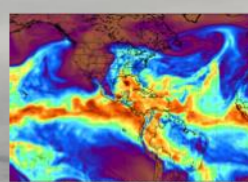
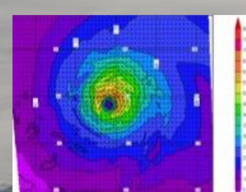
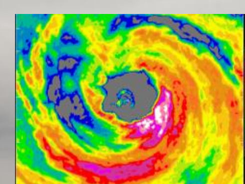
Optimizing observations and observing strategies to better evaluate and improve model physical processes

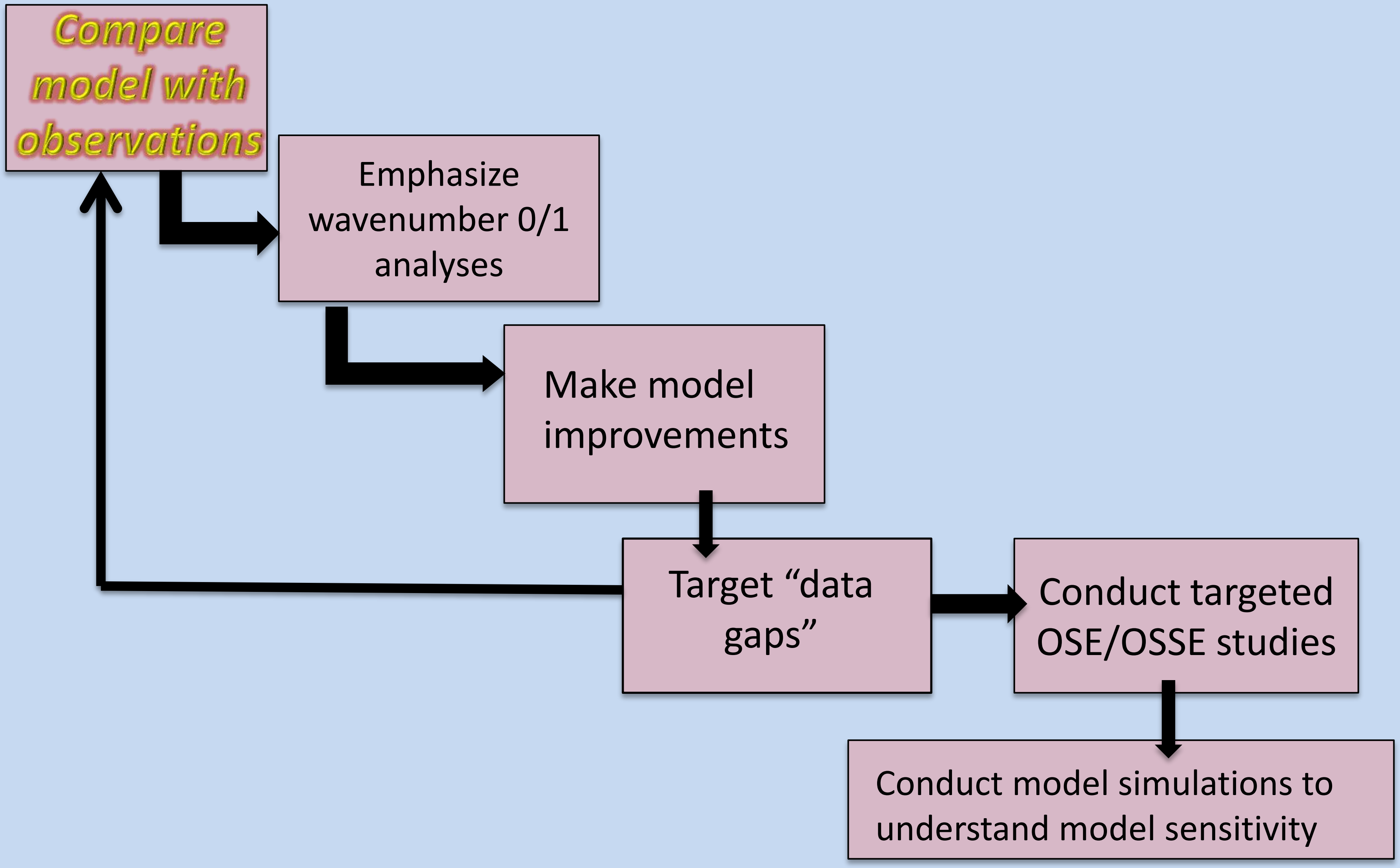
Joseph Cione
HFIP telecon
22 October 2014

Motivation

Overarching Objective…

Improve forecast performance through a systematic evaluation process, whereby model biases are documented, understood, & ultimately eliminated by implementing accurate, observation-based physical parameterizations.

Model Evaluation & Improvement Methodology…



Workshop:

Strategic use of observations to reduce model physics uncertainty

7-8 August 2014

NOAA's Earth System Research Laboratory
Boulder, Co

- A Joint effort by: ESRL's Physical Sciences Division and AOML's Hurricane Research Division

<u>In support of:</u> *NOAA's funded Sandy Supplemental project: "**The Impact of Emerging Observing Technologies on Future Predictions of Hurricane Structure and Intensity Change"** and NOAA's Hurricane Forecast Improvement Project.*

Workshop Goals

<u>(Short-term) goal</u>: Within the context of NOAA's operational hurricane prediction system, look to identify areas of high uncertainty within the coupled modeling system that can be minimized by modifying existing observing strategies and/or utilizing new and emerging technologies and observing systems.

- ***Primarily from a coupled modeling perspective, highlight a few known (or perceived) key areas of model physics uncertainty or bias***
- ***Highlight the use of upcoming observational resources that could potentially (and practically) be used to minimize model physics uncertainty within these key areas (e.g. via modified sampling strategies, enhanced data coverage in time/space, use of new observing platforms, etc.)***
- ***Formulate, 'best practice' strategies to use existing observational resources to optimally target specific physical processes and 'high value' areas of the storm environment.***
- ***Or, in simpler terms…identify and 'oversample' the low hanging fruit!***

Workshop Goals

<u>(Medium-term) goal</u>: Begin an *<u>ongoing</u>*, model physics evaluation and improvement dialogue between observationalists and modelers (of all scales) within and outside the hurricane research and operational communities.

- ✧ Discuss model physics evaluation and improvement activities and future possibilities within the context of other (non-hurricane) regional and global modeling systems
- ✧ ***Identify common (cross-cutting) physics evaluation themes and approaches to potentially work on and/or target jointly***
- ✧ ***Discuss the potential advancement of new observing technologies that could help data coverage or quality in areas that currently do not allow for adequate model physics analysis (e.g. use of UAS, new aircraft, sensors, observing strategies, platforms, etc.)***
- ✧ Identify existing (re-programming) and new potential funding resources that could help advance future model physics evaluation and improvement activities
- ✧ ***Continue the model physics evaluation and improvement dialogue and look to identify the next possible workshop timeframe/venue/host/theme***

Model Physics Evaluation and Improvement Workshop
Boulder 6-7, 2014
Group-Identified Areas of "High Priority"...

A. TC Warm core structure – Lead: Jason D.; (Jun Z.)

1. Desired measurements – environmental p, T, q; inner core p, T, q
2. Minimum measurement accuracy requirements – N/A
3. Platforms/Instr – dropsondes, globalhawk HAMSR, globalhawk scanning HIS, future uplooking radiometer
4. Time of day – N/A
5. Mission frequency – At least once per day; more frequently for RI
6. Radial/azimuthal coverage – For enviro, 400 km or greater, for core, 150 km or less
7. Flight level – GH 55-60k ft, G4 41-45k ft, WB-57 60-65k ft

B. Radial profile of rainfall – Lead: Chris F.

1. Desired measurements – reflectivity (precipitation)
2. Minimum measurement accuracy requirements – 1 dBZ
3. Platforms/Instr – P-3 TDR, P-3 Cloud micro package, Ku-band WSRA, C-band SFMR, G4 TDR and SFMR, Globalhawk HIWRAP, GH HIRAD
4. Time of day – N/A
5. Mission frequency – At least twice per day
6. Radial/azimuthal coverage – Fly rotated fig. 4 pattern, standard leg lengths (coverage out to at least 200 km)
7. Flight level – GH 55-60k ft, G4 41-45k ft, P-3 8-12k ft

C. LWC radial profile – Lead Bao; (Evan K.), (Ferrier)

1. Desired measurements – Droplet spectra and concentration, ice-water discrimination, frozen hydrometeor characteristics, fall speed
2. Minimum measurement accuracy requirements –
3. Platforms/Instr – P-3 TDR (nadir/VI mode scanning), P-3 Cloud micro package, P-3 HIRAP, G4 TDR, Globalhawk HIWRAP
4. Time of day – N/A
5. Mission frequency – At least twice per day
6. Radial/azimuthal coverage – Fly rotated fig. 4 pattern, standard leg lengths (coverage out to at least 200 km)
7. Flight level – GH 55-60k ft, G4 41-45k ft, P-3 8-12k ft

D. TPW – Lead Bao; (Ferrier), (Evan K.)

1. Desired measurements – integrated water vapor
2. Minimum measurement accuracy requirements – 1mm
3. Platforms/Instr –GH HAMSR (as well as satellite sensors: SSMI, SSMI/S, AMSR2), G4/GH/WB-57 dropsondes
4. Time of day – N/A
5. Mission frequency – 1-2x/day
6. Radial/azimuthal coverage – Fly rotated fig. 4 pattern or lawn mower patterns; radial coverage out to ~400 km)
7. Flight level – GH 55-60k ft, G4 41-45k ft, WB-57 60-65k f

E. Ocean Initial Structure – Leads: Eric U., George H.; (Benjamin)

1. Desired measurements – T, S, V
2. Minimum measurement accuracy requirements
3. Platforms/Instr – Profiling floats, gliders, airborne profiles (XBT, XCTD, XCP) from P-3 and AF C-130, chained drifters, thermistor chains
4. Time of day – N/A
5. Mission frequency – 3 flights before, during, and after storm
6. Radial/azimuthal coverage – Prestorm: uncertainty forecast cone 2 days out
7. Flight level – P-3 5k ft for XCP and XCTD

F. Ocean Core Structure – Leads: George H., Eric U.; (Benjamin)

1. Desired measurements – T, S, V, surface winds/waves
2. Minimum measurement accuracy requirements
3. Platforms/Instr – Profiling floats, gliders, airborne profiles (XBT, XCTD, XCP) from P-3 and AF C-130, chained drifters, thermistor chains, P-3 dropsondes
4. Time of day – N/A
5. Mission frequency – within 3 RMW
6. Radial/azimuthal coverage – Typical Fig. 4 pattern
7. Flight level – P-3 8-10k ft

G. Near-Surface Observations – Lead: Joe C.; (Eric), (Bao), (Jun), (Evan K.)

1. Desired measurements – T, q, surface flux estimates, sea spray, BL/near surface vertical motion (w)
2. Minimum measurement accuracy requirements
3. Platforms/Instr – P3s, COYOTE, pending W-band radar, GPS dropsondes (P3s; GIV; WB-57; GH); (HIWRAP AV-6), XBTS, IR sondes
4. Time of day – 3:43.5
5. Mission frequency – Whenever feasible
6. Radial/azm coverage – All 4 SR quads inside 400 km
7. Flight level – P-3 <= 10k ft, Coyote 100 m to BL top

H. Cirrus Canopy – Lead: Jason D.

1. Desired measurements – T, q, winds
2. Minimum measurement accuracy requirements
3. Platforms/Instr – G-IV (flight-level, dropsondes, TDR); GHs: AV-1 (HAMSR, HIWRAP), AV-6 (Cloud Physics Lidar, S-HIS, dropsondes); WB-57 (dropsondes)
4. Time of day – daytime (several hrs before local sunset) and near/after local sunset
5. Mission frequency – 1-2x/day
6. Radial/azimuthal coverage – inner core out to R=400-600 km
7. Flight level – G-IV (41-45K ft), GH (55-60K ft), WB-57 (60-65K ft)

I. Vertical Velocity Probability Distribution at various altitudes – (R. Rogers)

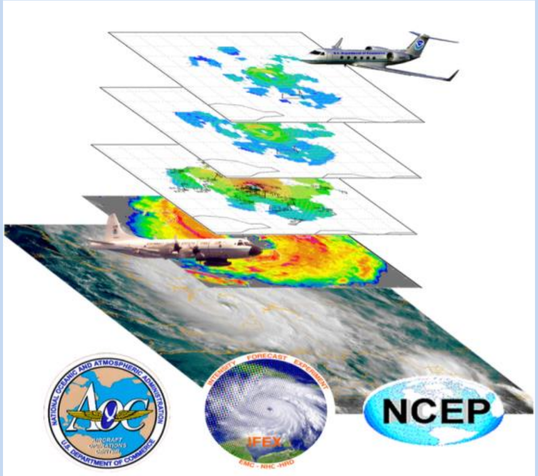
1. Desired measurements – winds (w)
2. Minimum measurement accuracy requirements
3. Platforms/Instr – G-IV (flight-level, dropsondes, TDR); GHs: AV-1 (HIWRAP), AV-6 (dropsondes); WB-57 (dropsondes)
4. Time of day – n/a
5. Mission frequency –
6. Radial/azimuthal coverage –
7. Flight level – G-IV (41-45K ft), GH (55-60K ft), WB-57 (60-65K ft)

Manned & Unmanned Aircraft Observing Strategies for Model Physics Evaluation (2014-2015)

Mission Description

The ideal experiment consists of coordinated three-plane missions designed to observe several mechanisms responsible for modulating convective activity, hurricane structure and storm intensity change including:

Air-sea energy exchange and boundary layer processes
Convection (storm and surroundings)
Dynamic/thermodynamic processes (storm and surroundings)
Cloud microphysics



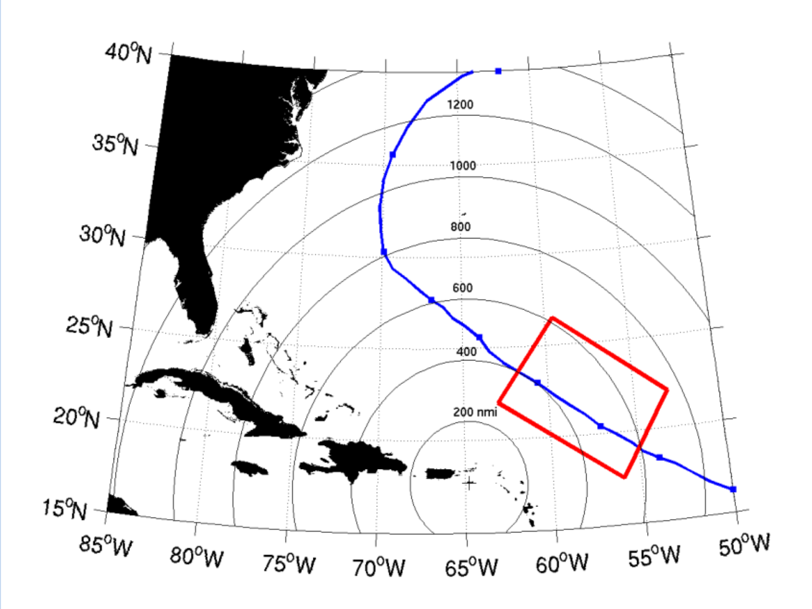
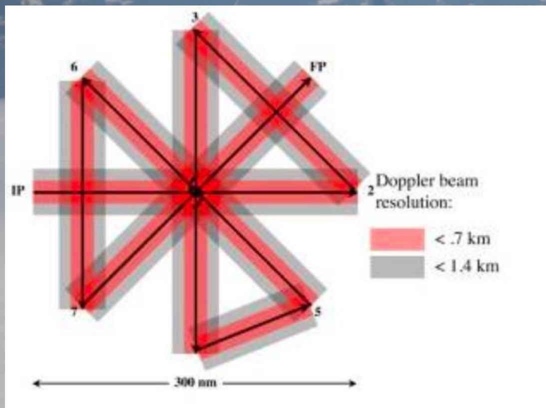
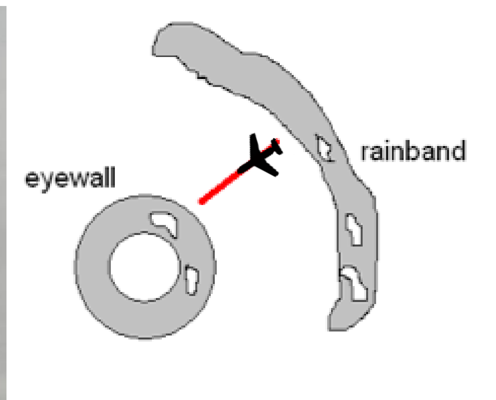


Figure 1. Storm track (blue), and observation region (red box), optimally suited for multi-aircraft experiment. Range rings are 200 nmi relative to forward operating base at STX (TISX). Track marks are spaced every 24 hrs.

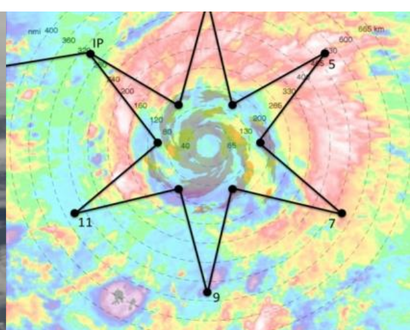
Plan: Establish a multi-aircraft experimental design in geographical areas with limited operational requirements over a 24h refresh cycle



One NOAA P3 → Captures the core, storm scale circulation (e.g. Current TDR mission profiles)



2nd NOAA P3 → Responsible for sampling predetermined areas of interest outside the immediate TC high wind inner core (e.g. Entrainment flux module)

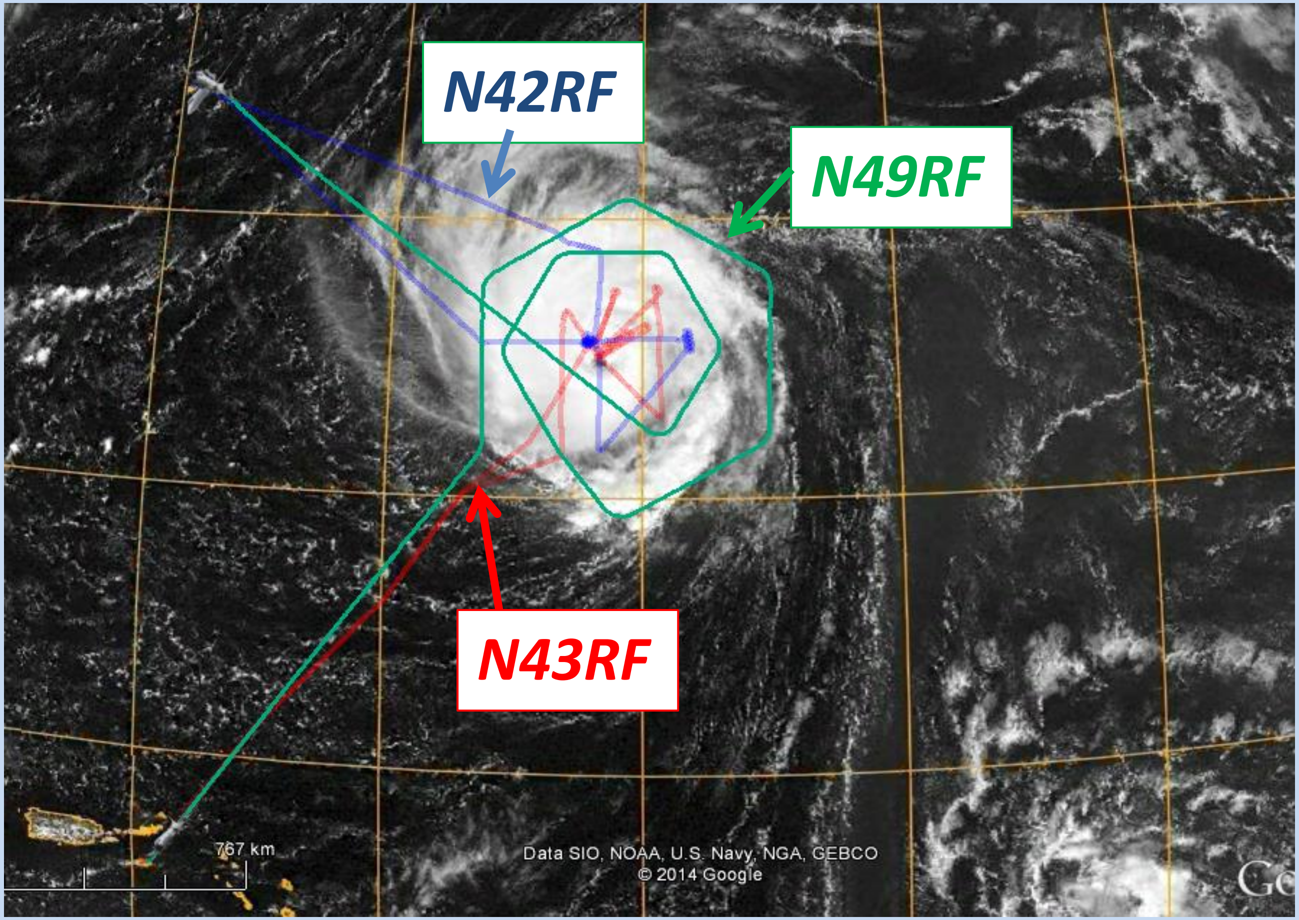


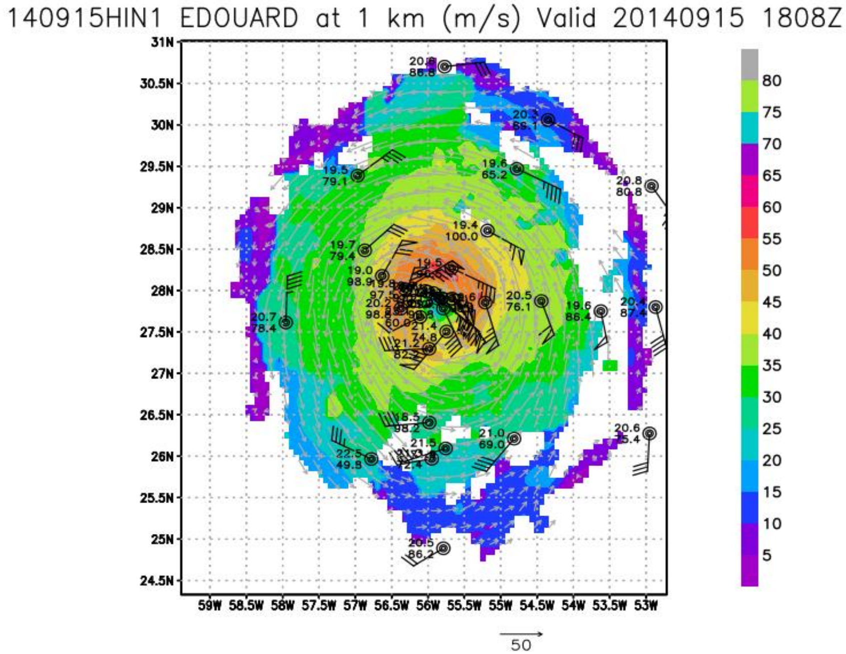
NOAA GIV → Primarily responsible for capturing the tropical cyclone's surrounding larger scale environment

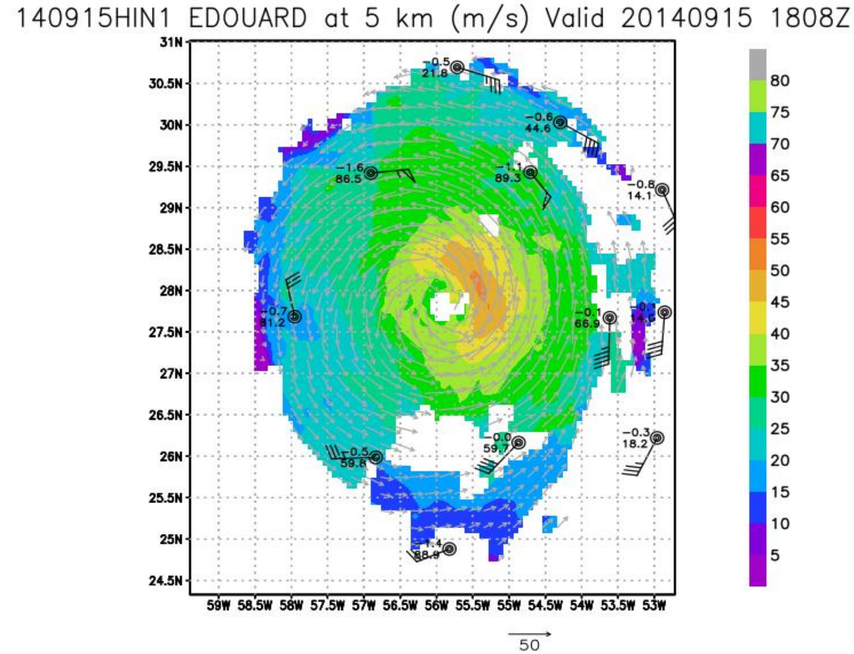
Hurricane Edouard Model Evaluation Field Deployment
Sept 11-19, 2014: STX/BDA

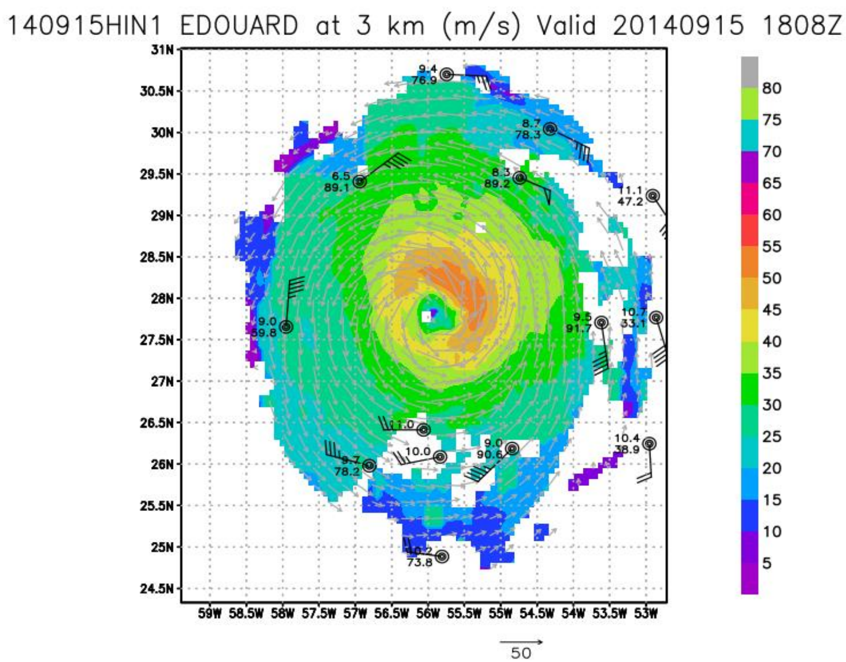
20140915I – Multi-aircraft MEEx

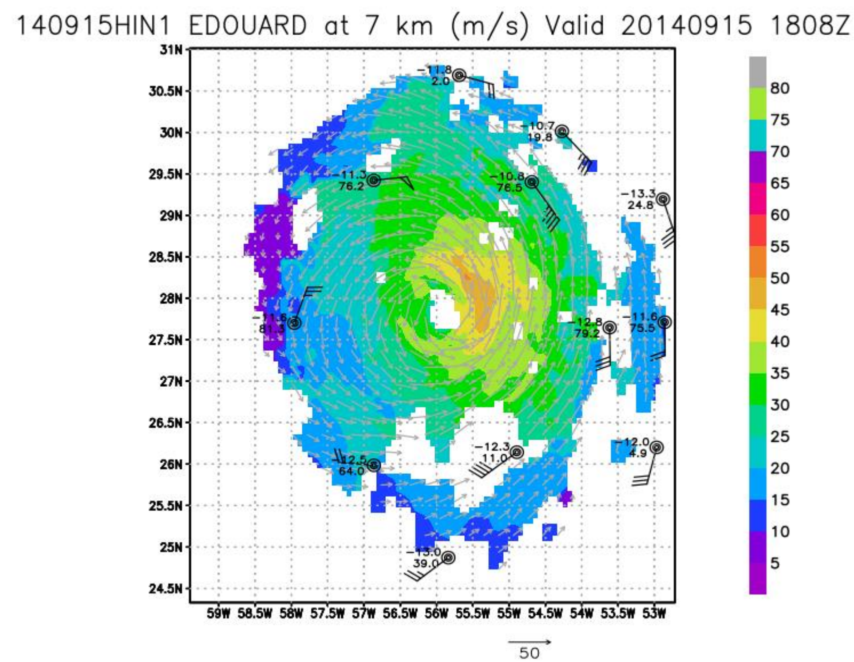
- 19 sondes (15 IR)
- 12 BTs
- 5 TDR analyses
- 8 hours STX-STX




140915HIN1 EDOUARD at 1 km (m/s) Valid 20140915 1808Z

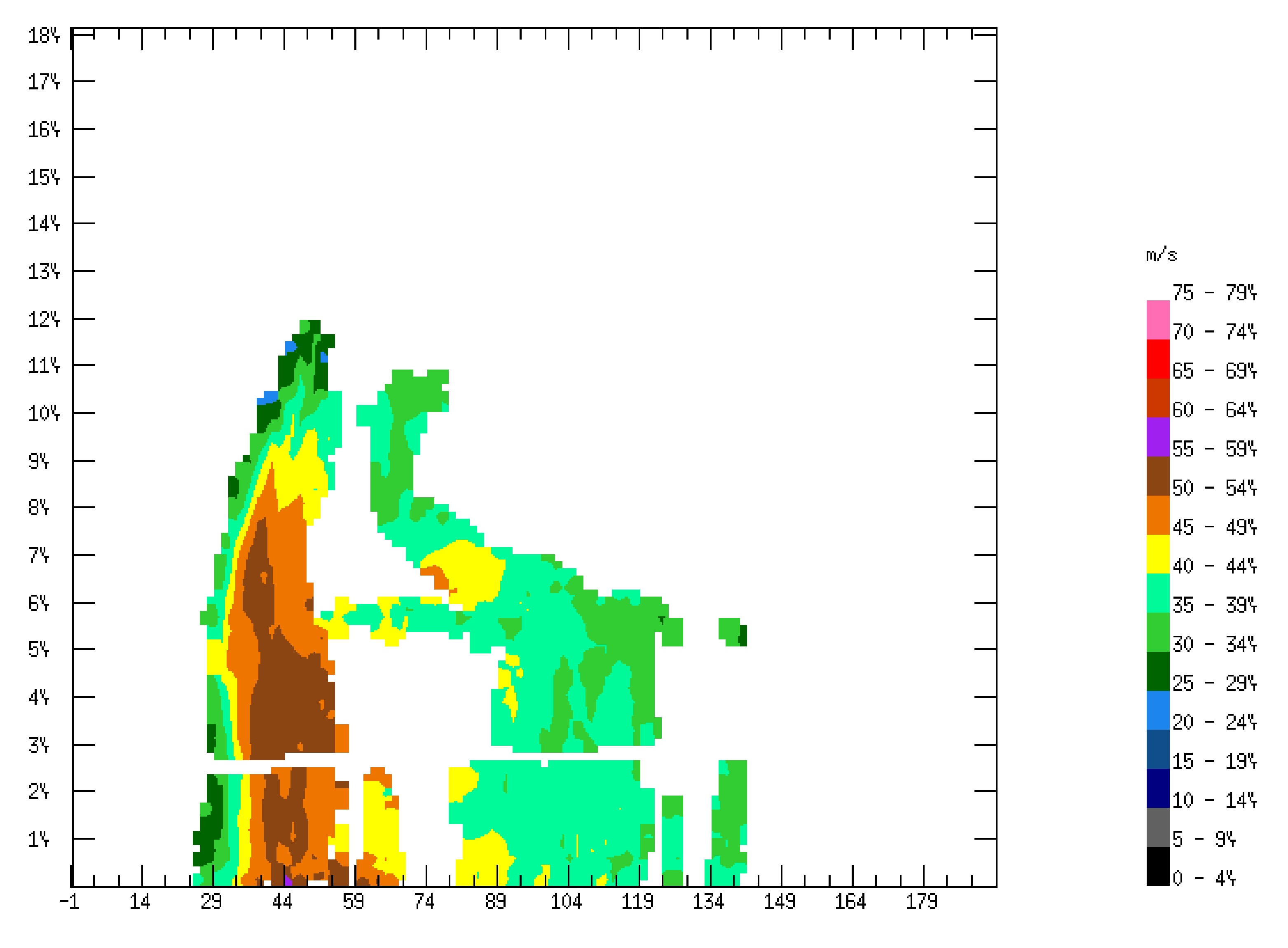

140915HIN1 EDOUARD at 5 km (m/s) Valid 20140915 1808Z


140915HIN1 EDOUARD at 3 km (m/s) Valid 20140915 1808Z


140915HIN1 EDOUARD at 7 km (m/s) Valid 20140915 1808Z

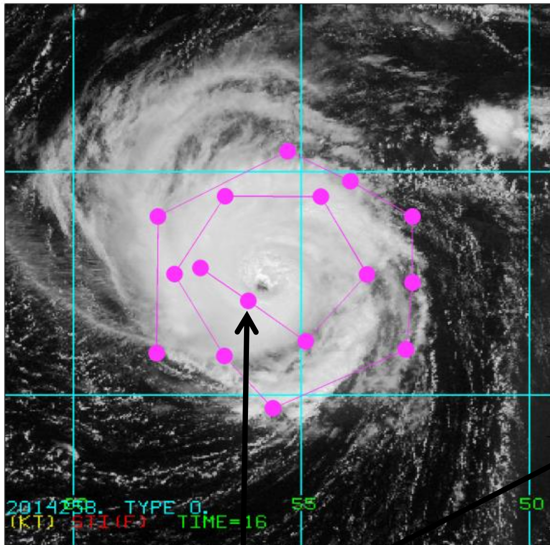
Hurricane Edouard: 15 Sept 2014:

Radar Cross-Section

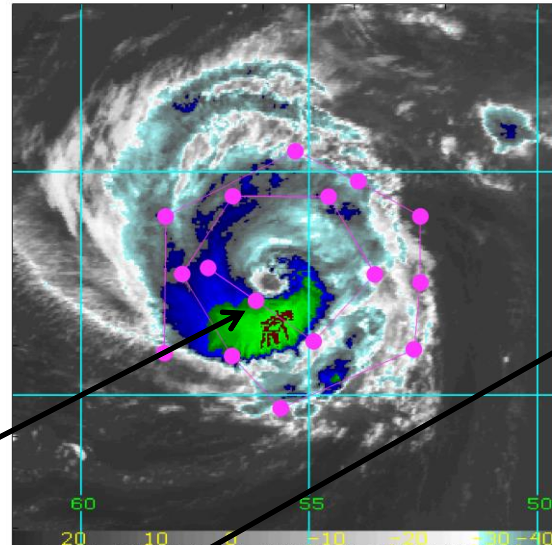


140915N1 (LPS: Aksoy)
Situational Awareness

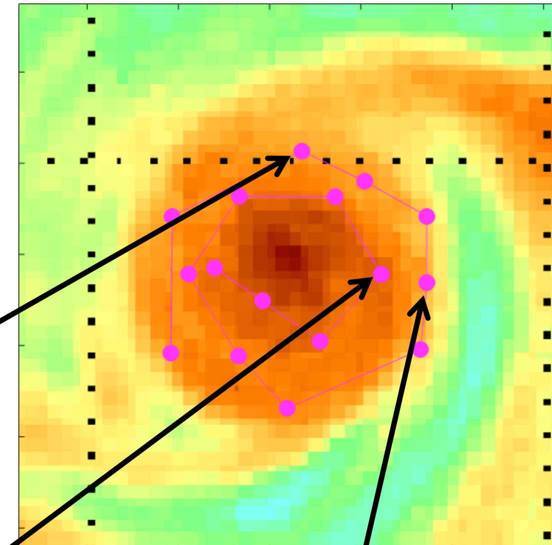
16Z Visible Satellite

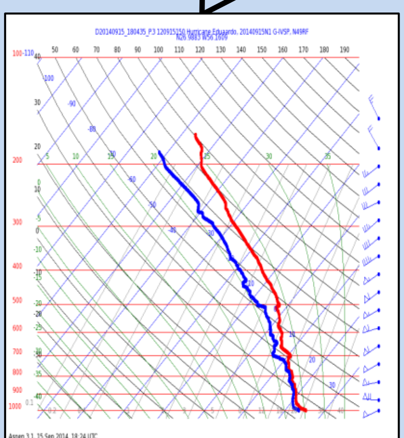


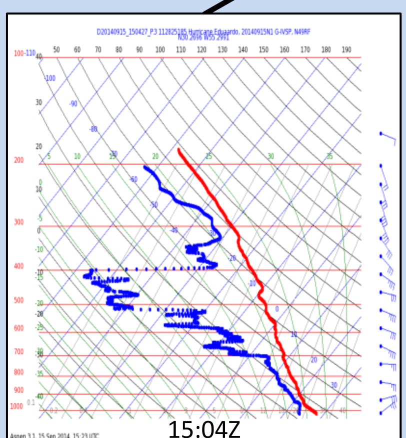
16Z IR4 Satellite

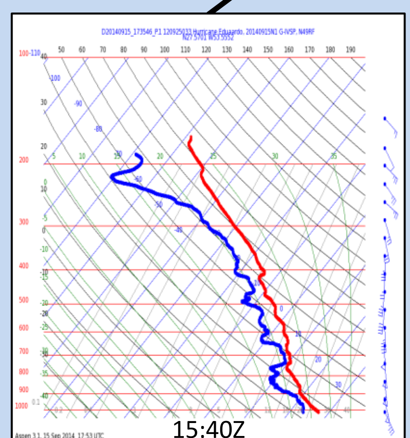


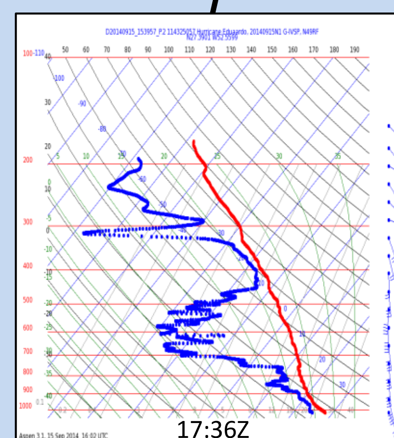
16Z TPW Image





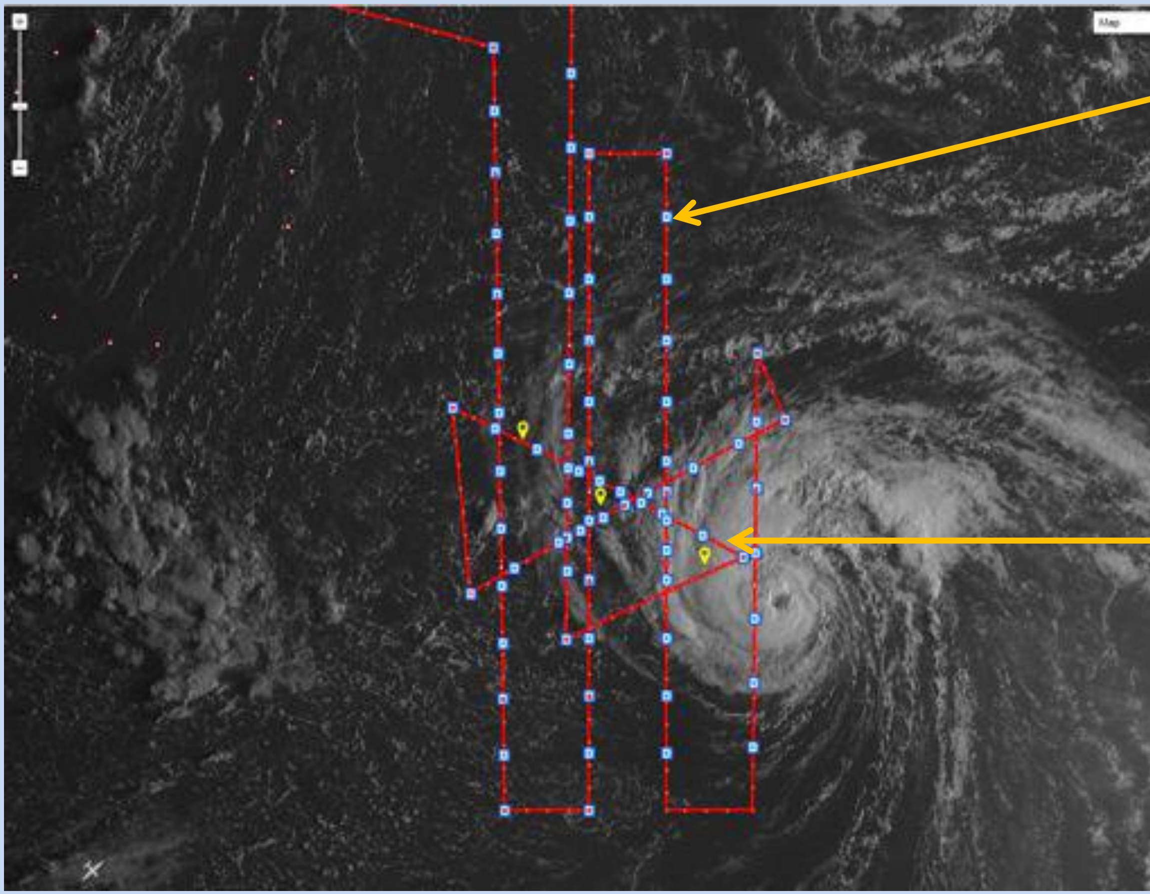






NASA Global Hawk also flies into into Hurricane Edouard

Flight plan for AV-6 Global Hawk flight 9/14-9/15

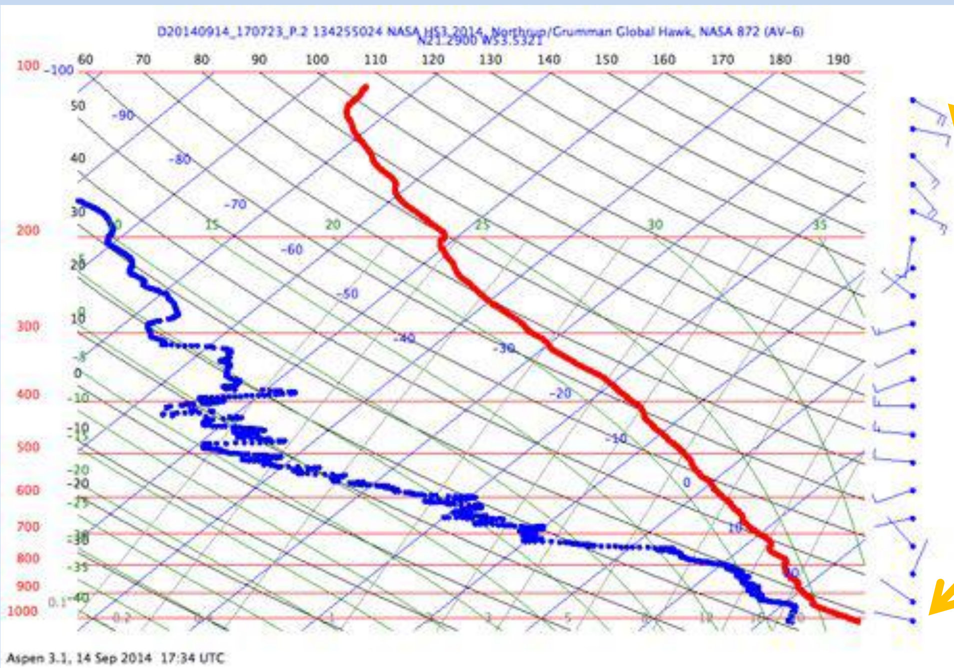


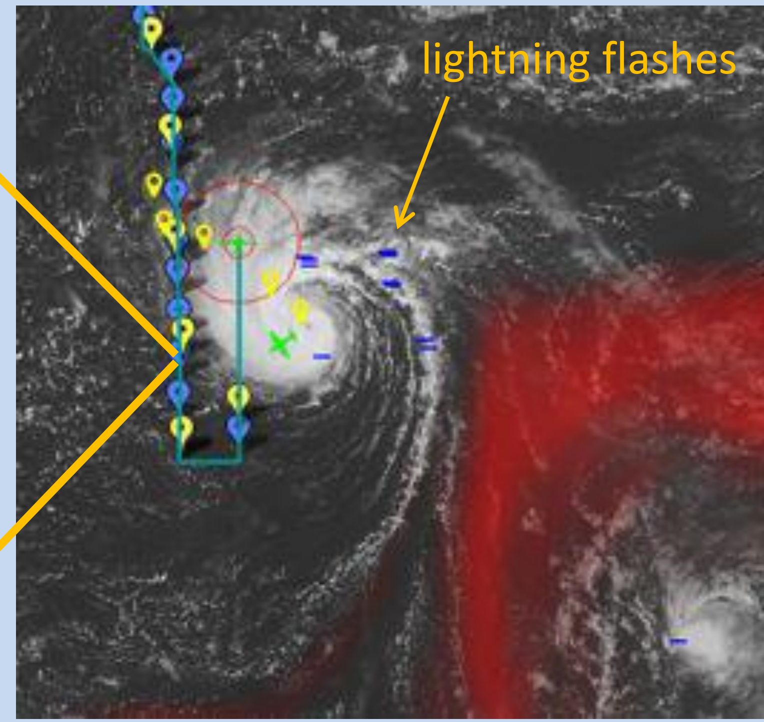
survey pattern

storm sampling

Dry air surrounding system

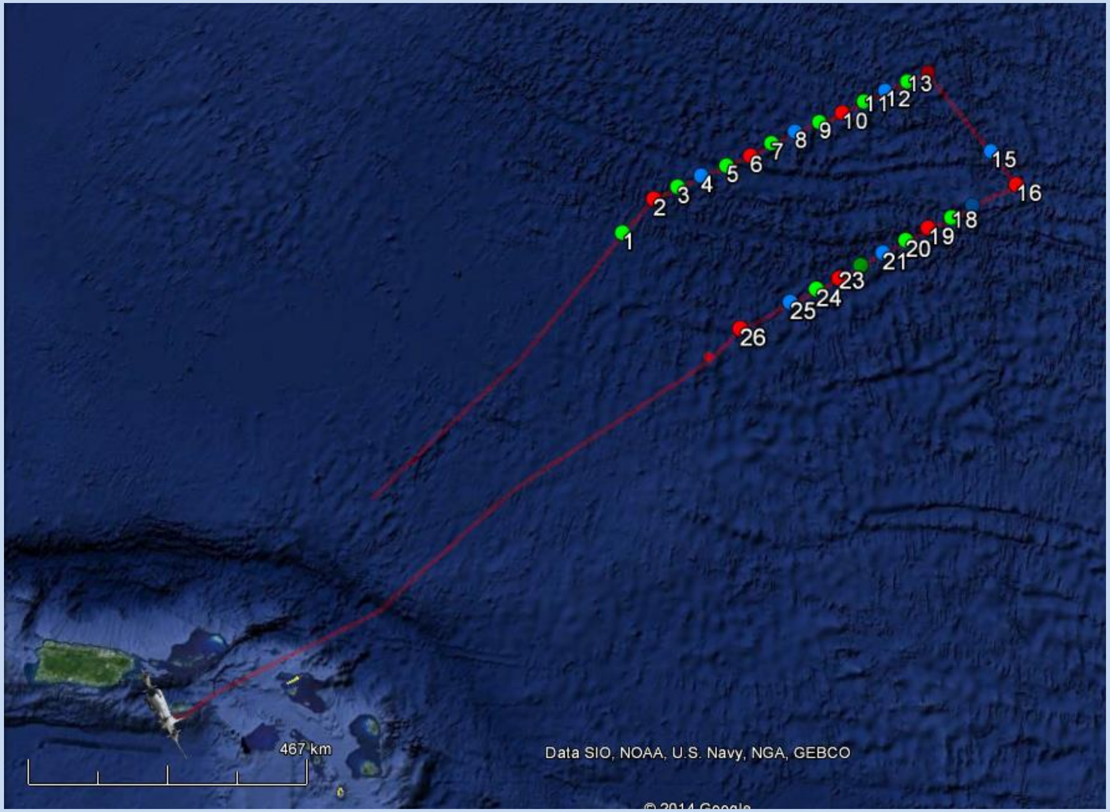
Very dry air on SW side of system. Lightning continues to fire along elongated rainband bordering between the dry slot and possible dusty layer to the SW. Red area indicates dust AOT from GEOS-5.



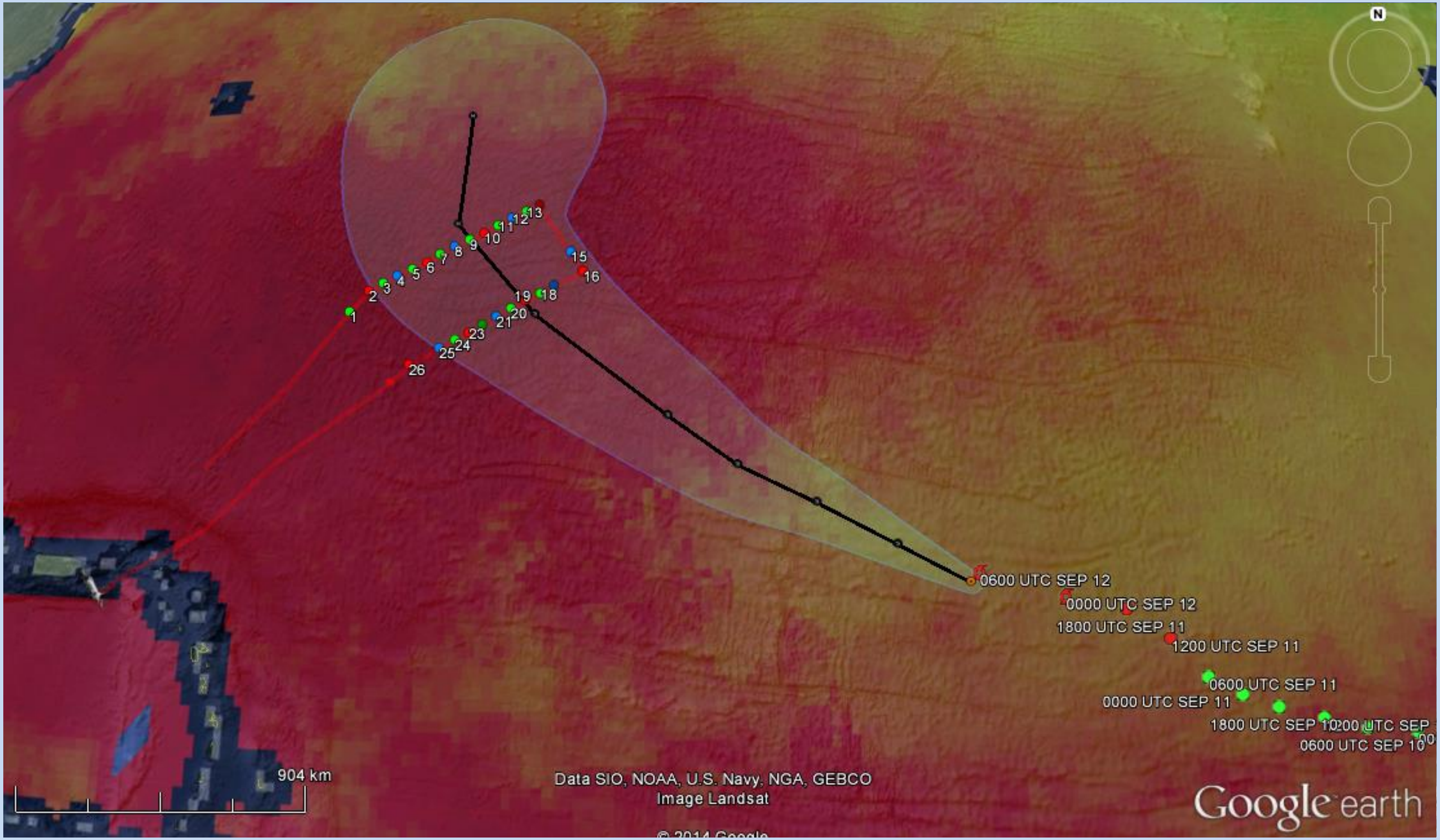


20140912I1 – Pre-storm ocean

- 26 ocean probes
  - 8 BT
  - 11 CP
  - 7 CTD
- 3 days prior to storm
- 7.5 hrs
- TS Edouard 35 kts/1005 mslp

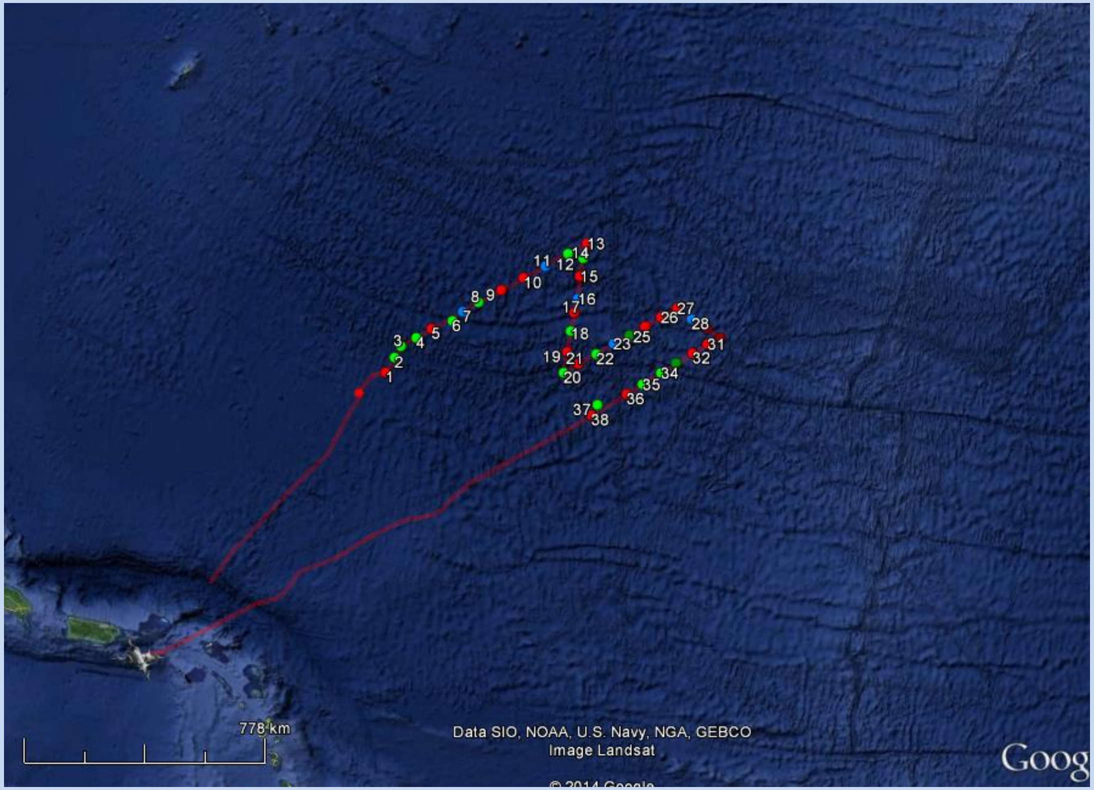


20140912I1 – Pre-storm ocean

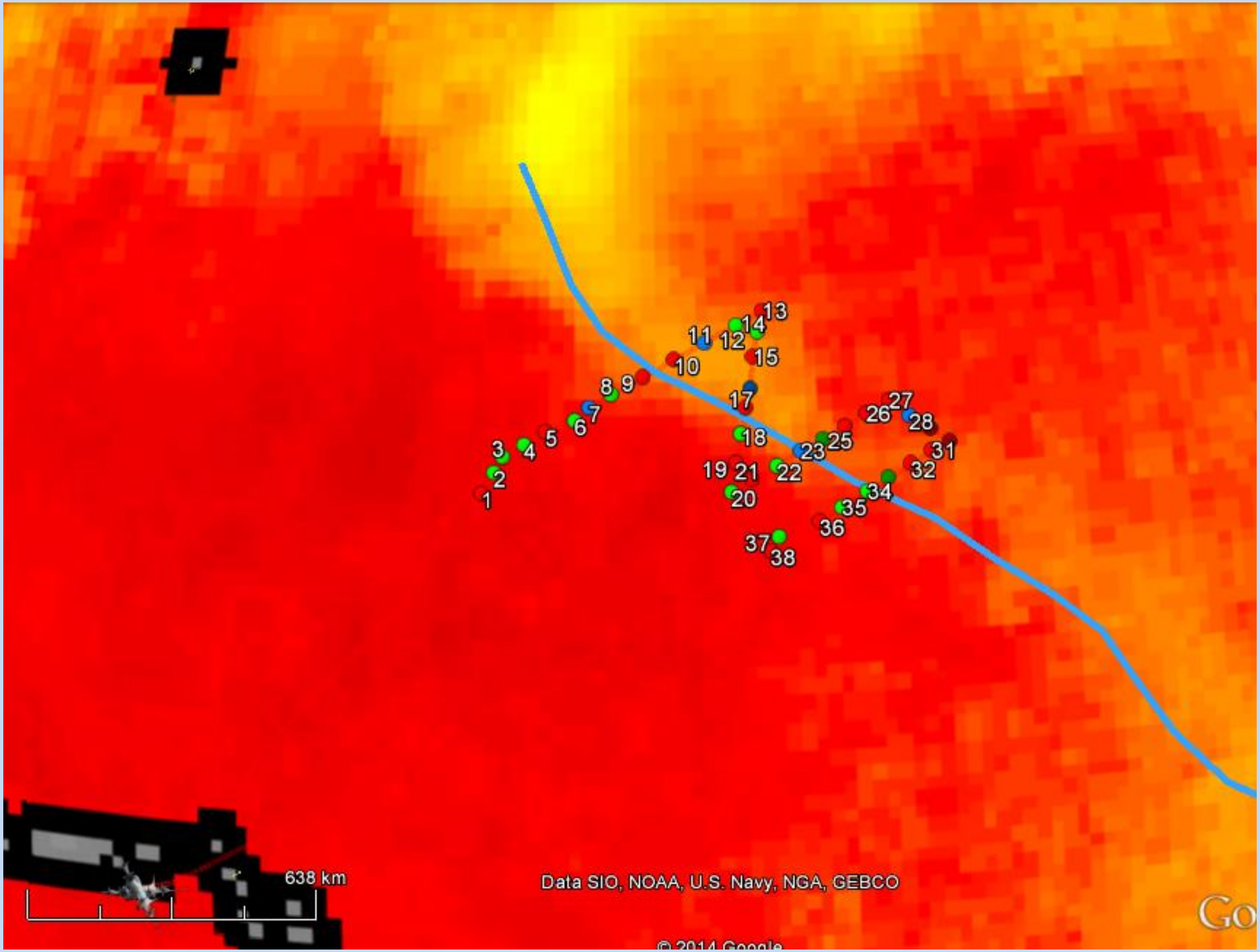


20140917I1 – Post-storm ocean

- ~1.5 IP after storm
- 38 ocean probes
  - 15 BT
  - 17 CP
  - 6 CTD
- HI-SFMR low-wind/large swell

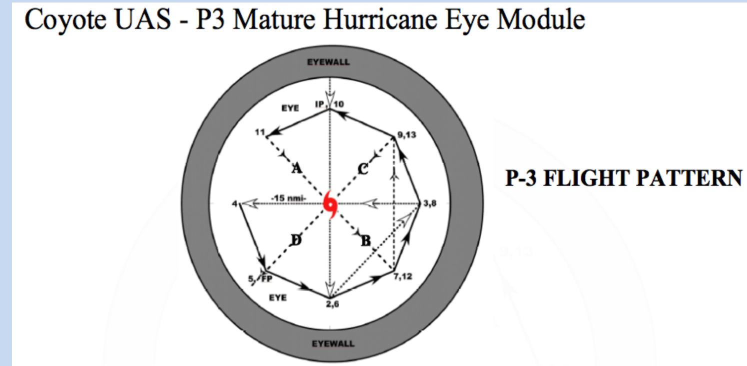


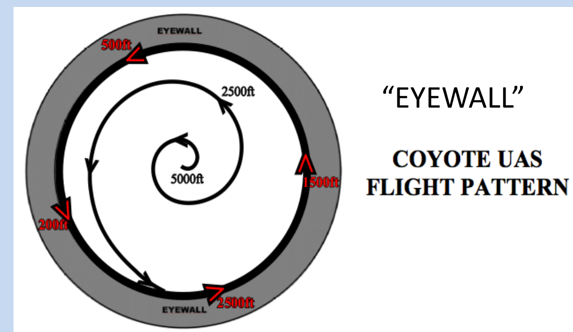
20140917I1 – Post-storm ocean

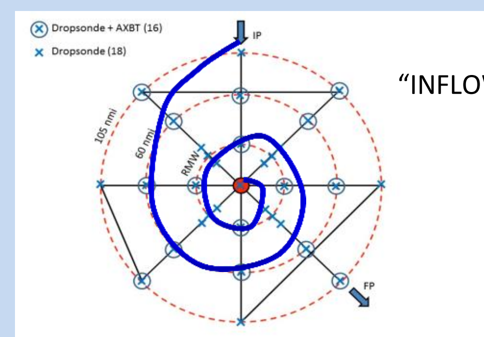


Coyote UAS: A new tool to help us better understand, evaluate and initialize…

Flight patterns







Small Unmanned Aircraft Vehicle Experiment (SUAVE)

Part of IFEX Goal 2: Develop new measurement technologies

SUAVE objectives:

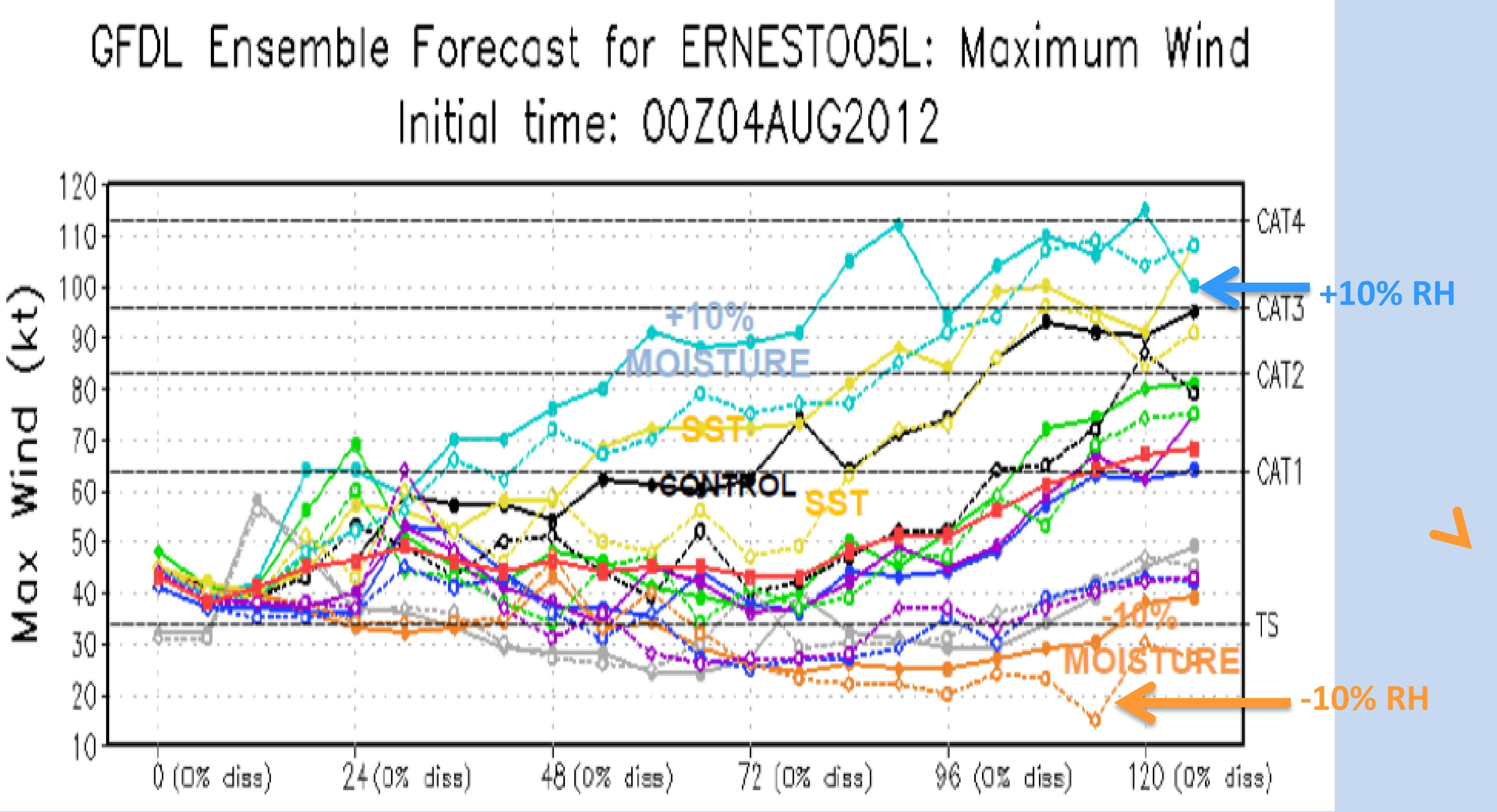
- Improve understanding of TC near-surface energy transfer process
  - Ocean/Atmosphere T/q/M exchange processes
  - Investigate eye/eyewall T/q/M exchange processes
  - **Significantly enhance existing sparse thermodynamic coverage (esp. moisture) within the TC boundary layer**

  Provide new (continuous) TCBL observations for use in Model evaluation:
  - Compare/contrast/validate w/coincident, instantaneous TC BL observations
  - Compare UAS BL fields w/existing numerical BL structure

Potential Operational Benefits:

1. Use UAS data to improve the accuracy of model initialization, parameterizations, physics (and ultimately) operational performance
2. Unique -continuous- measurements of V_{10} in the eyewall (better Vmax?)
3. Early detection of rapid intensity change (→ 'loitering' in the eye)

Model Extreme Sensitivity to Small Differences in Inner-Core Moisture as it relates to Hurricane Intensity



First air-deployed UAS mission into a hurricane (a major one at that)

When: 1432Z September 16th 2014

Where: Deployed into Major Hurricane Edouard's eye (then eyewall)

Deployment aircraft: NOAA WP-3D Orion (42)

UAS flight duration: 28 minutes

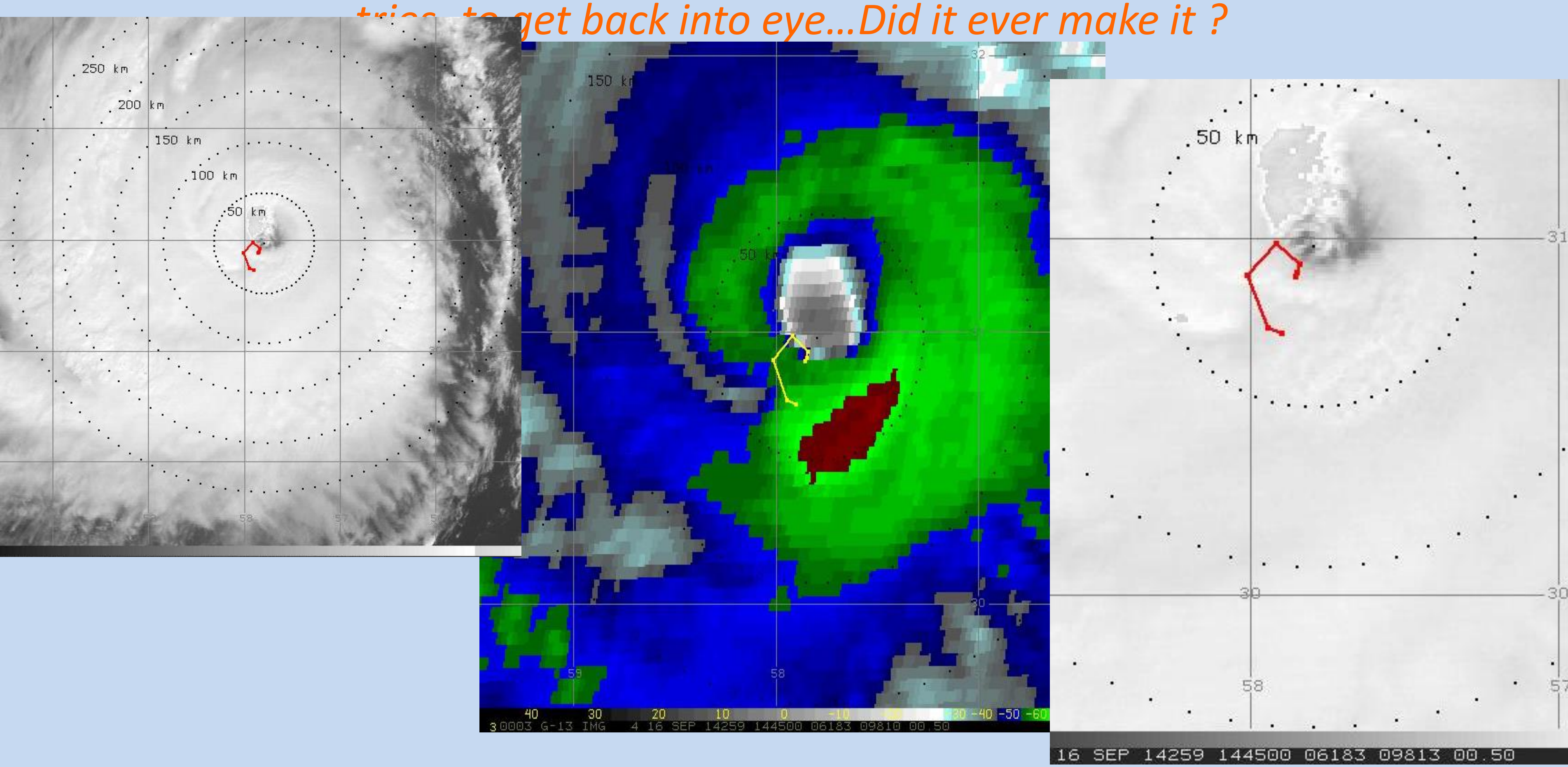
Minimum Altitude: 896m

Maximum Wind Speed: 100kt @971m (in SW eyewall) Platform record!

Coyote UAS in Edouard's eye… and eyewall..

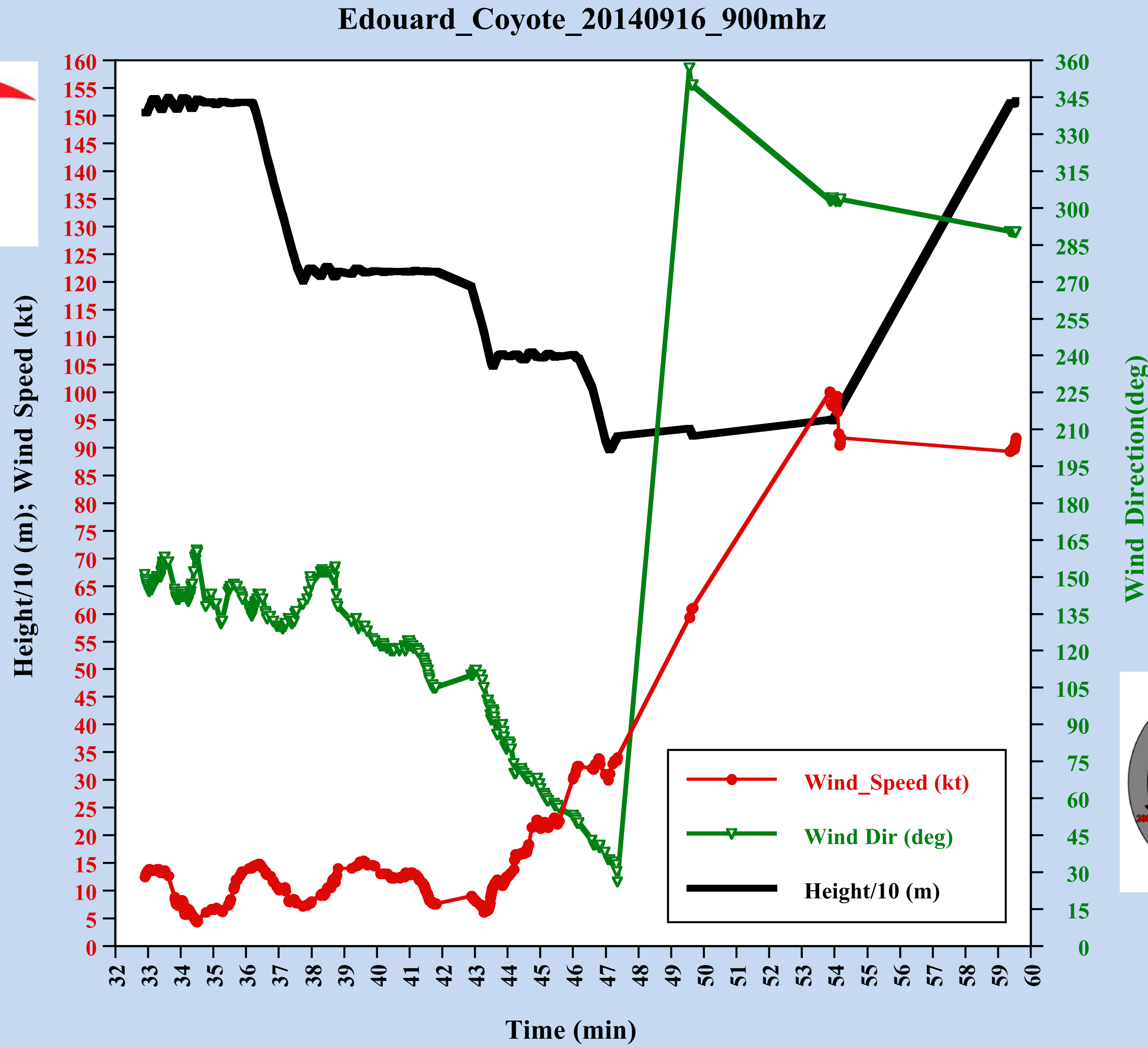
Visible and IR (1445Z Sept 16th)

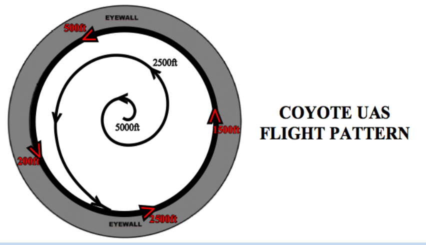
Angle of Satellite image distorts co-location of Coyote in Edouard's eye…After losing communications via satellite and the P-3, @ ~1454Z the UAS climbs and -tries- to get back into eye…Did it ever make it ?



Coyote UAS in Edouard's eye…and eyewall..

~10kt SE in eye; Max 100kt in SW eyewall (Δt~10 min!)





Record duration Coyote UAS mission!

Thermodynamic and kinematic radial profile within the boundary layer of Hurricane Edouard

When: 1507Z September 17th 2014

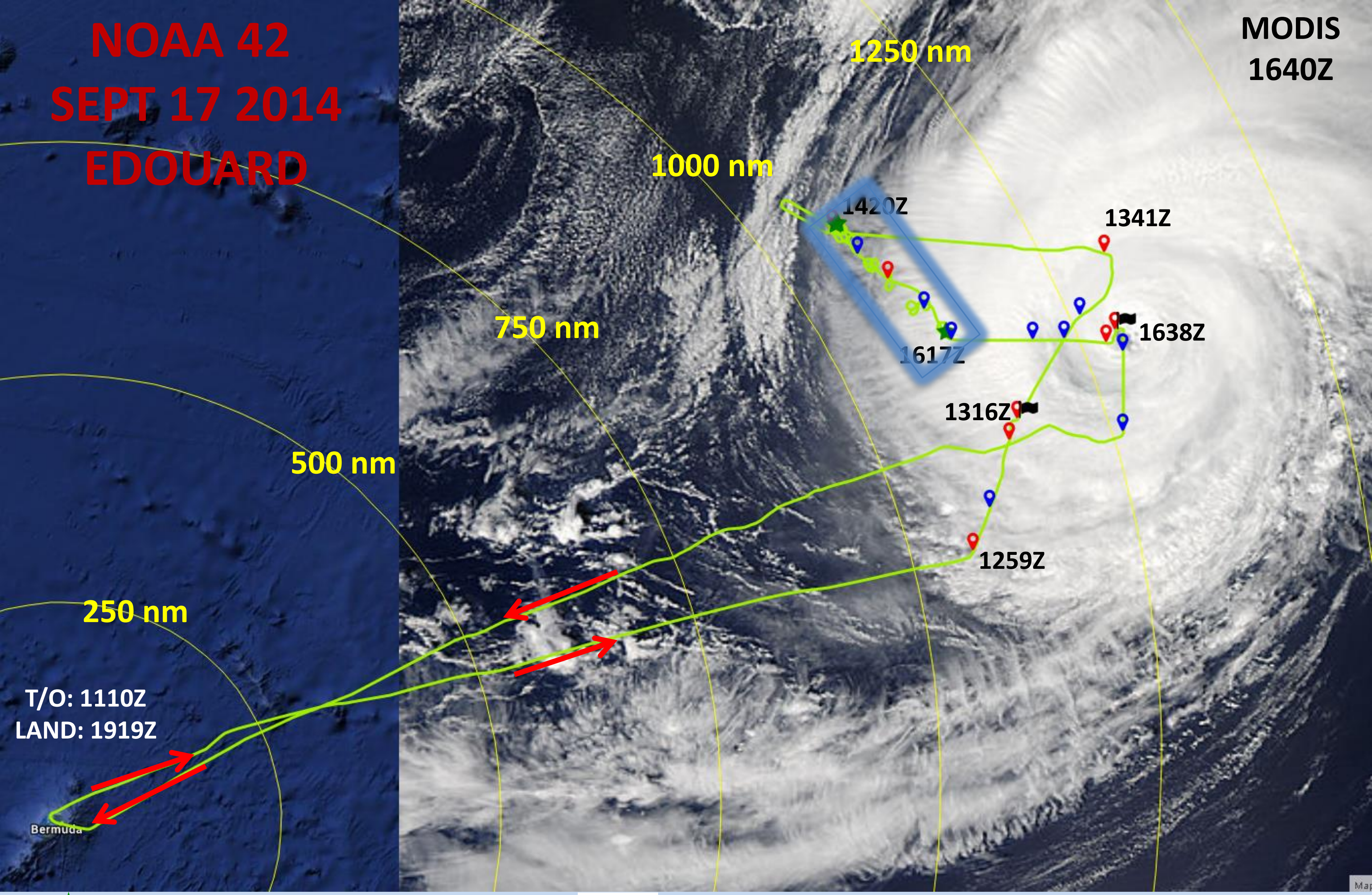
Where: Deployed along Hurricane Edouard boundary layer inflow channel

Deployment aircraft: NOAA WP-3D Orion (42)

UAS flight duration: 68 minutes (platform record!)

Minimum (controlled) Altitude: 400m

Maximum Wind Speed: 53kt @6m



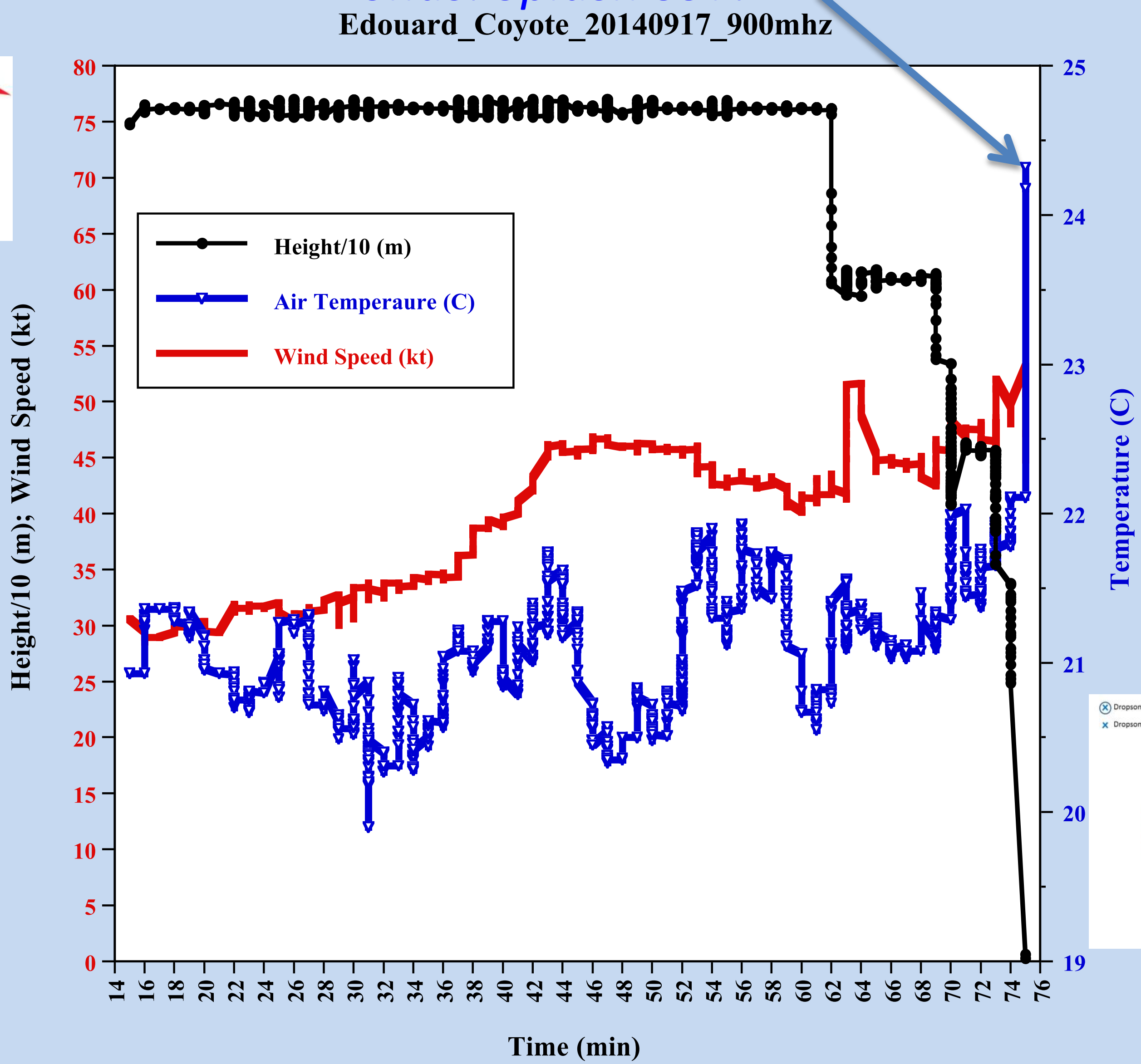
Coyote Launch/Splash | Center Fix | Sonde | Sonde + BT

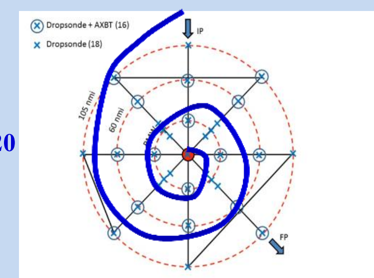
Total expendables: 17 sondes (1 bad) and 8 BTs

Coyote UAS inflow module in Edouard…

Evidence of high frequency variations in radial temperature, winds

Bonus: Splash SST!





Summary

- It's time to think of "model evaluation" in a more fundamental way...
  - In this sense, model evaluation is *not*...
    - Model vs. Best Track
    - Forecast A vs. Forecast B
    - Model X vs. Model Y
  - Instead...How well are we simulating reality (physical fields, processes)?
  - How often do we get the right answer (forecast) for the wrong reason?
  - Where are the model biases, what physical processes are causing them?
  - Where are the (model sensitive) data gaps and how can we best fill them?
- In a world of limited resources we need to....
  - Identify the low hanging fruit (and grab it)
  - Maintain realistic goals:
    - Target evaluation and improvements linked to wave number 0 (mean) and wave number 1 (asymmetric) structure and phenomenon...

Next Steps...

- We have the data (Edouard) and we have the interest (model physics evaluation)...

It's now time to *pair up the modelers and the observations* and get started -

Starting Points:

- **August 2014 Boulder Model Physics Workshop-identified *'areas of high priority' (see slide 6 from this presentation)***
- **Data from Edouard:**
  - ***HRD:*** ***http://www.aoml.noaa.gov/hrd/Storm_pages/edouard2014/***
  - ***Edouard Debrief (overview of all data collected including observations from NASA):*** **https://drive.google.com/a/noaa.gov/folderview?id=0B2kMCC0obcENNkxTLUtQb180S0k&usp=sharing**

- **Think "Ven diagram"...Where do the observations from Edouard best match up with the area that have been identified as highest priority for HWRF/POM model evaluation?**
- **Once 'obs and model' teams are identified in specified areas, the goal should be to produce "apples to apples" analyses from model output and observations from Edouard.**
- **Present preliminary findings at the HFIP annual meeting in Miami (Nov. 18-20, 2014)**

Note: By 11/1, please email Joe C (Joe.Cione@NOAA.gov) and Bao (Jian-Wen.Bao@NOAA.gov) with the area you plan to analyze and what modeler/observationalist you paired up with to conduct the corollary analyses...