Strategies for Utilizing SHOUT Rapid Response Global Hawk Observations for Improving and Augmenting Hurricane track and Intensity Forecasting

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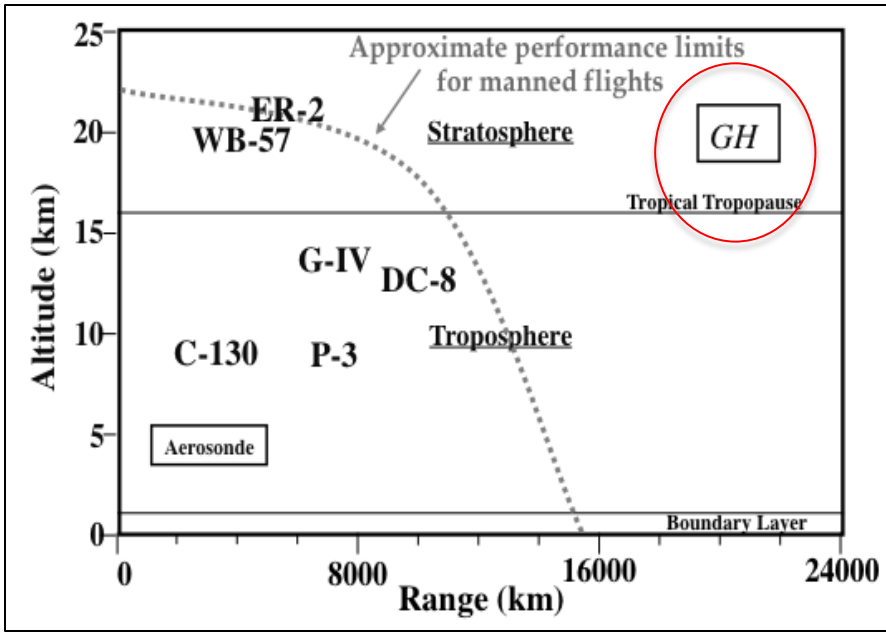
Global Hawk Operational Demonstration: HOPE/EPOCH Potential Reconnaissance and Surveillance Flight Strategies

- GH flight experience gained with Research Flights:
  - GRIP (2010)
  - HS3 (2012-2014)
- Additional GH flight experience gained with Experimental Operational Flights:
  - SHOUT (2015)
  - SHOUT- El Niño Rapid Response (ENRR-2016)
  - SHOUT-Hurricane Rapid Response (HRR-2016)
- SHOUT-HRR represents GH unique reconnaissance and surveillance opportunities due to extreme endurance (~24 hr) and altitude (20 km)



Global Hawk

SHOUT TCRR Operational Demo Observational Objectives

Sensing Hazards with Operational Unmanned Technologies (SHOUT)
Tropical Cyclone Rapid Response (TCRR)

Measure & Evaluate: transition from research (HS3) to operations (SHOUT)

Hurricane and Severe Storm Sentinel (HS3)

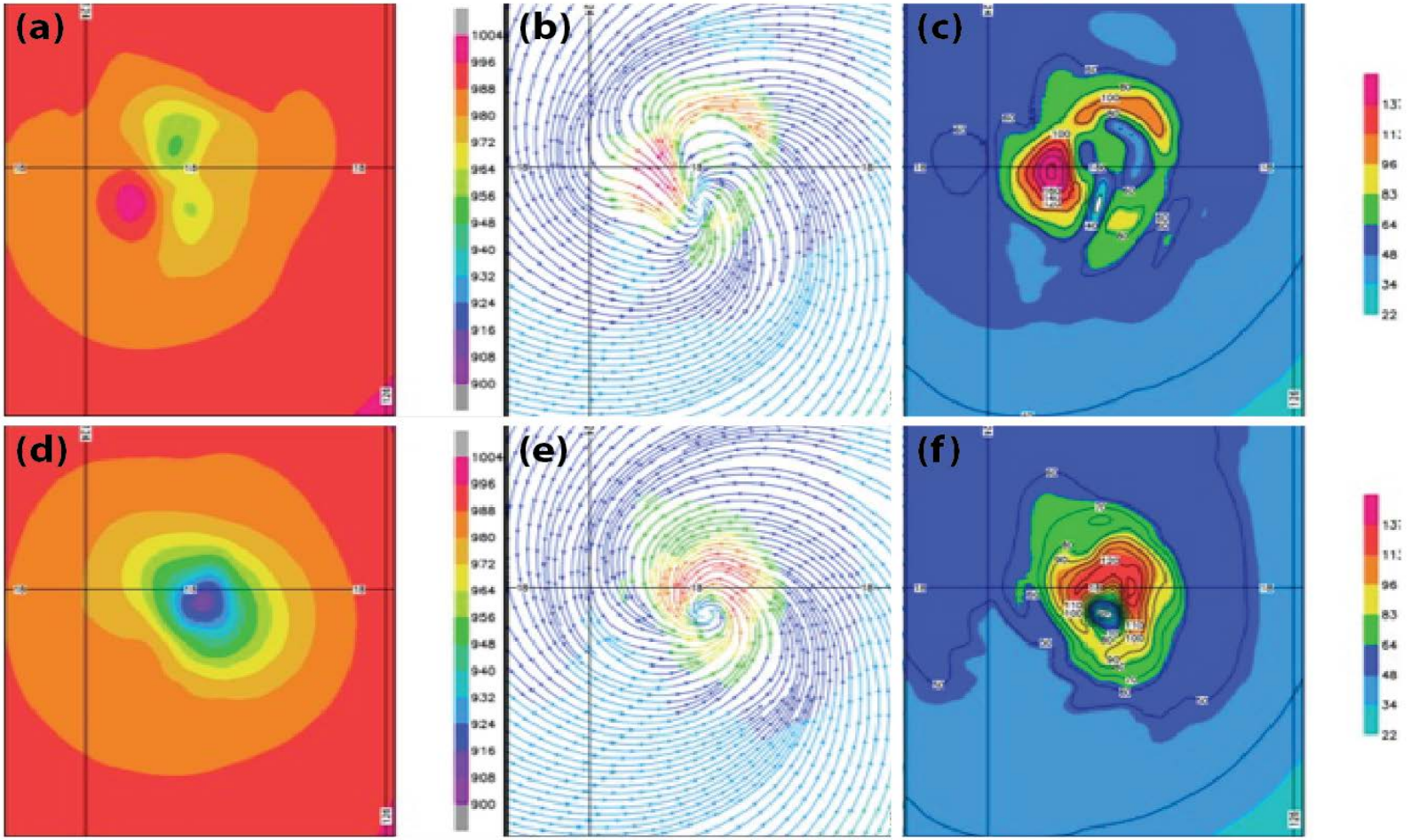
- Operational Impact on model predictions:
  - Hurricane intensity/ size/ structure change: V_{max}, P_{min}, RR, RMW, R_{64}, R_{50}, R_{34}
  - Hurricane track change
  - Global Downstream Environmental Adjustment (Sipple, Tallapragada, Howard)

TC Model Real-Time Data Assimilation

- Improve targeting (timing/location/pattern) of *Real Time* dropsondes
- Optimal sonde input format, i.e. BUFR (full res) vs Temp Drop (single location)
- Techniques for data thinning/ super-obing (averaging) to match model resolution
- **Instrumentation strategy** for input to TC models: AVAPS/HIWRAP/HAMSR
  High Altitude MIMIC Sounding Radiometer/High-altitude Wind and Rain Atmospheric Profiler
- In future: HIRAD (surface wind/ rain rate)- Hurricane Imaging RADiometer

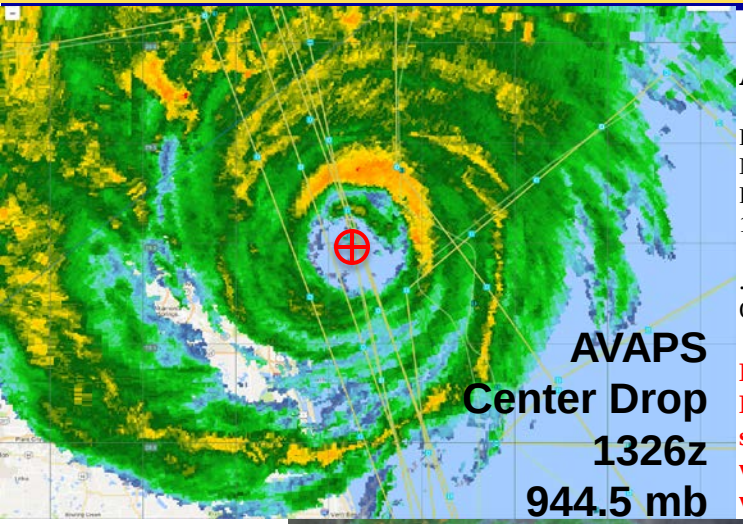
Satellite GAP Mitigation for High-Impact Weather

- Operational Impact Studies for alternatives to satellite data



HRD HEDAS analyses with dropwindsonde data assimilated at the locations provided in the TEMPDROP messages (top) and at the HRD-calculated locations (bottom). From left to right, the analyses are surface pressure (hPa), surface wind velocity and surface wind speed from Aberson, et al., 2017.

Global Hawk Instrument Suite



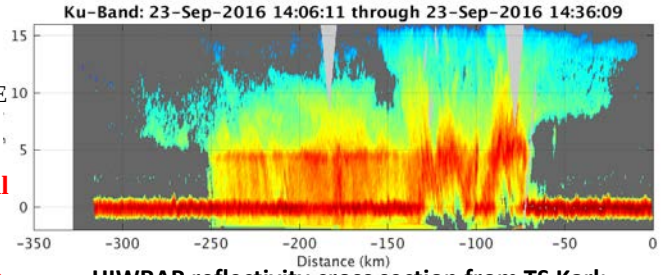
AVAPS IMPACT:

HURRICANE GASTON TROPICAL CYCLONE UPDATE
NWS NATIONAL HURRICANE CENTER MIAMI
FL AL072016
1215 AM AST THU AUG 25 2016

...GASTON BECOMES THE THIRD HURRICANE OF THE ATLANTIC SEASON...

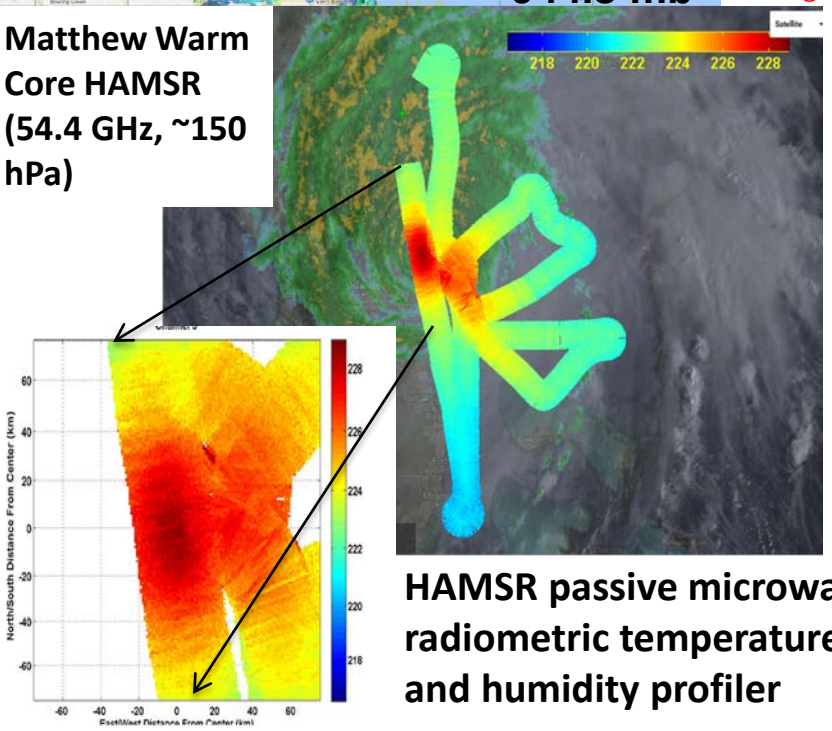
Dropsonde data from a NASA/NOAA Global Hawk mission indicate that Gaston has strengthened to a hurricane. The maximum winds are estimated to be 75 mph (120 km/h) with higher gusts.

HIWRAP Doppler radar profiler



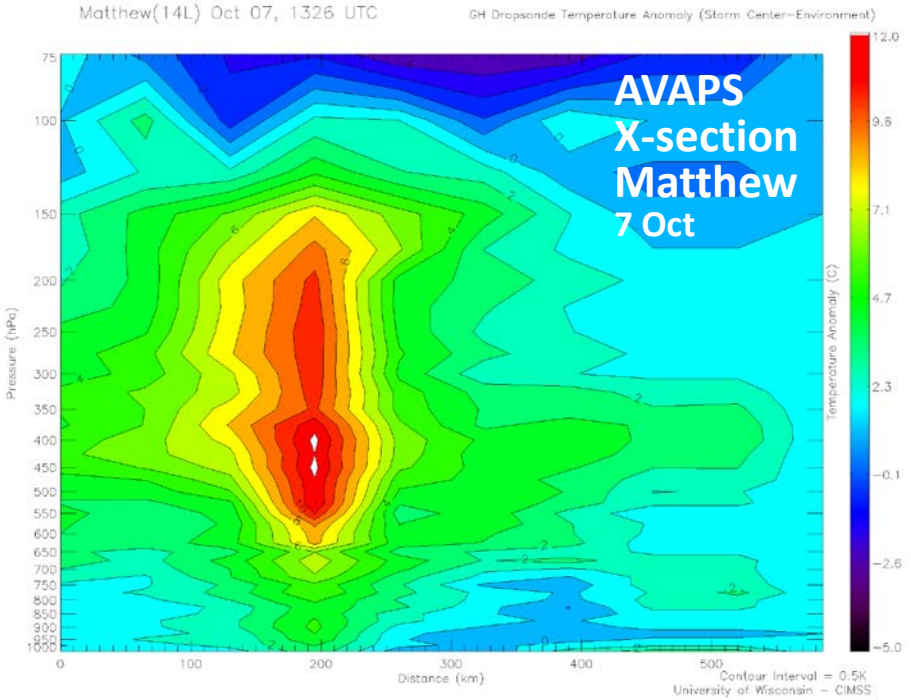
HIWRAP reflectivity cross section from TS Karl: convective cores, high tops and extensive stratiform precipitation

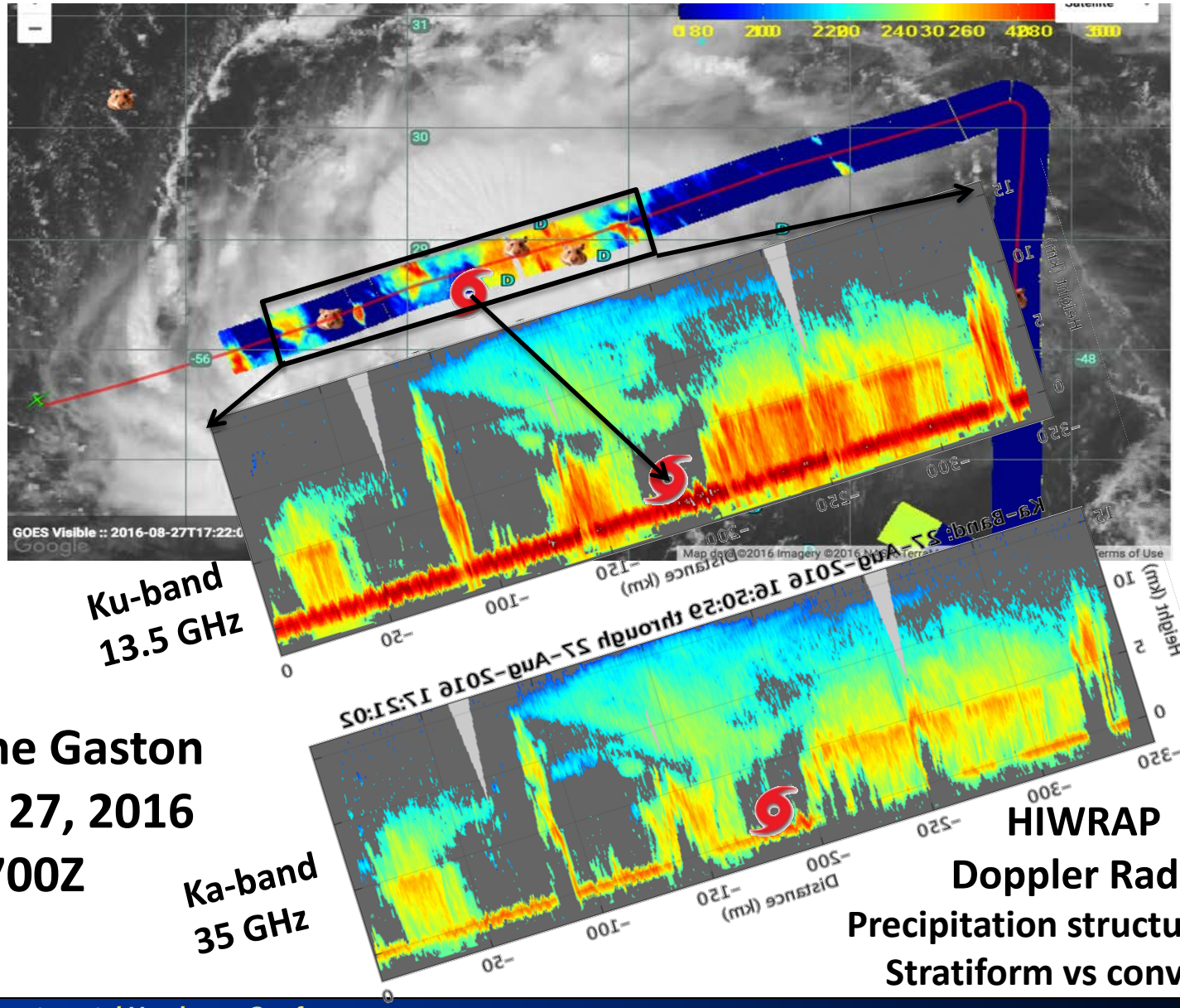
Matthew Warm Core HAMSR (54.4 GHz, ~150 hPa)



HAMSR passive microwave radiometric temperature and humidity profiler

Warm Core of Matthew





Hurricane Gaston
August 27, 2016
1700Z

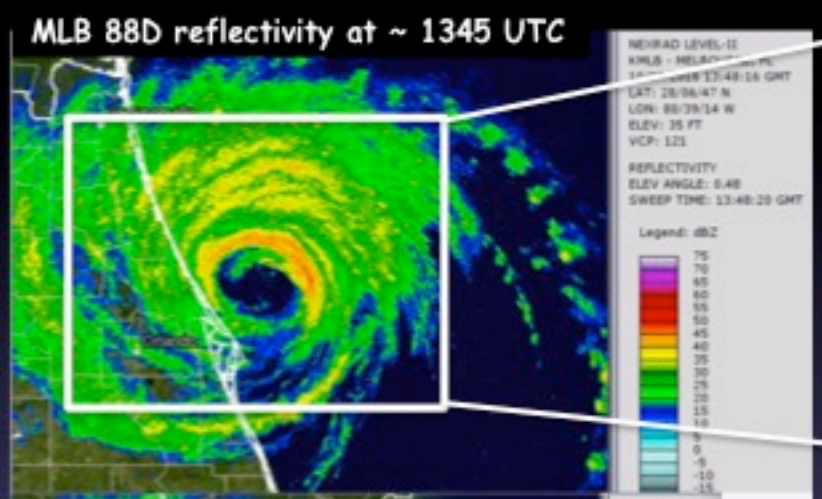
HIWRAP
Doppler Radar
Precipitation structure/ Type
Stratiform vs convective

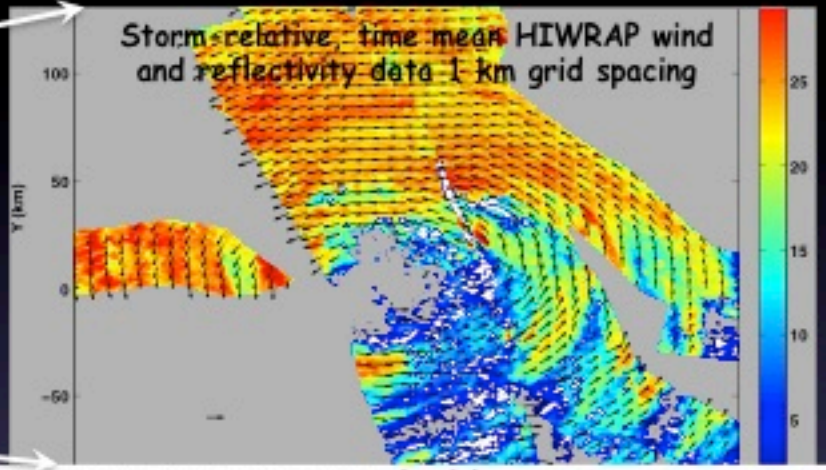
NOAA SHOUT – Hurricane Matthew October 7, 2016 (~ 09 – 19 UTC)
HIWRAP Ku Band Reflectivity and Wind Vectors at 1 km Height

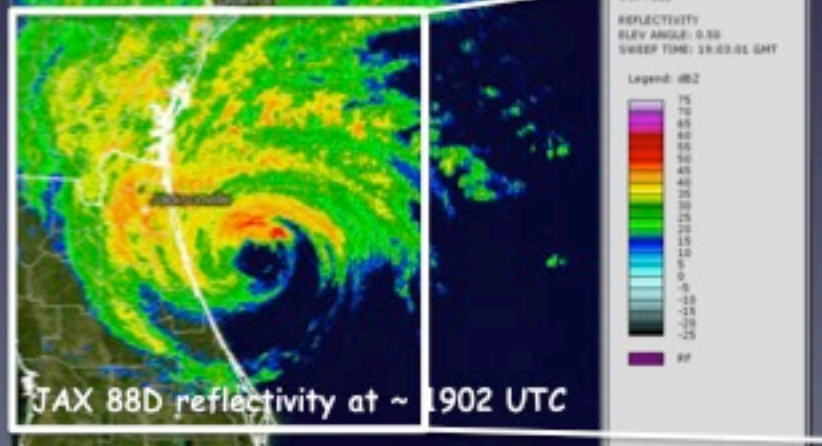
By Steve Guimond (UMD/NASA GSFC), Matt McLinden (NASA GSFC) and Gerald Heymsfield (NASA GSFC)

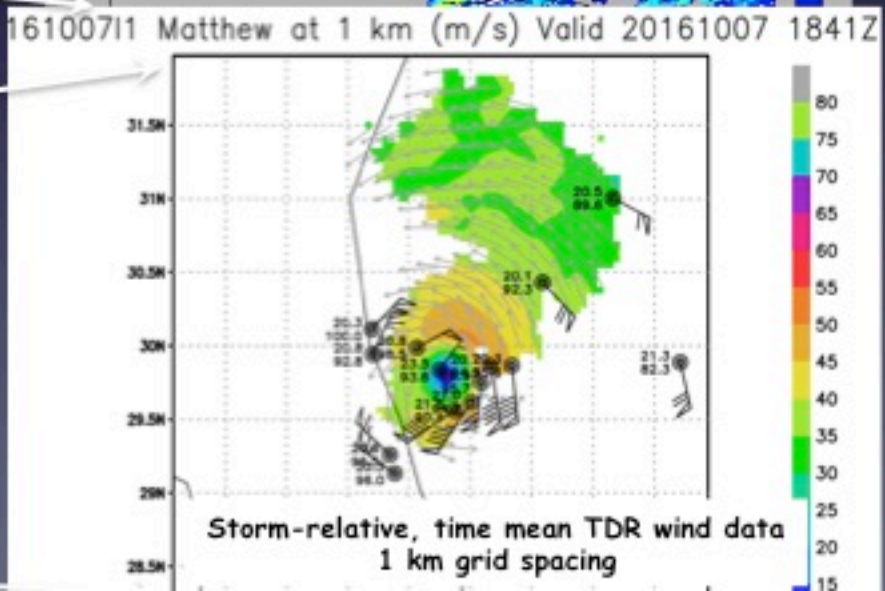
NOAA IFEX – Hurricane Matthew October 7, 2016 (~ 1830 UTC)
WP-3D LF Reflectivity and TDR/dropsonde Wind Vectors at 1 km Height

By Rob Rogers (NOAA/OAR/AOML/HRD), Frank Marks (NOAA/OAR/AOML/HRD) and Peter Black (NOAA/UASPO/CNT)



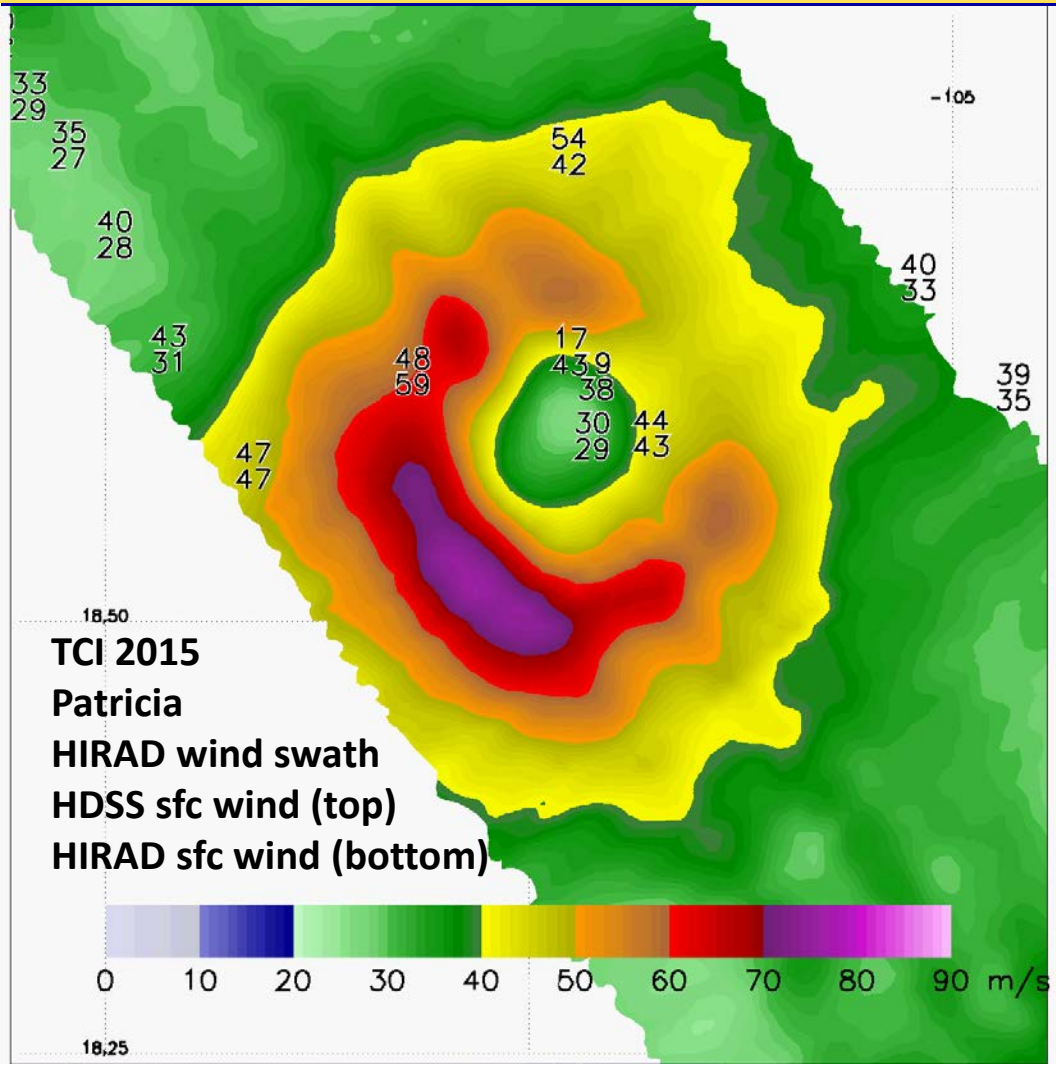


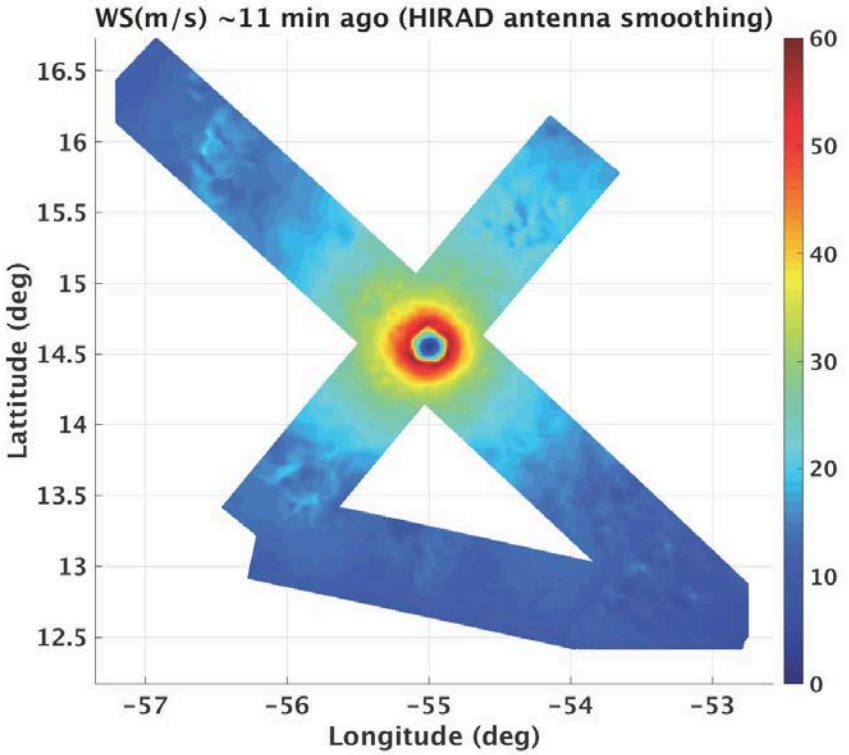




HIRAD example
In the future for GH

Eyewall surface winds mapped In 5 minutes





Courtesy Dan Cecil, IHC 2017

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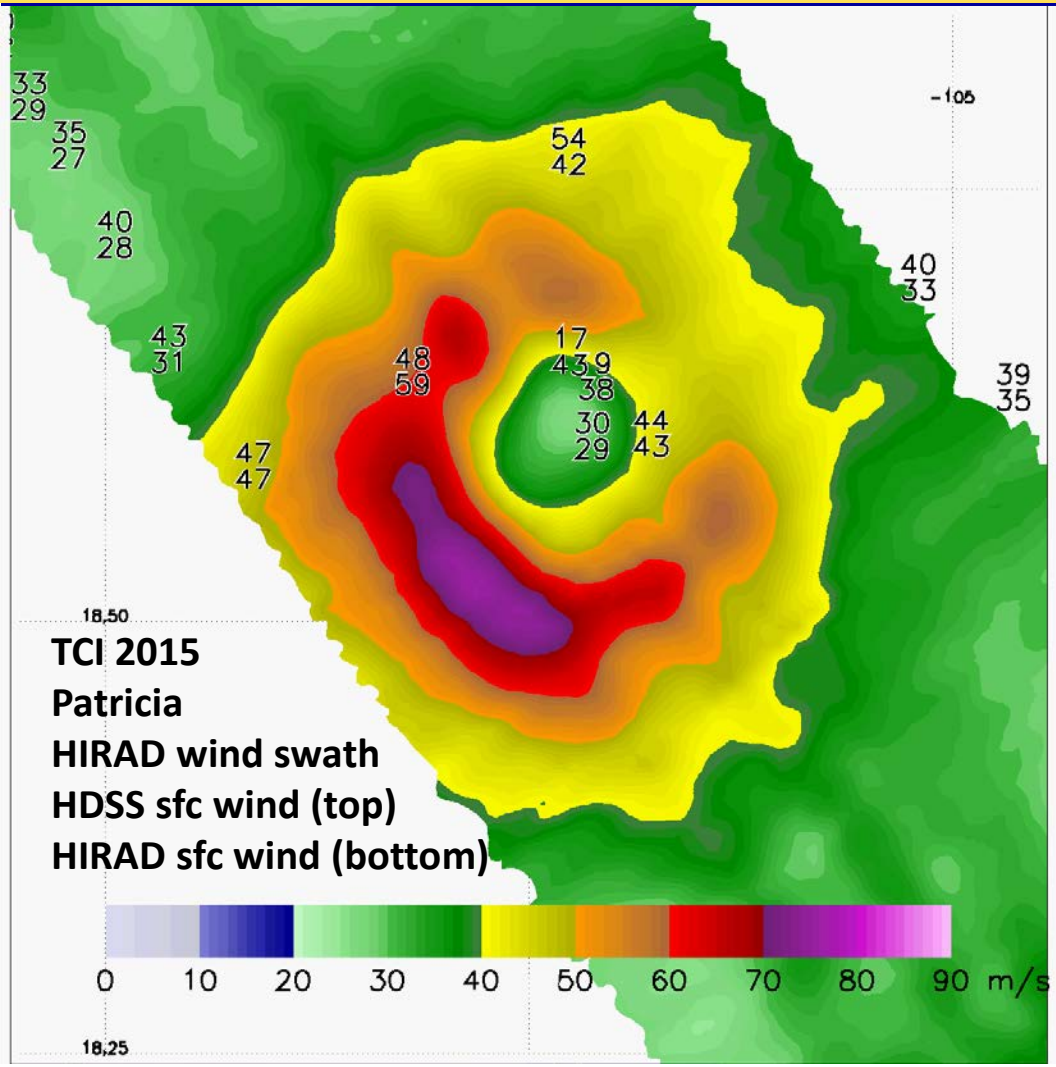
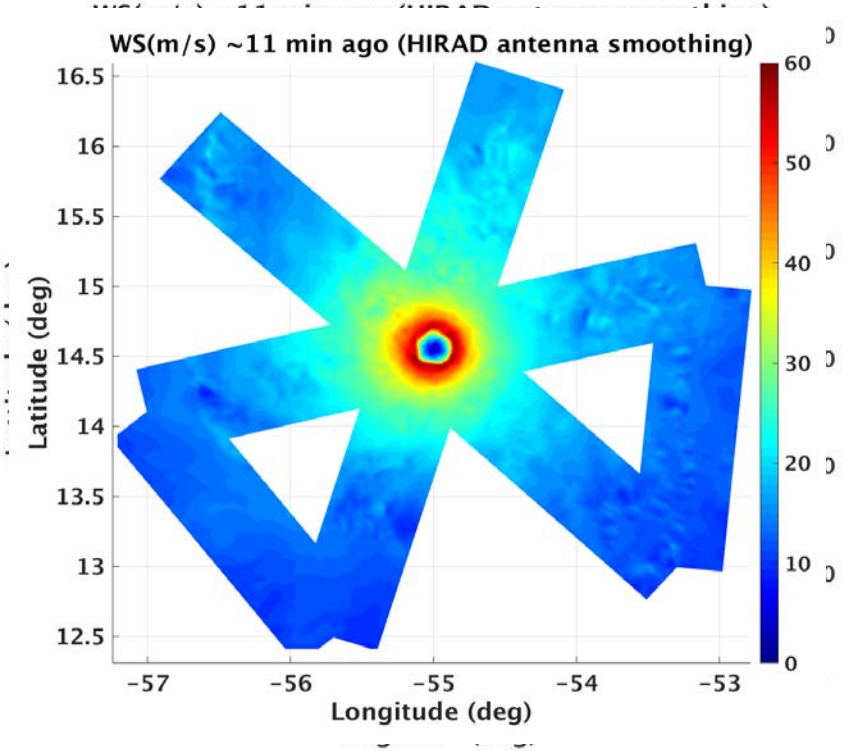


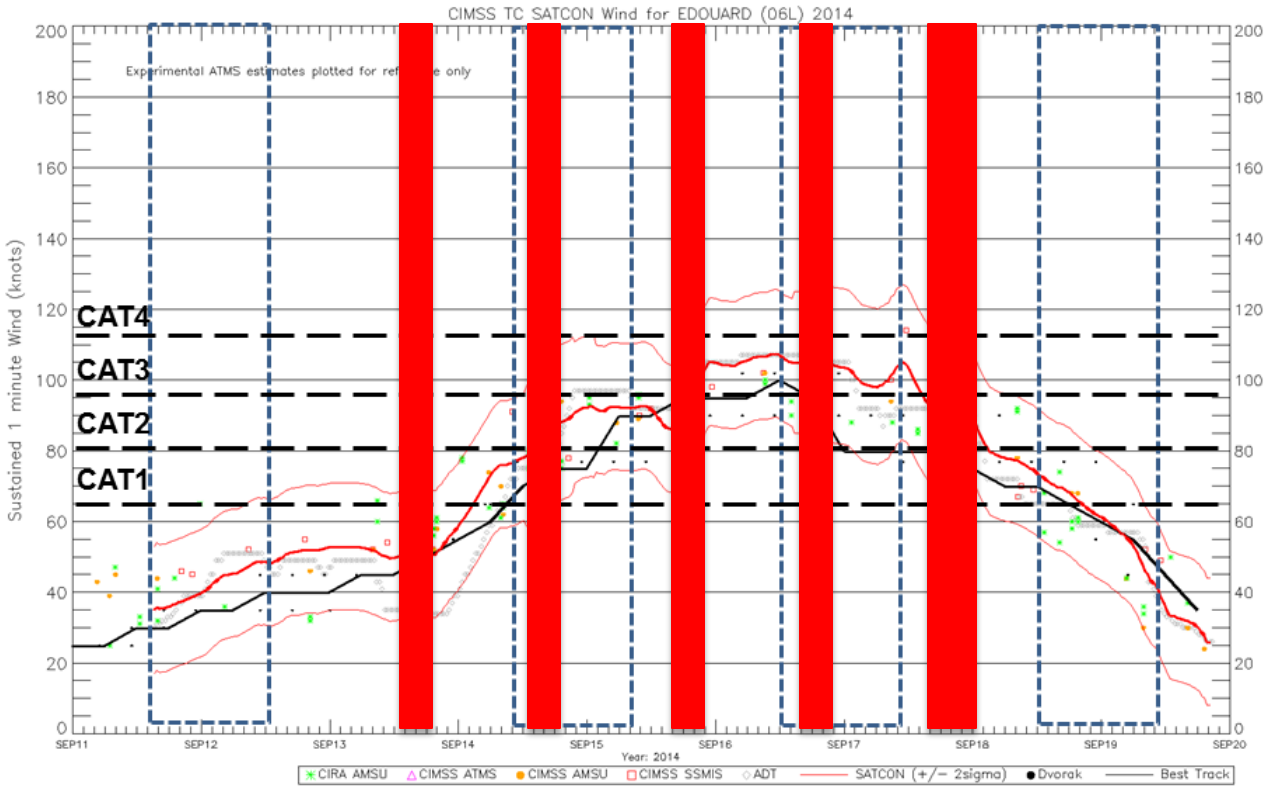


Courtesy Dan Cecil, IHC 2017

Complementary Unmanned/Manned Sampling Strategy for Maximum Benefit: GH vs P-3/GIV

Present/Past: Sondes over storm and environment for 18-24 Hr every other day for 8 da.

Future: EVERY DAY for 8 da with two aircraft/ 6 crews



Edouard 2014
Global Hawk UAV
AVAPS Minisondes
Synoptic Forcing

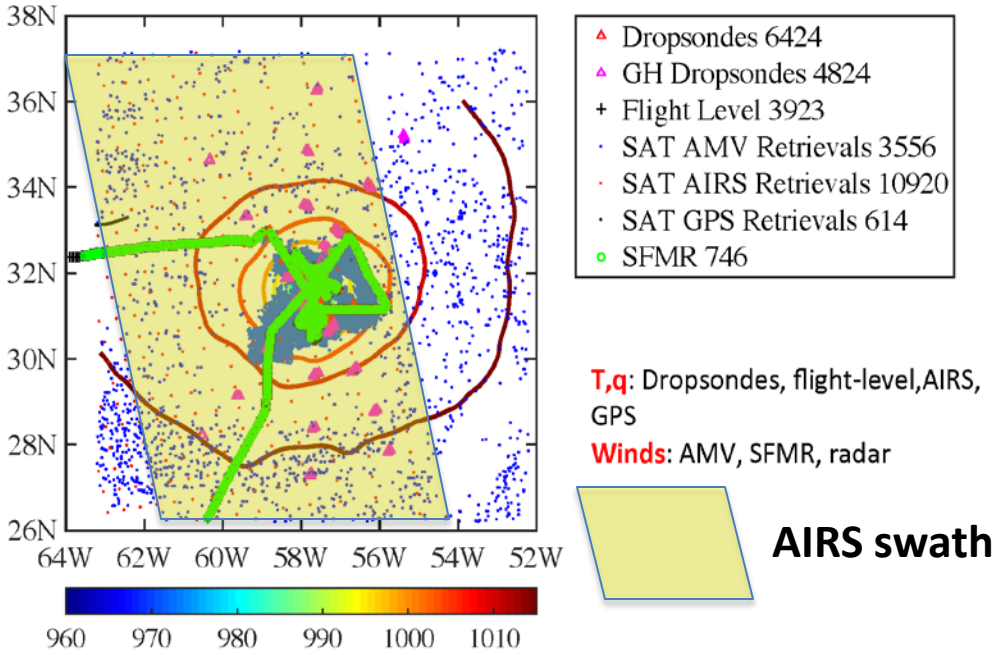
Global Hawk flights:

NOAA WP-3 flights:

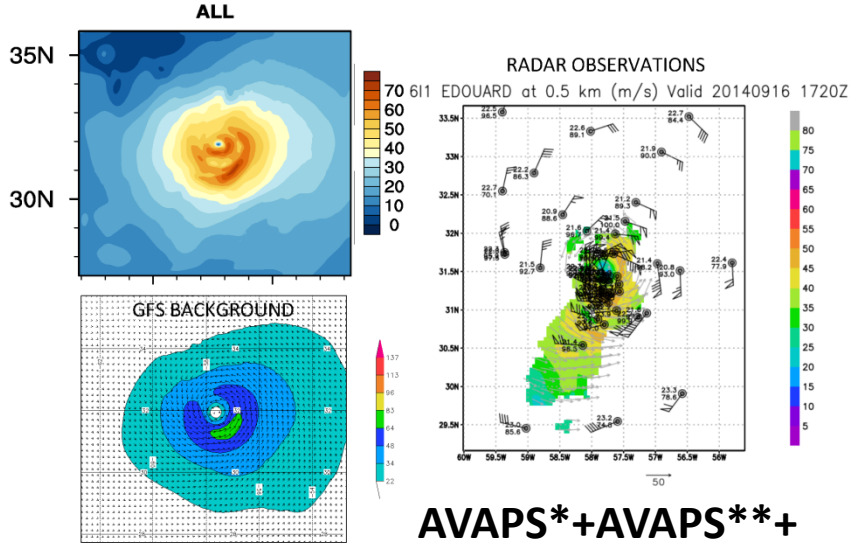
Aksoy, Christophersen, Dahl- 32HURR

Case Study: Hurricane Edouard (2014) 1800

Initial Data sources (sat overpass time):
GH AVAPS (pink) + WP3 SFMR/ AVAPS*/ TaDoppler (green) + Upper AMV (blue) + AIRS sat thermo profiles (yellow swath)**



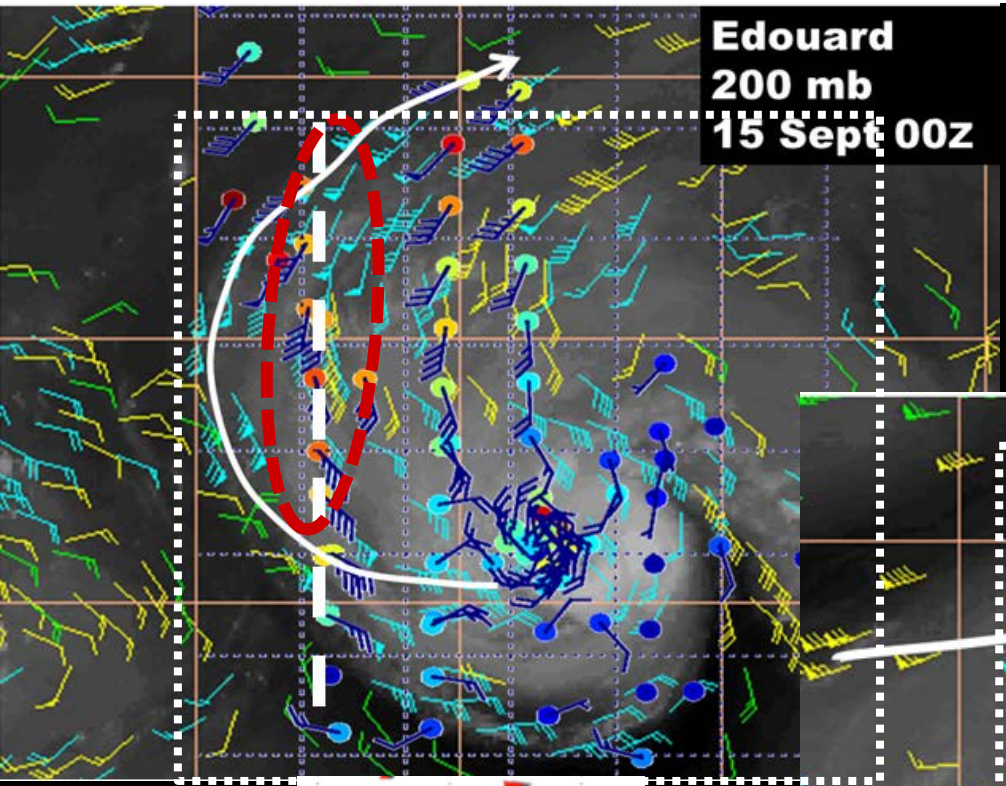
Comparison of 10-m Wind Speed



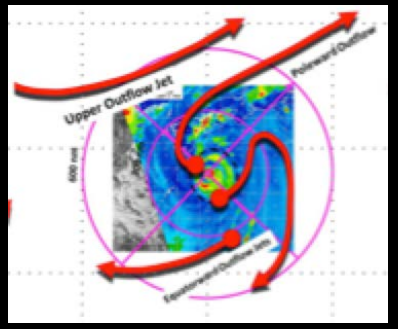
AVAPS*+AVAPS+ TaDoppler (500-m)**

WP3 Aircraft AVAPS*/Doppler/SFMR relative to GH AVAPS/HAMSR, AIRS & AMVs**

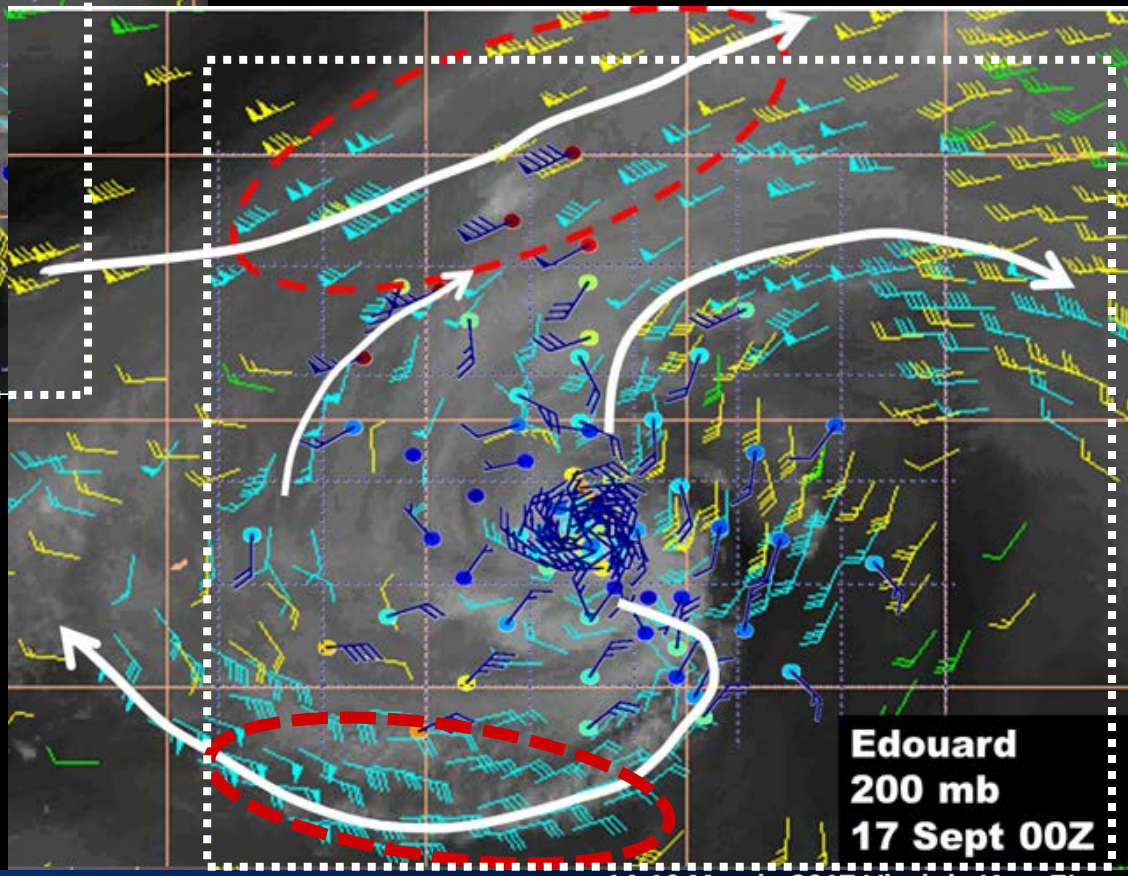
AVAPS*: WP3 RD-94 dropsondes
AVAPS: GH NRD-94 minisondes**



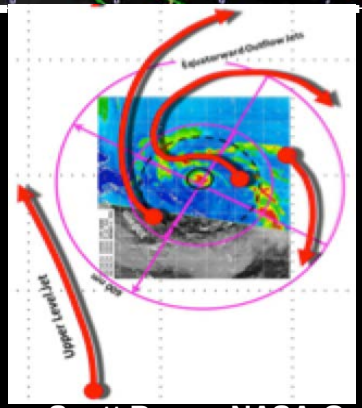
Efforts to sample both inner-core and large-scale environment



Phase II



Phase I

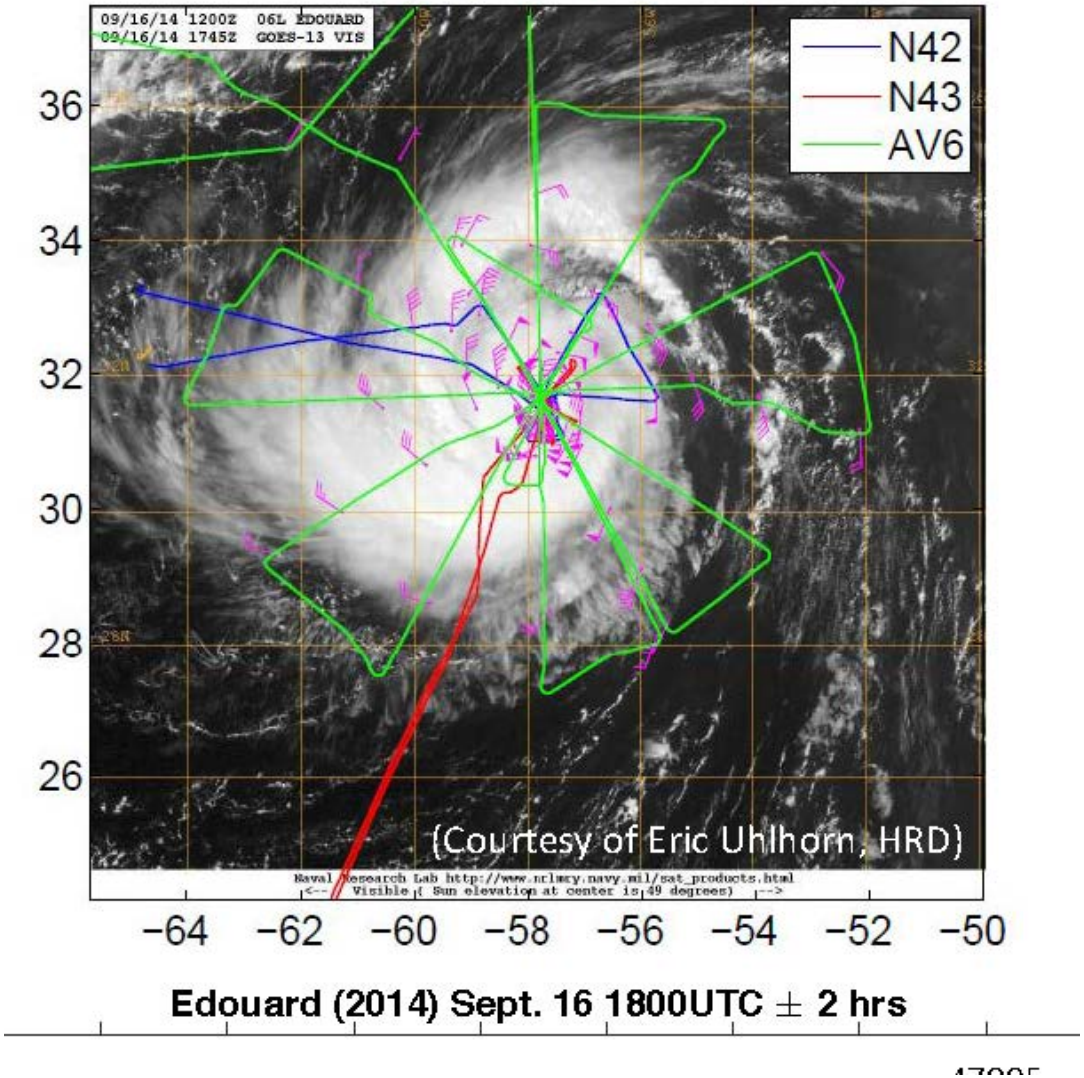


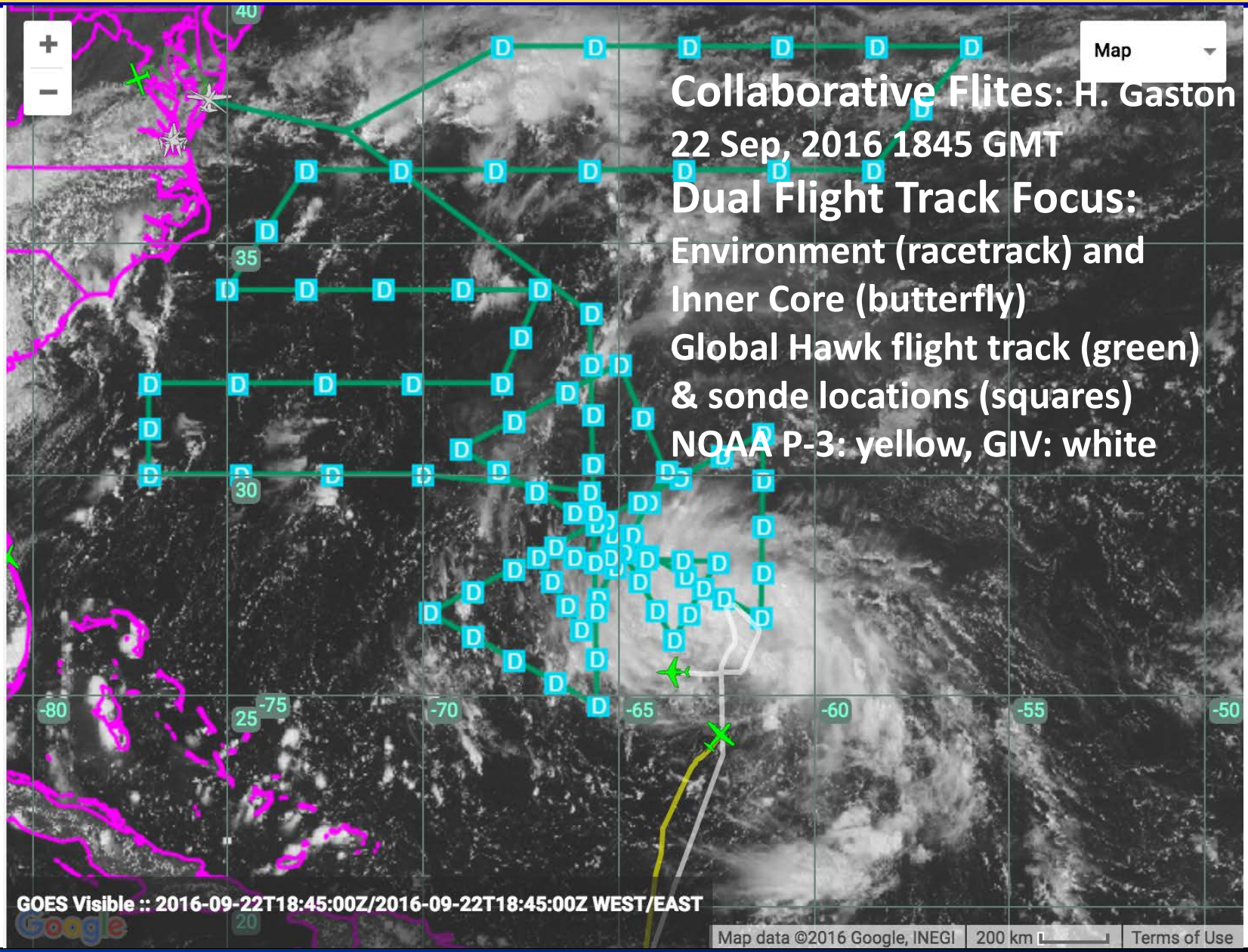
(Sonde plots courtesy Scott Braun, NASA Goddard)

(Rapid-Scan AMVs courtesy Chris Velden, CIMMS)

Aksoy, Christophersen, Dahl, SHOUT Brief 22May16

H. Edouard 16 Sept. Missions

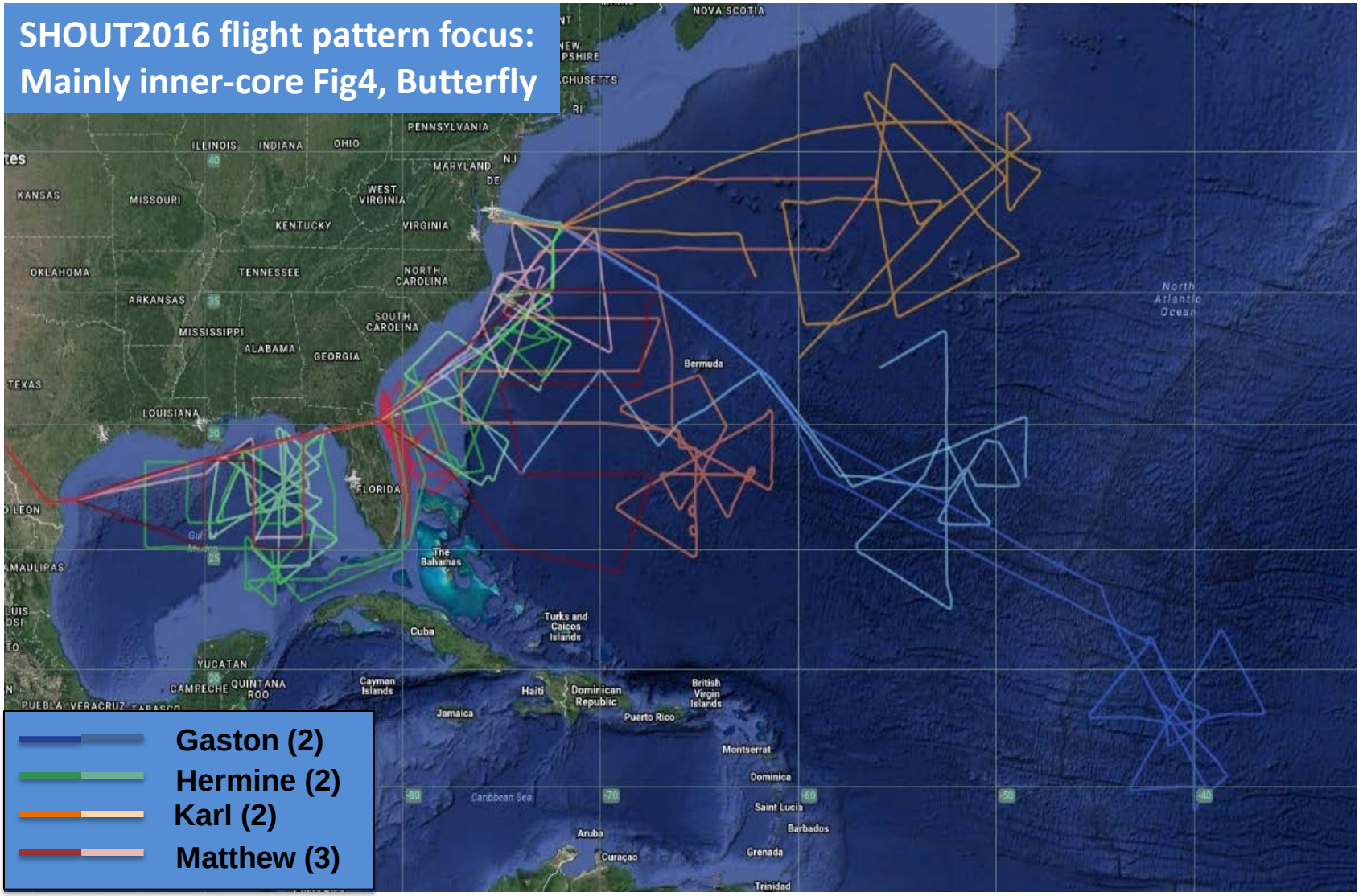



Map
Collaborative Flites: H. Gaston
22 Sep, 2016 1845 GMT
Dual Flight Track Focus:
Environment (racetrack) and
Inner Core (butterfly)
Global Hawk flight track (green)
& sonde locations (squares)
NOAA P-3: yellow, GIV: white
40
35
30
25
20
-80
-75
-70
-65
-60
-55
-50
GOES Visible :: 2016-09-22T18:45:00Z/2016-09-22T18:45:00Z WEST/EAST
Google
Map data ©2016 Google, INEGI
200 km
Terms of Use

SHOUT 2016 Summary

- Five Storms (2 landfalls), 9 flights in 7 weeks:
  - 2 Gaston,
  - 2 Hermine (1 pre-landfall)
  - 2 Karl,
  - Record 3 Matthew (back-to-back-to-back, one landfall)
  - 1 Matthew/ Nicole
- 214 Flight Hours (23.8 hr/flt)
- 647 sondes (72 sondes/flt)
  - 97% in real time to GTS
  - 95% passed HWRF and ECMWF QC
- Record 90 sondes in pre-Hermine flight
- Significant operational cost reduction due to improved efficiency, reduced/remote staffing, rapid response
- Dual operation from Armstrong and Wallops (Matthew)

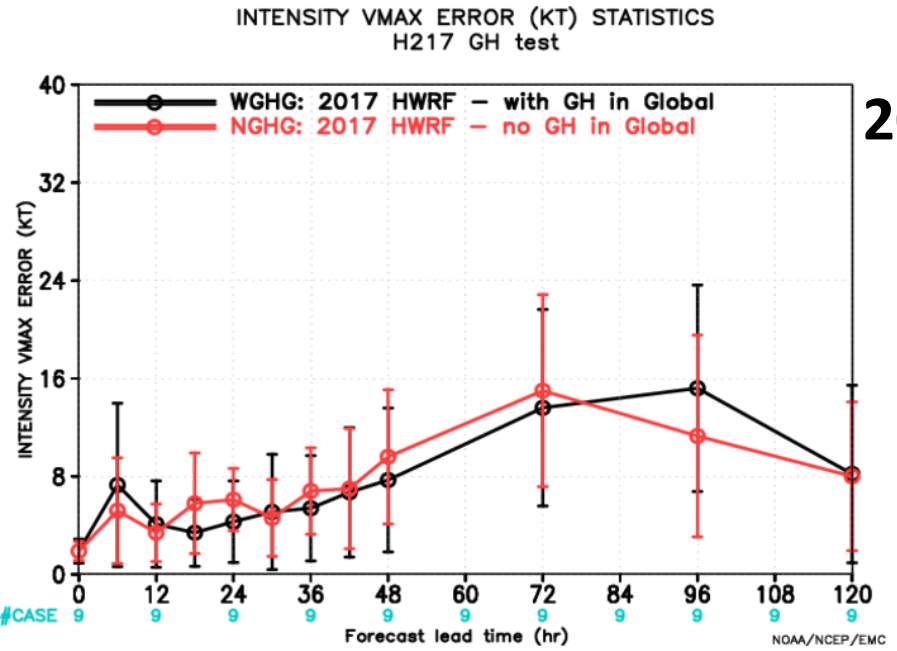
SHOUT2016 flight pattern focus: Mainly inner-core Fig4, Butterfly

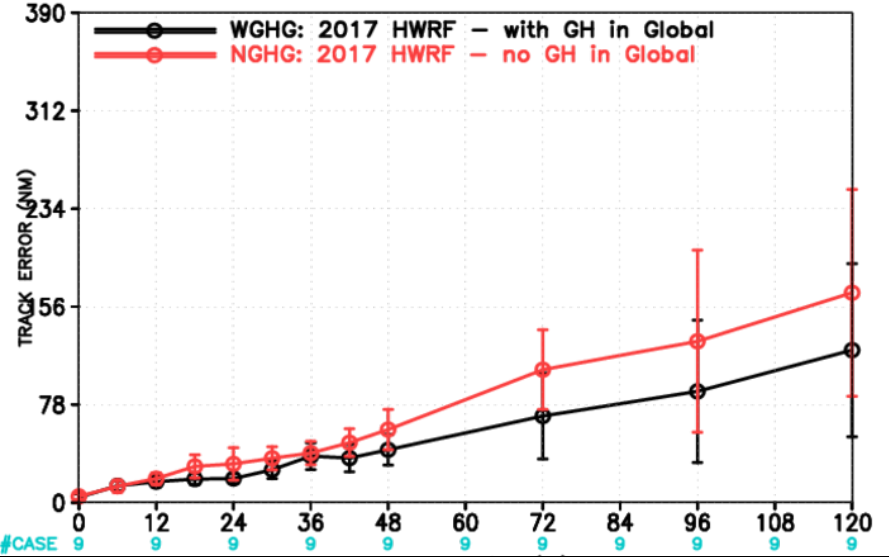


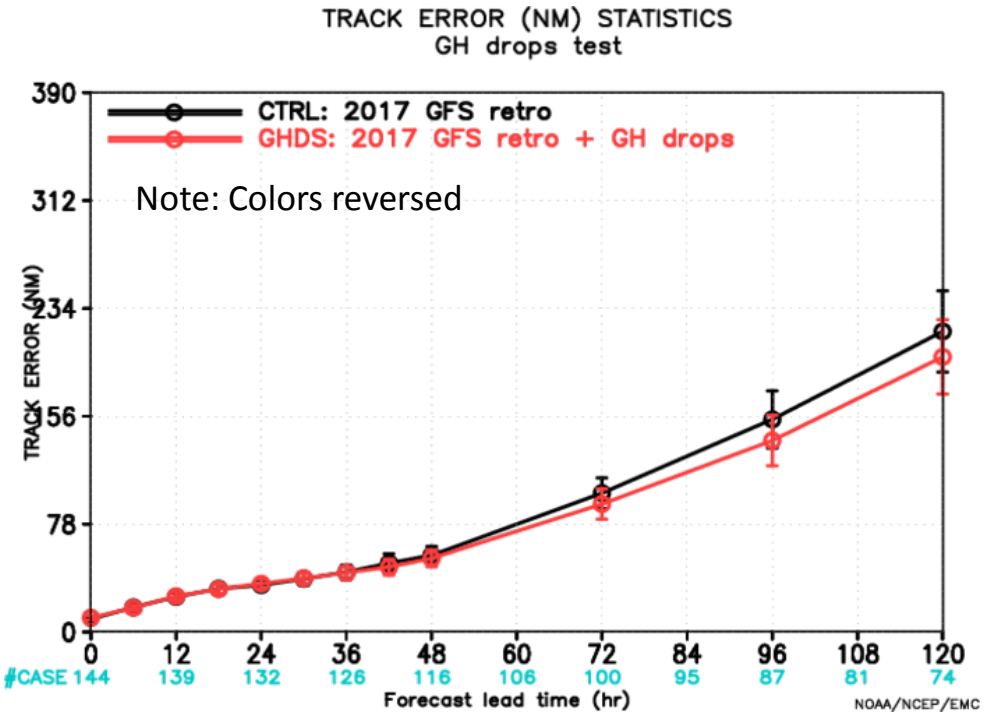
Global Hawk flight tracks during Sensing Hazards with Operational Unmanned Technology (SHOUT) Hurricane Rapid Response (HRR) 2016

Initial Sampling Strategy Results: 2016 SHOUT GH minisonde GFS impact

- 2016 GH flight impact on GFS model
- Utilizing BUFR formated sonde data
- Observed point by point position







From Howard, Sipple, Talapragada IHC2017

Global Hawk Flight Data Usage by National Hurricane Center 2016: Advisory and warning input

- 10 NHC forecast discussions in which Global Hawk observations referenced, i.e. > twice/ storm (Gaston, TD9/Hermine, Karl, and Matthew)
- Of nine Global Hawk flights, five provided observations used in forecast discussions, advisories.
- Represents continuity between standard reco/ surveillance flights and a key benefit of having an airborne asset that can remain on station for day-long time period
- Dropsonde data used in models operationally by HWRF (regional) and ECMWF (global)

Flight Plan Strategy Summary

1. Pattern alignment
   a. Storm-relative
   b. Shear-Relative
   c. Earth-relative
2. Feature-Relative
   a. Inner-core features
      i. Convective bursts
      ii. Outflow Roots
   b. Environmental features
      i. Outflow jets
      ii. Upper cold lows
      iii. Subtropical jet streaks
   c. Ocean features
      i. Pre-existing eddies
      ii. Cold wake
3. Pattern Temporal Phasing
   i. DA cycle (Phase/Duration)
   ii. RI onset time
   iii. Diurnal convective/outflow surge onset
4. Collaborative Observation times
   i. Aircraft
   ii. Satellite

NOAA SHOUT Global Hawk flight crew: Jon Neuhaus and Will Odell, pilots; Chris Sloan, Mission Director; Mark Rogers, GHOC mission operator (L to R)