Impact of Global Hawk dropsonde data assimilated in the NCEP GFS model during SHOUT: Hurricanes Matthew and Nicole in 2016

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NOAA Sensing Hazards with Operational Unmanned Technology (SHOUT) 33\textsuperscript{rd} Conference on Hurricanes and Tropical Meteorology 18 April 2018
What impacts do Global Hawk dropsonde observations have on tropical cyclone prediction under:
   a. Current satellite configuration 
   b. Satellite data gap scenario

1. Use targeted observing effort with Global Hawk 
   • Ensemble Transform Sensitivity (ETS) technique 
   • Performed during SHOUT Hurricane Rapid Response (HRR)

2. Quantify impact of UAS data on high-impact weather events

3. Assess effectiveness of UAS to mitigate a satellite data gap
Methods: OSE Configuration: Analysis and Forecast System

NCEP’s GDAS/GFS (Q3FY17) – Operational version at NCEP July 19, 2017

- GDAS cycles every 6 hours (4DEnVar GSI)

- Global cycling for HRR case studies (3 total)
  - October 5-10, 2016 (Matthew – 3 GH missions)

- Withholding Suomi-NPP satellite assimilation
  - Evaluate UAS under possible satellite data gap

- Experiment names:
  - CTL: Operational observations without GH
  - GH: CTL + GH dropsondes
  - noNPP: CTL w/o Suomi-NPP
  - GH_noNPP: noNPP + GH dropsondes

- 10 day spin-up prior to dropsonde observations
- GFS run at T670L64, GSI at T254L64 (highest resolution supported)
Methods: Verification

Datasets

• Independent ECMWF analysis

• National Hurricane Center best-track data

• Stage IV 4-km precipitation dataset (Lin 2011)

• GFS forecasts; GFDL Vortex Tracker

Quantitative evaluation of forecasts

• Averaged track and maximum wind speed errors

• Paired t-test to assess statistical significance

• Traditional forecast metrics of RMSE, Equitable Threat Score, and analysis/forecast increments

*Hurricanes Matthew and Nicole (2016)*
SHOUT-HRR GH missions: **October 5\(^{th}\), 7\(^{th}\), and 9\(^{th}\), 2016**
SHOUT-HRR GH mission and ETS Sensitivity: October 5th, 2016

- Targeted observing employed prior to October 5 Global Hawk flight
- Sensitivity in vicinity of Matthew, Gulf of Mexico, and North Atlantic north and east of Florida
- Resultant path sampled large portion of sensitivity over Atlantic

ETS Sensitivity and Dropsondes 10/05/2016

GEFS mean 500 hPa height for 10/5/2016 with ETS sensitivity for targeting time of 10/5/00Z and verification time of 10/7/00Z
Results: Matthew Storm Track, SLP, and maximum wind speed error

Track Error Matthew

SLP Error Matthew

Wind Error Matthew

Track Error Difference Matthew

SLP Error Difference Matthew

Wind Error Difference Matthew

CTL   GH
Results: Nicole Storm Track, SLP, and maximum wind speed error

- Track Error Nicole
- SLP Error Nicole
- Wind Error Nicole
- Track Error Difference Nicole
- SLP Error Difference Nicole
- Wind Error Difference Nicole

CTL  GH
Results: Improvements in environmental fields led to track improvements

SLP, 700 hPa HGT and WND RMSE averaged over Western North Atlantic

Reduced RMSE across all metrics with assimilation of GH dropsondes
Results: Improvements in environmental fields led to track improvements for Matthew.

GH dropsondes initialized stronger northward flow over the Atlantic, helping to partially shift Matthew north.
Results: Improvements in environmental fields led to track improvements Matthew

GH experiment shows stronger ridge east of Matthew, helping to partially shift Matthew north
Results: Improvements in environmental fields led to track improvements

Matthew

GH dropsondes reduce 700 hPa wind error at analysis/forecasts times
Results: Improvements in environmental fields led to track improvements

Nicole

GH dropsondes initialized stronger ridge east of Nicole, helping to partially shift Nicole north
Results: Improvements in environmental fields led to track improvements

Nicole

GH experiment shows stronger ridge east of Nicole, helping to partially shift Nicole north
Results: Precipitation – Closer agreement with observations

Equitable Threat Score

GH dropsondes improve precipitation forecast over southeastern United States
Results: **Precipitation – Closer agreement with observations**

**Equitable Threat Score**

*Accum. Precipitation (mm) ending on: 10/09/16 18 UTC*

**48-72 hour forecast**

**GH dropsondes improve precipitation forecast over southeastern United States**
Results: Satellite data gap scenario – Hurricanes Matthew and Nicole
GH_noNPP vs noNPP

Track Error Matthew

Track Error Nicole
Conclusions and Next Steps

What impacts do Global Hawk dropsonde observations have on tropical cyclone prediction under:
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What We Know
- Adding GH dropsondes improves TC track two cases investigated
- Track improvements tied to changes in synoptic environment
- Subsequent improvement in precipitation
- Results mixed during satellite data gap scenario
- Positive improvements during ENRR for both satellite scenarios

Next Steps
- Evaluate remotely sensed data on GH with dropsondes
  - HAMSR
  - Simulations with HWRF and GFS
- Include many more cases, including comparison with other aircraft
Acknowledgements

• Co-Author Lidia Cucurull

• Gary Wick and SHOUT Team

• Kate Friedman (NOAA/NWS/NCEP/EMC Engineering and Implementation Branch)

• Quantitative Observing System Assessment Program (QOSAP)
Backup slides

- Targeted observing employed prior to February 21 Global Hawk flight
- Sensitivity in vicinity and east of extratropical storm in Central North Pacific
- Resultant path sampled rapidly deepening storm system

GEFS mean 500 hPa height for 2/21/2016 with ETS sensitivity for targeting time of 2/21/12Z and verification time of 2/24/00Z
Results: Feb 21 case: Improvements in environmental fields over verification region

850 hPa Wind, Temperature, and Relative Humidity

Reduced RMS error over southeastern United States after assimilation of GH dropsondes
Results: Feb 21 case: Satellite data gap scenario

850 hPa Wind, Temperature, and Relative Humidity

Reduced RMS error over southeastern United States after assimilation of GH dropsondes
Results: **Feb 21 case: Severe Weather Event over Southeast US**
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