Sensing Hazards with Operational Unmanned Technology (SHOUT)

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Project Goal and Objectives

Overall Goal

Demonstrate and test prototype Unmanned Aircraft Systems (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

Objectives

Evaluate data impact, affordability, and operational feasibility of UAS operations

Comparison of Joint Polar Satellite System (JPSS) and Aircraft Sensors

JPSS Sensor	*JPSS Observation*	*Aircraft Sensor*	*Aircraft Observation*	*Aircraft Integration History*
Advanced Technology Microwave Sounder (ATMS)	Remotely sensed atmospheric temperature and moisture profiles in clouds	High Altitude Monolithic microwave integrated circuit Sounding Radiometer (HAMSR)	Remotely sensed atmospheric temperature and moisture profiles in clouds	NASA Global Hawk NASA ER-2
		Airborne Vertical Atmospheric Profiling System (AVAPS)	*In situ* atmospheric temperature, moisture, wind speed and wind direction profiles	NASA Global Hawk NCAR Gulfstream 5
Cross-track Infrared Sounder (CrIS)	Remotely sensed atmospheric temperature and moisture profiles in clear air	Scanning High-resolution Interferometer Sounder (S-HIS)	Remotely sensed atmospheric temperature and moisture profiles in clear air	NASA Global Hawk NASA ER-2 NASA DC-8
		Airborne Vertical Atmospheric Profiling System (AVAPS)	*In situ* atmospheric temperature, moisture, wind speed and wind direction profiles	NASA Global Hawk NCAR Gulfstream 5

NASA Global Hawk Unmanned Aircraft System (UAS)

Flight Level: ~ 55,000-63,000 ft

Duration: ~26 hr

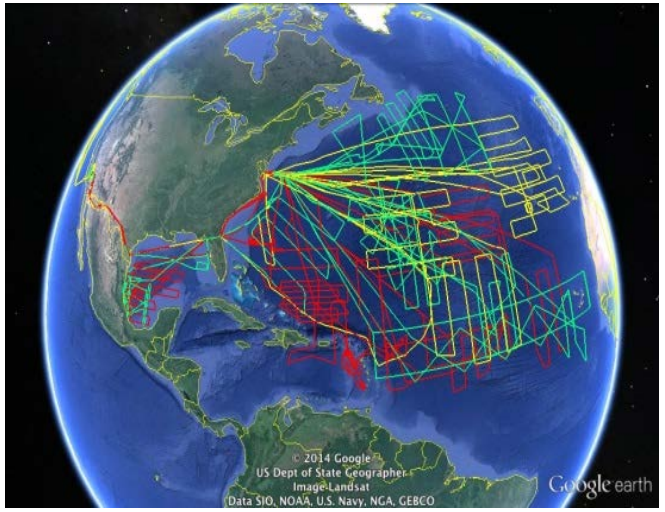
Range: ~11,000 nm

Payload: ~1,500+ lbs

Deployment Sites*:

West Coast - ***NASA Armstrong Flight Research Center (Edwards AFB)***

East Coast - ***NASA Wallops Flight Facility (Wallops Island, VA)***



***Mobile Ground Control Station can be deployed at any feasible runway location and has been demonstrated at Edwards AFB, Wallops FF, and Andersen AFB, Guam.**

Data Impact

Change (%) in NWS Hurricane Weather Research and Forecasting Model Prediction Skill due to Global Hawk Dropsondes

(green = improvement, red = degradation)

Forecast period	Without Satellite With Global Hawk Dropsondes		With Satellite With Global Hawk Dropsondes	
	Track	Intensity	Track	Intensity
12 hour	0	-5	-11	+2
24 hour (1 day)	+12	+10	-3	0
36 hour	+22	+10	-2	+2
48 hour (2 day)	+14	+15	+1	0
60 hour	+20	+45	+3	+6
72 hour (3 day)	+18	-20	+5	+14
84 hour	+22	-5	+6	+10
96 hour (4 day)	+4	-5	+8	+8

Change (%) in NWS Global Forecasting System Predictions for Atlantic Tropical Cyclones during 2014-2016 due to Global Hawk Dropsondes

Forecast Period	With Satellite With Global Hawk dropsondes
	Track
12 hour	0
24 hour (1 day)	+1
36 hour	0
48 hour (2 day)	+7
60 hour	+12
72 hour (3 day)	+16
84 hour	+13
96 hour (4 day)	+14
108 hour	+11
120 hour (5 day)	+7

Affordability

Daily and Per Flight Hour Global Hawk Operational Rates

	Home Base Operations		Deployed Operations	
	Daily cost	Flight hour cost	Daily cost	Flight hour cost
Global Hawk Aircraft	$15.1K	$4.3 K	$23.7K	$4.6K
Mission Science and Payload		$4.9K		$4.9K
Information Management		$1.4K		$1.4K

Notes:

- Costs based on historical NOAA costs from SHOUT Program.
- Future rates will vary due to basing location, staffing model, and status of the NASA/Northrop Grumman partnership.
- Standard Aircraft Program Cost Calculated Based on Office of Management Budget Circular No. A-126

2016 SHOUT Hurricane Rapid Response
NOAA Total Costs

Category	Cost (Deployment from WFF & AFRC)
Global Hawk Aircraft Operations	$2.953K
Mission Science and Payload Support	$1.163K
Information Management	$0.329K
Total	**$4.445K**

2016 HRR Totals:

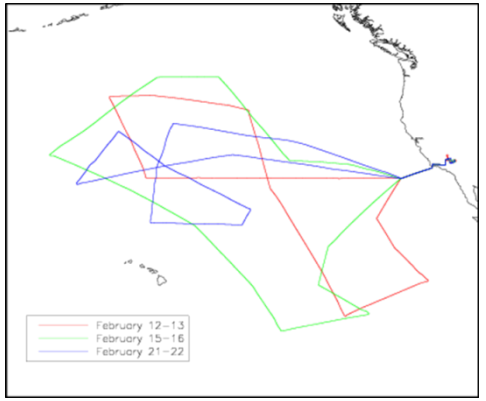
- **Flight Hours Total: 239 hrs**
- **Dropsondes Total: 648**
- **Flight Operations: 10 Weeks**

Operational Feasibility

2016 Operational Demonstration of Flight Capabilities

- Rapid response: 2016 El Nino and Hurricane Rapid Response
- Bi-coastal operations
- 24-hour flights releasing more than 80 dropsondes per flight
- Reduced on-site staffing for scientists and payload personnel
- Increased use of remote access for planning discussions
- Saved $125K in travel funding while doubling the number of missions

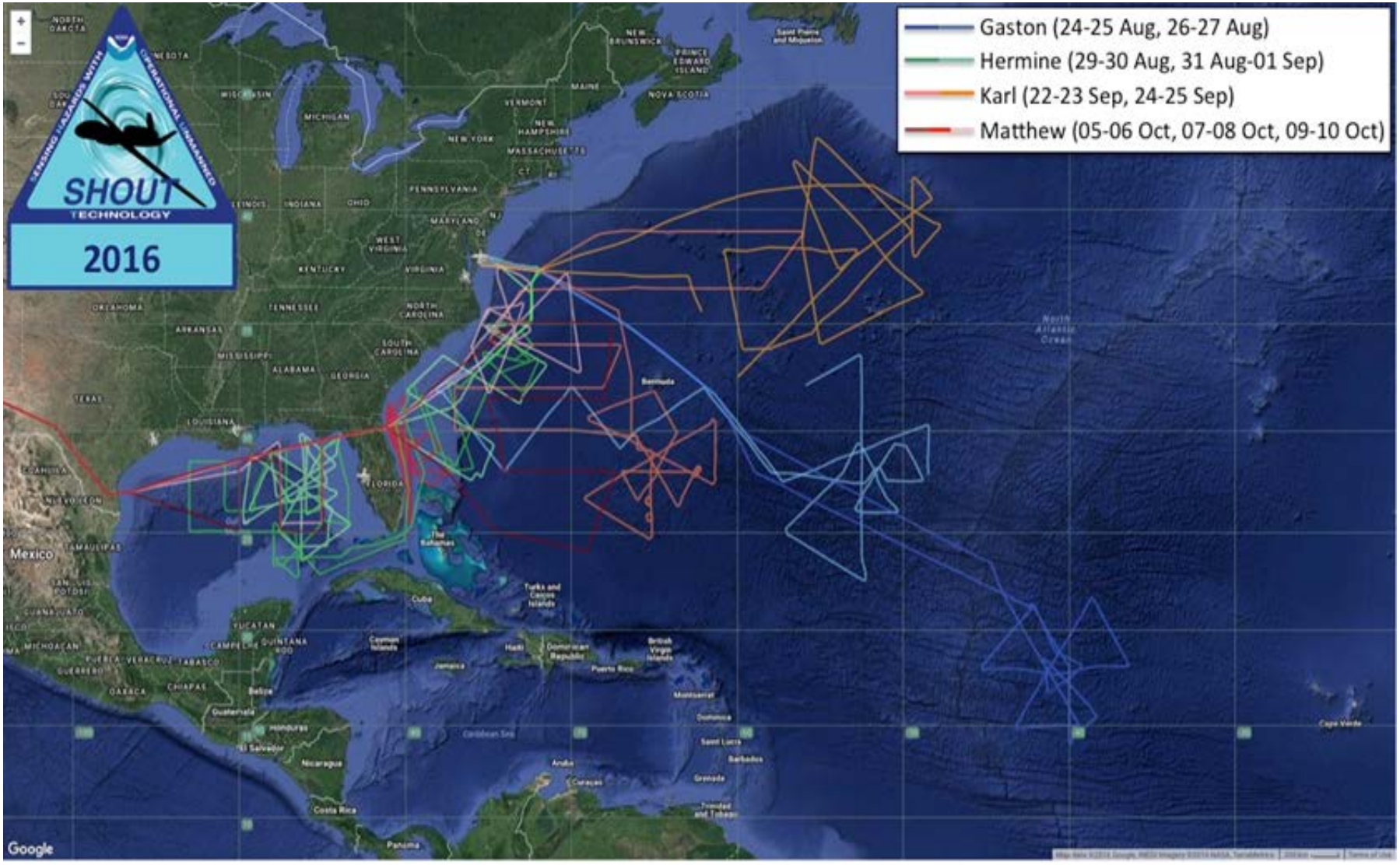
El Nino Rapid Response



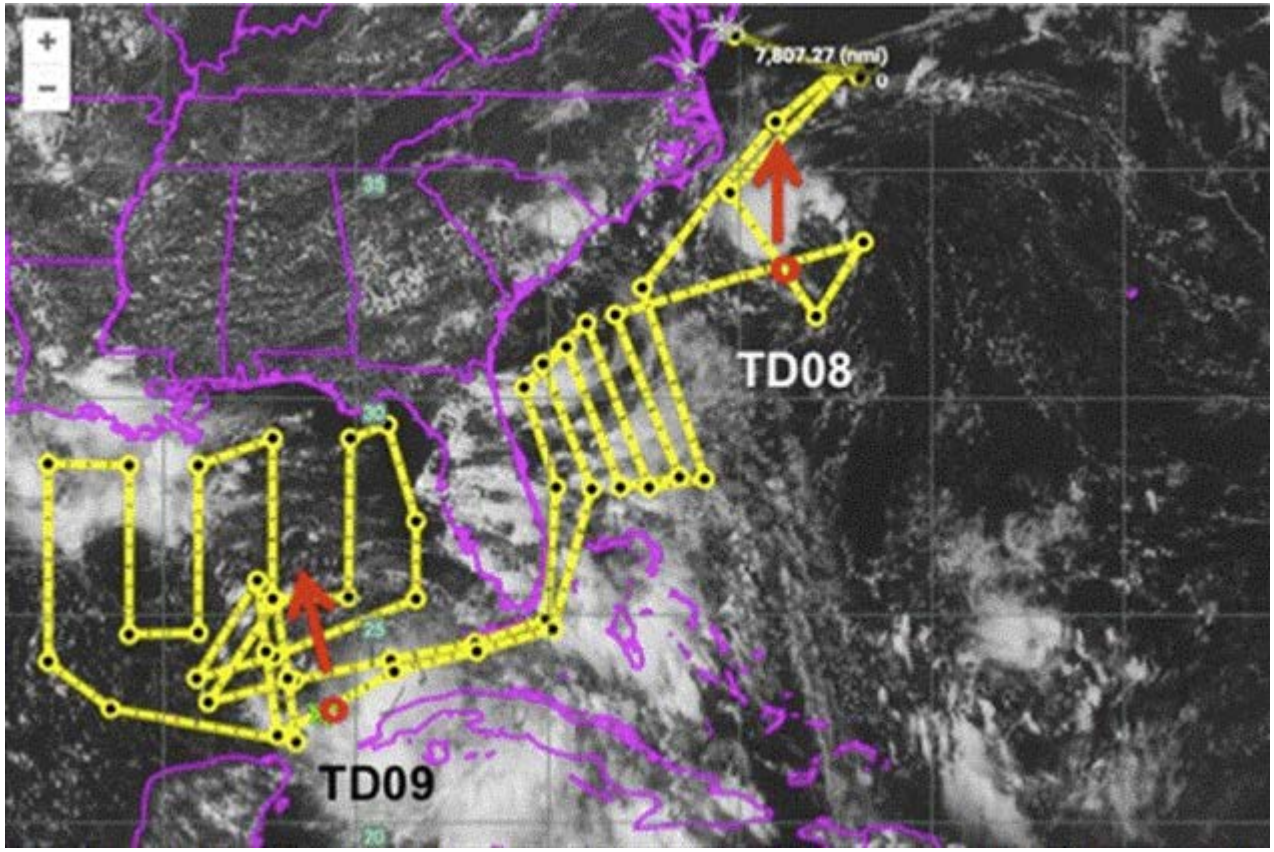
Global Hawk Flights
2016 SHOUT HRR

Dates (2016)	Target	Duration (hours)	# Sondes Deployed
24-25 August	Gaston	23.9	85
26-27August	Gaston	23.8	55
29-30 August	Hermine	23.8	90
31 August – 1 September	Hermine	22.8	87
22-23 September	Karl	24.0	82
24-25 September	Karl	22.8	81
5-6 October	Matthew	24.7	62
7-8 October	Matthew	23.7	43
9-10 October	Matthew	24.8	63

Global Hawk Flight Tracks
2016 SHOUT HRR



SHOUT 2016 3rd Science Flight Over TD 8 & TD 9



NASA/NOAA Global Hawk concludes 24 hour mission after dropping a record 90 sondes supplying real-time data to the National Hurricane Center.

Project Outcome

This study demonstrates high altitude long endurance UAS observations are feasible, affordable, and provide positive scientific impact as a risk mitigation option to maintain weather forecast skill for high impact storms at sea when a major satellite failure occurs.

Additional Project Benefits

Change (%) in NWS Global Forecasting System Predictions for Pacific Tropical Cyclones during 2016 due to Atlantic Global Hawk Dropsondes

Forecast Period	With Satellite With Global Hawk Dropsondes	
	Eastern Pacific	Western Pacific
12 hour	-4	0
24 hour (1 day)	-3	6
36 hour	-2	9
48 hour (2 day)	0	6
60 hour	3	10
72 hour (3 day)	6	12
84 hour	12	12
96 hour (4 day)	16	12
108 hour	10	10
120 hour (5 day)	6	9

Initial Transition from Research to Operations

Global Hawk Dropsonde Information as *Data of Opportunity*

- ***NWS National Hurricane Center Forecasters have used real-time Global Hawk dropsonde information for tropical cyclone intensity assessments when data are available***

- ***NWS Environmental Modeling Center will assimilate Global Hawk dropsonde data into operational Global Forecasting System and Hurricane Weather Research and Forecasting models when data are available***

Future of High Altitude Long Endurance Observing Capability

NOAA/NASA partnership has been successful in demonstrating this observing capability for NOAA data acquisition and is available for future utilization and transition.

Other Project Benefits

- Increased the reliability of automated Advanced Vertical Atmospheric Profiling System (AVAPS) dropsonde system with new increased sampling rate
- Collected and archived new wealth of tropical cyclone research- quality data
- Gained NOAA expertise in high altitude long endurance UAS operations with OAR, OMAO and NESDIS
- Developed a process for evaluating new observations that could be a model for similar studies conducted for the Weather Research and Forecasting Innovation Act

Acknowledgments

Internal Partners

Offices: OAR, OMAO, NWS, NESDIS

OAR Laboratories:

Atlantic Oceanic and Meteorological Laboratory (AOML)
Earth System Research Laboratory (ESRL)

Cooperative Institutes:

Cooperative Institute for Marine and Atmospheric Studies (CIMAS)
Cooperative Institute for Meteorological Satellite Studies (CIMSS)
Cooperative Institute for Research in Environmental Studies (CIRES)
Cooperative Institute for Research in the Atmosphere (CIRA)

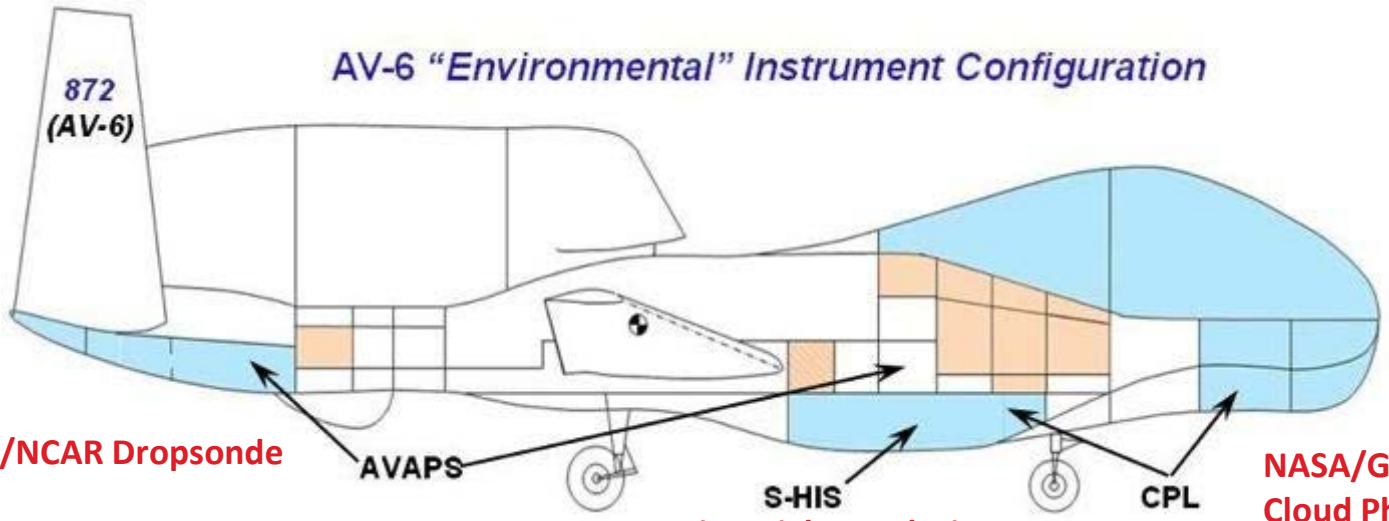
External Partners

National Aeronautics and Space Administration
National Science Foundation
Northrop Grumman
US Navy

Questions and Feedback

Backup Slides

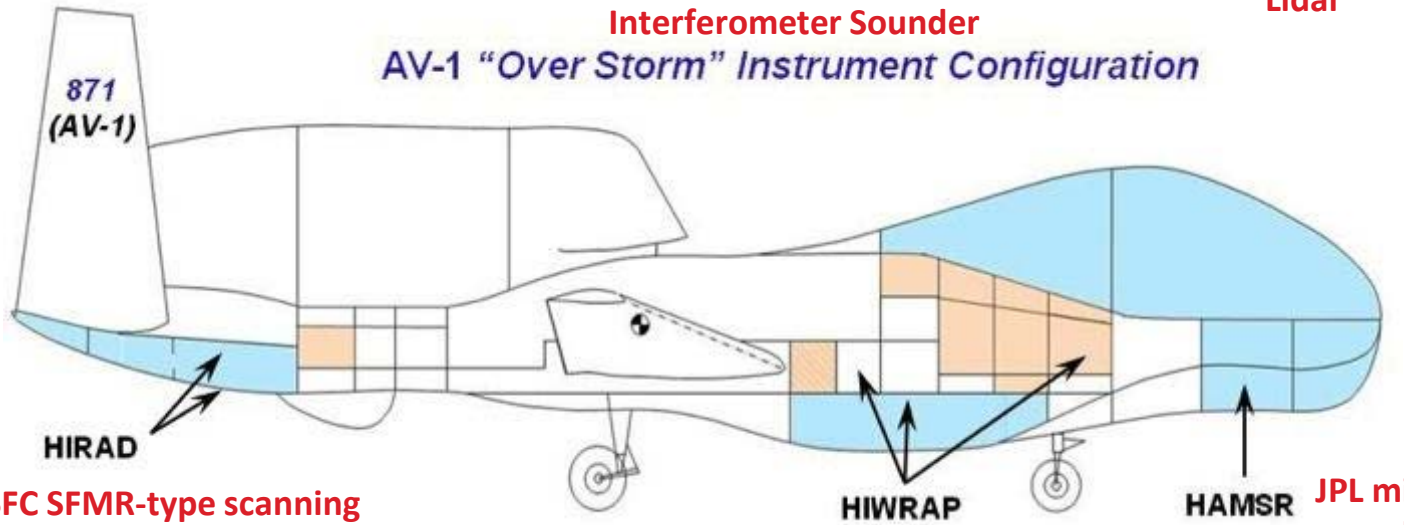
NASA Hurricane Severe Storm Sentinel (H3) Payloads



NOAA/NCAR Dropsonde

Scanning High Resolution Interferometer Sounder

NASA/GSFC Cloud Physics Lidar



NASA/MSFC SFMR-type scanning radiometer

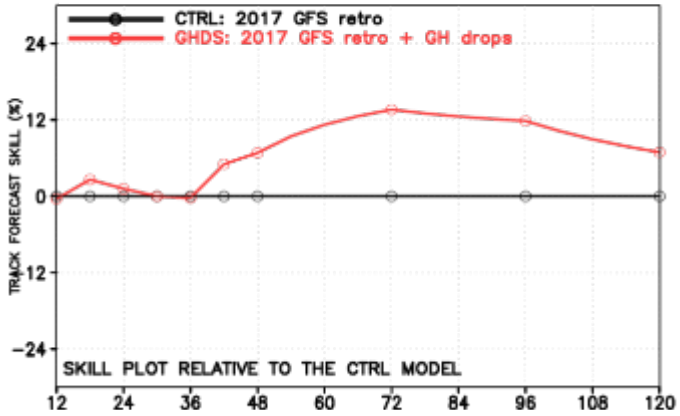
NASA/GSFC Doppler radar

JPL microwave sounder

NWS Global Forecast System (GFS) Atlantic 2014-16

- Results prove GH is VERY useful for improving hurricane track forecasts
- Peak improvement about 15% at 72 h
- Statistically significant improvement at 72 and 96 h

Track skill – 2014 all AL available

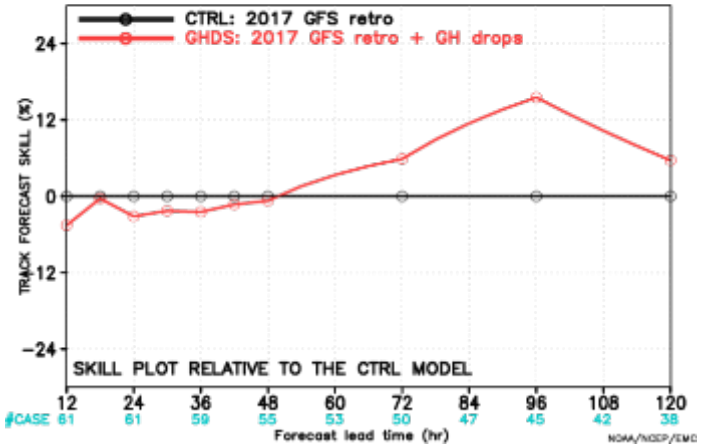


Track error – 2014 all AL available

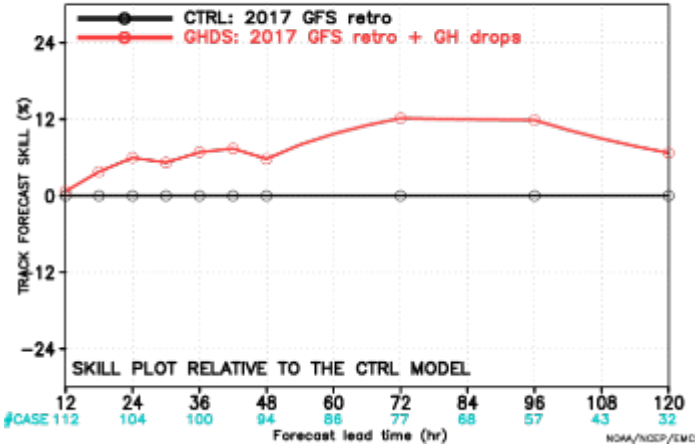
Results courtesy Jason Sippel and Vijay Tallapragada, NOAA/NCEP/EMC

Results: GFS other basins 2016

Track skill – EPAC



Track skill – WPAC

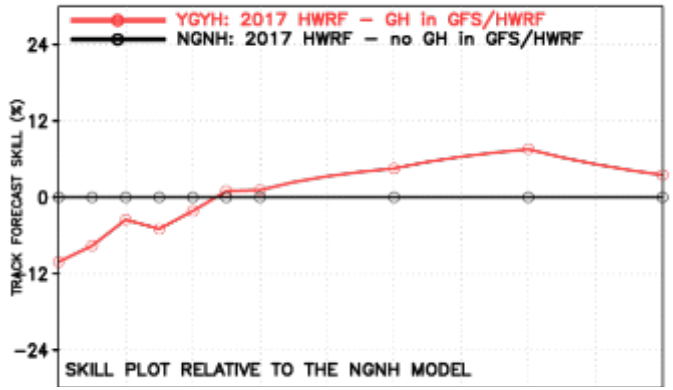


Results courtesy Jason Sippel and Vijay Tallapragada, NOAA/NCEP/EMC

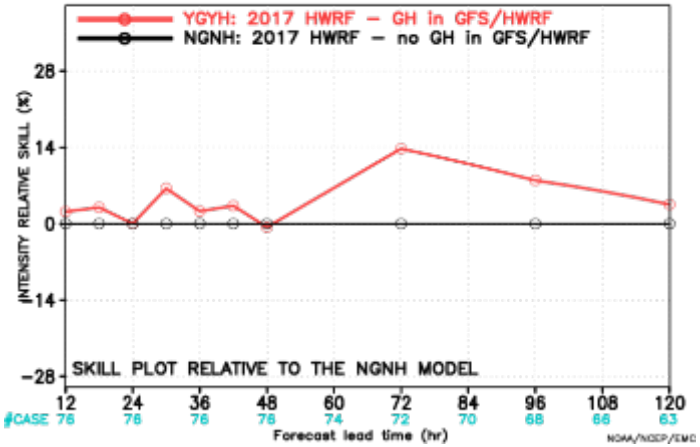
NWS Hurricane Weather Research and Forecast (HWRF) System Atlantic 2016

- Improvement in GFS has major impact on downstream models
- GFS retrospectives fed into new HWRF DA system
- Intensity improves by ~15% at 72 h

Track skill – 2016



Intensity skill – 2016



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