

GOESR3 Final Report

Reporting Period: July 2017 – June 2020 (full 3-year period)

Team Lead: Jun Li

Team Members: Jinlong Li, Chris Velden, William E. Lewis, and Dave Stettner

Project Title: Improving the Assimilation of High-Resolution GOES-16 Water Vapor Variables and Atmospheric Motion Vectors in the HWRf Model

Project Number: 439

Executive Summary

Reliable forecasts of landfalling tropical cyclones (TCs) such as Hurricane Sandy (2012), Matthew (2016), Harvey (2017), Irma (2017) and Maria (2017) are critical for decision making and better preparation. Obtaining good TC intensity forecasts remains one of the most challenging aspects in NOAA operations. Observations of atmospheric water vapor variables and winds in the TC environment as well as in the inner core at high spatiotemporal resolution are very important to the prediction of the storm evolution and landfall impacts. Optimizing the assimilation of that information into the operational Hurricane WRF (HWRf) model is a vital step towards improving TC forecasts. To help address this need, the Advanced Baseline Imager (ABI) (Schmit et al. 2005; 2017) onboard NOAA's next generation of geostationary weather satellites (GOES-R series), beginning with GOES-16 launched on 19 November 2016, is routinely providing high temporal (every 1-5 minutes) and spatial (0.5-2 km) resolution imagery that can provide rapid-update moisture variables and atmospheric motion vector (AMV) information not previously available. The primary goal of this study was to optimize the impact of the high spatiotemporal resolution GOES-R series water vapor information and AMVs for improving TC analyses and forecasts in HWRf. In particular, our study focused on using GOES-16 observations in the analysis-sensitive regions associated with the TC near-environment, TC inner core, and optimizing the effective assimilation of these data into HWRf for improving TC moisture, wind, track, and intensity forecasts.

During this study, very high spatiotemporal resolution AMVs have been processed from rapid-scan GOES-16 ABI meso sector measurements for selected major hurricane cases. Effective assimilation of these AMV datasets in the HWRf model leads to consistent improvements in Hurricanes Harvey, Irma and Maria forecasts, mainly from better initialization in the hurricane core region. Through targeted GOES-16 rapid-scan observations, the new generation of NOAA/NESDIS geostationary satellites can provide an important data source for hurricane forecast improvement.

ABI water vapor radiance assimilation over land can be improved by implementing a quality flag (QF) through surface skin temperature Jacobian. The HWRf forecasts of TCs such as Harvey can be improved by effectively assimilating ABI three water vapor absorption band radiances over land with this QF.

Two manuscripts from this study have been published.

Final Year Milestones (FY19) and Project Deliverables

The FY19 milestones include:

- (a) Investigate quality control (QC) procedures for more effective use of ABI moisture measurements and AMVs in HWRf/GSI;
- (b) Test the hourly and 3-hourly data assimilation experiments when the configurable cycling is available for HWRf from EMC;
- (c) Run combined experiments including both GOES-16 moisture plus AMVs for selected TC cases;
- (d) Conduct a full hurricane season experiments on typical hurricanes and compare impact results against benchmarked Control and operational forecasts;
- (e) Final report and publish findings.

In the final year of this project (FY19), the tasks listed above have been accomplished, as planned and expected, for example tasks (a), (b), (c), and (d) have been done, (e) has been done after this final report. The assimilation of GOES-16 meso sector rapid-scan AMVs into the HWRf model has been optimized, and three selected hurricanes from 2017 (Harvey, Irma and Maria) have been re-run with consistently improved forecast results. A manuscript titled “Impact of rapid-scan-based dynamical information over the inner-core region of hurricanes from GOES-16 ABI on HWRf hurricane track forecasts” has been published in Journal of Geophysical Research: Atmospheres.

ABI water vapor radiance assimilation over land can be improved by implementing a quality flag (QF) through surface skin temperature Jacobian. It has been demonstrated that forecasts of Hurricane Harvey can be improved by effectively assimilating ABI three water vapor absorption band radiances over land with this QF. A manuscript has been accepted by AGU’s open journal Earth and Space Science. The assimilation of GOES-16 rapid-scan ABI AMVs and water vapor information (three layered precipitable water - LPWs) together into HWRf s also been tested for the Hurricane Harvey case. Notable value-added forecast impact from ABI rapid-scan AMVs and LPWs on Harvey track forecasts was found, showing consistent improvement from AMVs, LPWs, and combined AMVs/LPWs, respectively.

Discussion of operational transition readiness for any project outcomes

The ABI meso sector rapid-scan based AMVs and water vapor radiances have been demonstrated in this project to have potential for operational use in NWP models, especially for improving hurricane forecasts through optimized assimilation in HWRf. It is recommended that the lessons learned from this project be followed to implement the procedures for optimized assimilation of AMVs and water vapor radiances:

- (1) Transition to NESDIS operations of the processing strategies for real-time GOES-16/17 meso sector AMVs during targeted hurricanes developed by the CIMSS AMV research team;
- (2) Use the latest version of operational HWRf assimilation and forecast system for implementation of GOES-16/17 data assimilation and QC strategies as found in this study.

Additional Information

1. Interaction with operational partners – communication with DTC and HWRF team on using the latest version of HWRF and updates. Dr. Jason Sippel from AOML/HRD provided feedback on AMV assimilation strategies in HWRF.
2. Conference/workshop participation – Jinlong Li attended the AMS/EUMETSAT Joint Satellite Conference, 29 Sept – 04 Oct 2019, Boston, MA, and gave a presentation titled “Impact of rapid scan based dynamic information in the inner-core region from ABI on HWRF hurricane forecasts.”
3. Outside project publicity – CIMSS SDAT webpage, GOES-16 LAP validation tool webpage.
4. Journal articles – Two papers published (one in the Earth and Space Science, another in the Journal of Geophysical Research: Atmospheres). The GOES-16 meso sector rapid-scan AMV paper in JGR got lots of attention from both the operational and research communities.

Key Graphics

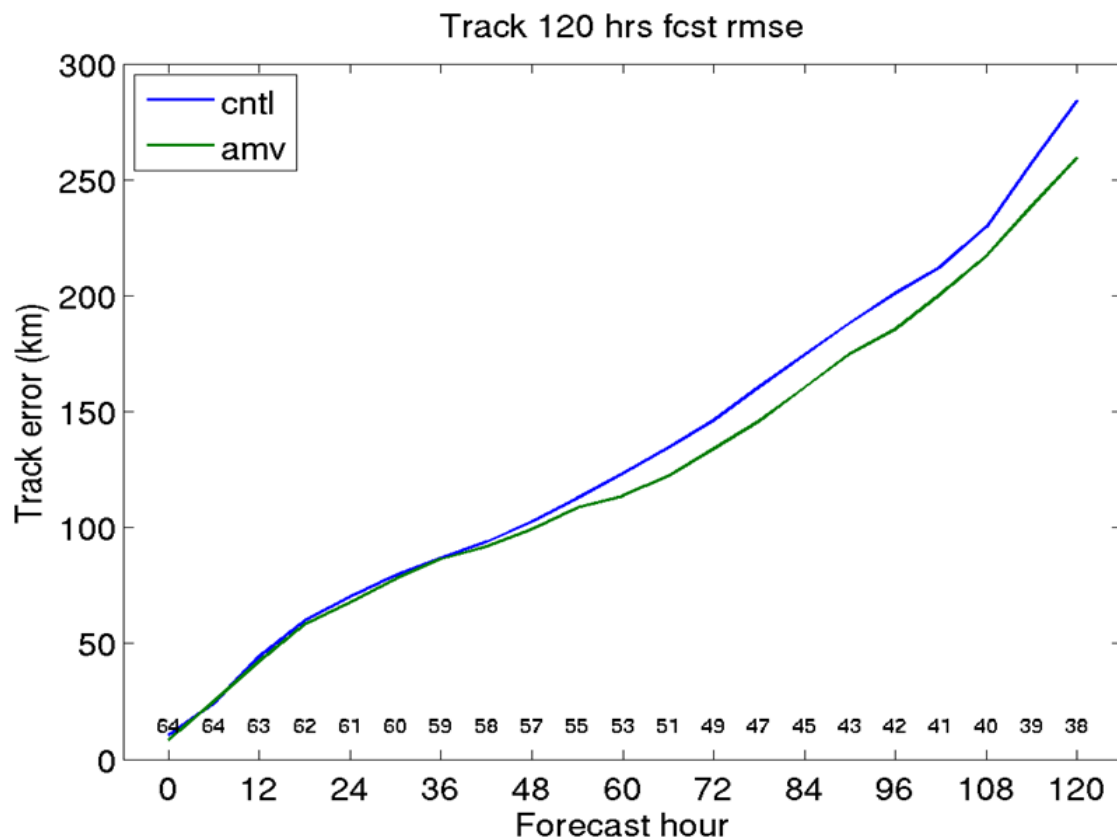


Figure 1. HWRF track forecast RMSE from the control and the ABI meso sector rapid-scan based AMV experiments for three hurricanes in 2017: Harvey, Irma and Maria altogether. The control has similar settings to the operational HWRF; the AMV experiment has the same settings as control plus assimilation of ABI meso sector rapid-scan based AMVs centered over the TC core areas.

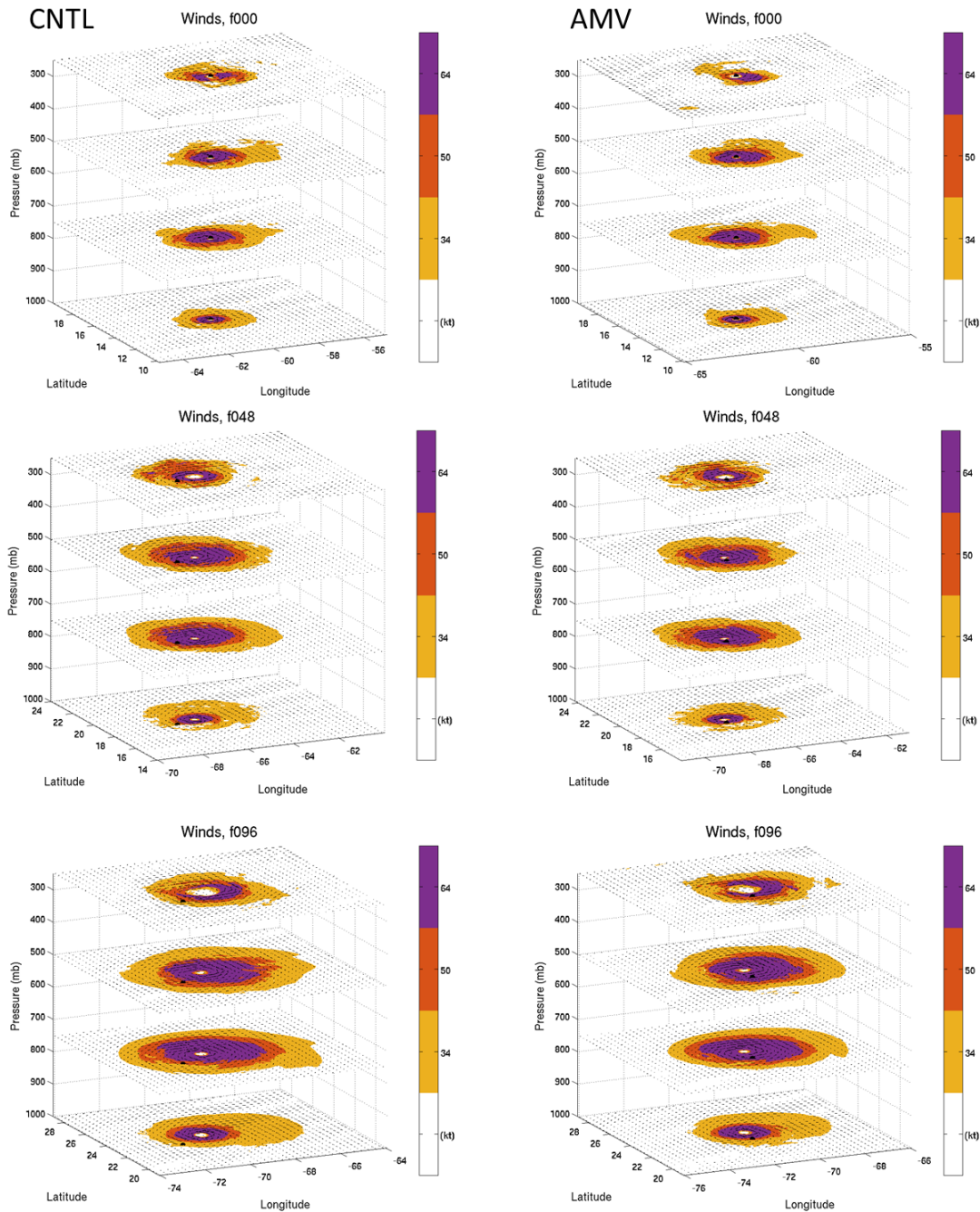


Figure 2. HWRF wind structure forecasts from Hurricane Maria for 4 pressure levels (250, 500, 750, 1000 hPa) starting from 18 UTC 18 September 2017. Left column: cntl run, right column: AMV exp. Top row: 0 hour forecast, middle row: 48 hour forecast, bottom row: 96 hour forecast. The three colors represent the 3 different wind speed ranges: purple for >64 kt wind, orange for >50 kt wind, and yellow for >34 kt winds. (from Li et al. (2020)).