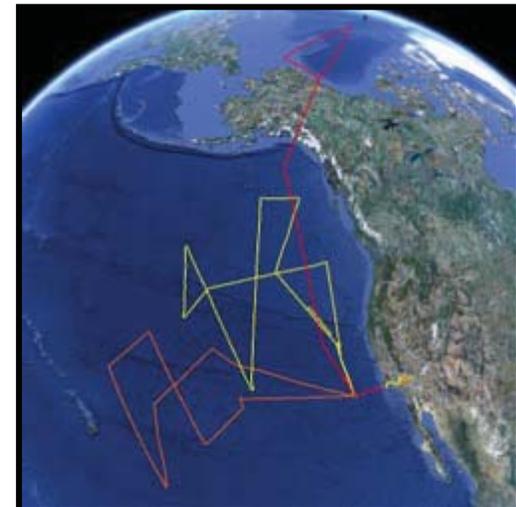
- First NOAA-sponsored Global Hawk Earth Science Campaign.
- 2 Instruments were installed on the aircraft; HAMSr and AVAPS
- 3 science missions were flown, with a total of 70 flight hours.
- First operational dropsonde deployment from any UAV (70 were deployed during a single flight).



Dropsonde Deployment



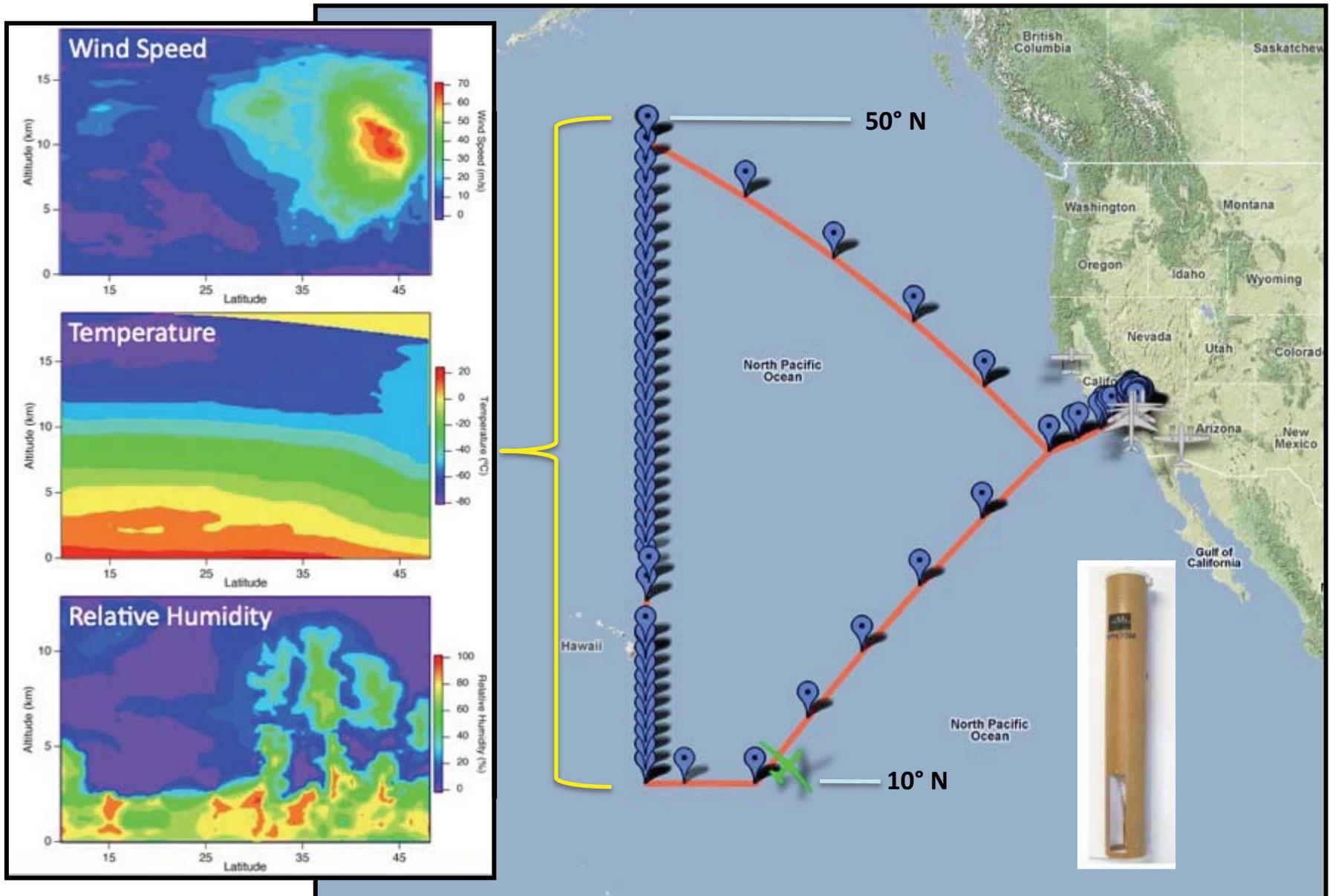
Dropsonde on Chute



Flight Tracks



# Example of Dropsonde Data from a Pacific Flight





# Airborne Tropical Tropopause Experiment Overview



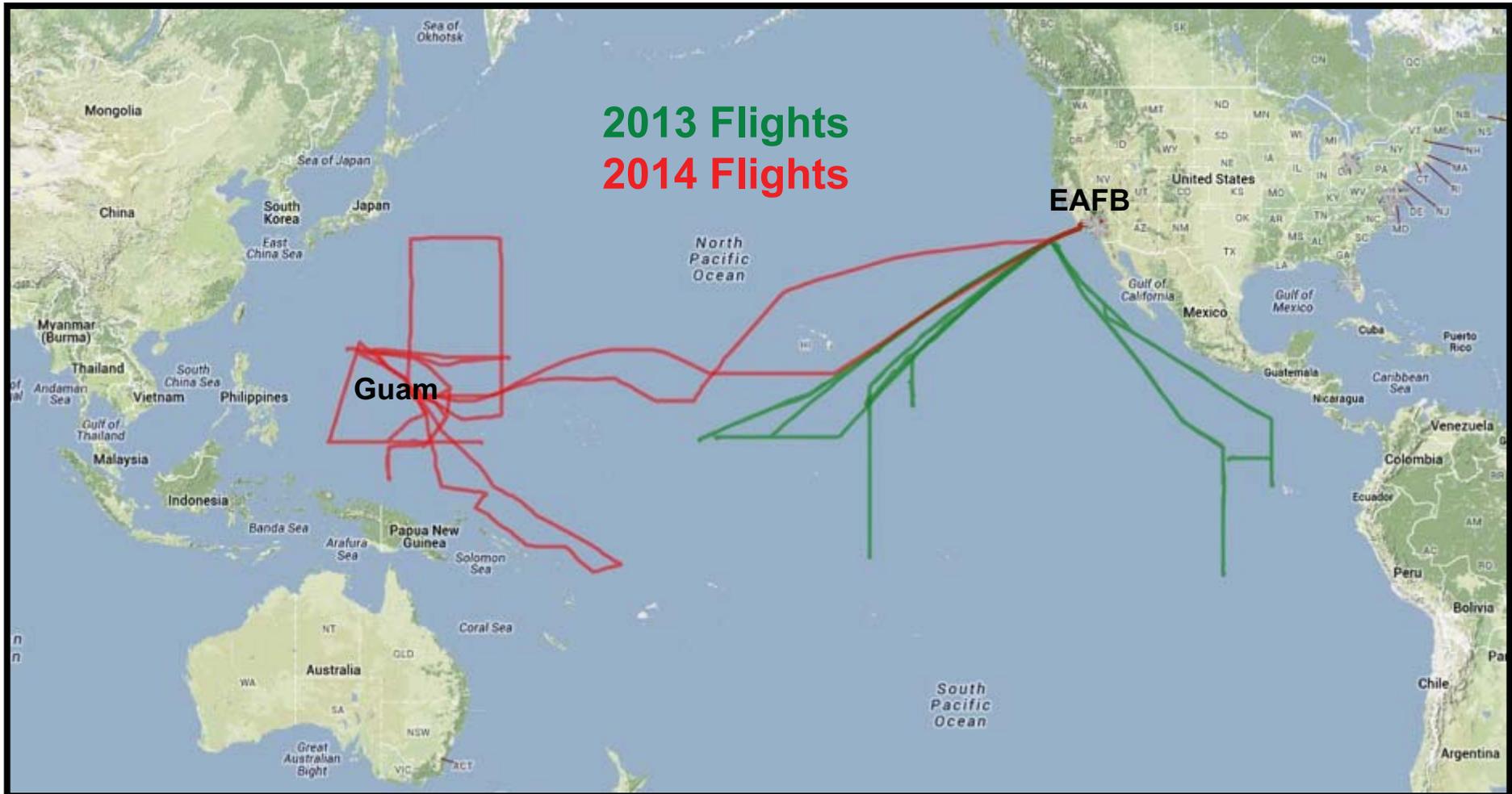
(October-November 2011, February-March 2013,  
January-March 2014)

- 11 instruments were flown on the NASA Global Hawk aircraft in 2011 and 2013 and 12 instruments were flown in 2014.
- 18 science missions, totaling 350 flight hours were flown during the 3 ATTREX campaigns.
- The flights in 2011 featured the first science demonstration in the tropics.
- The flights in 2014 featured the first OCONUS deployment for NASA Global Hawk.





# ATTREX Flight Tracks





# Hurricane and Severe Storm Sentinel Overview



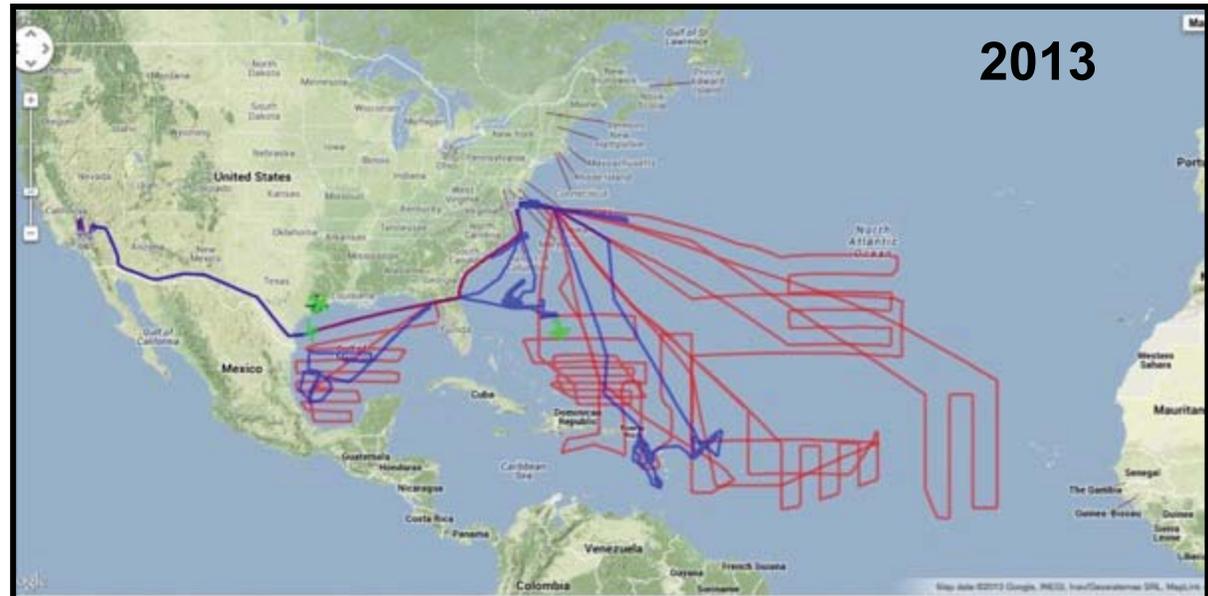
(August-September 2011, August-September 2012, August-September 2013)

- 3 instruments were installed on each of the two NASA Global Hawk aircraft.
- 19 science missions, totaling 475 flight hours have been flown during the first 3 years of HS3.
- The flights in 2011 featured the first science demonstration utilizing dropsondes in real time.
- Over-flights of many named storms, including hurricanes, have been conducted.





# HS3 2012 and 2013 Flight Tracks





# HS3 2014 Flight Tracks



**Eleven  
Science  
Flights**

**Eye of  
Hurricane  
Edouard by  
Moon Light**

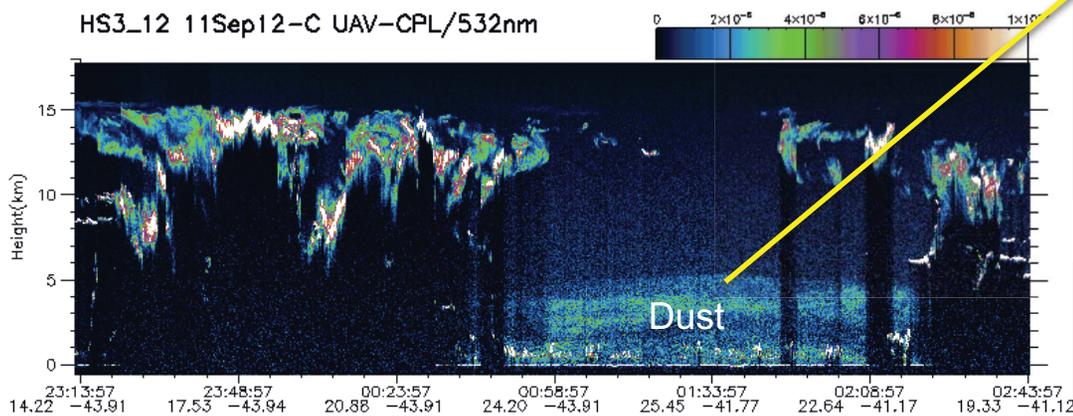
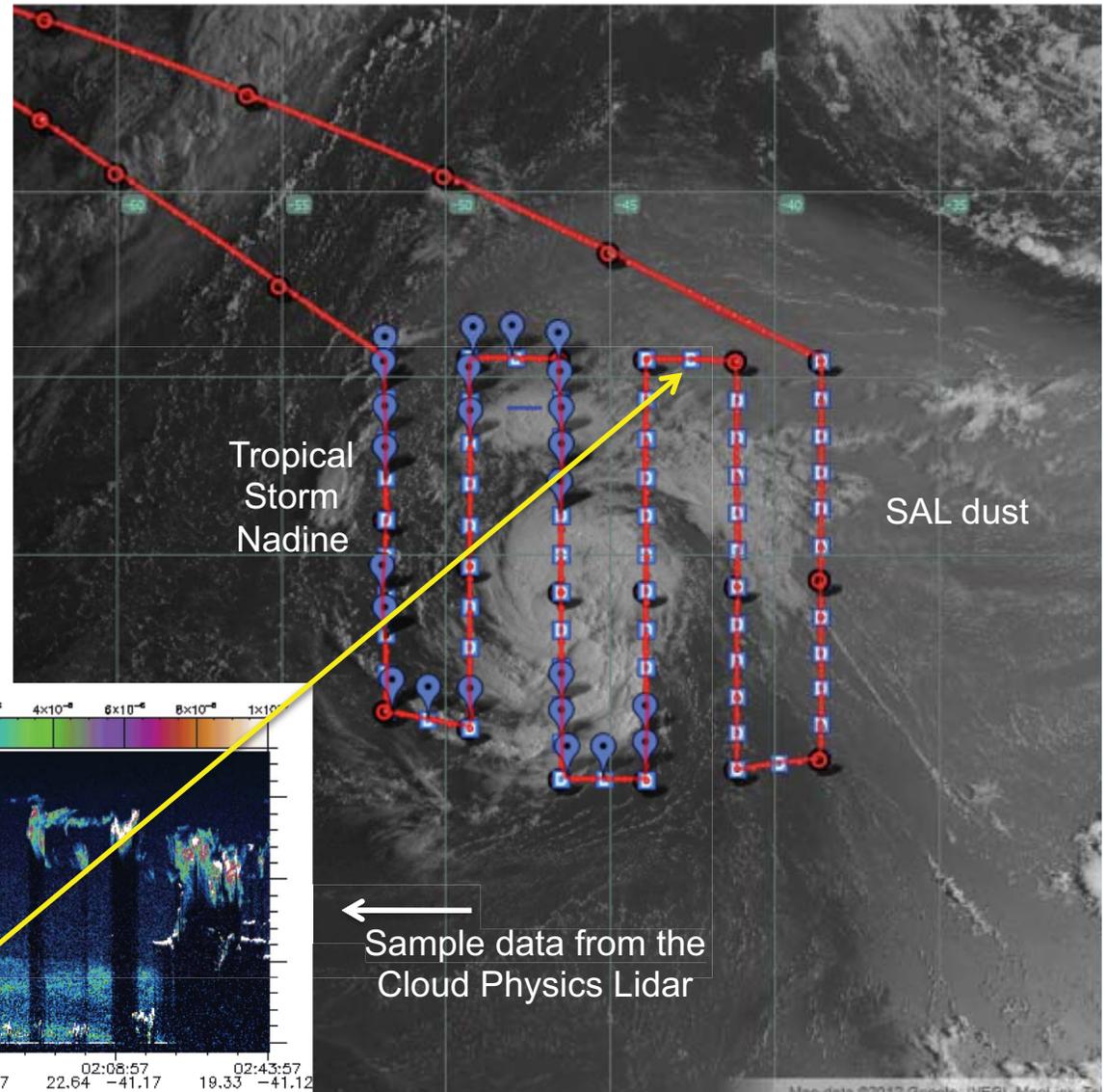




# HS3 Explored Nadine's Interaction With the SAL (Sept. 11-12, 2012)

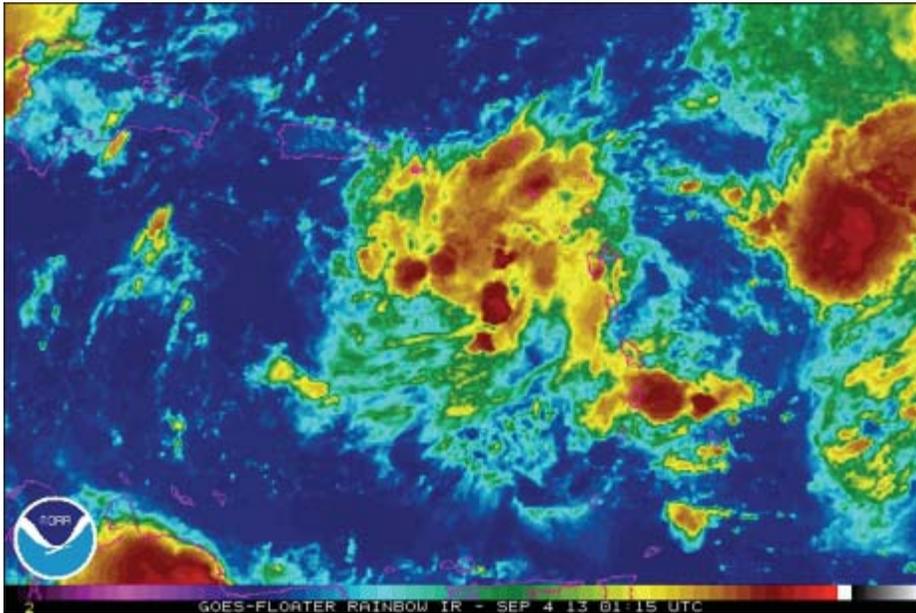


Warm, dry, dusty air wrapped around the eastern and northern side of Nadine, but didn't get into the storm circulation





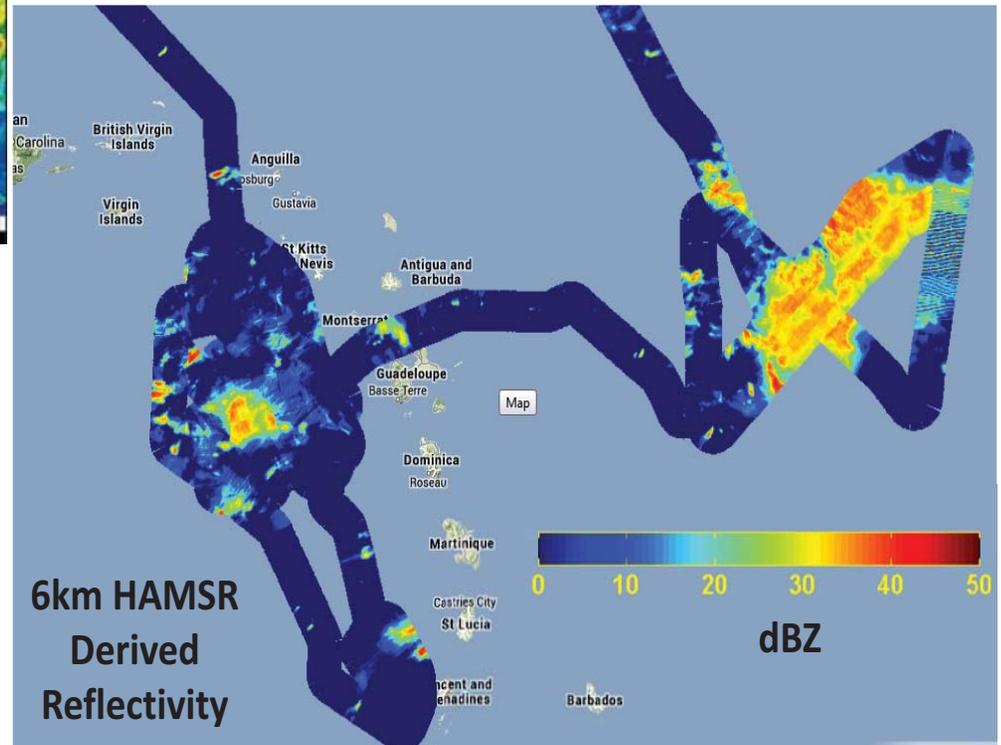
# HS3's First AV-1 Flight: Precursors to TS Gabrielle (Sept. 3-4, 2013)



(Above) GOES imagery shows two systems with potential for development

More widespread rain in the eastern system, but the western one later becomes Gabrielle

(Right) HAMSAR shows estimated mid-level precipitation intensity



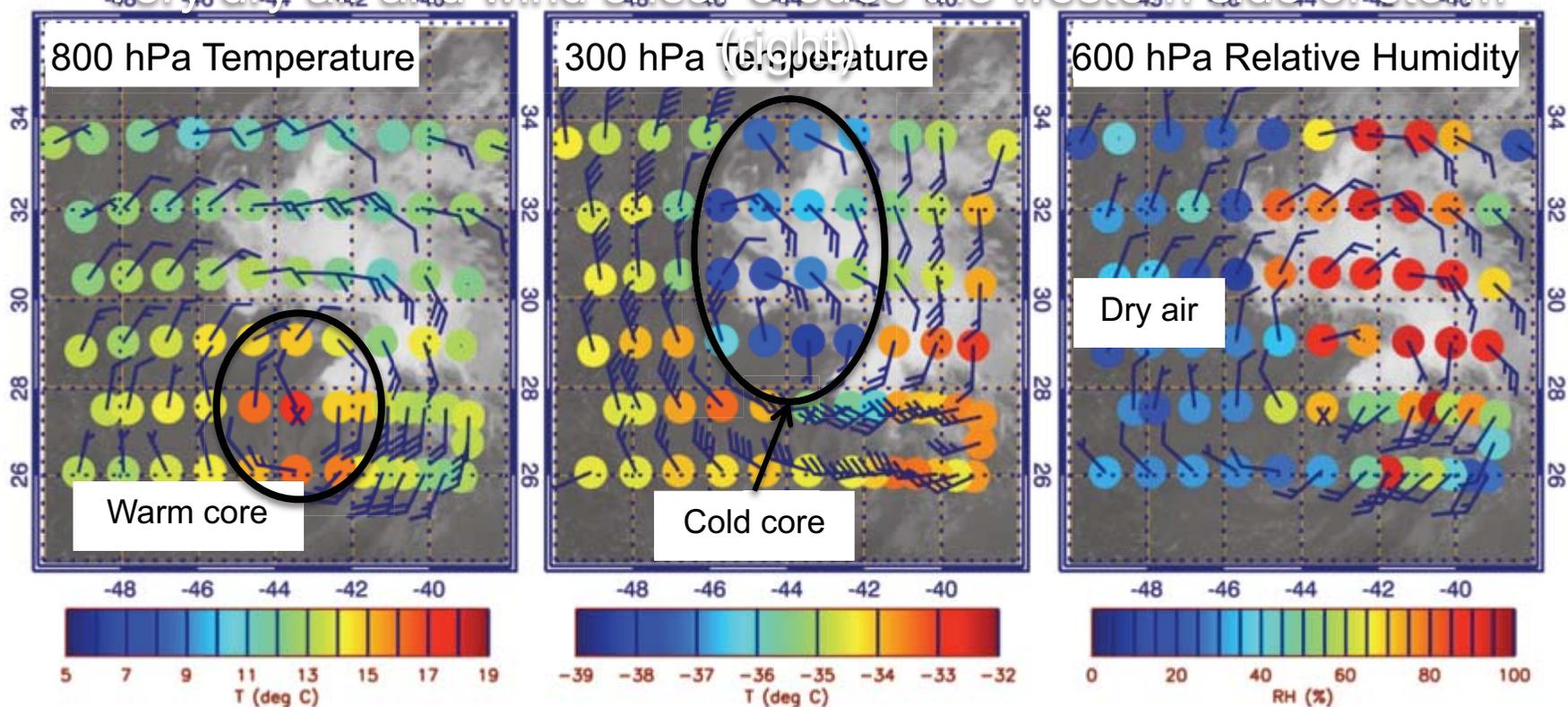


# Humberto Redevelops As A Hybrid System (Sept. 16-17, 2013)



- Warm air near center at low levels (left), cold air at upper levels (center) makes Humberto a hybrid tropical-extratropical storm

• Very dry air and wind shear erodes the western side of storm

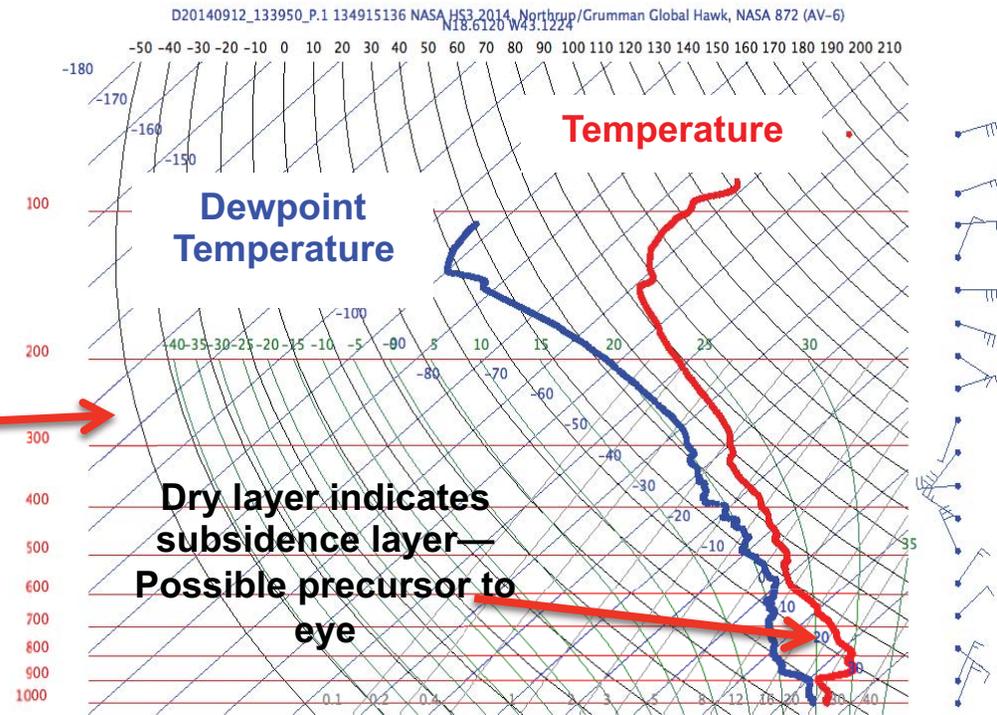
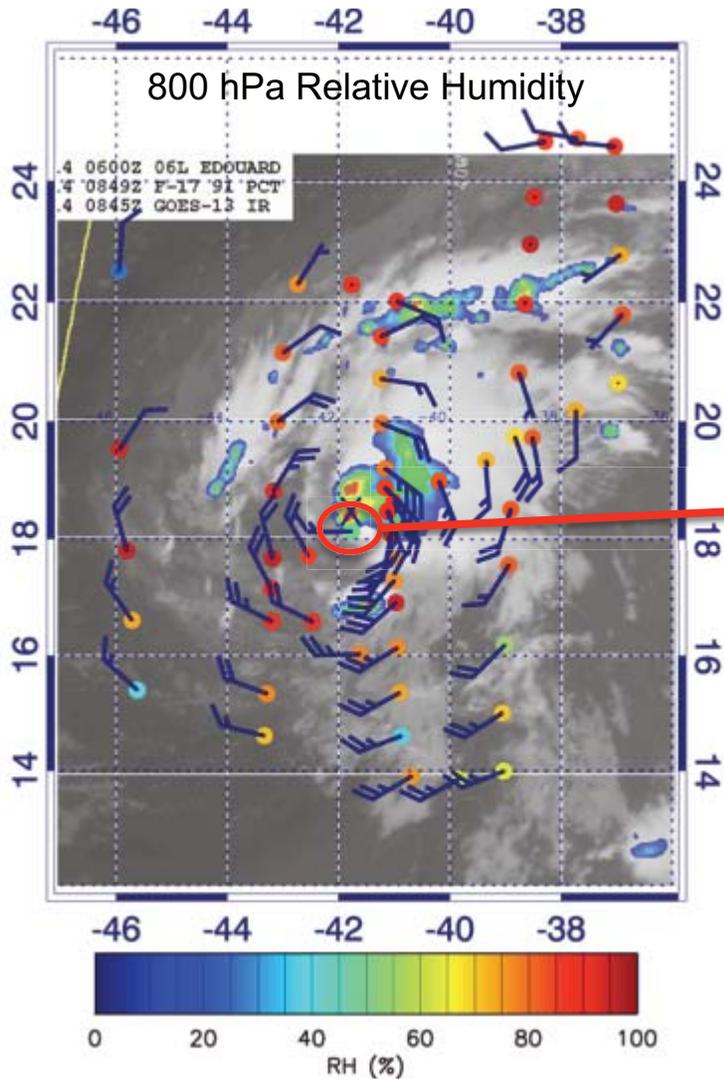




# Tropical Storm Edouard Forms



September 11-12, 2014



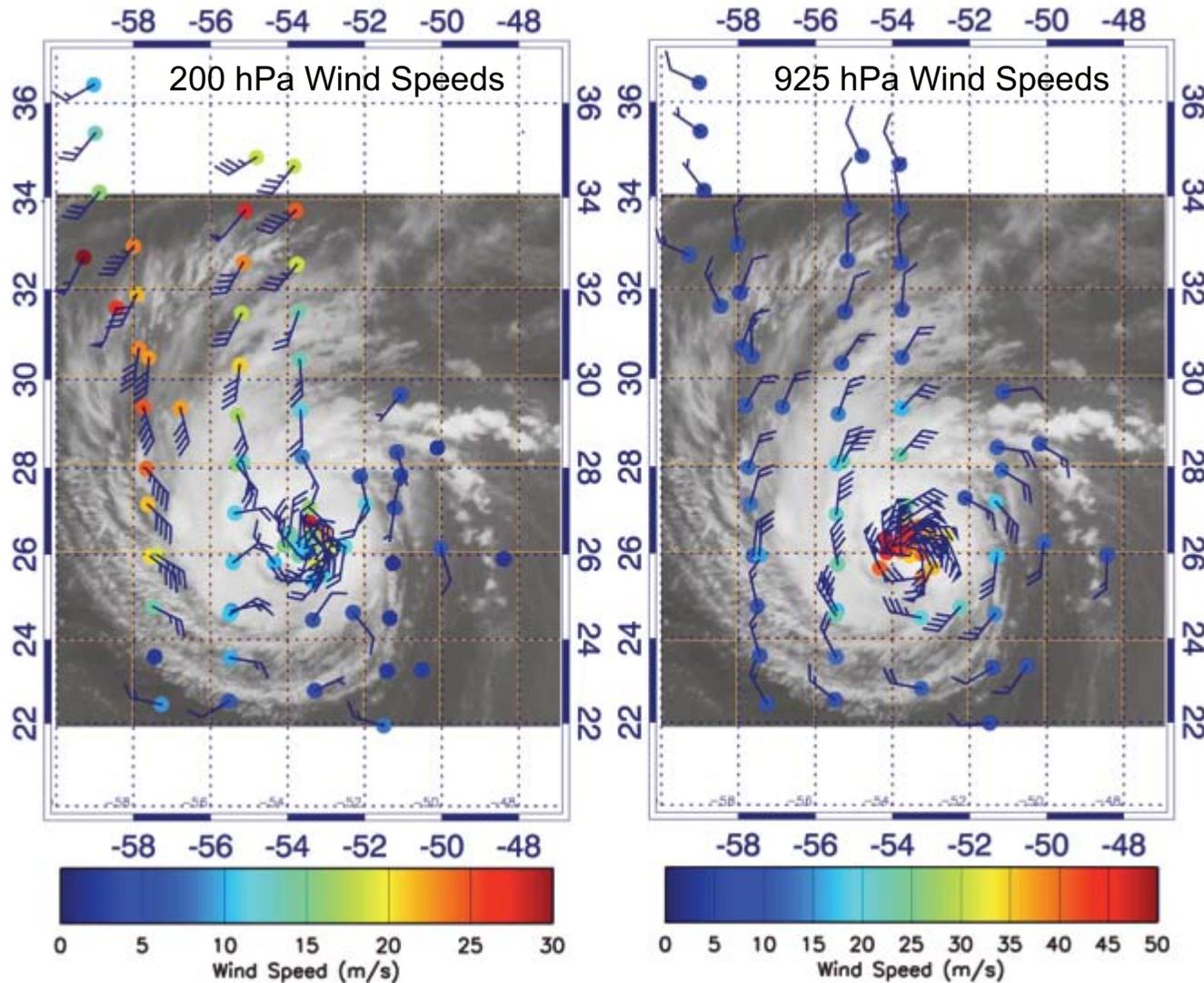
Aspen 3.1, 12 Sep 2014 15:16 UTC



# Edouard Rapidly Intensifies



September 14-15, 2014

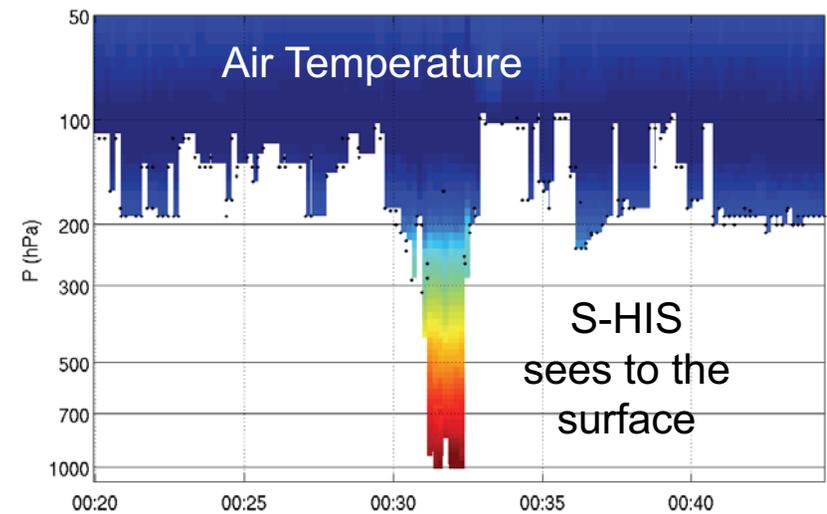
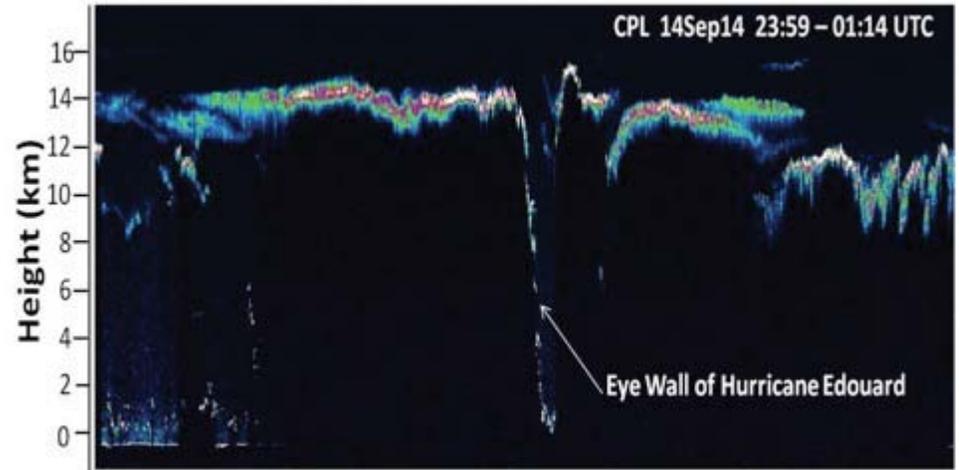
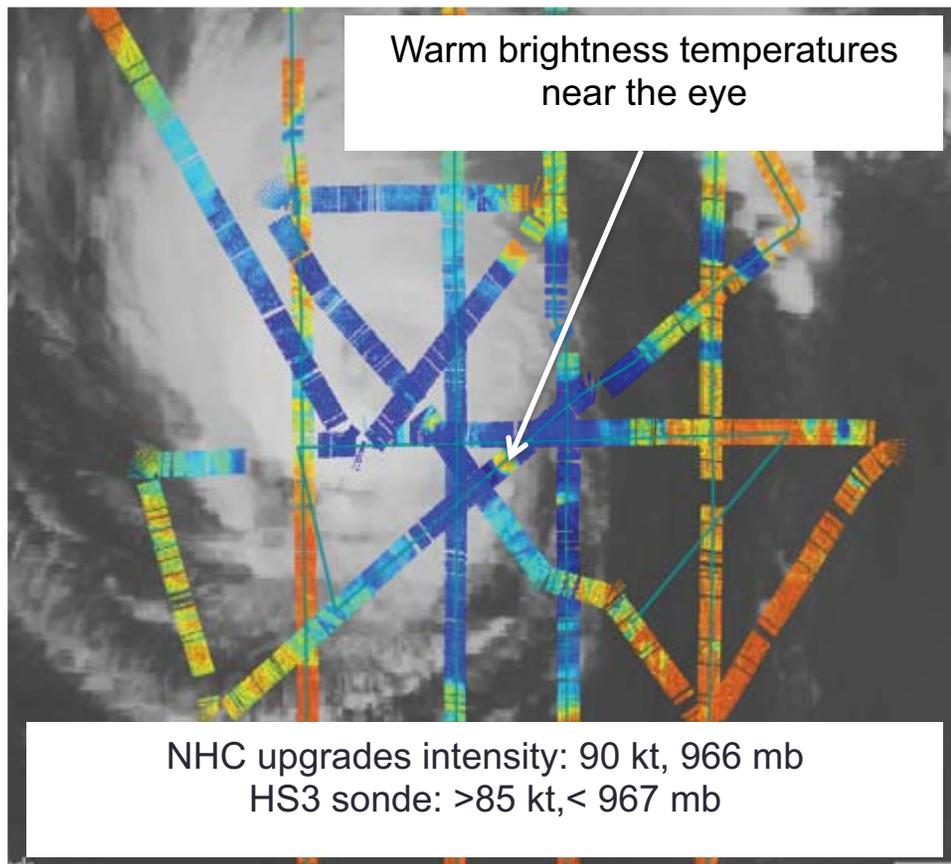


Maximum winds increases from 60 to 90 kt from 09 UTC Sept. 14 to 09 UTC Sept. 15

Strong outflow jet to northwest



# Bullseye For The Global Hawk on Second Pass Over Edouard—NHC Upgrades Intensity Estimate

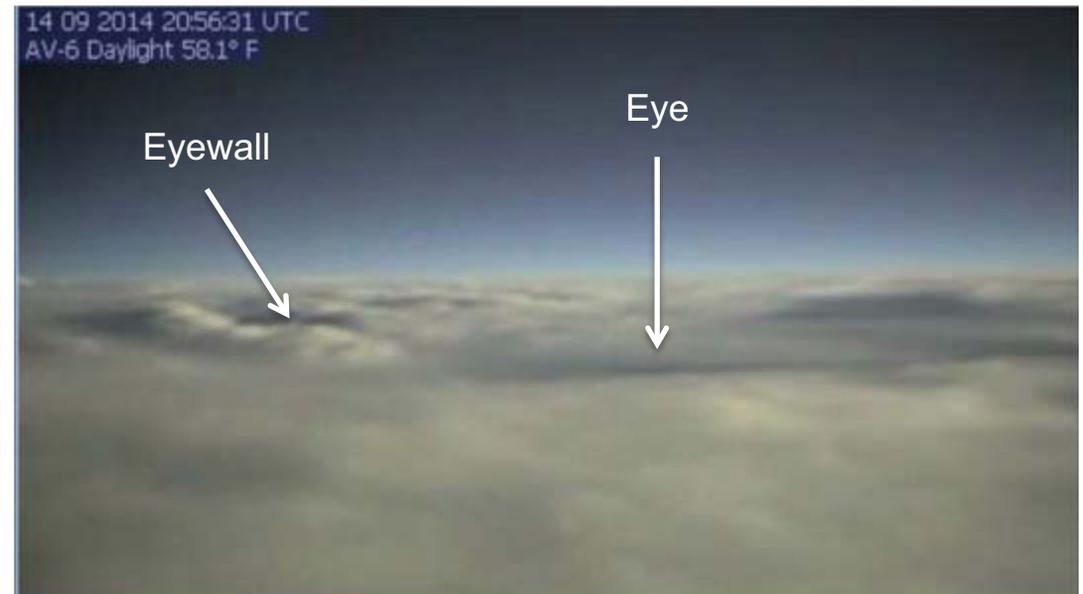




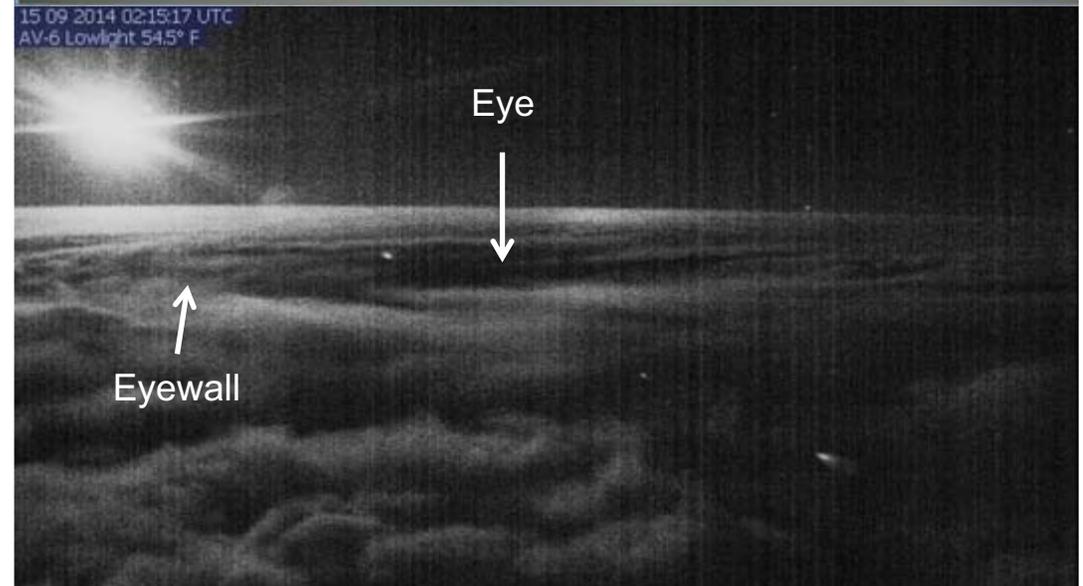
# Camera Views of Edouard



Top image:  
Daylight camera view of  
the eye of Edouard during  
the first eye crossing



Bottom image:  
Low-light camera view of  
the the eye (and moon)  
during the third eye  
crossing





# Edouard at Maximum Intensity

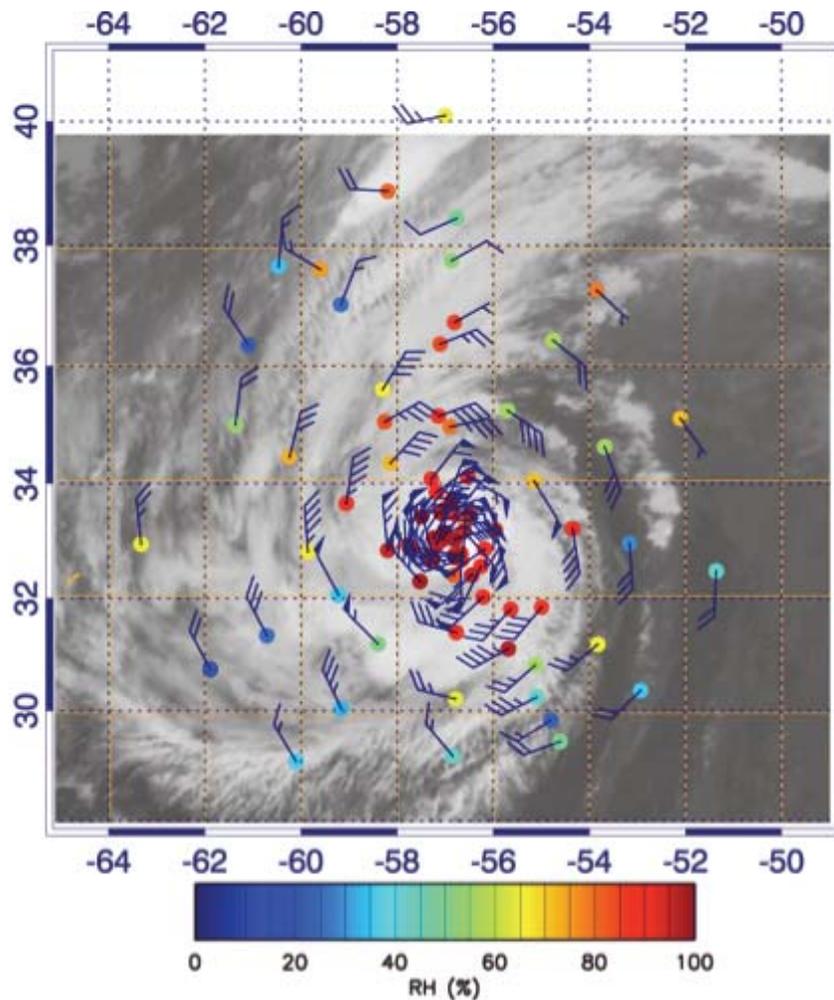
September 17-18, 2014



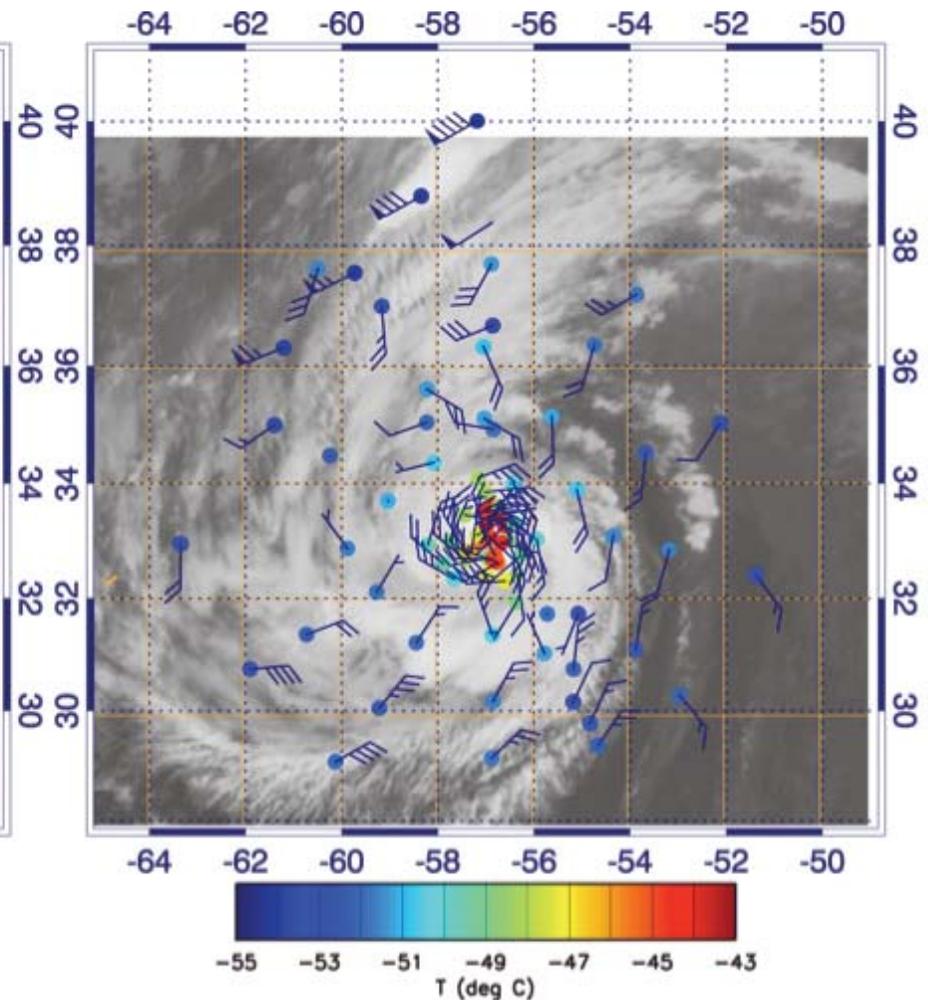
Dry air wraps around Edouard at mid levels, but stays well outside the core

Two primary regions of outflow, one to the north, one south

700 hPa Relative Humidity



200 hPa Temperature





# IceHawk

(December 2013)



- The UAV Synthetic Aperture Radar (UAVSAR) was integrated onto the aircraft.
- A single flight was conducted over the Pacific Ocean and Canada.
- This flight marked the first UAVSAR flight outside of the EAFB range and the first NASA Global Hawk flight over a foreign country.
- Coordination with the Canadian Government was straightforward.
- The IceHawk flight was funded by NGC.

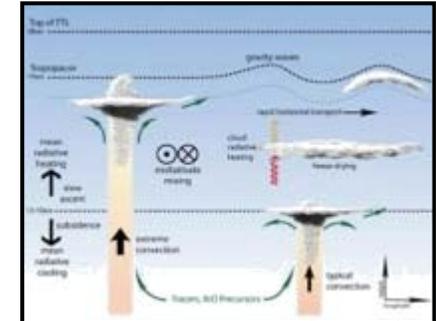




# Future Global Hawk Missions



- **Coordinated Airborne Studies in the Tropics (CAST) (2015)**
  - 1 aircraft with 8 instruments
    - 2 new instruments from UK's NERC (Natural Environment Science Instruments)
    - 6 legacy instruments from ATTREX
  - Integration/Test – December 2014-February 2015
  - 4-6 flights from AFRC to Pacific tropics – February-March 2015
  
- **Sensing Hazards with Operational Unmanned Technology (SHOUT) (2015)**
  - NOAA Reimbursable Agreement covering 2015-2017
  - 1 aircraft with 3-4 instruments (same instruments as GRIP 2010)
  - Integration/Test – July-August 2014
  - 10 flights from AFRC or WFF – August-October 2014

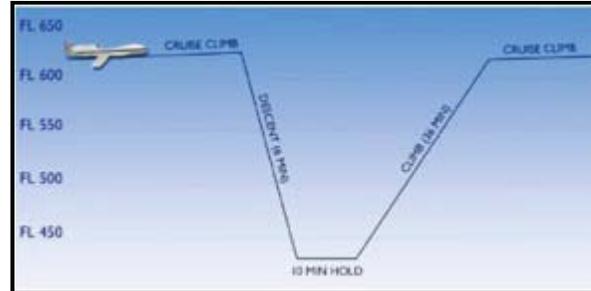




# Global Hawk “Firsts” Accomplished by the NASA/NGC Team (1 of 3)



- 1) Flights above 70 deg latitude. The aircraft has reached 85 deg N three times.
- 2) Flights over hurricanes and severe storms, including a single flight that included 15.5 hours over a hurricane and 20 over-flights of the eye.
- 3) Vertical profile maneuvers during science flights for the collection of atmospheric data.
- 4) Release of dropwindsonde weather instruments in the National Airspace System. (First FAA approval for release of stores from a Global Hawk)
- 5) First Global Hawk operations at Wallops Flight Facility and first science flights from Andersen AFB.
- 6) Autonomous formation flight of two Global Hawk aircraft The two aircraft were as close as 30 feet apart while flying in formation for 2.5 hours.





# Global Hawk “Firsts” Accomplished by the NASA/NGC Team (2 of 3)



- 7) Implementation of an independent payload power and data telemetry system on Global Hawk.
- 8) First flight of the AESA-360 radome on a Global Hawk aircraft. This radome provides greater volume for instruments under the aircraft and has been used to house the HiWRAP and Twilite Instruments.
- 9) Implementation of wing mounted instruments on an ACTD aircraft (Hawkeye for ATTREX 2014).
- 10) Ku system implementation for payload data telemetry, payload C2, and Ku ATC.
- 11) Implementation of ARTS on a Global Hawk aircraft.
- 12) Implementation of a rear payload mounting capability in the tail cone and on the bottom of the aircraft under the rear pressurized compartment.

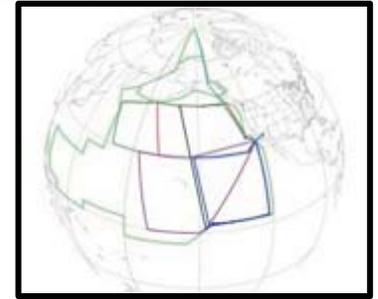
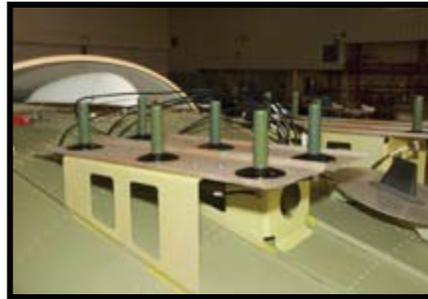
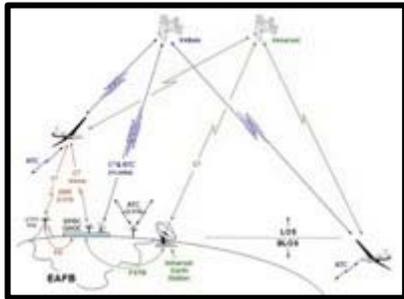




# Global Hawk “Firsts” Accomplished by the NASA/NGC Team (3 of 3)



- 13) Aircraft command and control with Iridium communications links.
- 14) ATC communications with Iridium communications links.
- 15) Dissemination of high definition pictures from the aircraft to the public in real time. These pictures and the flight track are shown on a publicly available website for public awareness of the science missions.
- 16) Largest geographical COA ever granted by the FAA. The GloPac COA covers most of the Pacific Ocean north of the Equator, and extends to the North Pole.
- 17) Most complex mission plan ever created. The GRIP mission plans contains many routes to ensure options for avoiding restricted areas and avoiding atmospheric conditions outside of aircraft limits.
- 18) Development of a new Ground Control Station, based on NGC’s Common System Architecture.



HDVIS/StarDot Sat Aug 28 23:08:01 2010 Flight -GLOPAC\_4  
Exposure: 5 MAC 0030F4-D1127B  
Frame number 379685  
Internal Temperature 14.0°C

**Global Hawk Project Manager**  
**[chris.naftel@nasa.gov](mailto:chris.naftel@nasa.gov)**  
**661-276-2149**

**Tropical Depression  
Frank - Aug 28, 2010**