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

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Background: Science Goals and Objectives

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

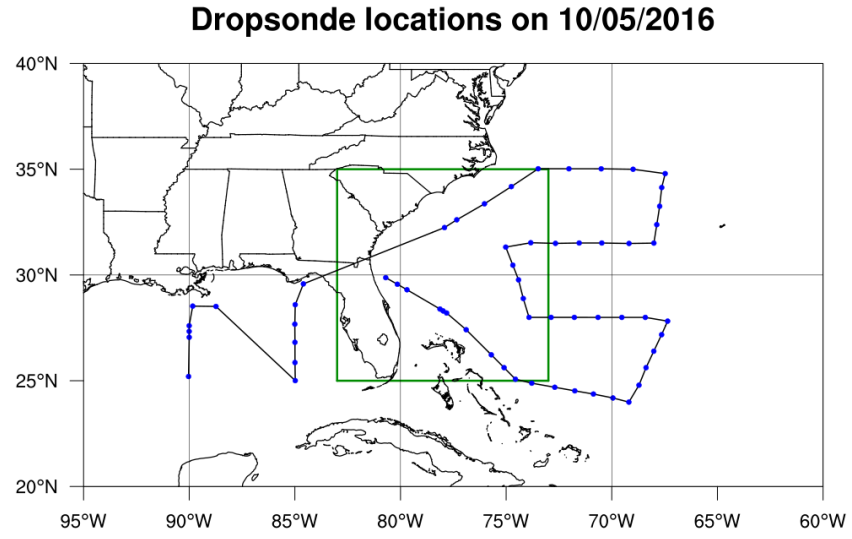
- Independent ECMWF analysis
- National Hurricane Center best-track data
- Stage IV 4-km precipitation dataset (Lin 2011)
- GFS forecasts; GFDL Vortex Tracker

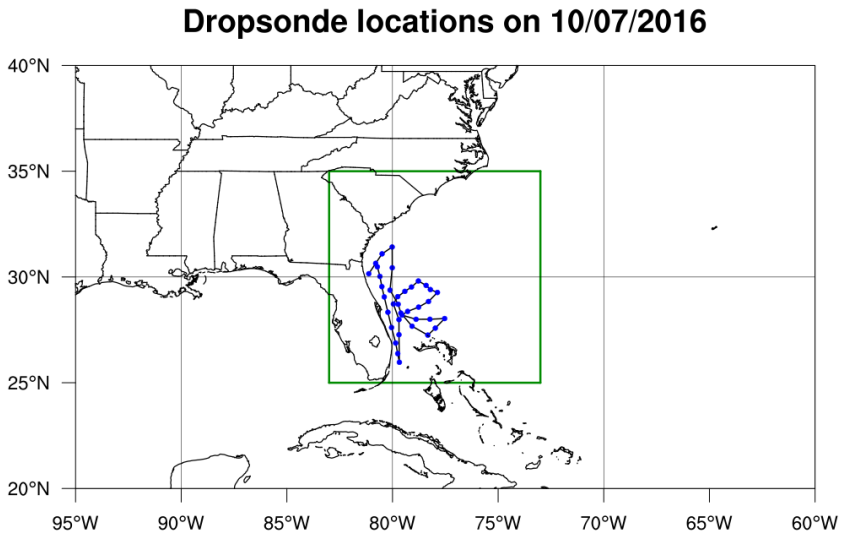
Hurricanes Matthew and Nicole (2016)

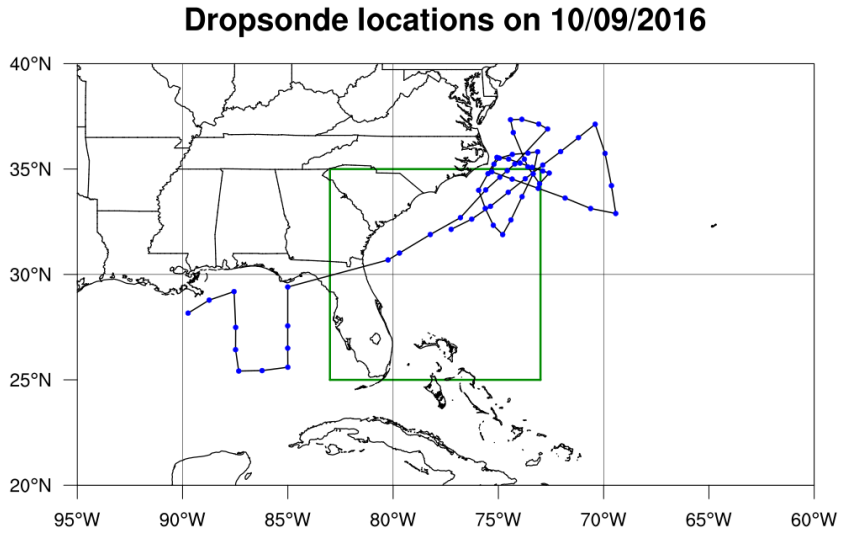
Quantitative evaluation of forecasts

- 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

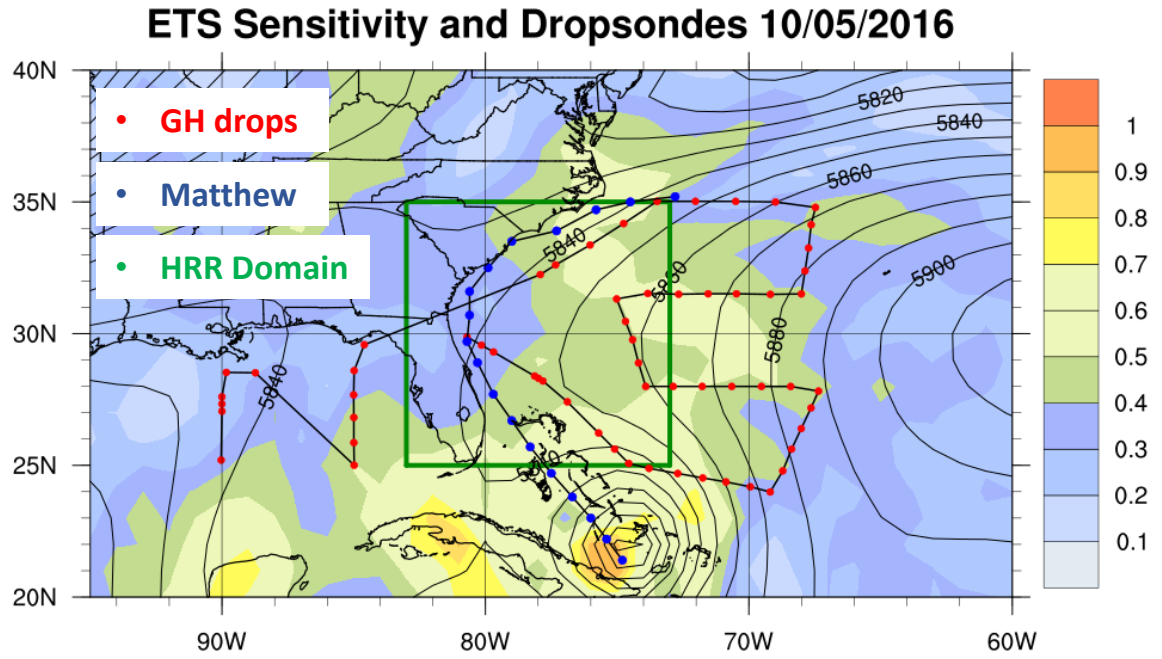
SHOUT-HRR GH missions: October 5th, 7th, and 9th, 2016







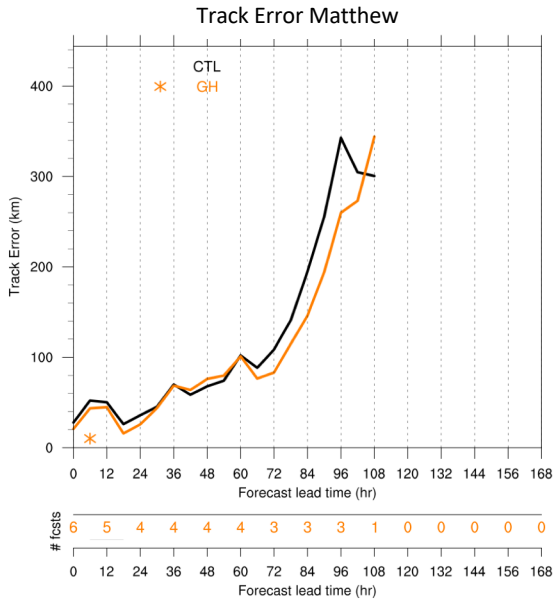
SHOUT-HRR GH mission and ETS Sensitivity: October 5th, 2016

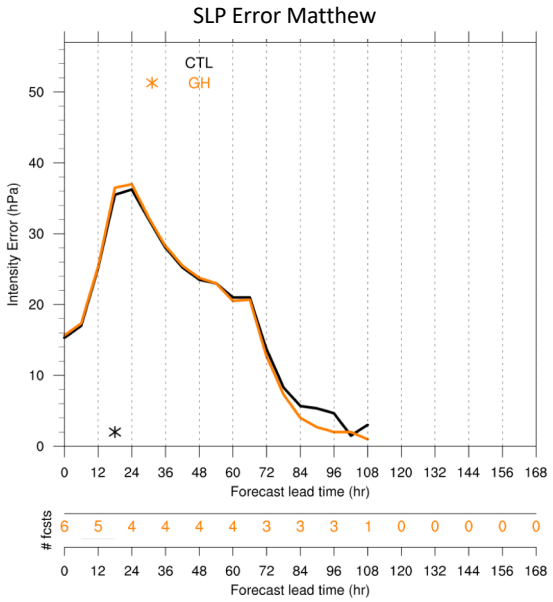


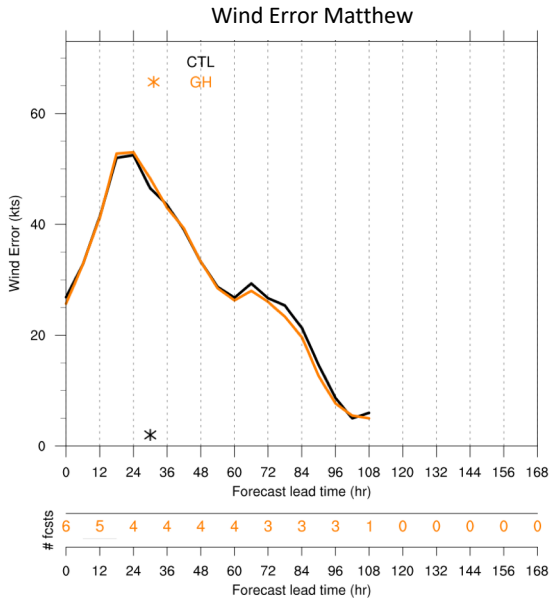
*GEFS mean 500 hPa height for 10/5/2016 with ETS sensitivity for targeting time of **10/5/00Z** and verification time of **10/7/00Z***

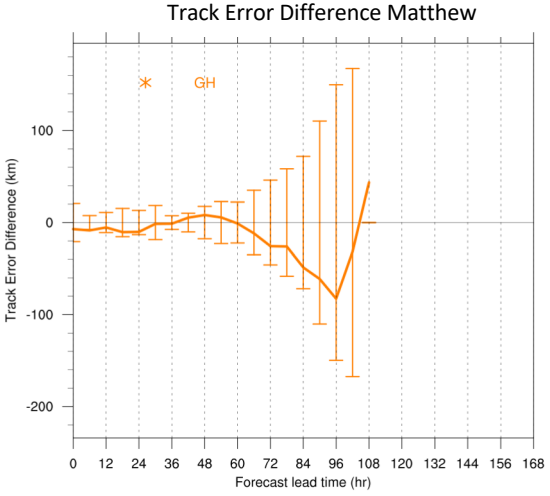
- **Targeted observing employed prior to October 5 Global Hawk flight**
- Sensitivity in vicinity of Matthew, Gulf of Mexico, and North Atlantic north and east of Florida
- Resultant path sampled large portion of sensitivity over Atlantic

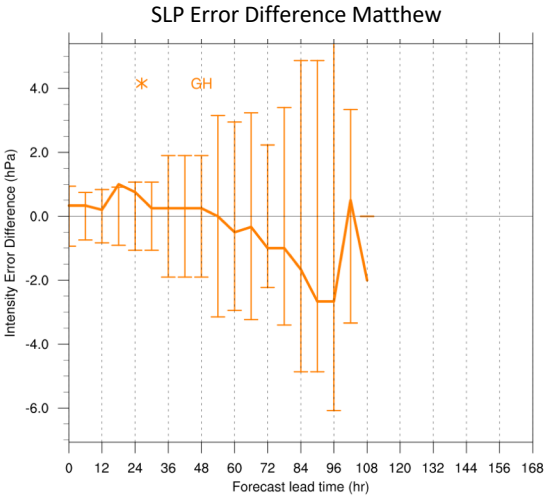
Results: Matthew Storm Track, SLP, and maximum wind speed error

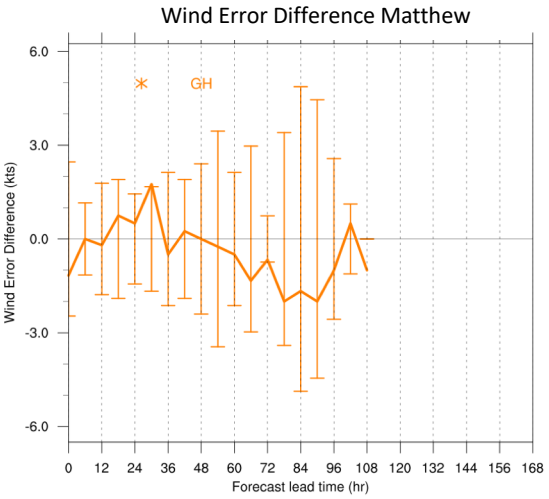






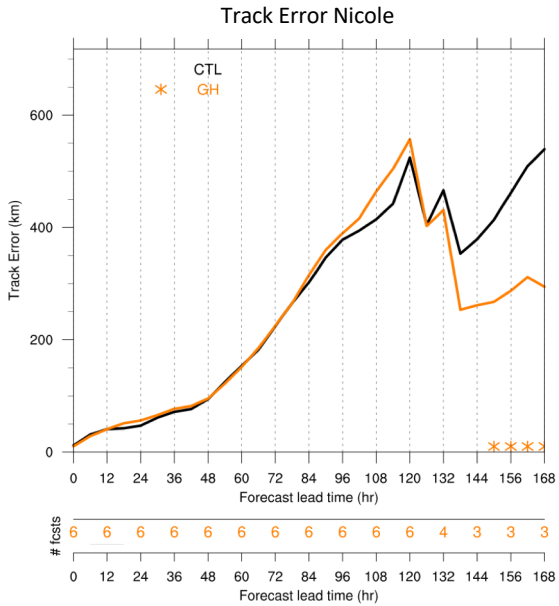


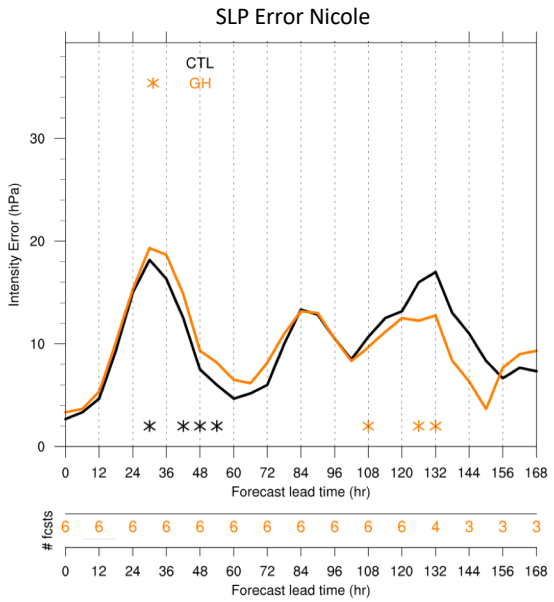


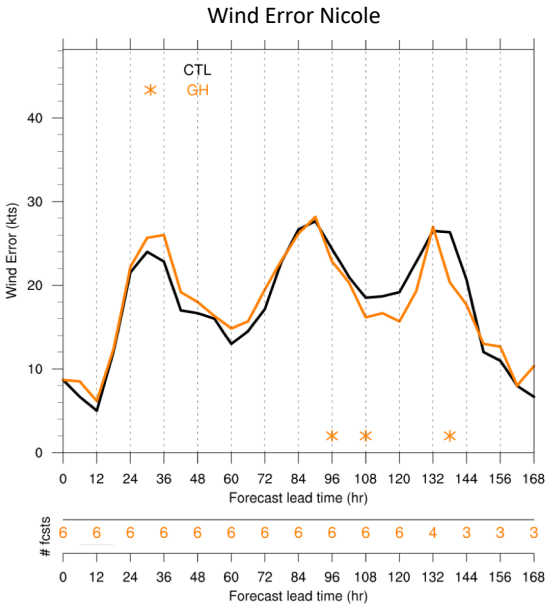


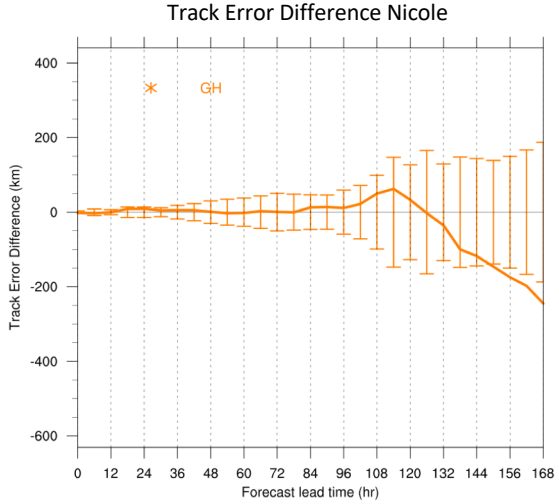
CTL GH

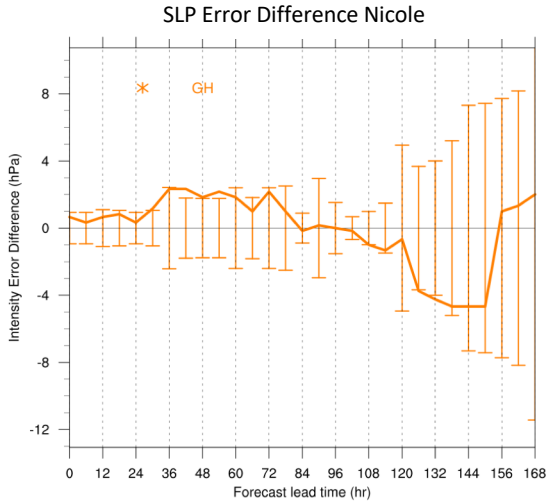
Results: Nicole Storm Track, SLP, and maximum wind speed error

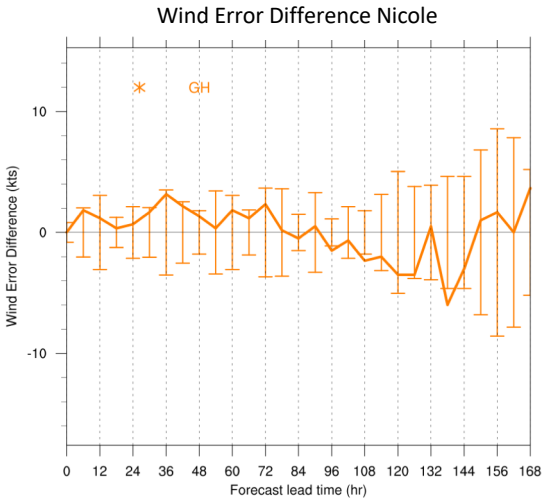








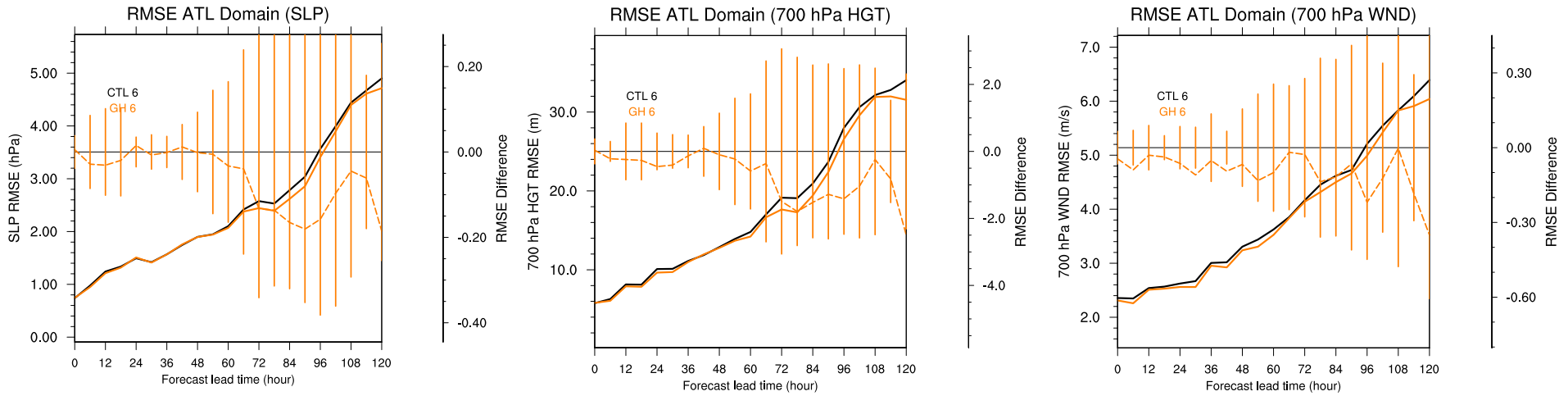




CTL **GH**

Results: Improvements in environmental fields led to track improvements

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

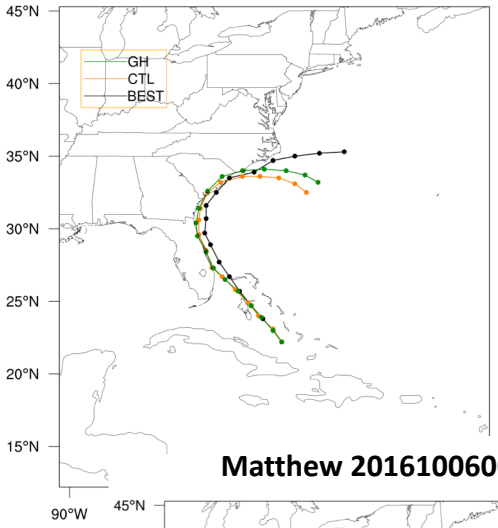


CTL GH

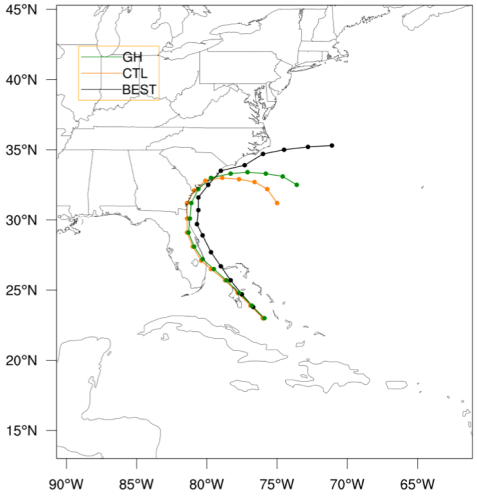
Reduced RMSE across all metrics with assimilation of GH dropsondes

Results: Improvements in environmental fields led to track improvements Matthew

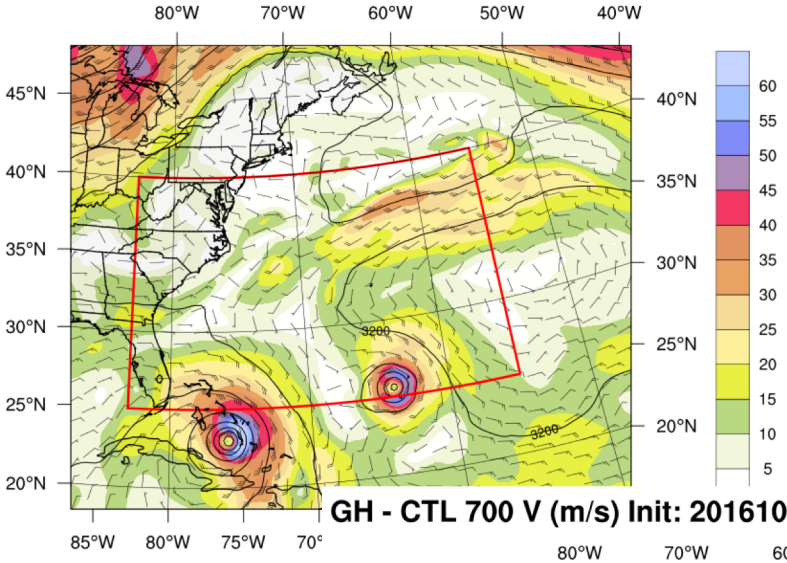
Matthew 2016100518



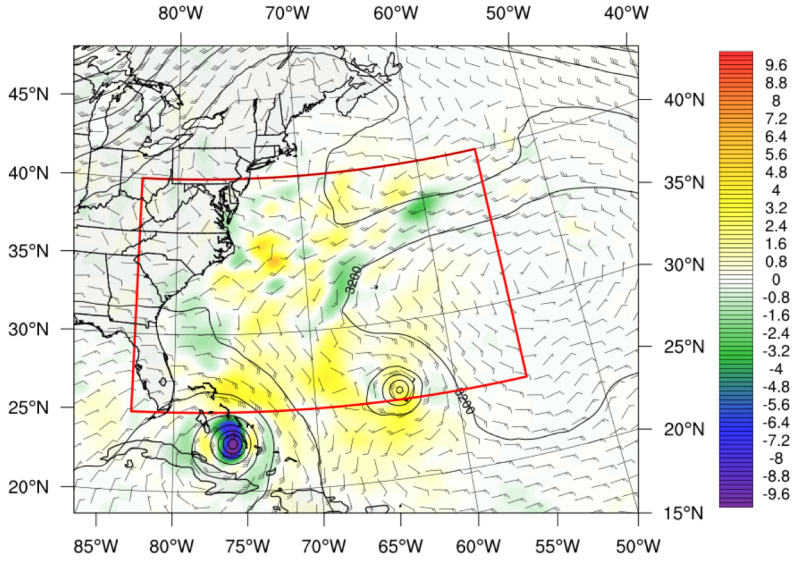
Matthew 2016100600



GH 700 hPa HGT/WND (m/s) Init: 2016100600 Valid: 10/06/16 00 UTC



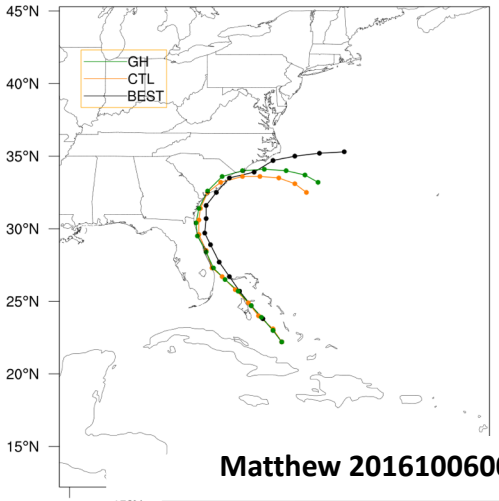
GH - CTL 700 V (m/s) Init: 2016100600 Valid: 10/06/16 00 UTC



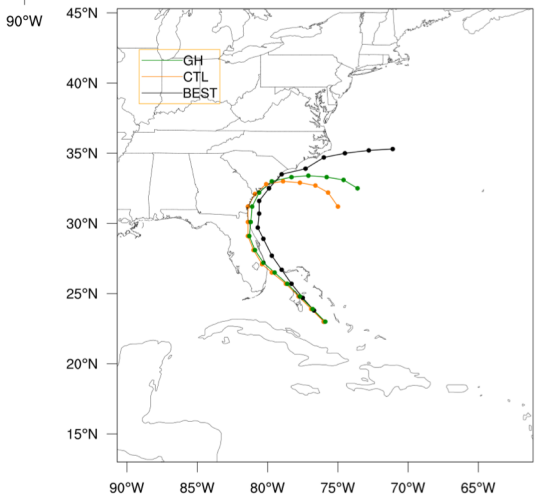
GH dropsondes initialized stronger northward flow over Atlantic, helping to partially shift Matthew north

Results: Improvements in environmental fields led to track improvements Matthew

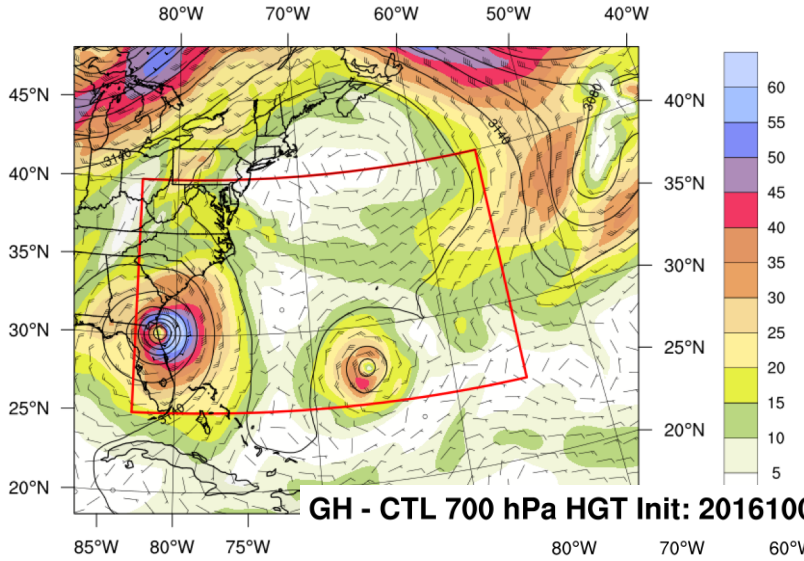
Matthew 2016100518



Matthew 2016100600

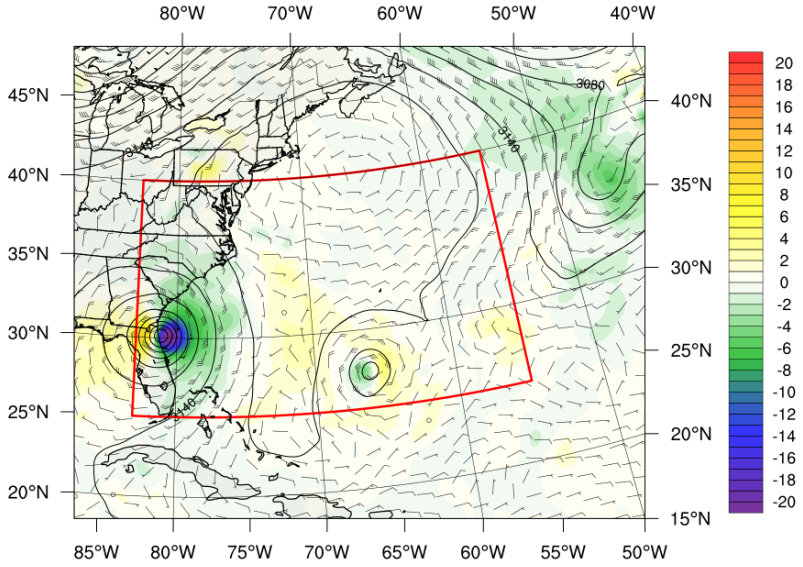


GH 700 hPa HGT/WND (m/s) Init: 2016100600 Valid: 10/08/16 00 UTC



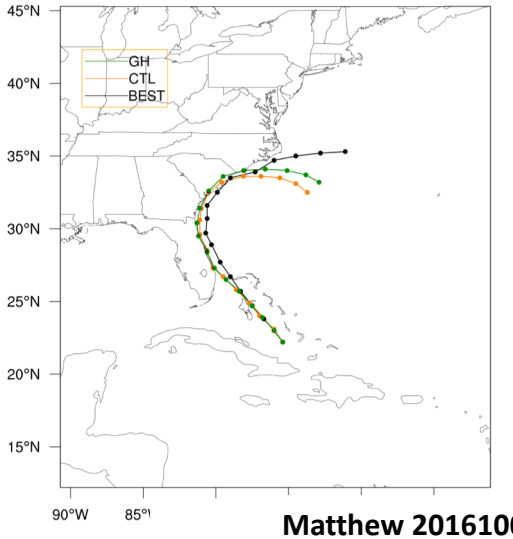
GH experiment shows stronger ridge east of Matthew, helping to partially shift Matthew north

GH - CTL 700 hPa HGT Init: 2016100600 Valid: 10/08/16 00 UTC

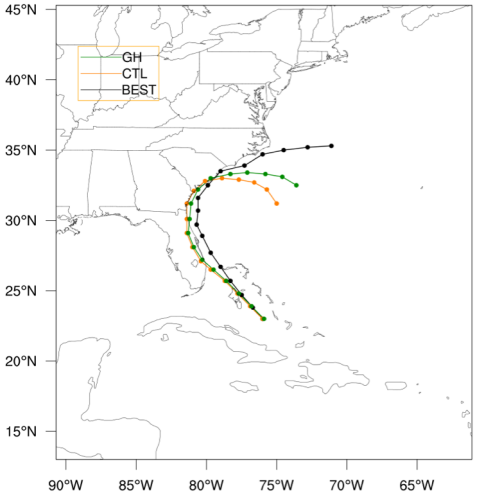


Results: Improvements in environmental fields led to track improvements Matthew

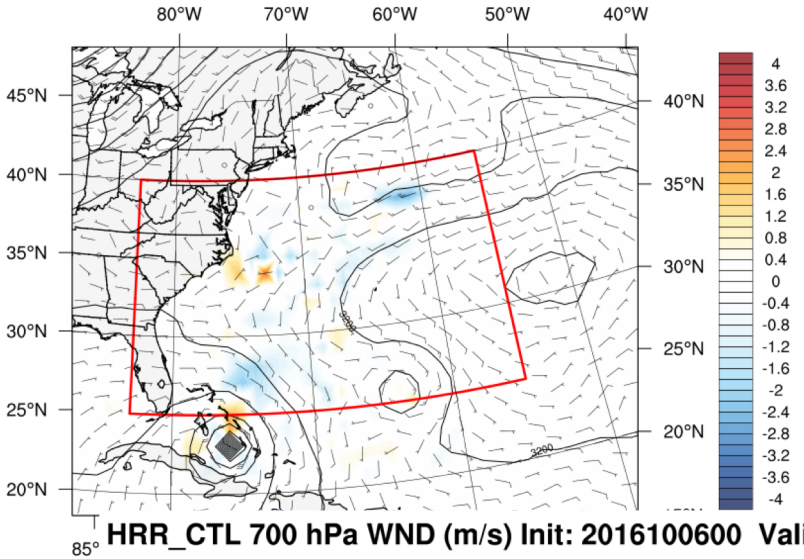
Matthew 2016100518



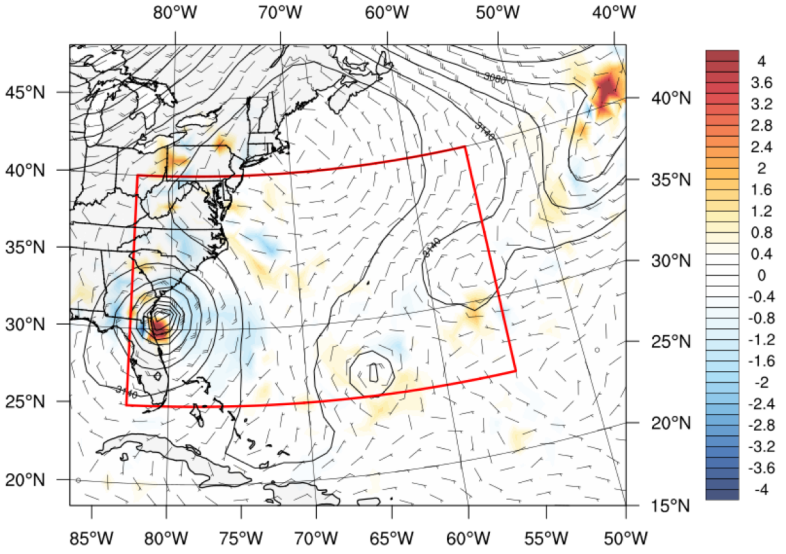
Matthew 2016100600



HRR_CTL 700 hPa WND (m/s) Init: 2016100600 Valid: 10/06/16 00 UTC



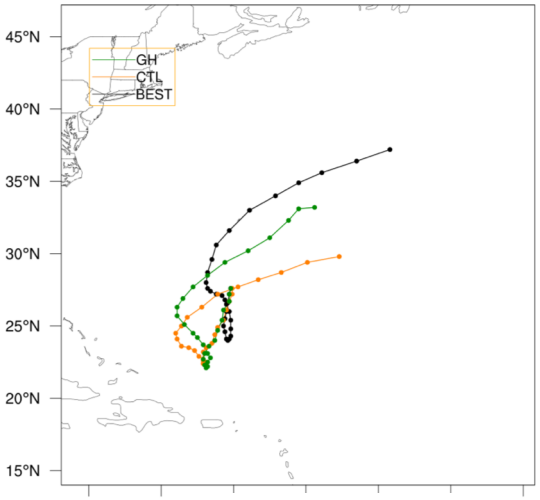
HRR_CTL 700 hPa WND (m/s) Init: 2016100600 Valid: 10/08/16 00 UTC



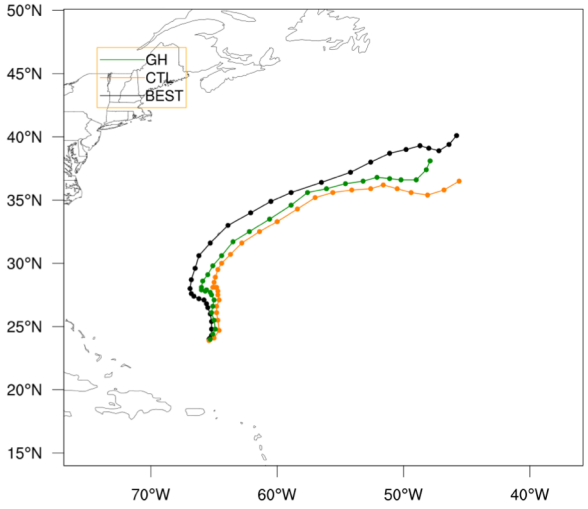
GH dropsondes reduce 700 hPa wind error at analysis/forecasts times

Results: Improvements in environmental fields led to track improvements Nicole

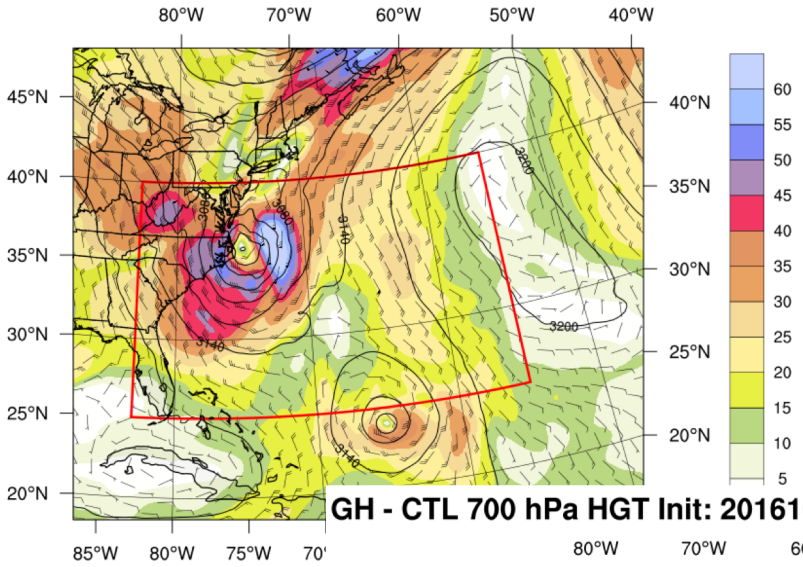
Nicole 2016100712



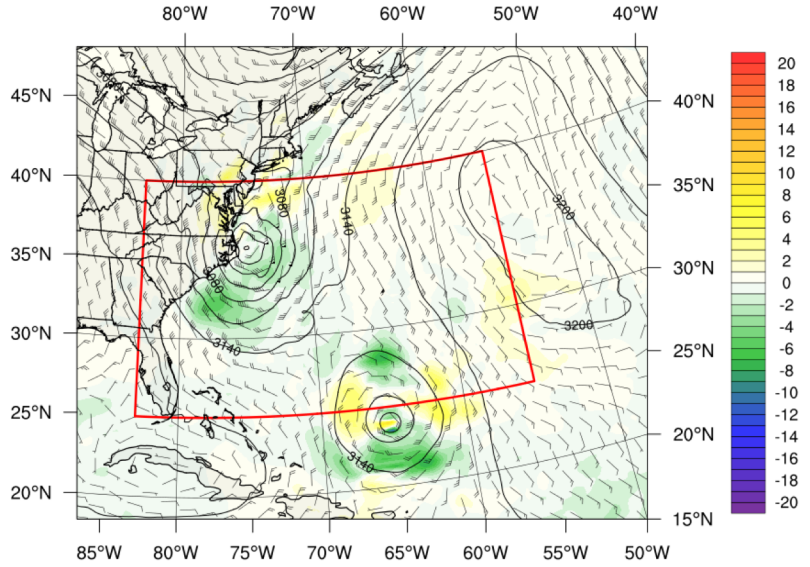
Nicole 2016100912



GH 700 hPa HGT/WND (m/s) Init: 2016100912 Valid: 10/09/16 12 UTC



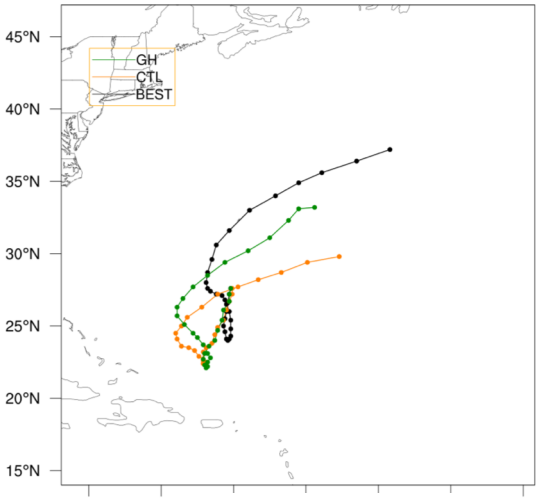
GH - CTL 700 hPa HGT Init: 2016100912 Valid: 10/09/16 12 UTC



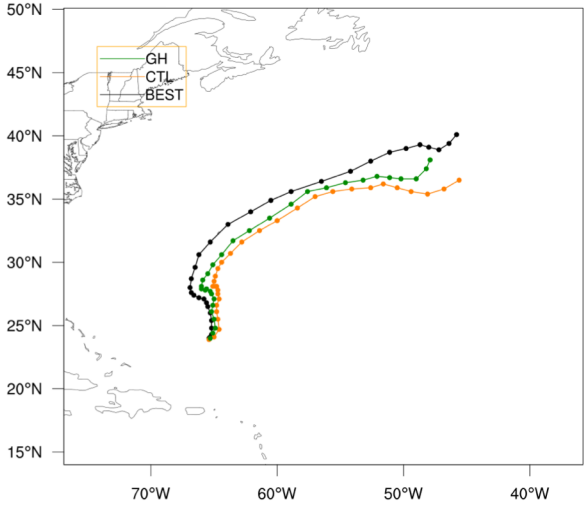
GH dropsondes initialized stronger ridge east of Nicole, helping to partially shift Nicole north

Results: Improvements in environmental fields led to track improvements Nicole

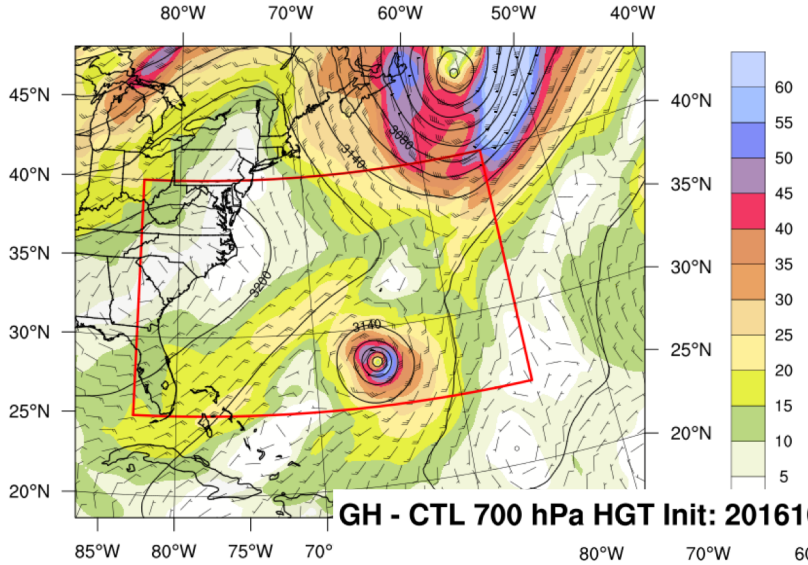
Nicole 2016100712



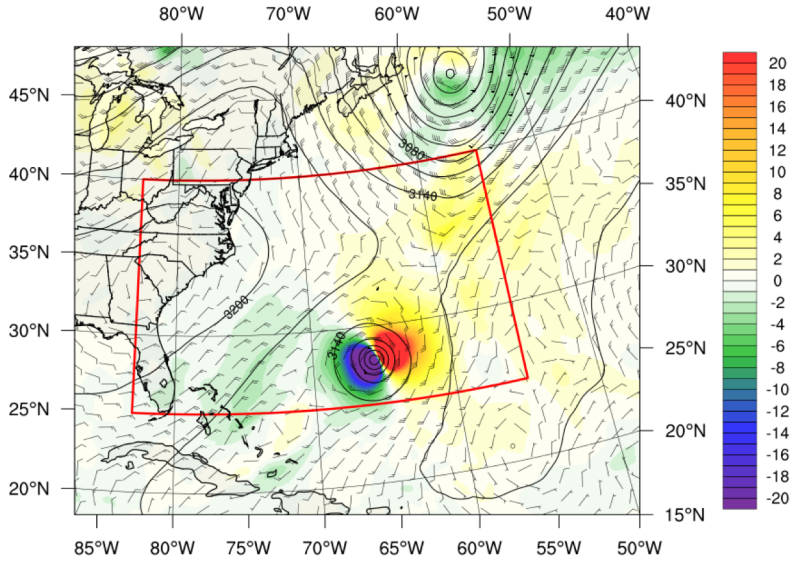
Nicole 2016100912



GH 700 hPa HGT/WND (m/s) Init: 2016100912 Valid: 10/11/16 18 UTC



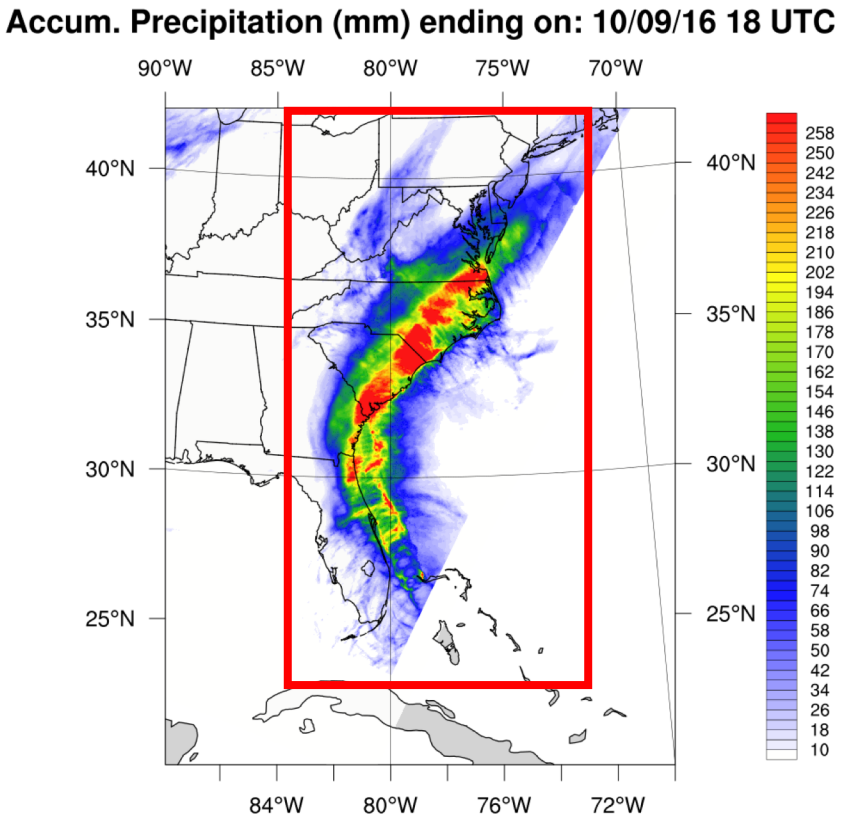
GH - CTL 700 hPa HGT Init: 2016100912 Valid: 10/11/16 18 UTC

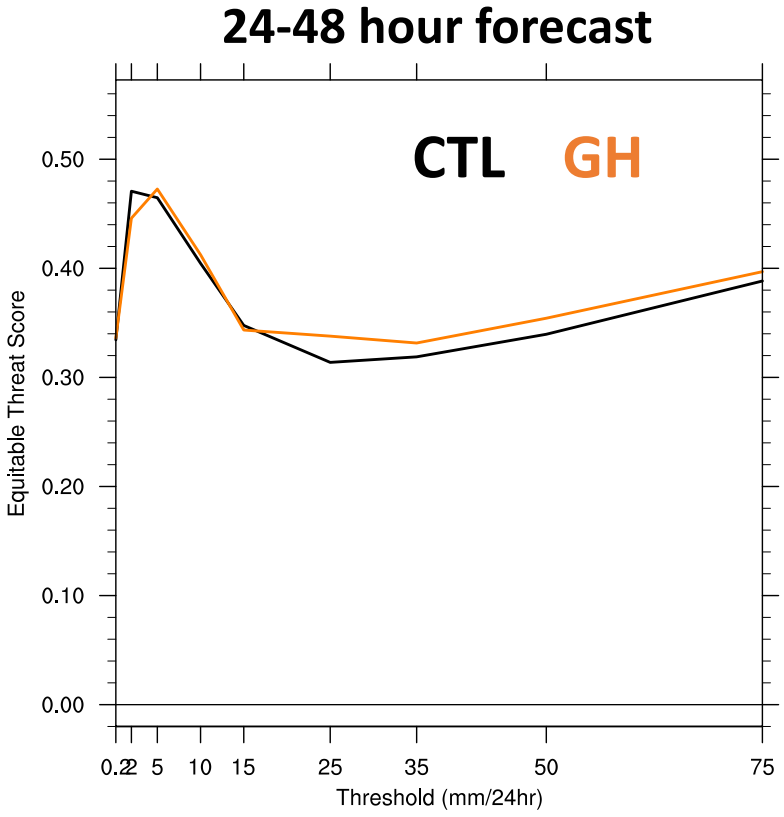


GH experiment shows stronger ridge east of Nicole, helping to partially shift Nicole north

Results: Precipitation – Closer agreement with observations

Equitable Threat Score

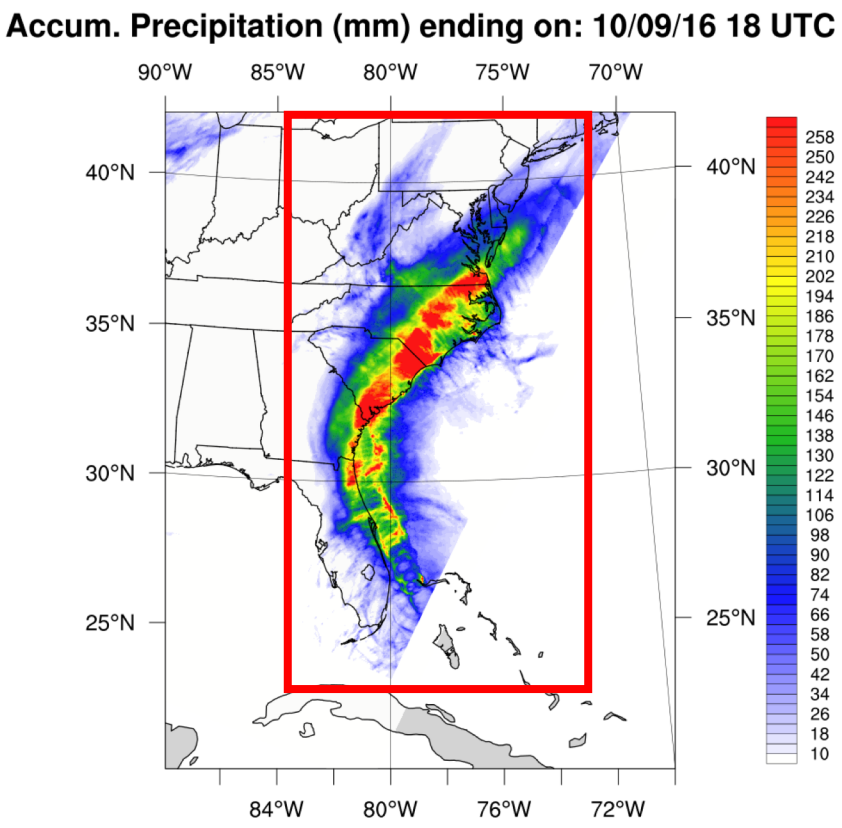


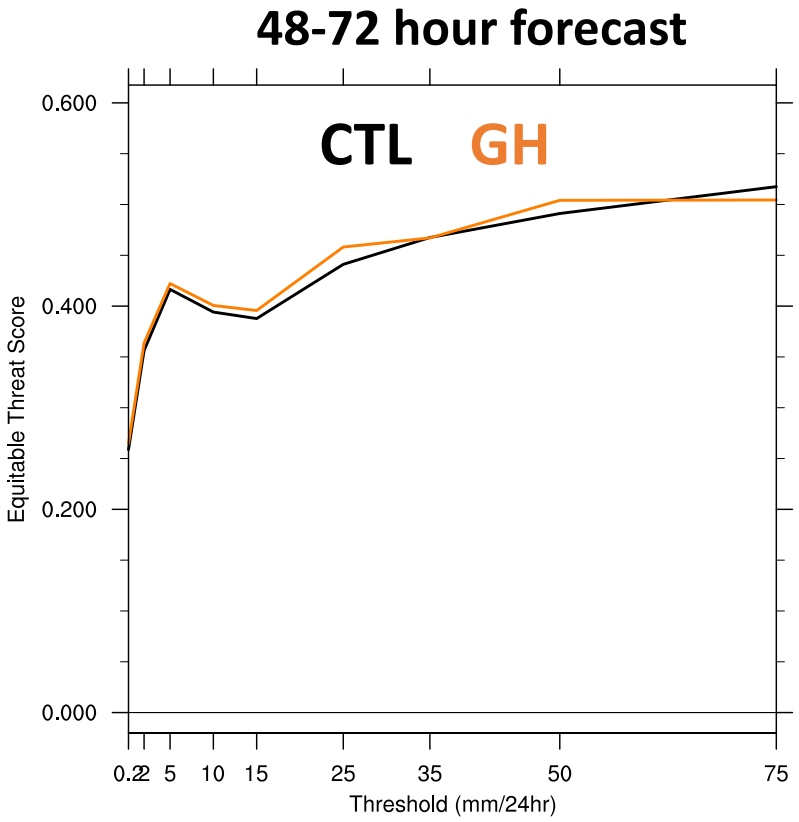


GH dropsondes improve precipitation forecast over southeastern United States

Results: Precipitation – Closer agreement with observations

Equitable Threat Score

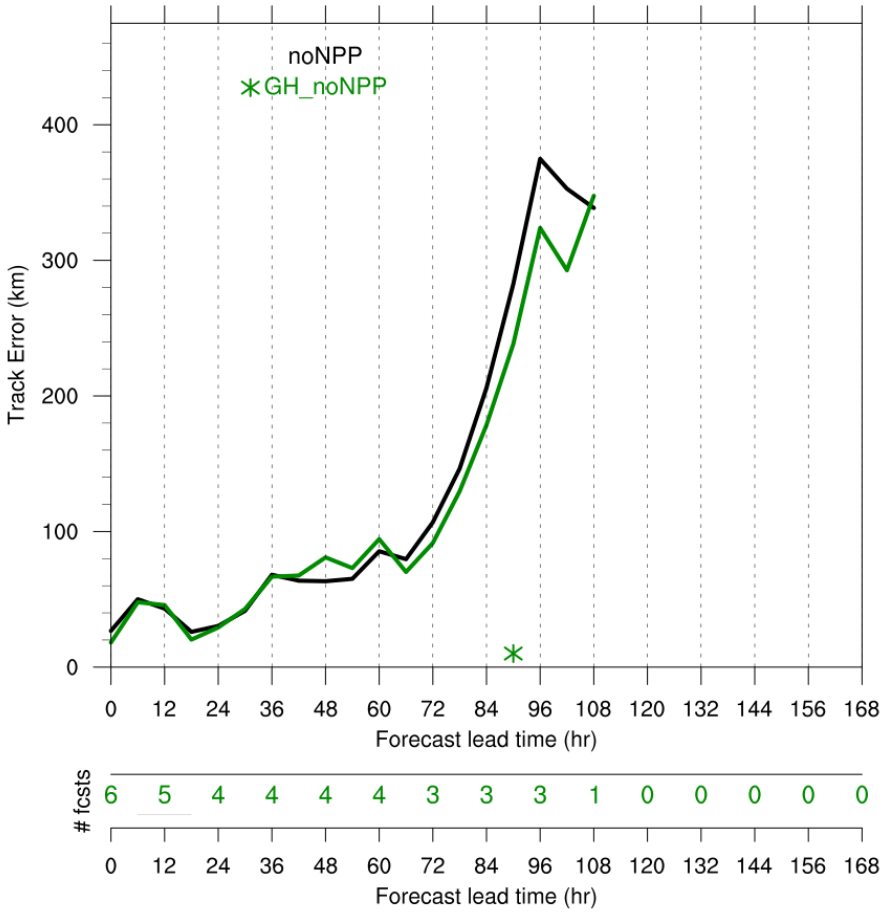




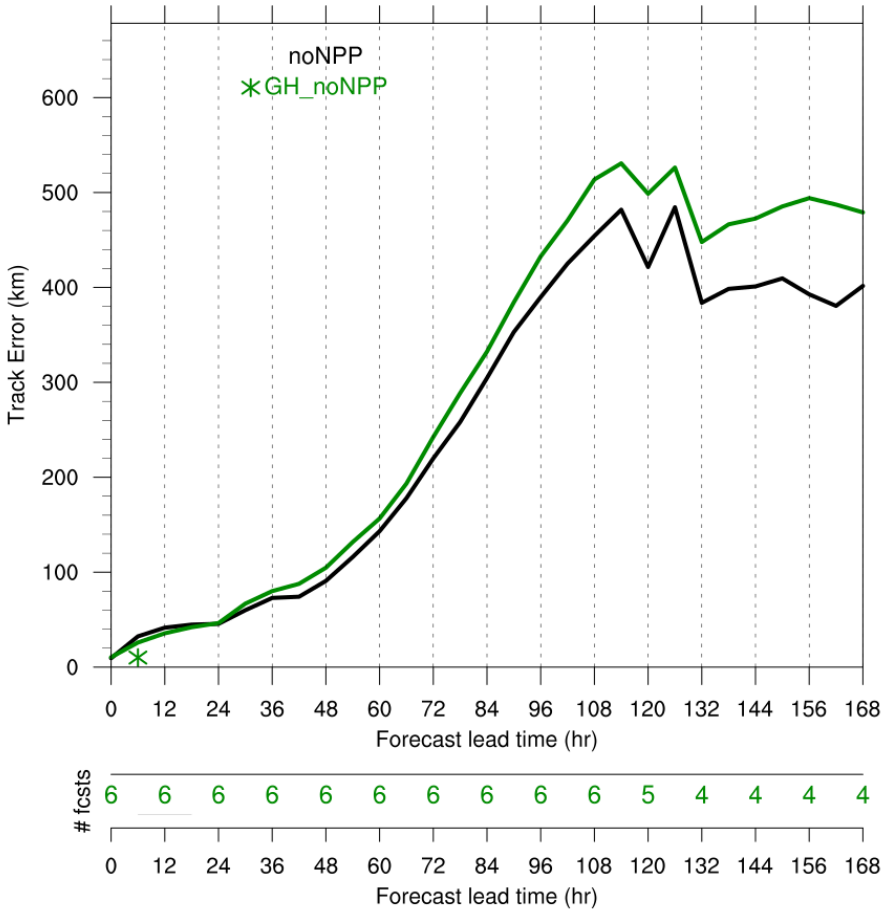
GH dropsondes improve precipitation forecast over southeastern United States

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:
a. Current satellite configuration
b. Satellite data gap scenario

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

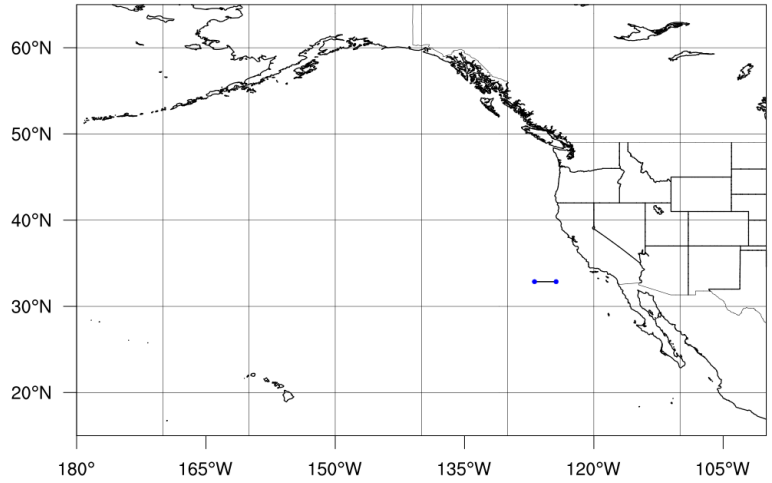
Acknowledgements

- 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)

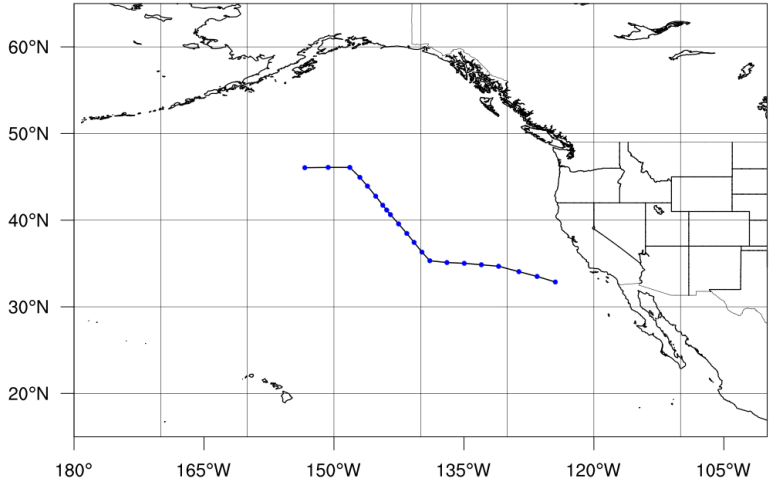
Backup slides

SHOUT-ENRR GH missions: February 12th, 15th, and 21st, 2016

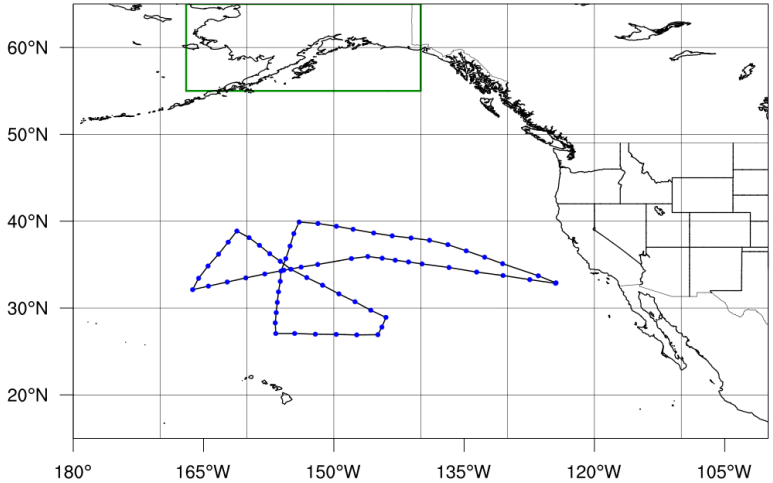
Dropsonde locations on 02/12/2016



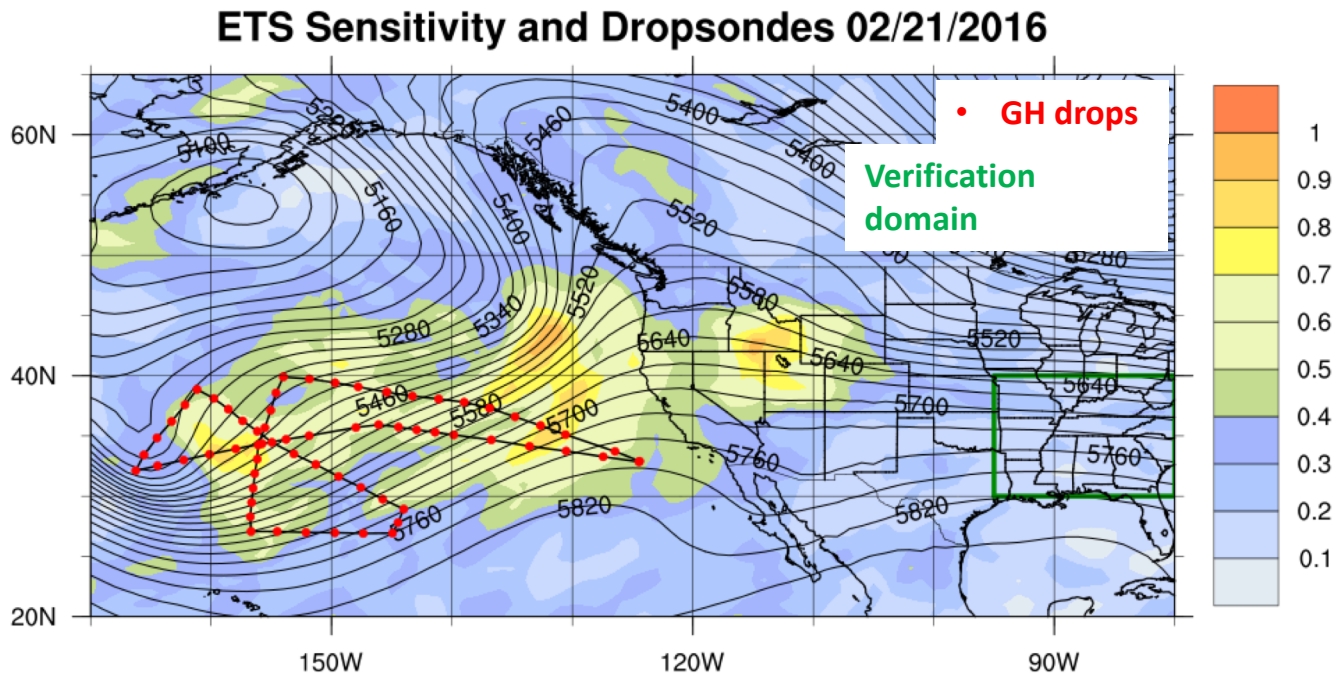
Dropsonde locations on 02/15/2016



Dropsonde locations on 02/21/2016



SHOUT-ENRR GH mission and ETS Sensitivity: February 21st, 2016

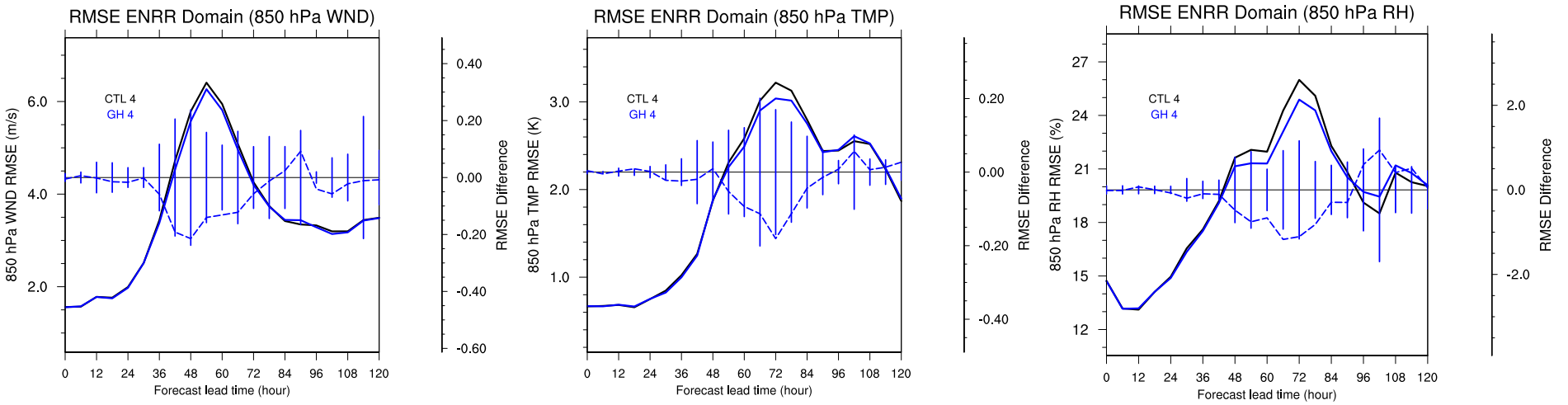


*GEFS mean 500 hPa height for 2/21/2016 with ETS sensitivity for targeting time of **2/21/12Z** and verification time of **2/24/00Z***

- **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

Results: Feb 21 case: Improvements in environmental fields over verification region

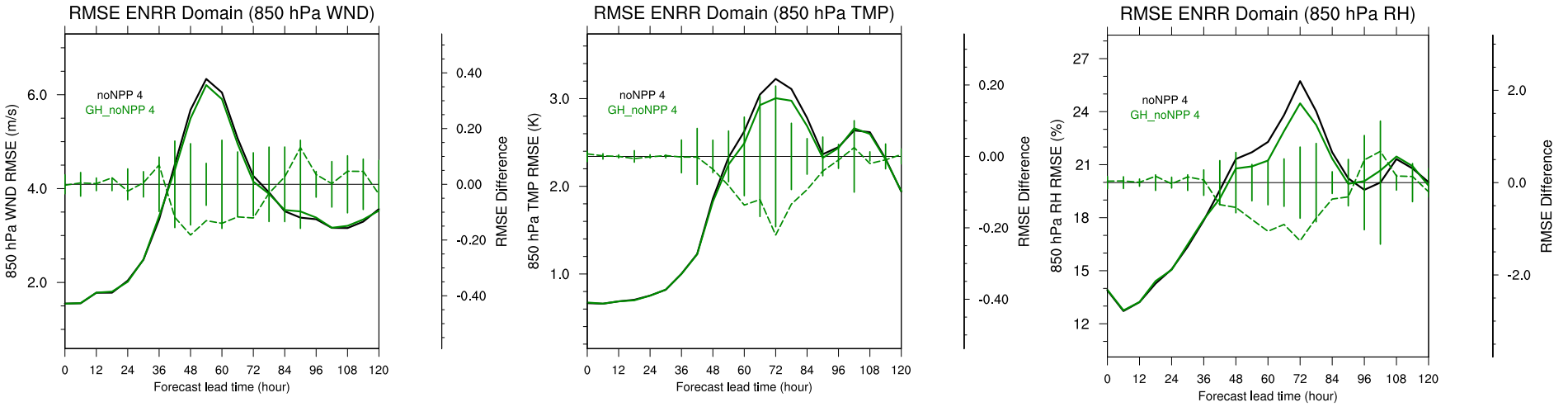
850 hPa Wind, Temperature, and Relative Humidity



Reduced RMS error over southeastern United States after assimilation of GH dropsondes

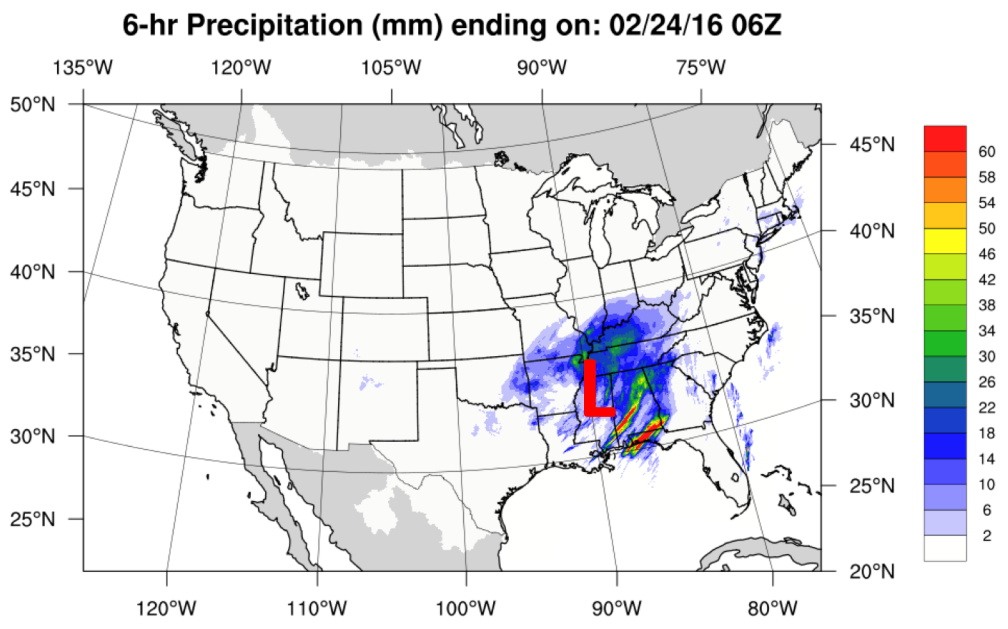
Results: Feb 21 case: Satellite data gap scenario

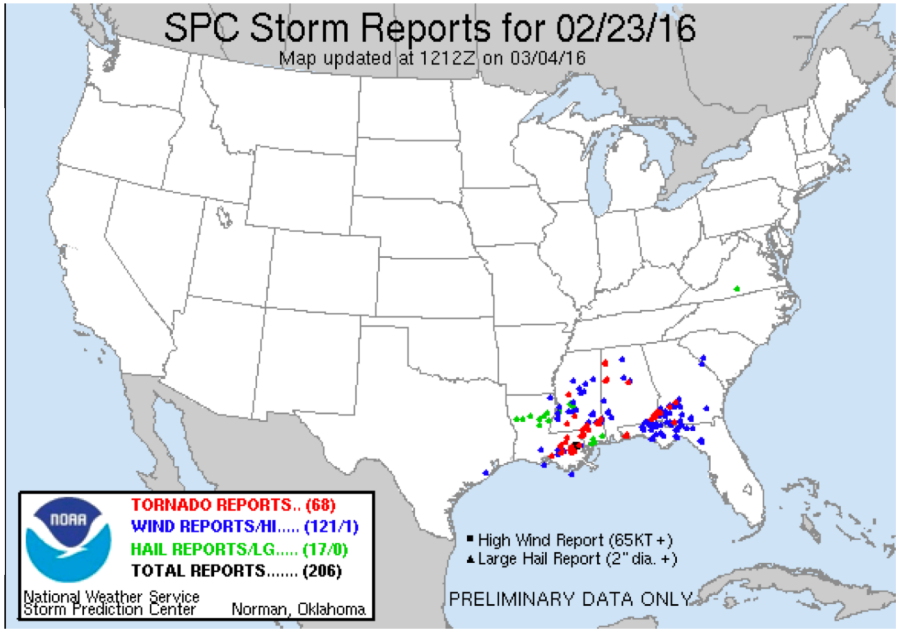
850 hPa Wind, Temperature, and Relative Humidity



Reduced RMS error over southeastern United States after assimilation of GH dropsondes

Results: Feb 21 case: Severe Weather Event over Southeast US





Results: Feb 21 case: Severe Weather Event over Southeast US