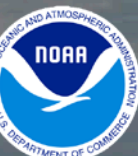


Operational Impact of Data Collected from the Global Hawk Unmanned Aircraft During SHOUT



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Outline

- SHOUT Objectives
- SHOUT Campaign
- Real-Time Data Utilization
- Forecast Impact
- Conclusions



Photo Credit: Steve Crowell, Northrop Grumman

SHOUT Objectives



Overall 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**

Objective 1

- **Conduct data impact studies**
 - **Observing System Experiments (OSE) using data from UAS field missions**
 - **Observing System Simulation Experiments (OSSE) using simulated UAS data**

Objective 2

- **Evaluate cost and operational benefit through detailed analysis of life-cycle operational costs and constraints**

Global Hawk Aircraft



- Flight Level: ~55-65,000 ft
- Duration: ~24 hr
- Range: 8-10,000 nm
 - G-IV ~3800 nm, P-3 ~2400 nm
- Payload: 1,500+ lbs
- Deployment Sites
 - NASA Wallops Flight Facility (Wallops Island, VA)
 - NASA Armstrong Flight Research Facility (Edwards AFB, CA)



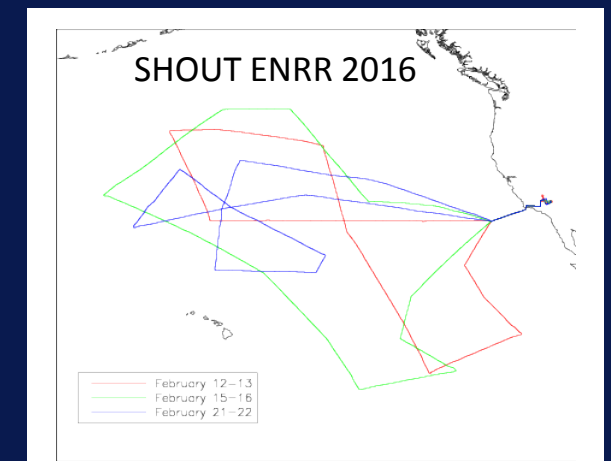
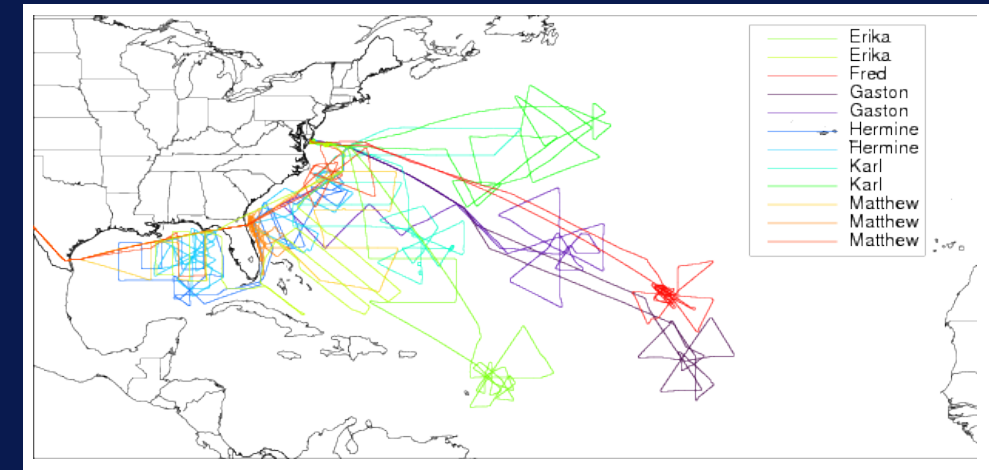
Global Hawk Operations Center, AFRC

SHOUT Field Campaigns



- Hurricanes 2015
 - 3 missions flown into 2 named storms
 - First NOAA-operational assimilation of Global Hawk dropsondes
- El Niño Rapid Response 2016
 - 3 Atmospheric River and winter storm missions
 - Demonstrated ability to plan and deploy on short notice
- Hurricane Rapid Response 2016
 - 9 missions flown into 4 named storms
 - Shift to operational deployment model
- EPOCH 2017
 - Operational dropsonde assimilation in GFS

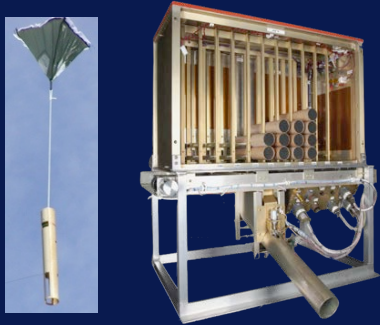
SHOUT Tropical Cyclone Campaigns 2015-2016



Global Hawk SHOUT Instrumentation



Airborne Vertical Atmospheric Profiling System (AVAPS)



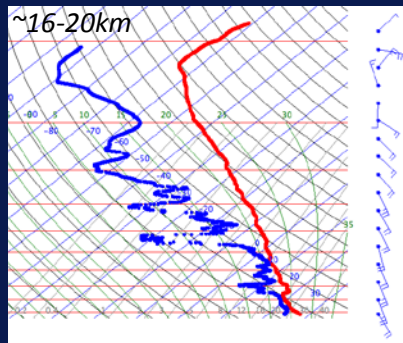
PI: Terry Hock, NCAR / Gary Wick, NOAA

Measurements:

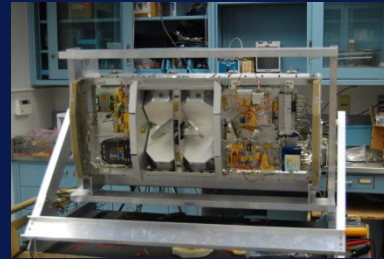
- temperature, pressure, wind, humidity profiles
- 90 dropsondes per flight

Resolution:

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



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



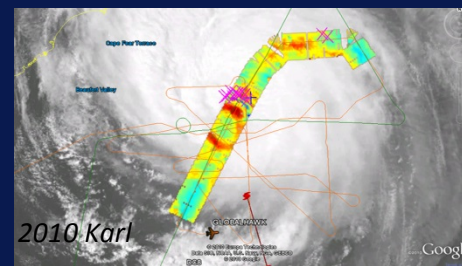
PI: Dr. Bjorn Lambrigtsen, JPL

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)



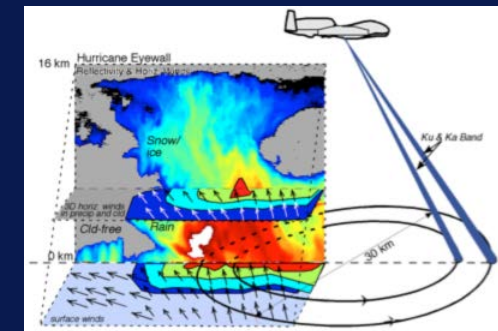
PI: Dr. Gerald Heymsfield, NASA GSFC

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;

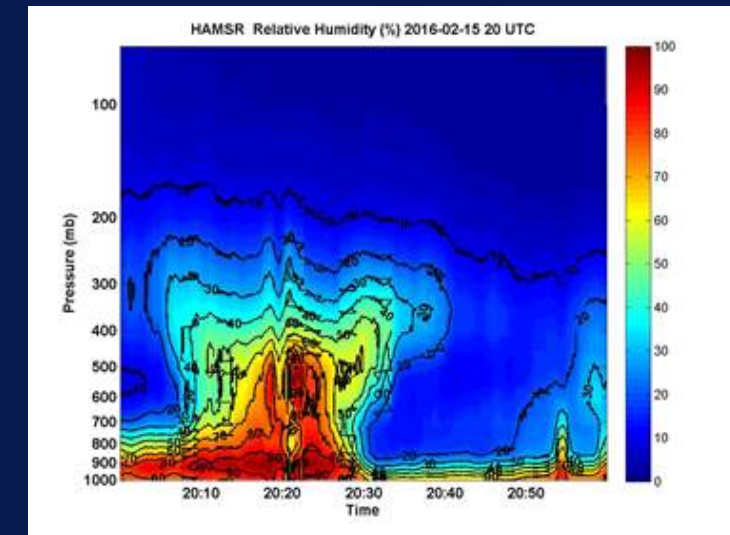
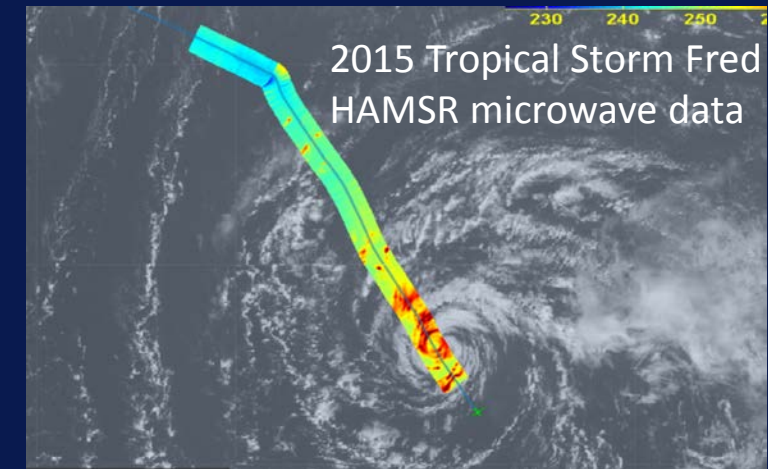


SHOUT Real-Time Data



- Tremendous flexibility in sampling location
 - ATC coordination with ~30 min notice
- High bandwidth real-time data access from platform
- Additional data processing in real time on ground
 - Both automated and human-in-the-loop
 - Dropsonde data submission through GTS

- Operational application to:
 - Forecaster input at National Hurricane Center
 - Assimilation in operational NWP forecast models

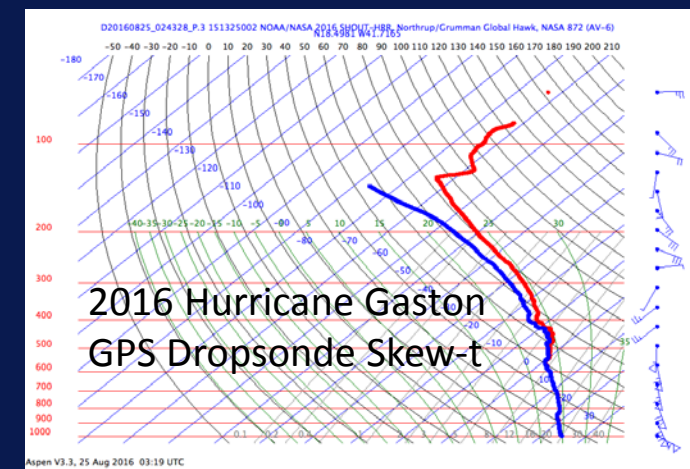
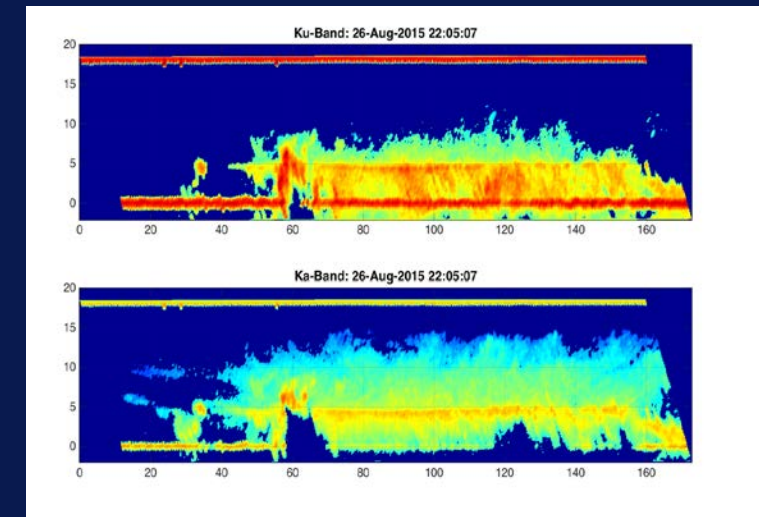


NHC Data Utilization



- Obtained feedback on desirable products
- Dedicated web page established and populated
- Dropsonde availability through operational GTS
- Data provided direct input to forecast discussions
 - 10 NHC discussions in 2016 cited Global Hawk data
 - Drawn from 5 of 9 flights spanning all four targeted systems

2015 TS Erika: HIWRAP Radar Cross-Section



Data Impact at NHC



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.”

SHOUT Forecast Impact Studies



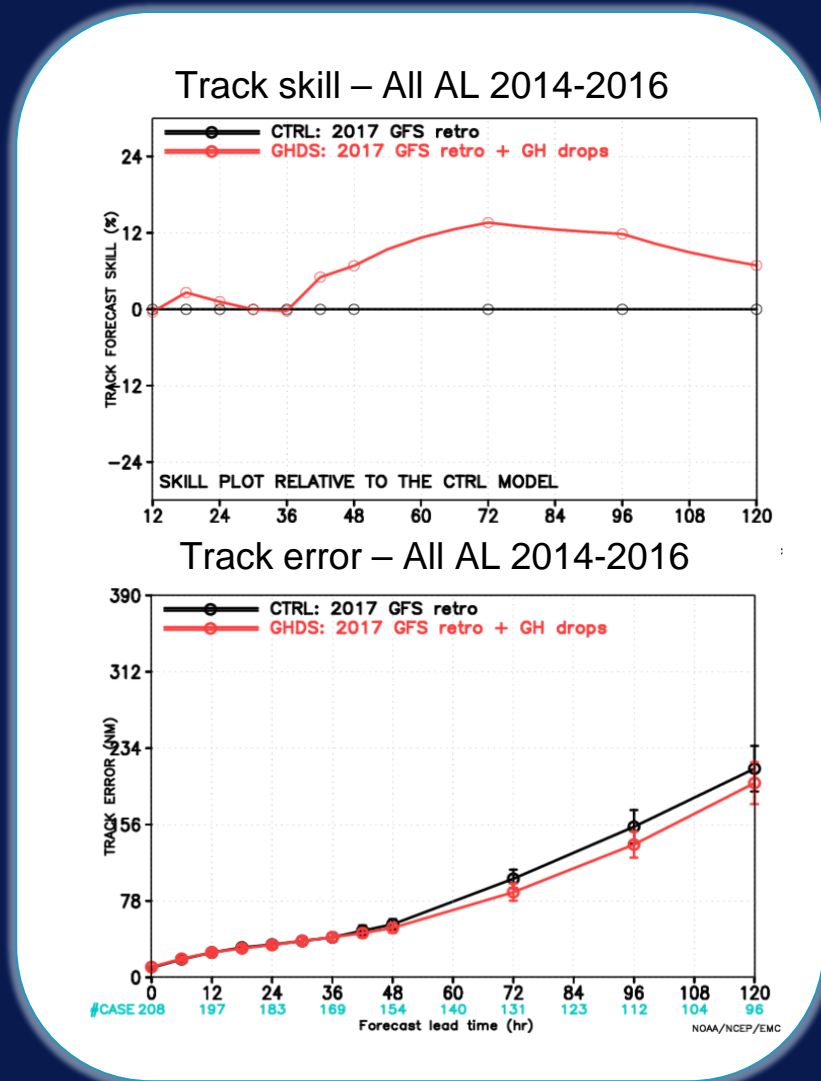
- NOAA/OAR/AOML/HRD
 - Regional hurricane modeling
 - HWRF with multiple data assimilation schemes
 - Dropsonde impacts and initial results for remote sensors
- NOAA/OAR/ESRL/GSD
 - Global model impacts for hurricanes and landfalling winter storms
 - GFS with 2015 operational configuration
 - Dropsonde impacts both with and without a satellite gap
- Collaboration with NOAA/NWS/NCEP/EMC
 - Operational GFS and HWRF with full observing system
 - Dropsonde impacts only

EMC Results – GFS Atlantic Storms 2014-6



- Dropsonde impact on operational GFS forecasts for Atlantic sampling in 2014-16
- Retrospective impact shown for 2017 model version relative to full current observing system
- Peak improvement about 15% at 72 h
- Statistically significant improvement at 72 and 96 h

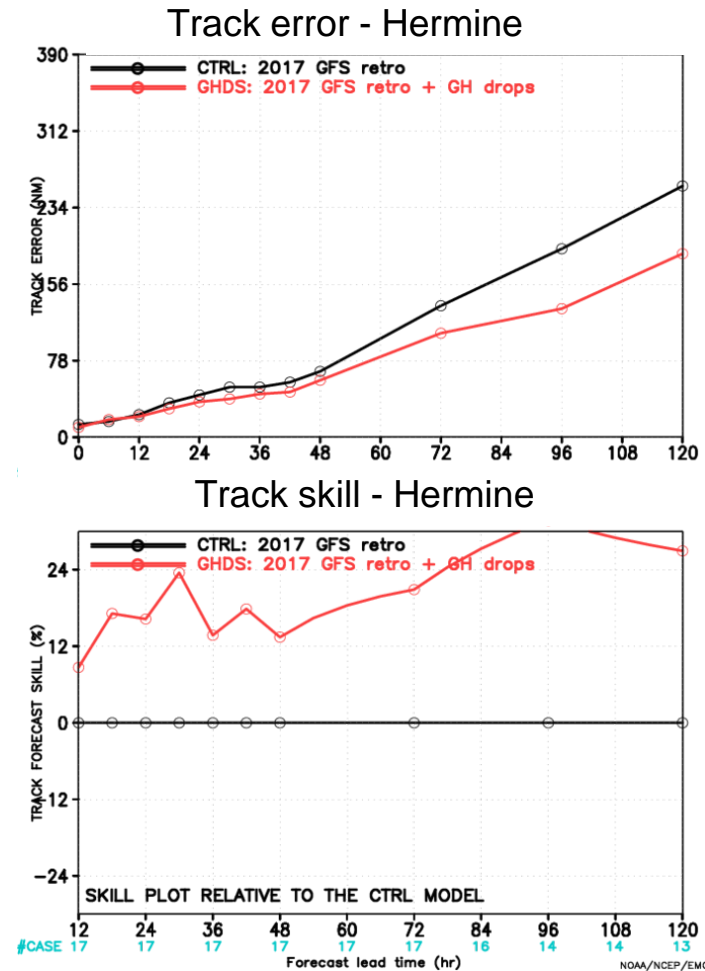
Results courtesy Jason Sippel and Vijay Tallapragada, NOAA/NCEP/EMC



EMC Results – GFS Single Storm Impact



- Dropsonde impact on operational GFS forecasts of Hermine 2016
- Higher track uncertainty in spite of extensive reconnaissance from C-130 and P-3 (no G-IV).
- Large skill improvements with addition of Global Hawk dropsondes



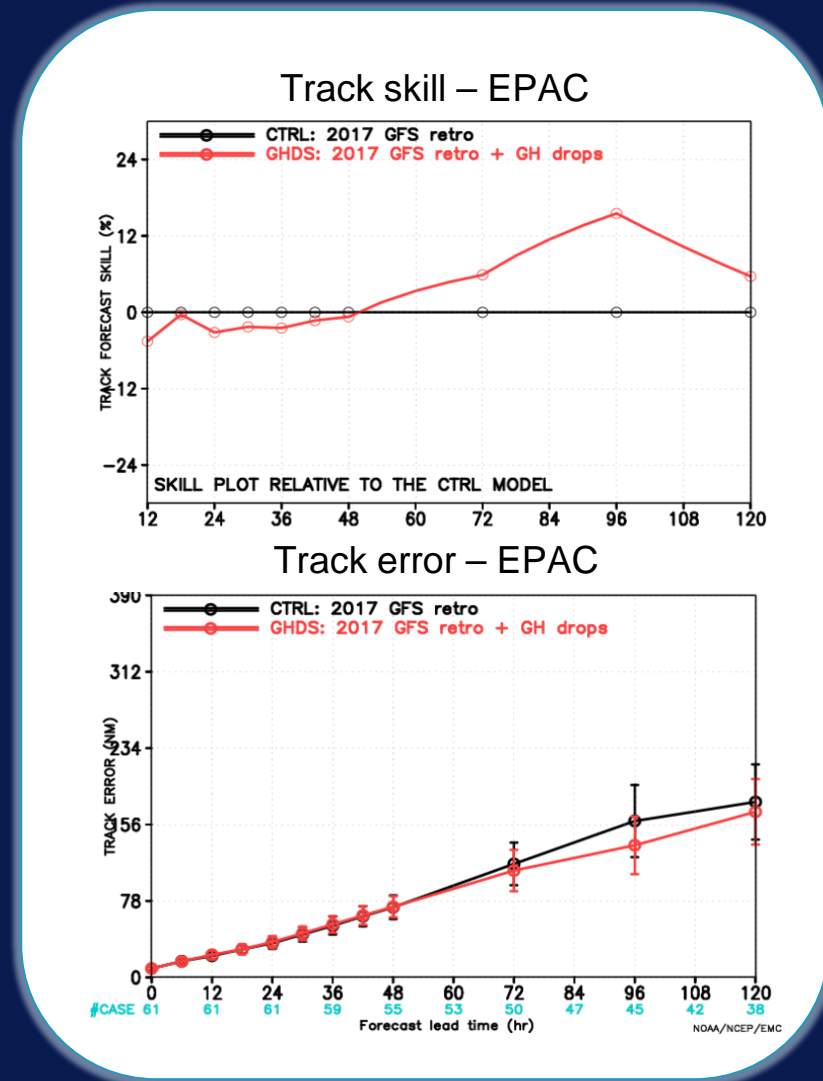
Results courtesy Jason Sippel and Vijay Tallapragada, NOAA/NCEP/EMC

EMC Results – GFS Remote Impact 2016



- Impact on operational GFS forecasts of Pacific storms from remote Atlantic dropsonde observations
- Largest Eastern Pacific track improvement at 96 h near statistical significance
- Results suggest remote influence not random
- Maybe dropsonde assimilation impacts satellite bias correction?

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



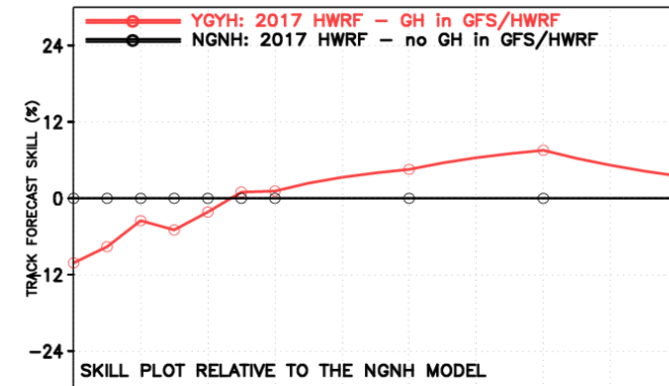
EMC Results – HWRF Atlantic 2016



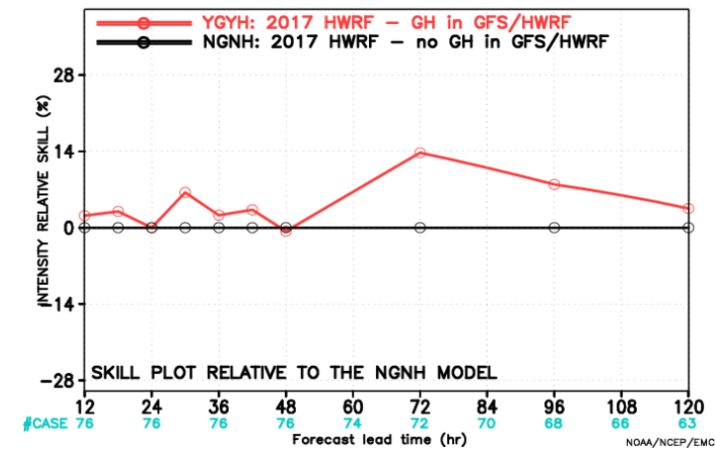
- Dropsonde impact on operational 2017 HWRF with new assimilation system
- Results also incorporate retrospective GFS boundary impacts
- Impact relative to full current observing system
- Significant track and intensity improvements at 72 and 96 h

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

Track skill – 2016



Intensity skill – 2016





Tropical Cyclone Data Impact Summary

Global Hawk Dropsonde Impact on 96-hour Hurricane Track Forecasts (% Improvement)

Model		All Observations		Satellite Gap	
		Multi Storm	Matthew 16	Multi Storm	Matthew 16
HWRF	V2015	N/A	N/A	10%	30%
	V2017	15%	N/A	N/A	N/A
	HEDAS	10%	N/A	N/A	N/A
GFS	V2015	8%	N/A	8%	N/A
	V2017	12%	28%	N/A	N/A

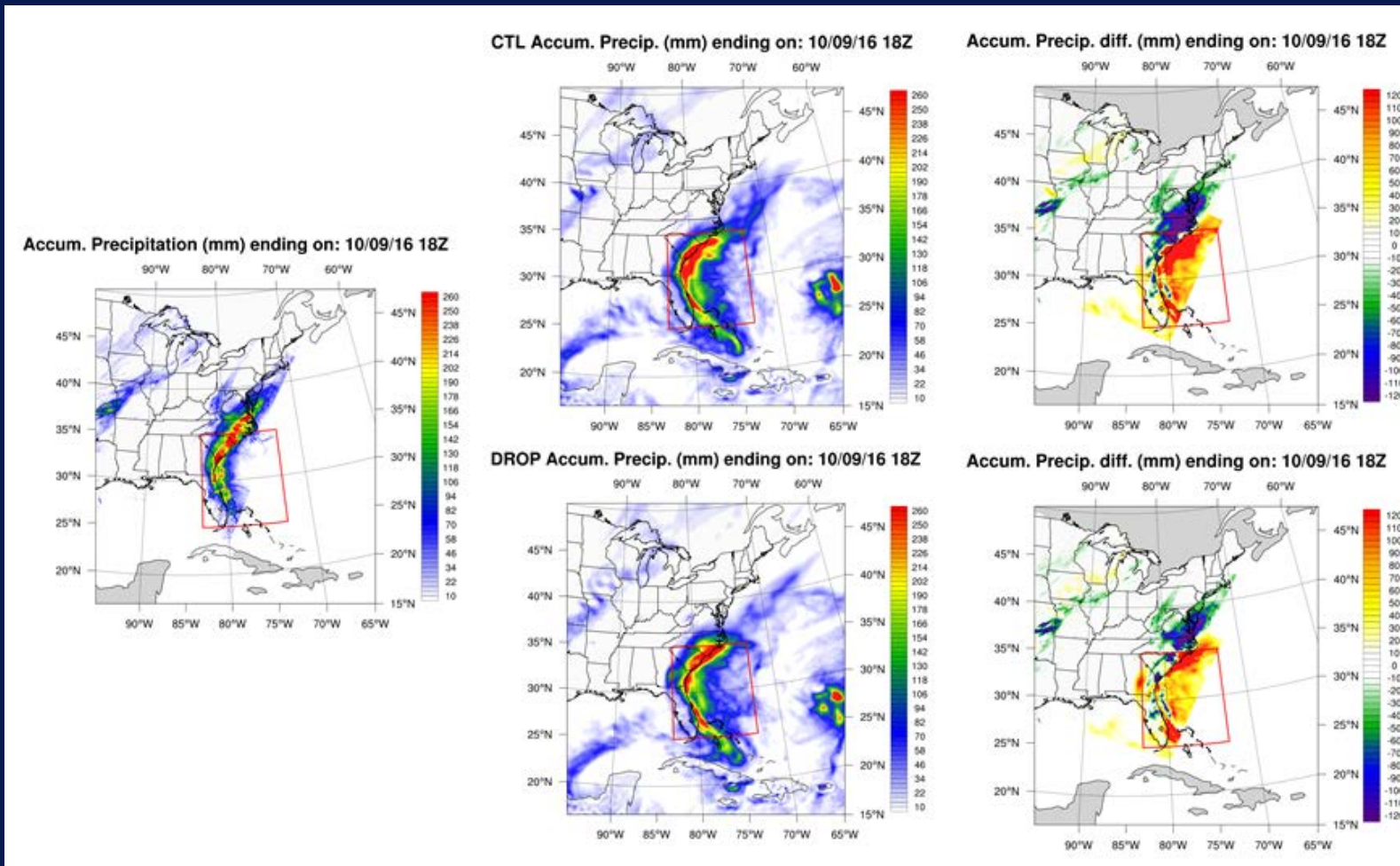


Conclusions

- SHOUT demonstrated the potential utility of Global Hawk observations for high-impact weather forecast improvement
- Global Hawk data availability approaching maturity of manned platforms
- Real-time data utilized by hurricane forecasters and operationally assimilated into NWP forecast models
- Diverse studies showing consistent positive forecast impact of the data for tropical cyclone track and intensity
- Impacts for Pacific winter storms smaller but still positive
- Additional studies still underway

Extra Slides

Precipitation Impact - Matthew



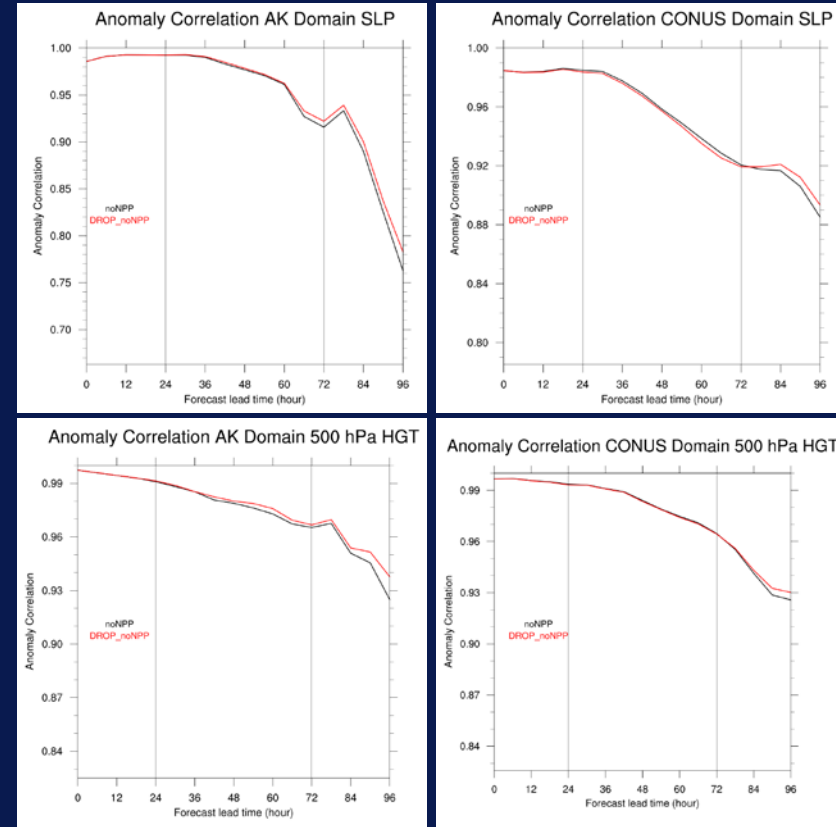
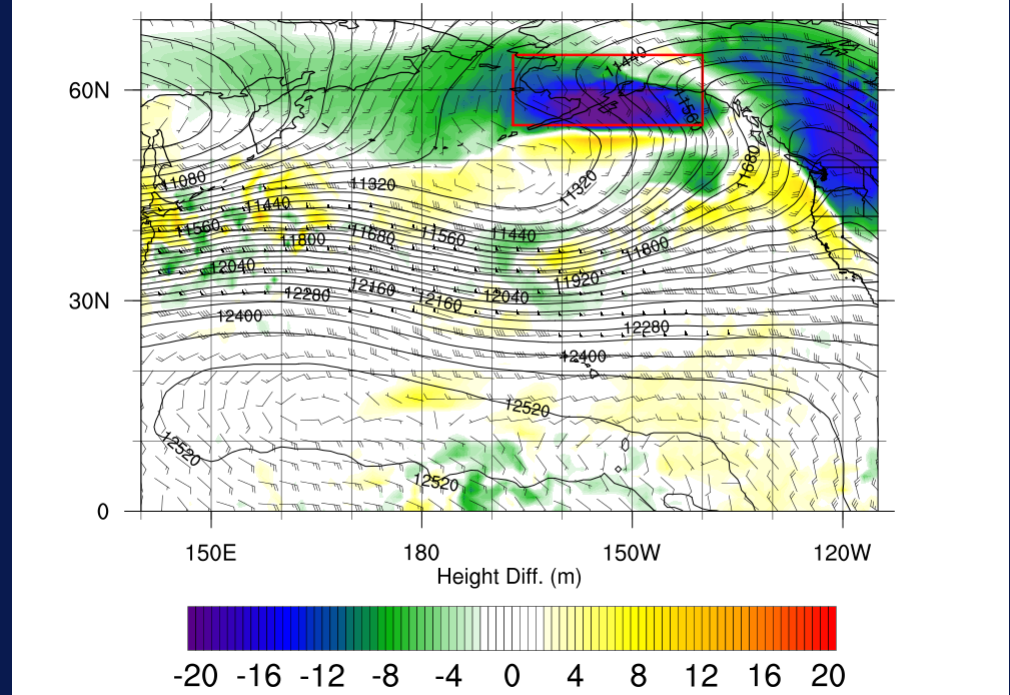
Results
courtesy
A. Kren

- Improved track forecast leads to improved precipitation forecast

GFS Dropsonde Impact - Alaska



200 mb Heights (DROP_noNPP - CTL) Valid: 02/24/16 00Z



- Results averaged over 4 forecast cycles
- Positive forecast impact observed in targeted high-impact area
- Neutral results or forecast degradation on larger scale

Results
courtesy
A. Kren