Sensing Hazards with Operational Unmanned Technology (SHOUT) Mission Concept

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SHOUT: Overarching Goal

Demonstrate and test prototype UAS concept of operations that could be used to mitigate the risk of diminished high impact weather forecasts and warnings in the case of polar-orbiting satellite observing gaps

NOAA's Weather-Ready Nation:

- *optimize UAS data collection to improve forecasts of high impact weather events*

SHOUT Objectives (Cont'd)

Objective 1: UAS Data Impact

- Observing System Experiments (OSE) using data from UAS field missions
- Utilize adaptive aircraft sampling strategies for improving real-time TC track and intensity forecasts
  - 80 member HWRF/50 member ECMWF model ensembles
- Observing System Simulation Experiments (OSSE) using simulated UAS data

SHOUT Objectives (Cont'd)

<u>Objective 2: Improved Understanding of Tropical Cyclones Processes</u>

- Investigate processes in the TC inner core (e.g. warm core), boundary layer, diurnal cycle, and upper-level environment (e.g. cirrus canopy) that impact intensity change and structure

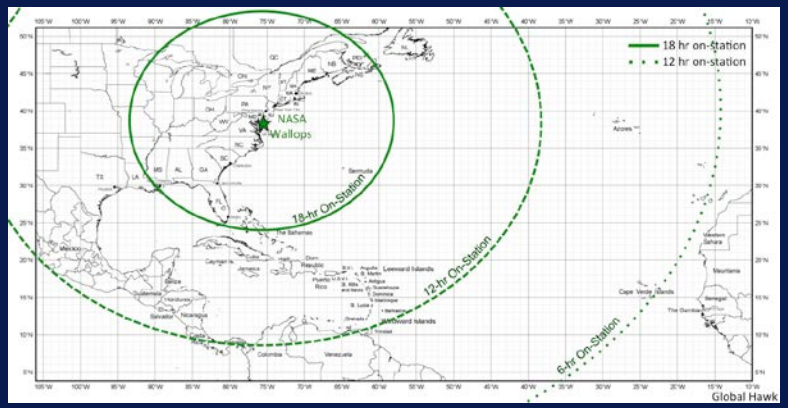
SHOUT Objectives (Cont'd)

Objective 3: Cost-Operational Benefit Analysis

- Quantify the cost and operational benefit of UAS observing technology for high impact weather prediction
- Conduct detailed analyses of life-cycle operational costs and constraints versus scientific benefit.

NOAA SHOUT Project Assets

Global Hawk Aircraft



- Flight Level: ~55-65,000 ft
- Duration: ~24 hr
- Flight Frequency
  - *1x per 48 hr (every other day)*
  - *3 consecutive flights*
  - *7 day max >> hard down*
- Range: 8-10,000 nm
- Deployment Sites
  - *NASA Wallops Flight Facility (Wallops Island, VA)*
  - *NASA Armstrong Flight Research Facility (Edwards AFB, CA)*
- Payload: 1,500+ lbs
- Global Hawk Operations Center (GHOC) mission support
  - *3 shifts per mission*

Global Hawk Instrumentation (2015-2016)

Airborne Vertical Atmospheric Profiling System (AVAPS)

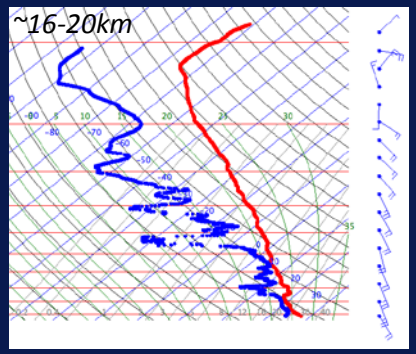
***PI**: Terry Hock, NCAR / Gary Wick, NOAA*

***Measurements**:*

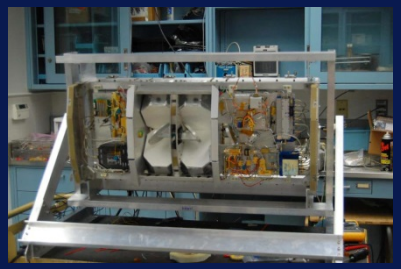
- *temperature, pressure, wind, humidity (vertical profiles)*
- *90 dropsondes per flight*

***Resolution**:*

- *~2.5 m (winds), ~5 m (PTH)*



High Altitude Monolithic Microwave Integrated Circuit (MMIC) Sounding Radiometer (HAMSR)



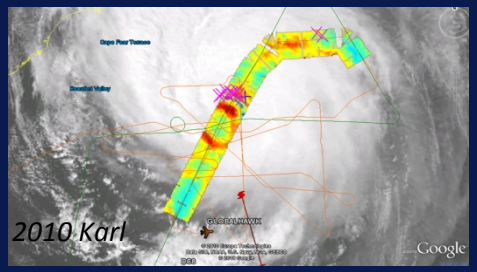
***PI**: Dr. Bjorn Lambrigtsen, JPL*

***Measurements**:*

- *Microwave AMSU-like sounder;*
- *25 spectral channels in 3 bands;(50-60 GHz, 118 GHz, and 183 GHz)*
- *3-D distribution of temperature, water vapor, & cloud liquid water;*

***Resolution**:*

- *2 km vertical; 2 km horizontal (nadir)*
- *40 km wide swath*



High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP)

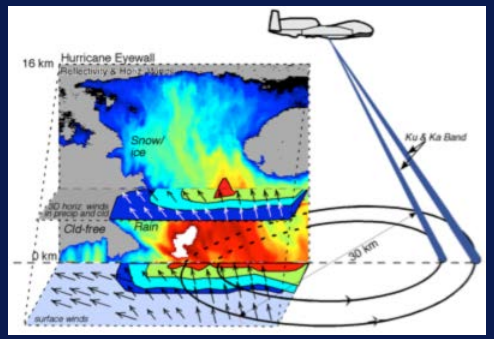
PI: Dr. Gerald Heymsfield, NASA GSFC

***Measurements**:*

- *Dual-frequency (Ka- & Ku-band), dual beam, conical scanning Doppler radar*
- *3-D winds, ocean vector winds, and precipitation;*

***Resolution**:*

- *60 m vertical, 1 km horizontal;*



NOAA SHOUT Project Assets

Personnel, Tools, and Collaborations

- NOAA Hurricane Research Division forecasting team, federal/university/ONR TCI mission scientist team
- Numerical simulations to optimize sampling strategies & observation types that will improve TC forecasts (OSEs, OSSEs, ensemble-based targeted observations)
- HRD aircraft track design software, real-time mission monitoring (NASA MTS)
- Real-time GPS dropsonde processing and transmission to the Global Telecommunication System (GTS)
- Collaborations: NOAA IFEX, NOAA ESRL, ONR TCI, NAWDEX

Global Hawk Flight Modules

On-Station Time

- ~14.0 hr (3.25 hr/6.5/3.0 hr)
- Small: R=0 to 120 nm (220 km)
- Large: R=0 to 240 nm (450 km)

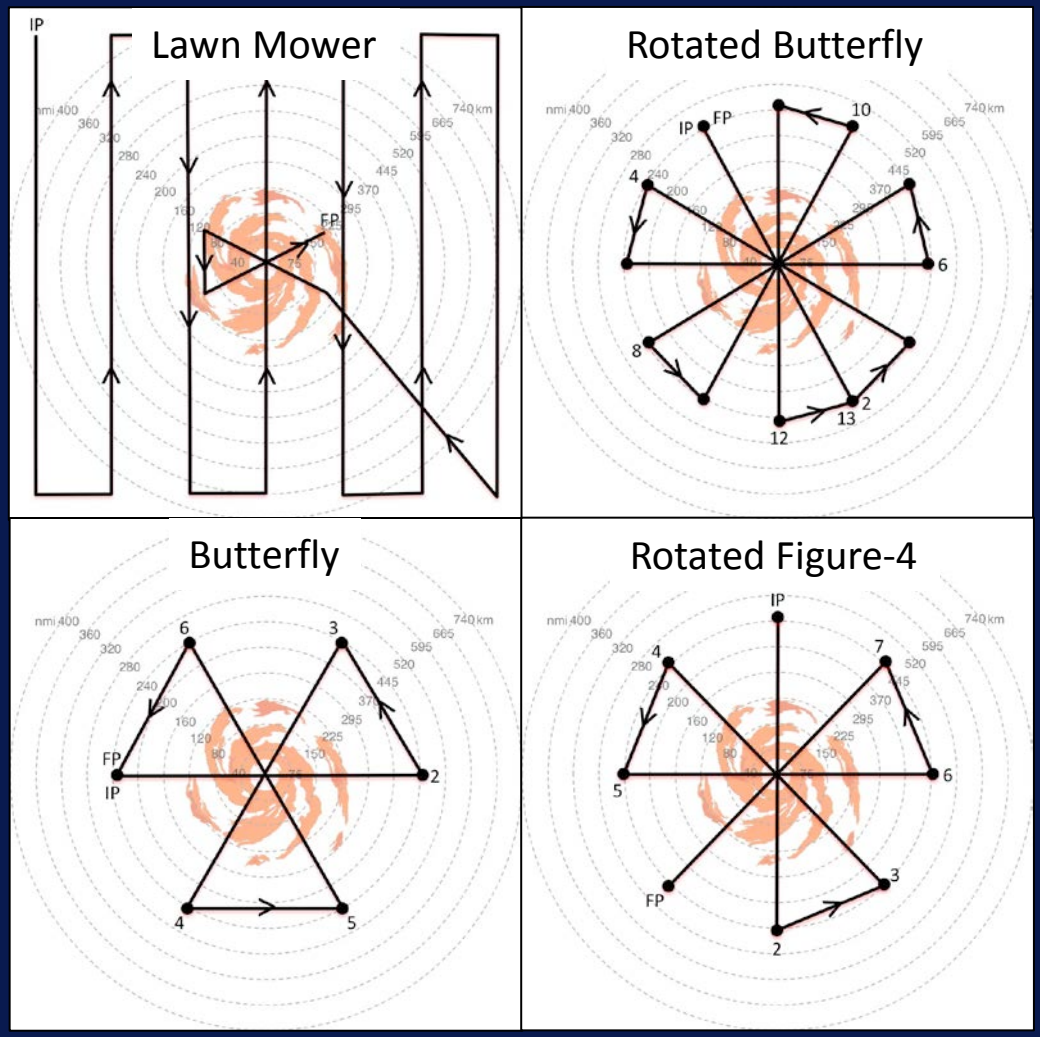
Advantages

- Radial/Azimuthal sampling
- 2 Inner core snapshots
- Radial gradients
- 9 center crossings
- Inner core & environ sampling
- HAMSR & HIWRAP >> inner core

Disadvantages

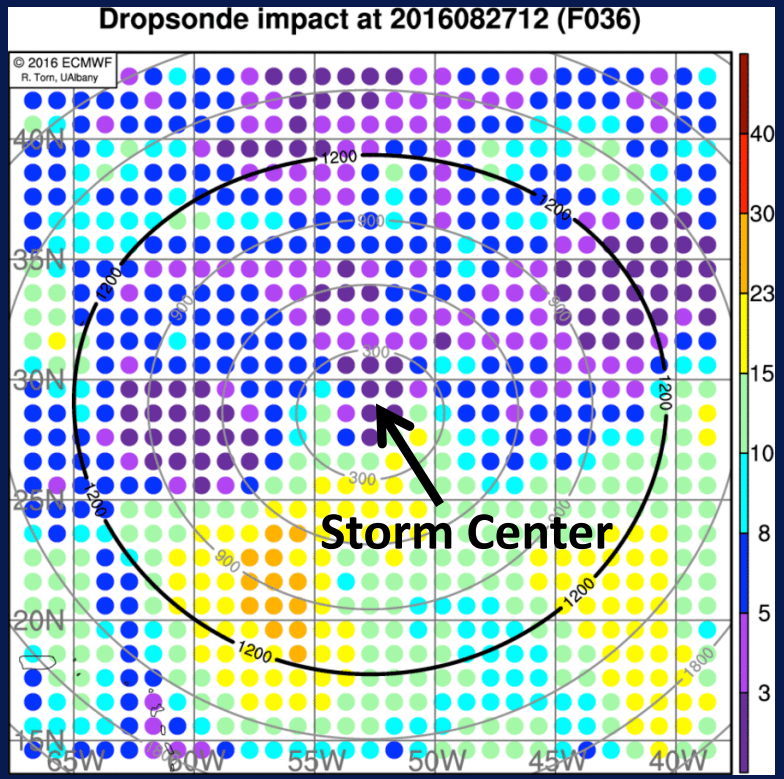
- Far field sampling limited
- Navigating center crossings

Butterfly (small-large-small)

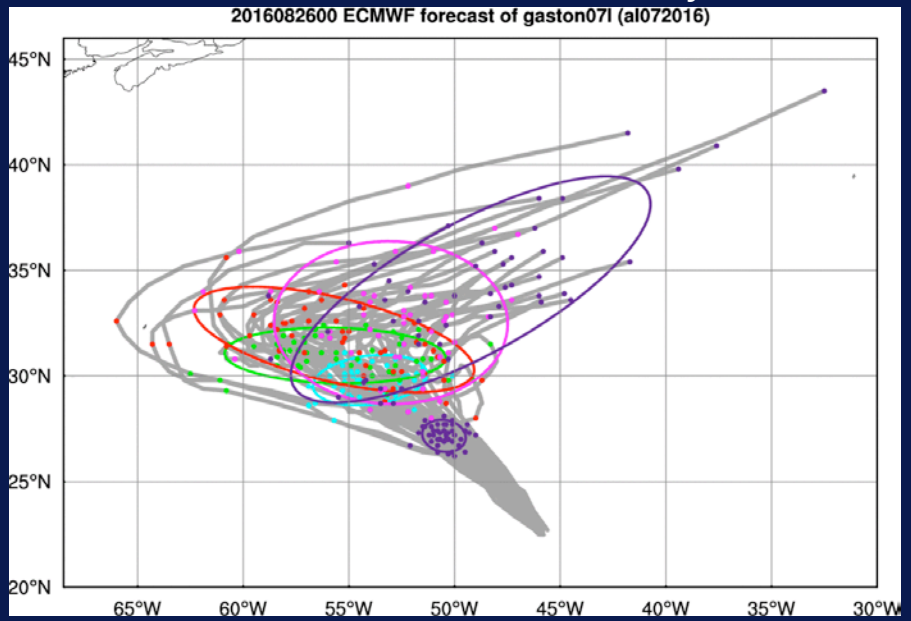


Adaptive Aircraft Sampling (GPS Dropsondes)

2016 Hurricane Gaston



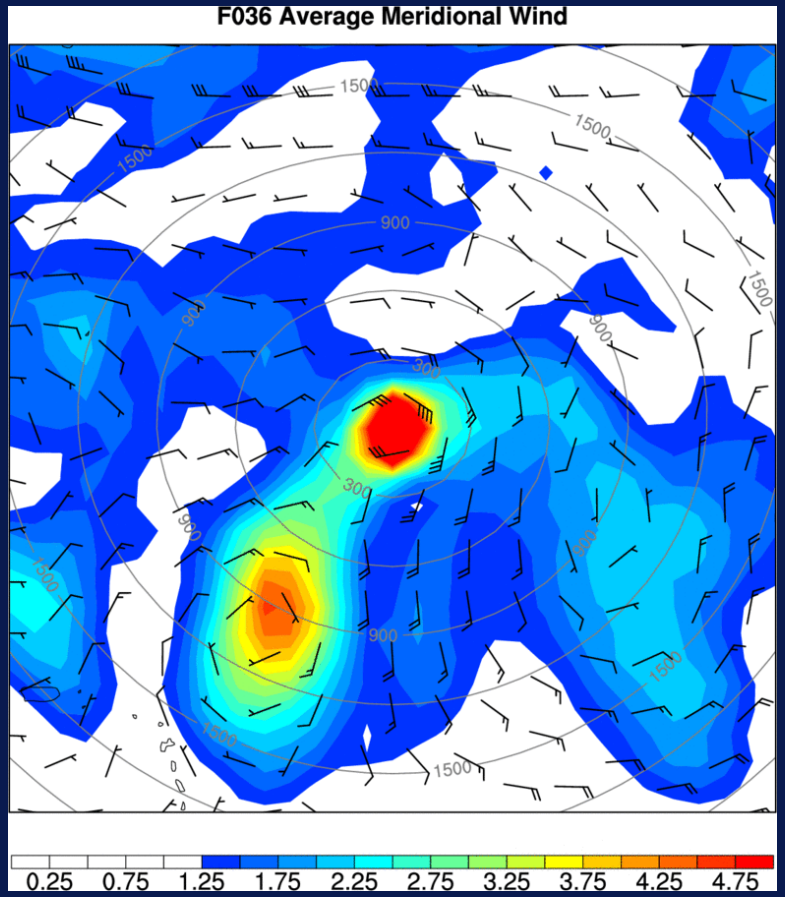
ECMWF 50 member ensemble track forecasts



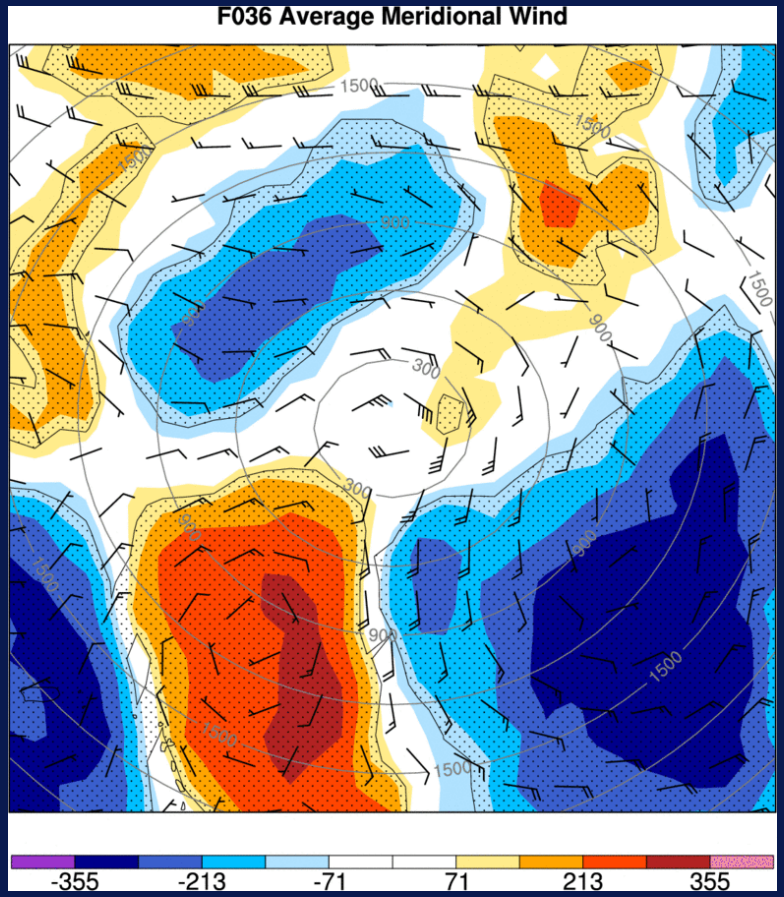
- Analyses based on 80 (50) member HWRF (ECMWF) ensemble forecasts
- (Left) Hypothetical reduction in model uncertainty due to assimilating GPS dropsonde observations at that location
- (Left) Warmer colors >> favorable regions for dropsonde sampling

Adaptive Aircraft Sampling (GPS Dropsondes)

Forecast Uncertainty

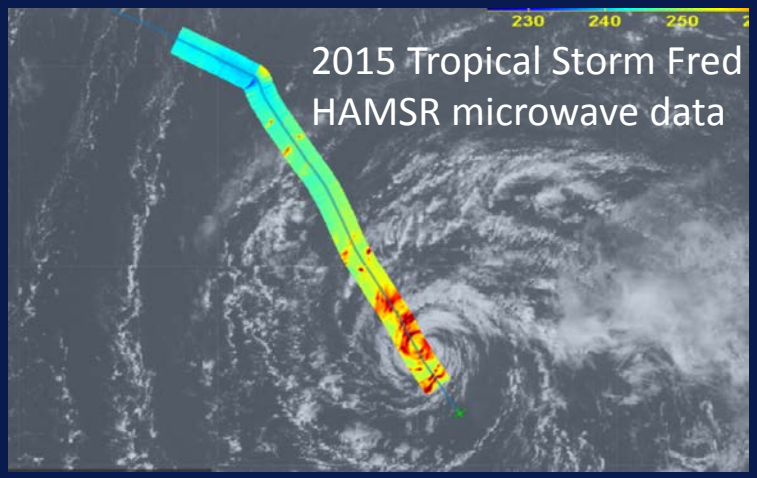


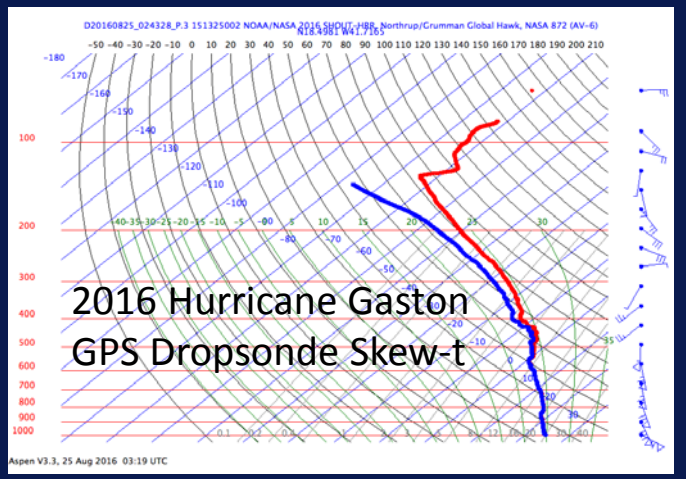
Sensitivity



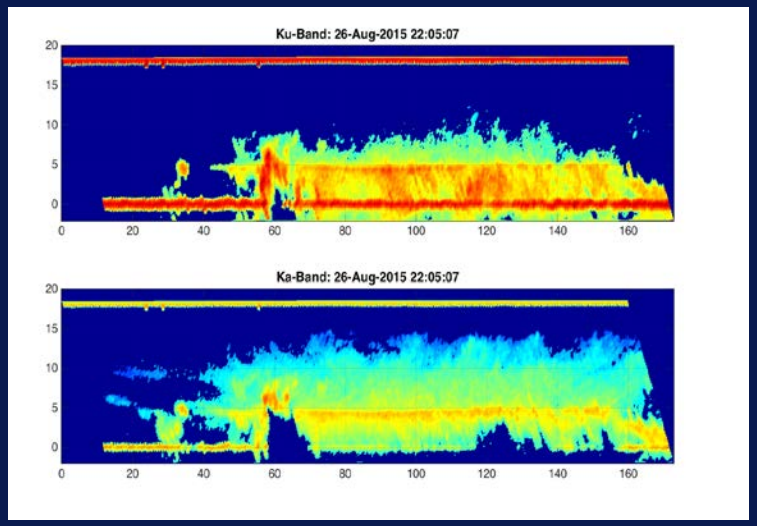
- Forecast Uncertainty: where is there uncertainty in the model forecast?
- Sensitivity: where is the model more vs less sensitive to observations?
- Where do you sample and will the model be sensitive to your added data?

Real-Time Data Products to the National Hurricane Center





2015 TS Erika: HIWRAP Radar Cross-Section



2016 Hurricane Gaston
GPS Dropsonde WMO Message

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000
UZNT13 KWBC 250321
XXAA  75031 99185 70417 04181 99995 24600 12069 00543 ///// /////
92640 21400 14584 85372 17800 15585 70023 11000 16566 50576 02105
17561 40751 12918 22537 30966 25731 24005 25095 36539 12022 20245
50550 12033 15426 66964 15517 10665 735// 12021 88133 733// 19013
88105 733// 10026 77999
31313 09608 80243
61616 NA872 WX07A GASTON1       OB 73
62626 MBL WND 13080 AEV 33270 DLM WND 16046 994666 WL150 12577 08
3 REL 1850N04172W 024327 SPG 1869N04179W 030132 =
XXBB  75038 99185 70417 04181 00995 24600 11850 17800 22717 12200
33428 07513 44402 12718 55327 21126 66257 34537 77185 54956 88139
70966 99130 743// 11125 689// 22123 681// 33110 727//
21212 00995 12069 11992 12568 22984 13082 33973 13076 44964 13085
55953 13584 66936 14075 77928 14084 88850 15585 99513 17563 11436
18538 22024 33420 23027 44387 23530 55346 23025 66330 21022
77318 21011 88289 00000 99272 10510 11255 12020 22243 10528 33227
11034 44209 11034 55186 14028 66163 14528 77152 14518 88134 19013
99130 18012 11127 20508 22119 12016 33116 11022 44110 12017 55104
10027
31313 09608 80243
61616 NA872 WX07A GASTON1       OB 73
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3 REL 1850N04172W 024327 SPG 1869N04179W 030132 =
XXCC  75037 99185 70417 04181 70877 731// 11033 88999 77999
31313 09608 80243
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62626 MBL WND 13080 AEV 33270 DLM WND 16046 994666 WL150 12577 08
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XXDD  7503/ 99185 70417 04181 11898 747// 22852 723// 33666 733//
21212 11946 14021 22893 13030 33845 12522 44820 14510 55801 10505
66777 06010 77734 08523 88711 11536 99666 09028
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51515 10190 50071
61616 NA872 WX07A GASTON1       OB 73
62626 MBL WND 13080 AEV 33270 DLM WND 16046 994666 WL150 12577 08
3 REL 1850N04172W 024327 SPG 1869N04179W 030132 =
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Real-Time Data Products NOAA NHC

Utilization of SHOUT Data by Forecasters

2016 Hurricane Gaston

NOAA NHC Tropical Cyclone Report

- *25 Aug: "Operationally, Gaston was analyzed as a 60-kt tropical storm until dropwindsonde data from a NASA Global Hawk unmanned aircraft mission indicated that the tropical cyclone was a hurricane."*

2016 Tropical Depression Nine (Hurricane Hermine mission)

NOAA NHC Discussion #7

- *30 Aug: "A dropsonde from the Global Hawk reported 33 kt surface winds, but the mean-layer wind over the lowest 150 m support winds closer to 30 kt. A very recent center drop from the unmanned aircraft indicate that the minimum pressure is 1003 mb."*

2016 Post-Tropical Cyclone Matthew

NOAA NHC Discussion #47

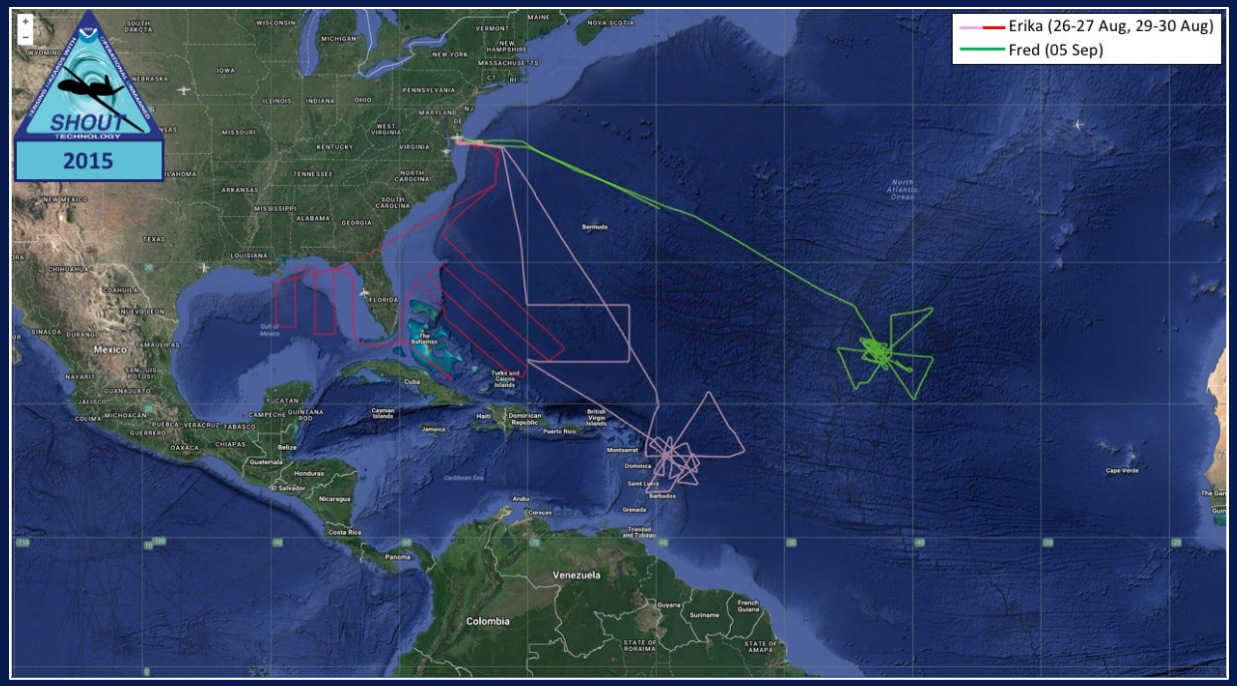
- *09 Oct: "Dropsonde data from a NASA Global Hawk mission into Matthew today indicate that the post-tropical cyclone has not weakened. The observations continue to show a band of 60-65 kt winds to the SW and west of the center."*

2016 NOAA SHOUT HRR
Mission Science Schedule

Science Operations:

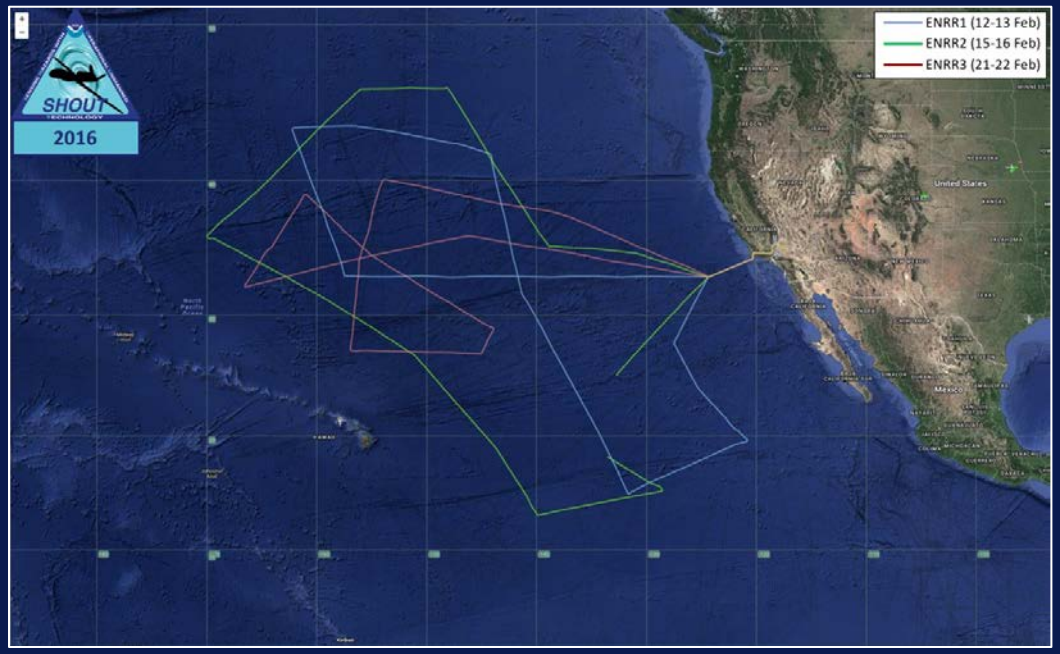
- 0730 EDT: daily cage meeting (shift-1 mission scientists & pilots)
- 0830 EDT: daily SHOUT coordination call
  - Wallops local weather (NASA Wallops-led Mo-Fr; SHOUT-led Sa-Su)
  - MS shift-1: lead with a 5-10 min weather update)
  - Discussion of flight plans and strategies
- 1000 EDT: Coordination call with NOAA IFEX and NAWDEX
- 1100 EDT: Coordination with pilots
- 1200 EDT: HRD map discussion (Mo-Fr); SHOUT-led map discussion (Sa-Su)

SHOUT Field Campaigns: Hurricanes 2015



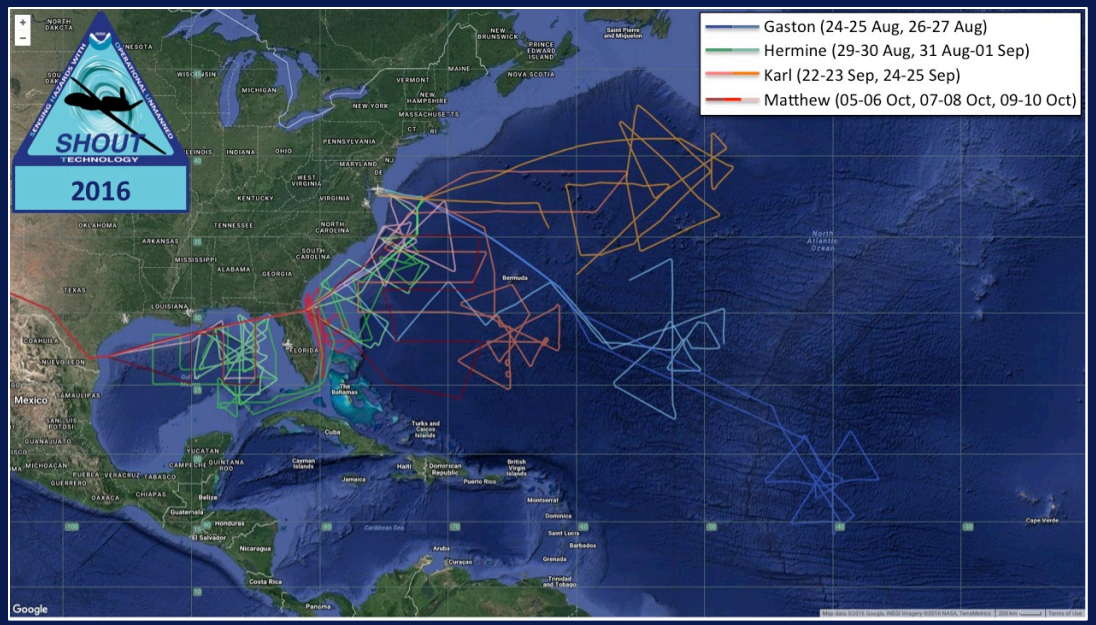
- 3 missions flown
  - Tropical Storm Erika (2) and Tropical Storm Fred (1)
- First NOAA-operational assimilation of Global Hawk dropsondes
- Refinement of real-time data delivery
- Demonstration of forecast sensitivity targeting (HWRF ensemble)
- Demonstration of bi-coastal operations

SHOUT Field Campaigns: El Nino Rapid Response 2016



- Demonstrated ability to plan and deploy on short notice
  - Reduced in-field staffing
- 3 missions flown
  - Atmospheric river impacts in Pacific NW (12-13 Feb)
  - Trough interactions and cutoff low in advance of southern California precipitation (15-16 Feb)
  - Dual impacts in Alaska and SE US; AF C-130 & G-IV coordination (15-16 Feb)
- Further advances to real-time data delivery

SHOUT Field Campaigns: Hurricane Rapid Response 2016



- 9 missions flown
  - Gaston (2), Hermine (2), Karl (2) and Matthew (3)
  - Initial NASA AFRC-based followed by a deployment to NASA WFF
- Shift to operational type demonstration
  - Deploy aircraft and science teams on demand
  - Increased reliance on offsite staffing (e.g. remote mission scientists)
- Collaborations with the NOAA IFEX and European NAWDEX field programs and the ONR TCI science team

Conclusions

- The NOAA UAS Program is evaluating the potential for unmanned aircraft to positively influence forecasts of high-impact weather events
- Three successful field deployments completed from 2015-2016
- Studies already underway demonstrating positive forecast impact from Global Hawk data
- Streamlined field operations have demonstrated operational applications for UAS platforms like the Global Hawk