GOESR3 Periodic Reporting

Reporting Period: 01 July 2018 – 31 December 2018

Team Lead: Jun Li

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

NOAA Collaborators: Jason Sippel (NOAA/NHC), Zhan Zhang (NOAA/EMC), and Timothy J. Schmit (CoRP/STAR/NESDIS)

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.

FY18 Milestones

(a) Begin initial experiments on assimilating ABI radiances versus assimilating LPWs for improving the utilization of moisture information;
(b) Begin initial experiments on assimilating these enhanced AMVs into HWRF;
(c) Test the impact of varying the assimilation window span on HWRF TC forecasts when assimilating ABI measurements (radiances or LPWs) and AMVs;
(d) Synthesize the initial findings and report on them;
(e) Collaborate with DTC and EMC TC/HWRF teams and provide feedback on research progress using GOES-16 LPW and AMV information for impact on HWRF TC forecasts;
(f) Publish findings.

Accomplishments (01 July – 31 December 2018)

(1) Most of the tasks listed in "FY18 milestones" have been accomplished, as planned and expected, for example tasks (a), (b), (d), (e), (f) have been mostly done, the remaining tasks are expected to be finished before 30 June 2019.
(2) ABI rapid scan based AMVs are all tested for three typical hurricanes in 2017: Hurricane Harvey, Irma and Maria with HWRF/S4; consistent improvement found on track forecasts from adding ABI rapid scan AMVs into assimilation, the improvement becomes bigger with longer forecast time. Value-added impact on intensity forecasts are mixed with neutral overall.

Below is a more detailed report on our progress:

1. Most of the tasks listed in "FY18 milestones" have been accomplished

(a) Begin initial experiments on assimilating ABI radiances versus assimilating LPWs for improving the utilization of moisture information;

This has been conducted using AHI, it is found that assimilation of derived three layered precipitable water (LPW) has advantage over the assimilation of radiances for heavy precipitation forecasts, this is due to the limited radiance assimilation over land with the current NOAA operational assimilation system - GTS. The LWP assimilation is a combined 1DVAR/3DVAR approach and it can separate the surface contribution in 1DVAR processing over land for LPW assimilation. A paper has been published under the support of this project:

Wang, Pei, Jun Li, Bing Lu, Timothy J. Schmit, Jiazhen Lu, Yong-Keun Lee, Jinlong Li, and Zhiquan Liu, 2018: Impact of moisture information from Advanced Himawari Imager measurements on heavy precipitation forecasts in a regional NWP model, Journal of Geophysical Research - Atmospheres, 123, 6022 - 6038. https://doi.org/10.1029/2017JD028012.

Further studies will be conducted using ABI; we want to confirm the same findings in Wang et al. (2018).

(b) Begin initial experiments on assimilating these enhanced AMVs into HWRF;
This has been done, more experiments are conducted, see section 2.

(c) Test the impact of varying the assimilation window span on HWRF TC forecasts when assimilating ABI measurements (radiances or LPWs) and AMVs;
This task is planned and to be investigated.

(d) Synthesize the initial findings and report on them;
Reports provided to GOESR3 program manager, another manuscript on rapid scan AMVs for TCforecast improvement is written and to be submitted to JGR-Atmospheres.

(e) Collaborate with DTC and EMC TC/HWRF teams and provide feedback on research progress using GOES-16 LPW and AMV information for impact on HWRF TC forecasts;
We have collaborated with DTC and EMC TC/HWRF teams to use the latest version of HWRF, and the updates from 2018 were incorporated into HWRF/S4 for experiments, therefore, the control run is close enough to the operational results, which is very important for us to understand the added impact from including ABI on TC forecasts in HWRF.

(f) Publishing findings.

Wang et al. (2018) has been published, another 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" by Jun Li, Jinlong Li, Chris Velden, Pei Wang, Timothy J. Schmit, and Jason Sippel, has been writem and to be submitted to Journal of Geophysical Research – Atmospheres.

2**. ABI rapid scan based AMVs are tested for three typical hurricanes in 2017: Hurricane Harvey, Irma and Maria with HWRF/S4, consistent improvement found**

GOES-16 rapid scan ABI AMVs have been tested for three typical TCs in 2017 (Hurricane Harvey, Irma and Maria). 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, types of wind to be assimilated include:

VIS - Ch 2 (0.64 μm), Visible, low level
SWIR - Ch 7 (3.9 μm), Cloud Drift, low level
WVCT - Ch 8 (6.19 μm), Cloud top water vapor, upper level
IR - Ch 14 (11.2 μm), Cloud Drift

Regarding the HWRF model used in our experiments, the DTC released HWRF v3.9a, similar to H217, is used, and we updated satellite wind module with H218, and revised satellite wind module to handle GOES-16 AMV data. HWRF model experiments are conducted at the Super Computer for Satellite Simulation and Data Assimilation (S4) physically located and hosted by University of Wisconsin-Madison/SSEC.

The setting of the control run is similar to the operational one:

(a) With ocean coupled;
(b) No hybrid ensemble;
(c) Vortex correction/relocation;
(d) Conventional, satellite, operational AMV data;

ABI rapid scan based AMV assimilation experiment: based on the control, the following information are further included:

(a) Same as control run;
(b) Adding GOES-16 AMV (IRLW, IRSW, visible, WVCT) into assimilation with QI>80;
(c) Rapid scan based AMV quality control (QC): cgross=2.5 for all channels and observation error scale is set as: ch2/ch7=0.75; ch8/ch14=1.00.

Analysis is updated every 6 hours, and a 120-hour forecast is followed after each analysis. The periods for three TCs in our experiments are:

Harvey case:
2017082306 – 2017082612 (14 analysis cycles)
Irma case:
2017090418 – 2017091000 (22 analysis cycles)

Maria case:
2017091700 – 2017092318 (28 analysis cycles)

There are total 64 groups of analyses/forecasts obtained in our statistics. Figure 1 shows the value added impact from ABI rapid scan AMVs on three TC track forecasts. It shows consistent improvement for all three TCs, improvement is significant for Maria and Irma.

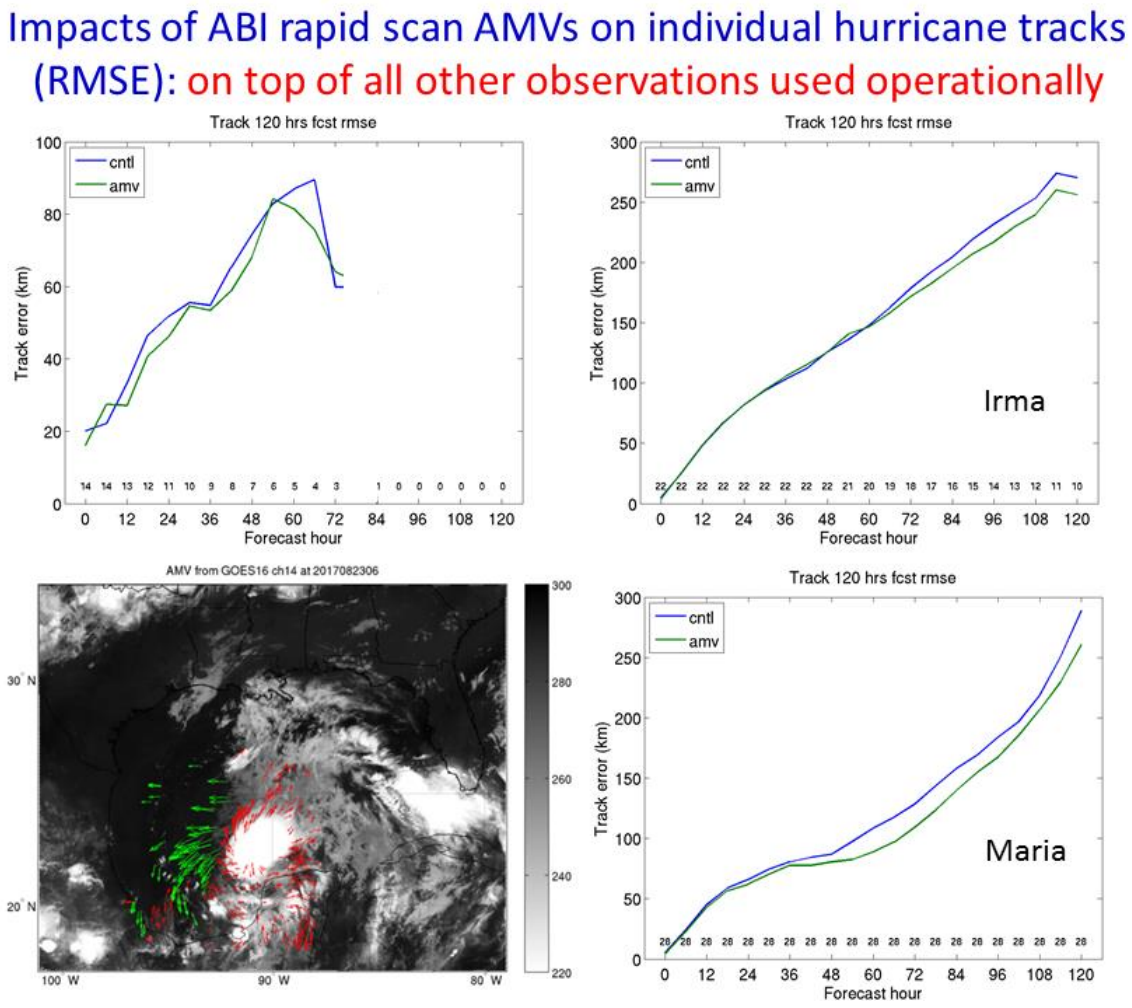

Figure 1. Track forecast RMSE from control and ABI rapid scan based AMV experiment for three hurricanes in 2017, Harvey, Irma and Maria, respectively.

Figure 2 shows the overall value added impact from ABI rapid scan AMVs on track forecasts. Total 64 groups are included in the statistics; forecast improvement gets bigger with longer forecast time, indicating consistent improvement on TC track forecasts by including the new information – the ABI rapid scan AMVs.

Overall impact from ABI rapid scan AMVs on hurricane track (RMSE): on top of all other observations used operationally

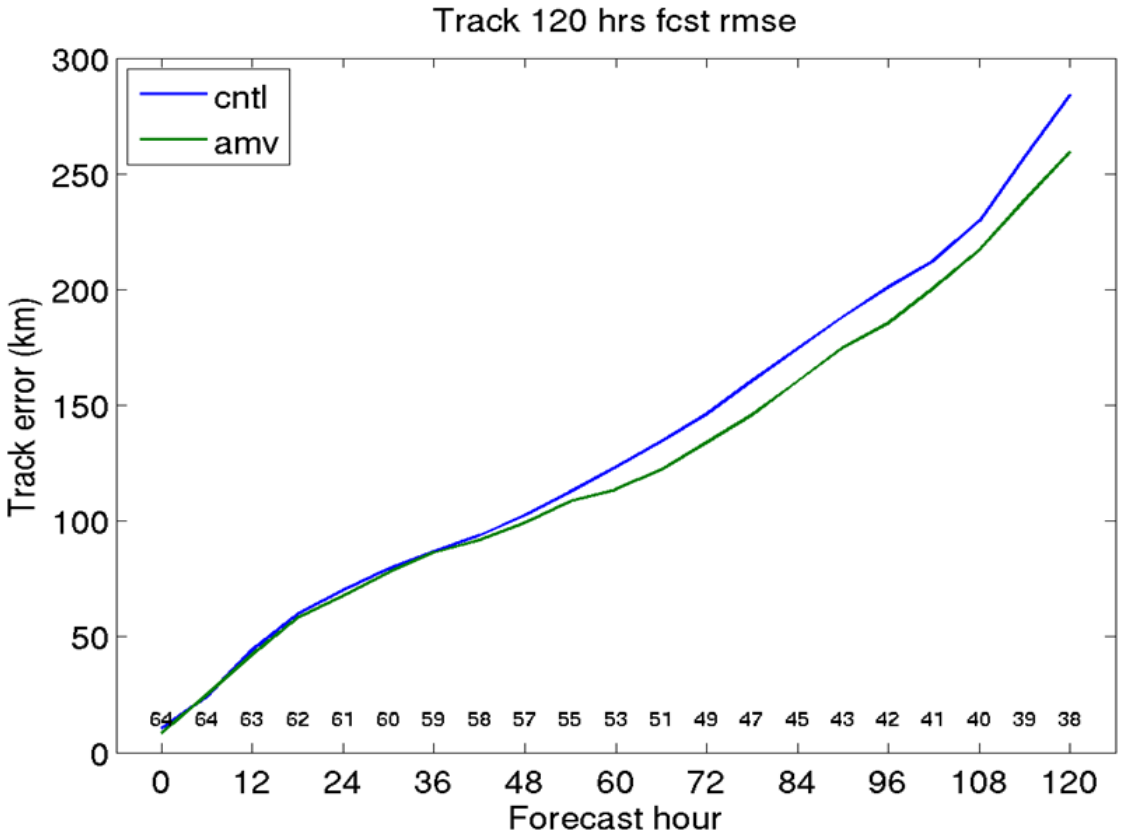

Figure 2. Track forecast RMSE from the control and the ABI rapid scan based AMV experiment for three hurricanes in 2017, Harvey, Irma and Maria altogether.

This demonstrates a novel way on using rapid scan information in NWP, especially the ABI rapid scan AMVs that provide important dynamic information in the inner core region, which is critical for improving TC forecasts. The overall impact from rapid scan AMVs on intensity forecasts are neutral, Figure 3 is the same as Figure 2 but for the maximum wind speed RMSEs from the control and the AMV experiments.

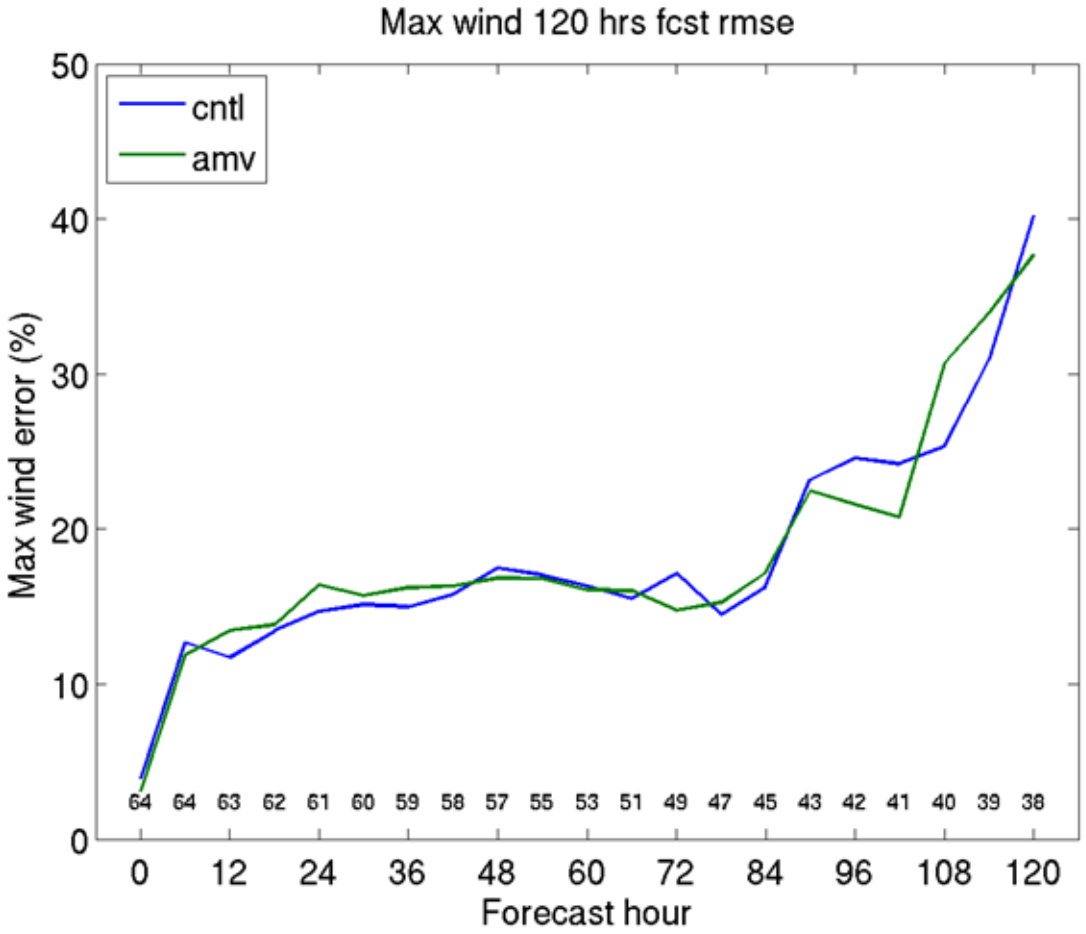

Figure 3. Maximum wind speed RMSEs (%) from the control and the ABI rapid scan based AMV experiment for three hurricanes in 2017, Harvey, Irma and Maria altogether.

Publications and conference presentations (01 July – 30 December 2018)

Peer-reviewed journal publications:

Lu, J., J. Li et al. 2019: Impact of assimilating Himawari-8 derived water vapour on WRF cumulus and microphysics parameterization schemes for typhoon prediction - a case study of Typhoon Hato, Journal of Geophysical Research – Atmospheres (in press).

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).

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 in press, another is to be submitted, see the above for the list.

Plans for the next Reporting Period

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- 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.

Key Graphics

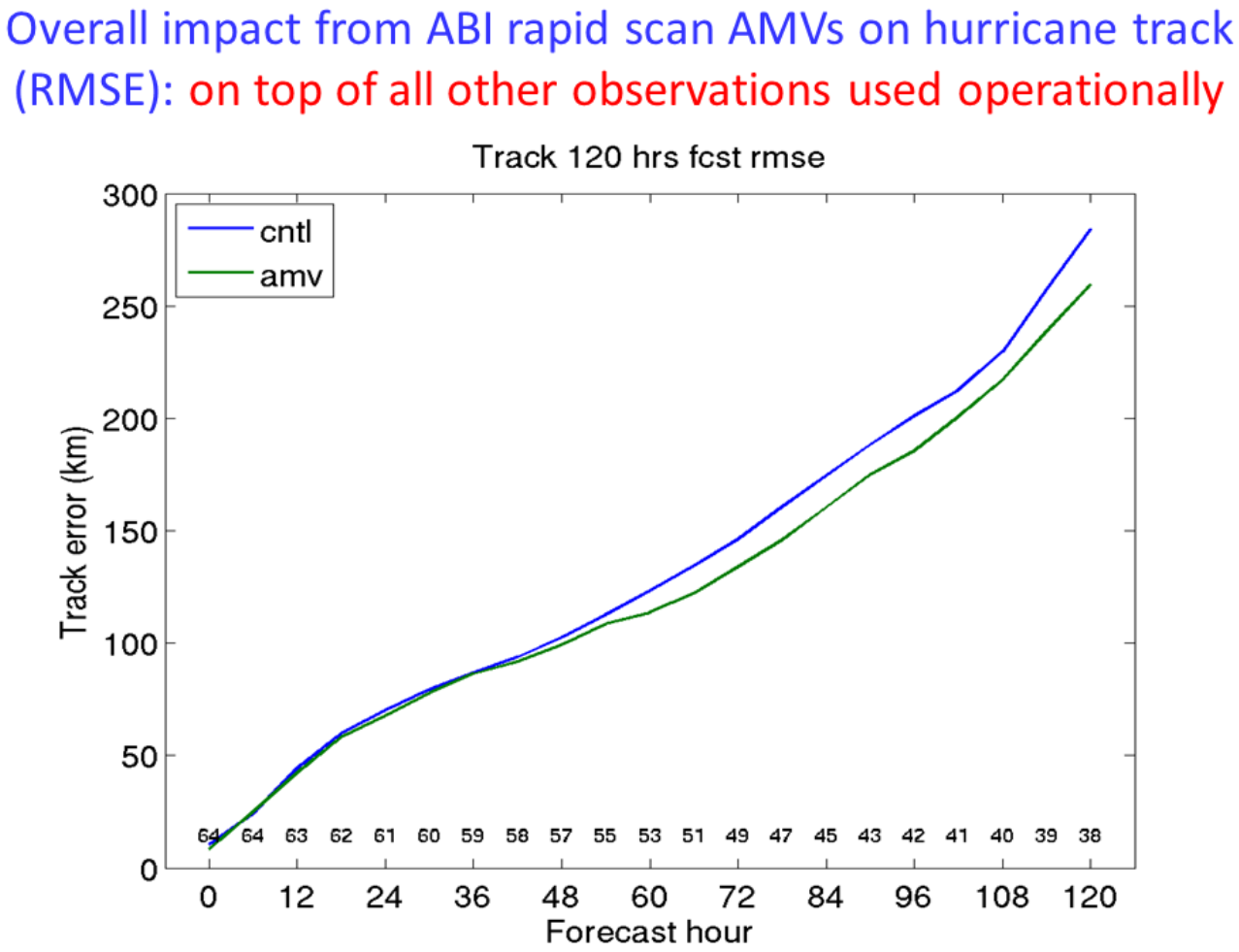

Figure 2. Track forecast RMSE from the control and the ABI rapid scan based AMV experiment for three hurricanes in 2017, Harvey, Irma and Maria altogether. Control has the similar setting of operational HWRF, AMV experiment has the same setting as control plus assimilating ABI rapid scan based AMVs in the TC inner core areas.