GOESR3 Periodic Reporting

Reporting Period: 01 January 2019 – 30 June 2019

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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. This proposed work is 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 will focus on using GOES-16 observations in the analysis-sensitive regions associated with the TC near-environment, and optimizing the effective assimilation of these data into HWRF for improving TC moisture, wind, track, and intensity forecasts.

FY19 Milestones

(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.

Accomplishments (01 January – 30 June 2019)

(1) Most of the tasks listed in "FY19 milestones" have been accomplished, as planned and expected, for example tasks (a), (b), (c), and (d) have been mostly done, the remaining tasks are expected to be finished before 30 June 2020.
(2) Combined ABI rapid scan based AMVs and water vapor information are tested for Hurricane Harvey (2017) case, consistent track and intensity improvement found when combining rapid scan AMVs and water vapor information.
(3) 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 written for submission to JGR-Atmospheres.

Below is a more detailed report on our progress:

1. Most of the tasks listed in "FY19 milestones" have been accomplished

(a) Investigate quality control (QC) procedures for more effective use of ABI moisture measurements and AMVs in HWRF/GSI.

ABI water vapor radiance assimilation over land can be improved by implementing a quality flag (QF) through surface skin temperature Jacobian. The forecasts of tropical cyclones such as 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:
Article ID: ESS2365
Article DOI: 10.1029/2019EA000711
Internal Article ID: 16552090
Article Title: ABI water vapor radiance assimilation in a regional NWP model by accounting for the surface impact
Journal Title: Earth and Space Science
Status: accepted.

(b) Test the hourly and 3-hourly data assimilation experiments when the configurable cycling is available for HWRF from EMC;

The hourly cycle configuration is not feasible in the currently used HWRF system. However, we take advantage of FGAT (First Guess at Appropriate Time) procedure in the HWRF, which can calculate the innovation (observation – background) at the observation time. The hourly LPW data have been processed and tested in HWRF/GSI, compared with 3-hourly and 6-hourly LPW data assimilation; it is found hourly data can provide better track forecasts, indicating the importance of high temporal information moisture information in TC forecast.

(c) Run combined experiments including both GOES-16 moisture plus AMVs for selected TC cases;

See the detailed explanations in this report.

(d) Conduct a full hurricane season experiments on typical hurricanes and compare impact results against benchmarked Control and operational forecasts;

The three typical hurricane cases (Harvey, Irma and Maria) in 2017 hurricane season have been tested; consistent positive results are found from using rapid scan based AMVs. A manuscript has been written for publishing. See detailed explanation on manuscript in this report.

(2) Both the ABI rapid scan AMVs and water vapor information are tested with Hurricane Harvey (2017) case, consistent track and intensity improvement found when combining rapid scan AMVs and water vapor information.

GOES-16 rapid scan ABI AMVs and water vapor information (three layered precipitable water - LPWs) have been tested for Hurricane Harvey (2017) case. Based on the ABI rapid scan mode during TC development, the observations are focused on the storm center domain (10 x 10 degree coverage centered on the TC storm), following the storm movement with time. The rapid scan based AMV datasets are produced at 15 minutes interval based on a set of sequential images scanned every minute for targeted meso sectors. To enhance the coverage, modifications of the minimum gradient, coherency and QC requirements are included. The types of wind to be assimilated include: VIS (0.64 μm) for low level, SWIR (3.9 μm) for cloud drift and low level, WVCT (6.19 μm) for upper level, and IR (11.2 μm) for cloud drift AMVs. For water vapor information, hourly derived three layered precipitable water (LPWs) are assimilated together with rapid scan based AMVs. The control run assimilated conventional data and operational satellite data, which is similar to the NOAA operational setting in HWRF.

Analysis is updated every 6 hours, and a 120-hour forecast is followed after each analysis. The period for Harvey experiment is **2017082306 – 2017082612 with 14 analysis cycles.** Figure 1 shows the value added impact from ABI rapid scan AMVs and LPWs on Harvey track forecasts. It shows consistent improvement from AMVs, LPW, and combined AMVs/LPWs, respectively. The next step is to combine the new information from ABI and NOAA-20 CrIS radiances.

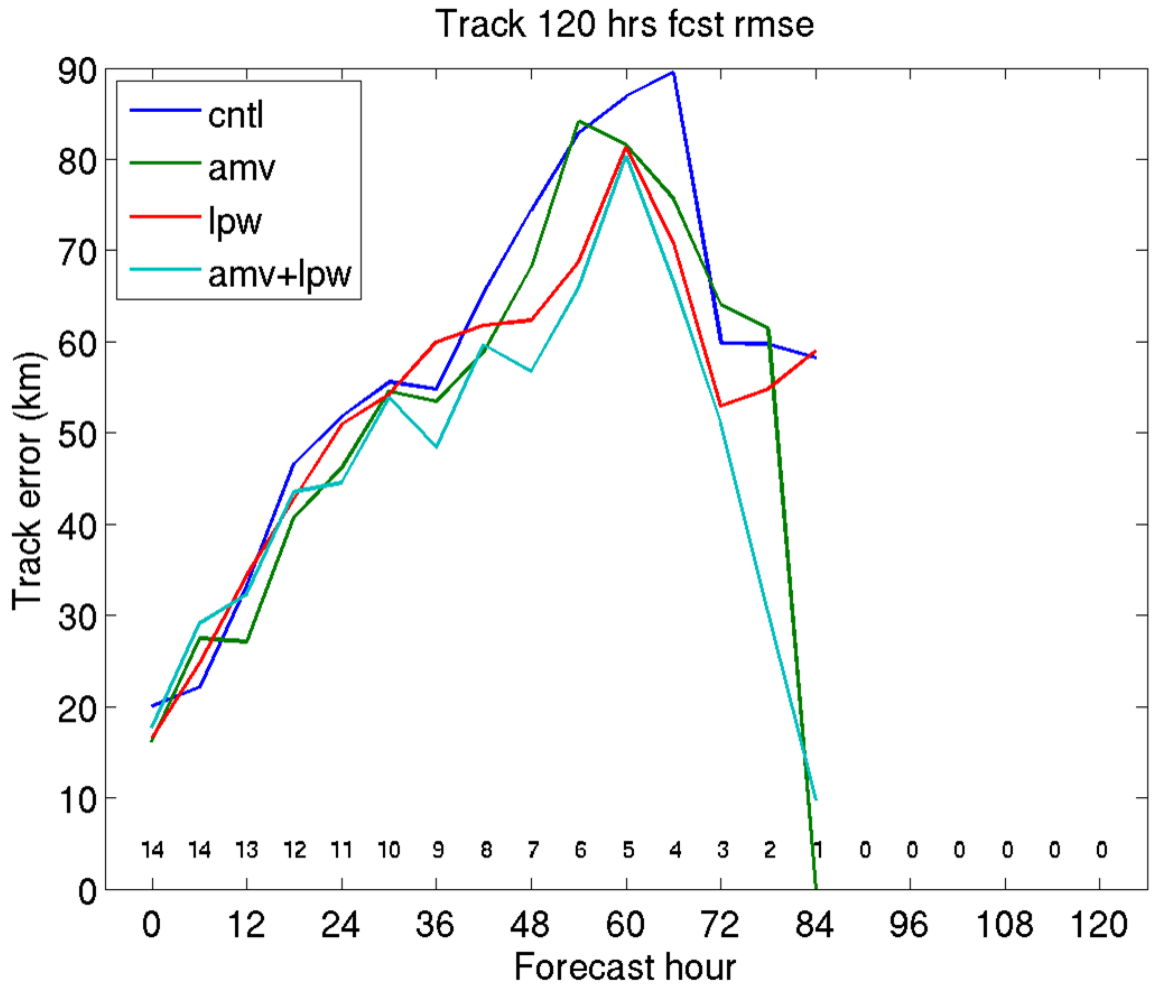

Figure 1. Track RMSE from four experiments: control, control+AMVs, control+LPWs, and control+AMVs+LPWs, respectively, for Hurricane Harvey (2017) in HWRF/S4.

(3) Manuscript on rapid scan AMVs for HWRF assimilation has been written for publishing

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 written for submission to JGR-Atmospheres. The key points and findings of this manuscript are: (a) Mesoscale atmospheric motion vectors (AMVs) have been developed from rapid scan GOES-16 ABI measurements; (b) Assimilation of inner-core regional rapid scan AMVs in HWRF model indicates consistent improvements on Hurricane Harvey, Irma and Maria forecasts; improvements are mainly from better initialization in the inner core region; and (c) Through rapid scan observation mode in the inner core region, the new generation of geostationary satellite provides an important way for hurricane forecast improvement.

Publications and conference presentations (01 January – 30 June 2019)

Peer-reviewed journal publications:

Li, Jun, Jinlong Li, Chris Velden, Pei Wang, Timothy J. Schmit, and Jason Sippel, 2019: Impact of rapid-scan-based dynamical information over the inner-core region of hurricanes from GOES-16 ABI on

HWRF hurricane track forecasts, Journal of Geophysical Research – Atmospheres (to be submitted in September 2019).

Additional Information

1. Interaction with operational partners – communication with DTC and HWRF team on using the latest version of HWRF and updates.
2. Funding concerns – no.
3. Outside project publicity – CIMSS SDAT webpage, GOES-16 LAP validation tool webpage.
4. Journal articles – one is accepted, another finalized for submission next month, see the above for the list.

Plans for the next Reporting Period

- More results and findings on assimilation of ABI radiances and AMVs in HWRF;
- Combining mesoscale AMVs and radiances;
- Publish a paper on assimilating mesoscale AMVs in HWRF;
- Final report.

Key Graphics