GOESR3 Periodic Reporting

Reporting Period: 01 July – 31 December 2018

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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; 2007) onboard NOAA's next generation of geostationary weather satellites (GOES-R series), beginning with GOES-16 launched on 19 November 2016, will routinely provide high temporal (every 5 minutes) and spatial (2 km) resolution 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, exploring and optimizing the effective assimilation of these data into HWRF for improving TC moisture, wind, track, and intensity forecasts.

FY17 Milestones

(a) Implement HWRF/hybrid GSI on S4 for hurricane forecast experiments;
(b) Implement forward operators for LPWs into hybrid GSI on S4;
(c) Process GOES-16 ABI LPWs for selected TC cases in 2017 and ingest them into BUFR for assimilation experiments;
(d) Begin initial experiments on assimilating ABI radiances versus assimilating LPWs for improving the utilization of moisture information;
(e) Derive AMV datasets at hourly intervals from GOES-16 during selected TCs in the 2017 season;
(f) Begin initial experiments on assimilating these enhanced AMVs into HWRF.

Accomplishments & Plans

Accomplishments (01 July – 31 December 2017)

(1) The latest version of HWRF/hybrid GSI systems have been implemented and tested on S4 for hurricane forecast experiments;
(2) The forward operators for layered precipitable water (LPWs) have been refined and implemented into hybrid GSI on S4;
(3) The GOES-16 ABI LPWs and AMVs for recent hurricane cases (Harvey, Irma and Maria) in 2017 have been processed and ingested into BUFR for assimilation experiments;
(4) Initial experiments on assimilating GOES-16 ABI LPW and AMVs started with SDAT, and positive impact found.

Below is detailed report on our progress.

1. The latest version of HWRF/hybrid GSI systems have been implemented and tested on S4 for hurricane forecast experiments

CIMSS scientists have conducted experiments using near real-time (NRT) research testbed called "Satellite Data Assimilation for Tropical storm forecasts (SDAT) (http://cimss.ssec.wisc.edu/sdat) and showed tropical cyclone (TC) forecast improvements from better assimilation of satellite data, especially in cloudy skies, however, tests in SDAT only show relative improvements, and it is hard to judge the true value of data and assimilation schemes in the operational numerical weather prediction (NWP) models for TC forecasts. Therefore, testing, using the latest version of HWRF, needs to be performed in a modeling system as close to operations as possible. In order to use the latest version of HWRF for GOES-16 data assimilation, CIMSS scientists have tested the latest version of the operational HWRF model at S4. The community HWRF_v3.9a from DTC was installed on S4 in November 2017 and tested with Hurricane Irma (2017) (including DA with hybrid GSI). Figure 1 shows the forecasts from control (HWRF/S4) and NOAA operational HWRF (HWRF/Op), for track and categories. The forecasts between HWRF/S4 and HWRF/Op are similar. The RMSE (root mean square error) statistics for track and maximum wind speed forecasts are also reasonably close (not shown) between HWRF/S4 and HWRF/Op. Therefore, HWRF/S4 can be used for DA research.

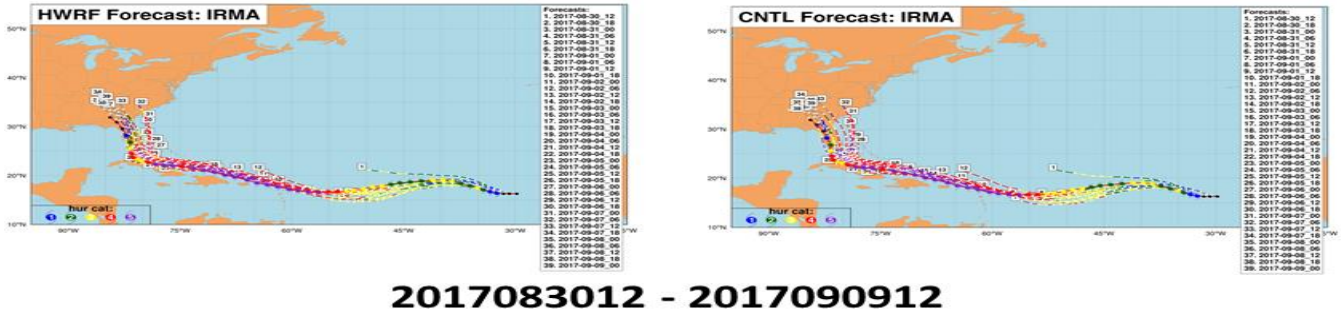

Fig 1. Forecasts from HWRF/Op (left) and HWRF/S4 (right) for hurricane Irma (2017).

2. The forward operator has been implemented into hybrid GSI on S4 for LPW assimilation studies

The layered precipitable water (LPW) forward operator has been implemented into the latest version of GSI. Codes are developed and added into GSI by taking into account the different methodologies between LPW generation and assimilation (e.g., the three LPWs are produced in sigma levels: 0.3 – 0.7, 0.7 – 0.9 and 0.9 – 1.0 in GOES-R series product generation, while the GSI assimilation system is based on the vertical pressure levels). The hybrid GSI with LPW operator included inside is ready for GOES-16 LPW and AMV assimilation.

3**. The GOES-16 ABI LPWs and AMVs for recent hurricane cases (Harvey, Irma and Maria) in 2017 have been processed and ingested into BUFR for assimilation experiments**

The LPW and AMV data from GOES-16 ABI have been processed and generated with quality control (QC) for recent hurricanes (Harvey, Irma and Maria). LPWs are from clear skies and AMVs are from mesoscale sectors, the available AMV data are: Ch 02 VIS, Ch 07 SWIR, Ch 08 WVCT, and Ch 14 IR. Figure 2 shows the AMV from ABI IR Channel 14 with QI>0.96 and EE<4.5. The red color indicates AMVs above 500 hPa and green color for AMVs below 500 hPa.

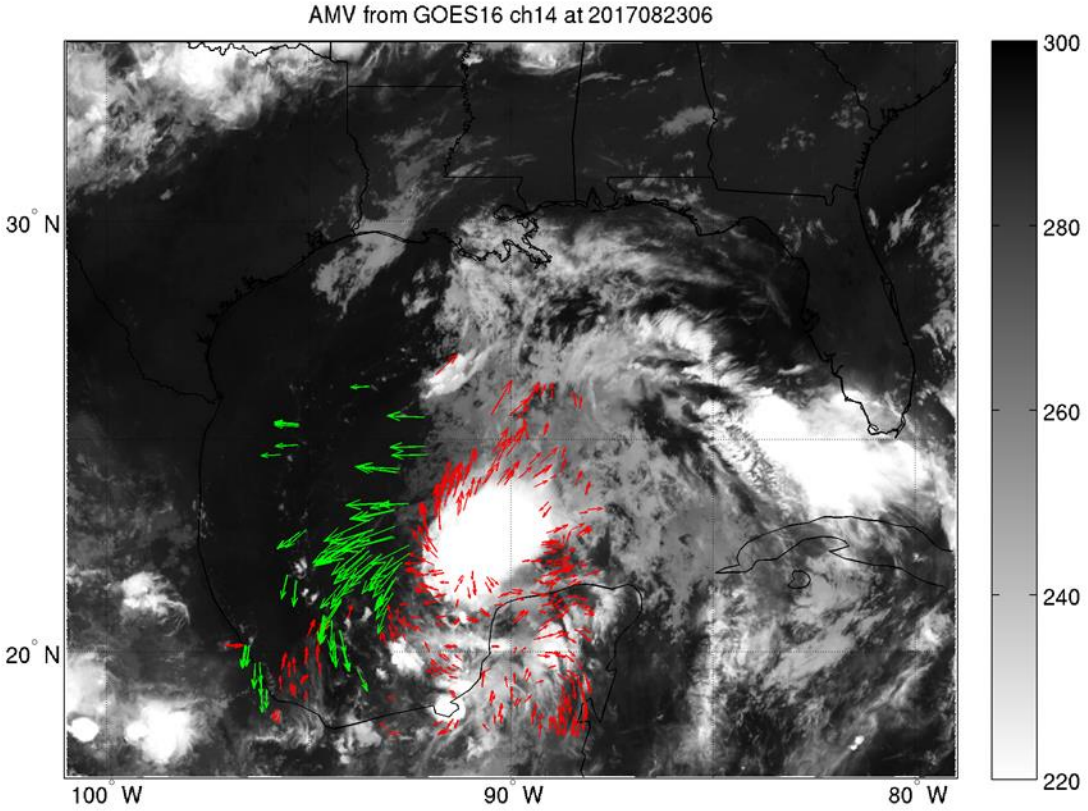

Figure 2. GOES-16 ABI AMVs at 06UTC 23 August 2017 (Hurricane Harvey) from IR channel 14 (11.2 µm).

Both AMVs and LPWs have been converted to BUFR format for GSI to assimilate.

4**. Initial experiments on assimilating GOES-16 ABI LPWs and AMVs started with SDAT, and positive impact found on Harvey forecasts**

GOES-16 ABI AMV and LPW assimilation experiments have been conducted for recent hurricanes (Harvey, Irma and Maria). SDAT (WRF-ARW v3.6.1 forecast system with 12 km resolution together with GSI assimilation system) is used assimilation experiments and impact studies. The control run contains the assimilation of conventional data from GTS (Global Telecommunication System) and satellite data from AMSU-A, IASI, ATMS and CrIS. The other three experiments include:
Control+CCRS, adding CrIS cloud-cleared radiances (CCRs) to control;
Control+LPW, adding three LPWs to control;
Control+AMVs, adding AMVs to control.

Data are assimilated every 6 hours followed by 72 hour forecasts. Figure 3 shows the assimilation and forecast experiments schemes. The experiments are designed to address whether the new satellite information provides value-added impact on TC forecasts.

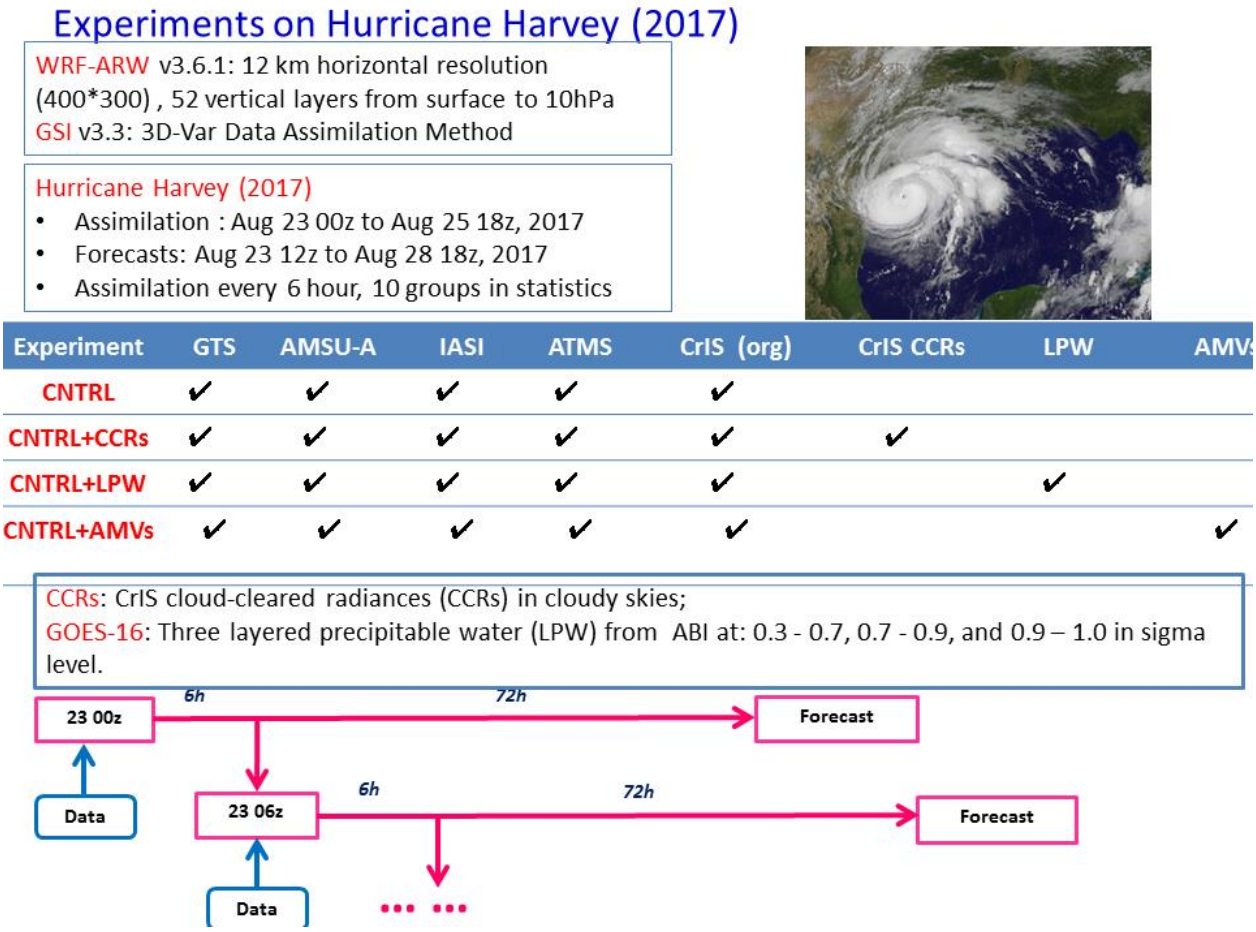

Figure 3. Data assimilation and forecast experiment schemes for hurricane Harvey (2017).

The hurricane track (HT) and central sea level pressure (SLP) Root Mean Square Error (RMSE) have been computed against the best track estimates from National Hurricane Center (NHC). Figure 4 shows the track and SPL forecast RMSE from control run and the other three experiments. It can be seen that, the new information from GOES-16 (either LPW or AMV) improves the control run, especially for later forecast hours (after 42 hours) for this Harvey case. Figure 5 shows the mean HT and SLP RMSE from control run and the three experiments. The atmospheric temperature, moisture, wind (U, V) profile forecasts are also improved with new GOES-16 ABI information assimilated into SDAT when compared with RAOBs (not shown).

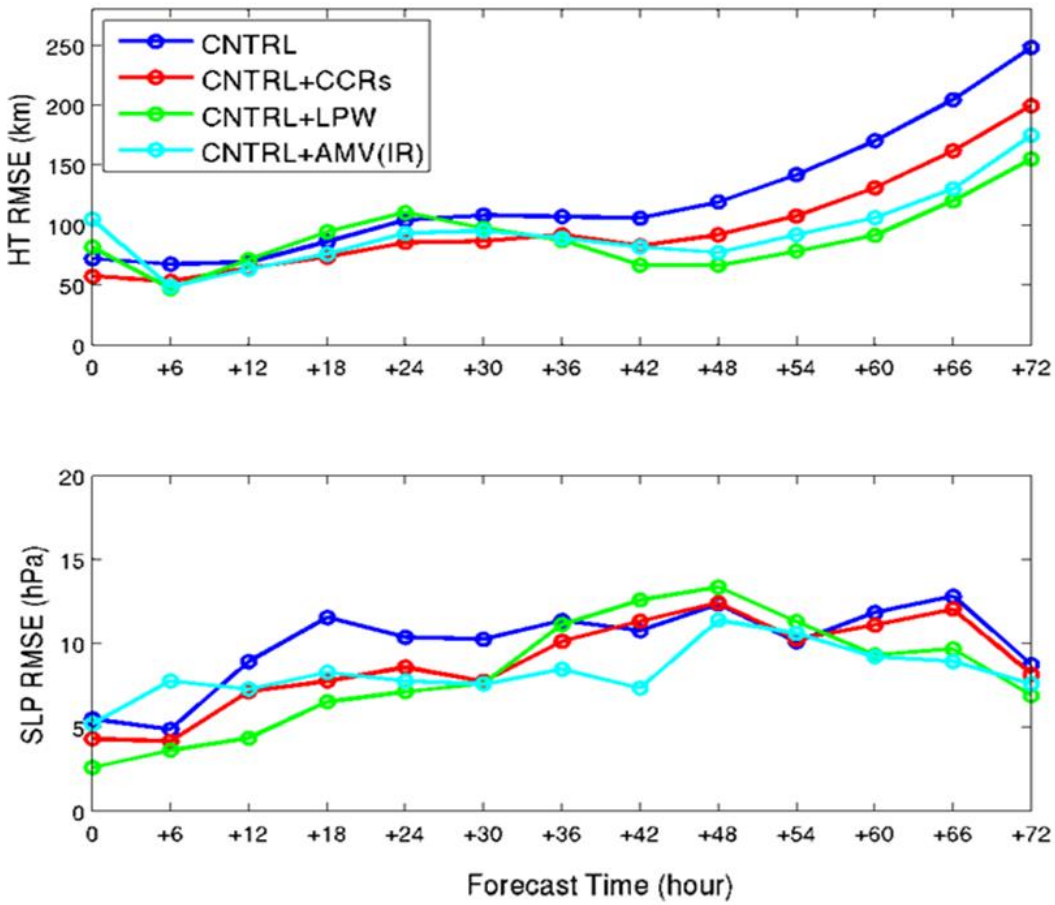

Figure 4. The track (upper) and SPL (lower) forecast RMSE from control run (blue) and the other three experiments, for Hurricane Harvey (2017) forecasts.

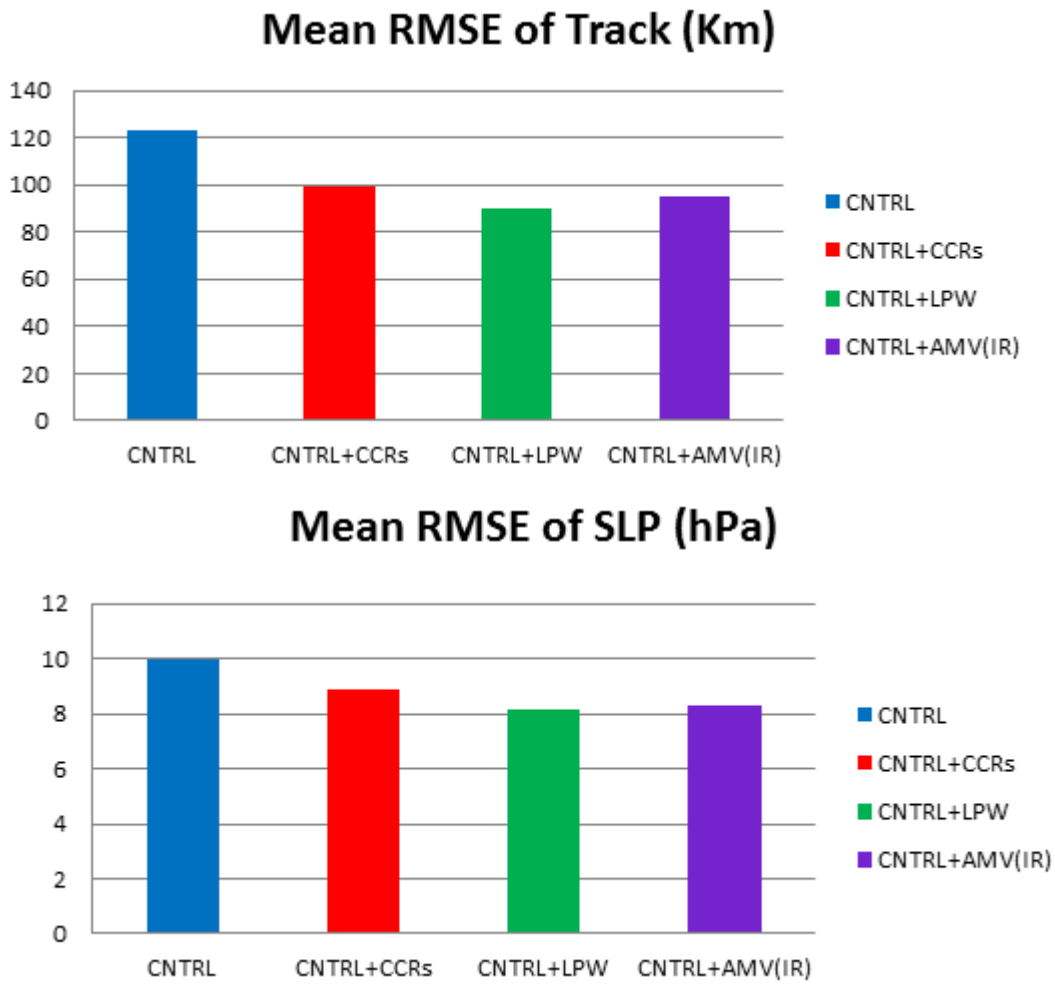

Figure 5. The mean HT (km) (upper) and SLP (hPa) (lower) RMSE from control run and the three assimilation experiments for Hurricane Harvey (2017).

The focus in the 6 months will be on HWRF/GSI assimilation of GOES-16 ABI new information. More experiments are also ongoing for Hurricane Irma (2017) and Maria (2017). In addition, combination of new information altogether for impact studies, as well as conducting comparison between ABI radiance assimilation and LPW assimilation, etc., are also ongoing efforts.

Publications and conference presentations (01 July – 31 December 2017)

Peer-reviewed journal publications:

Wang, Pei, Jun Li, Timothy J. Schmit, Jiazhen Lu, Bing Lu, Yong-Keun Lee, Agnes H. N. Lim, Jinlong Li, Zhiquan Liu, Chian-Yi Liu, and Wei Han, 2018: Impact of Moisture information from Advanced Himawari Imager Measurements on Heavy Precipitation Forecasts over land in a regional NWP model, Journal of Geophysical Research – Atmospheres (submitted).

Lee, Yong-Keun, Jun Li, Zhenglong Li, and Tim Schmit, 2017: Atmospheric temporal variations in the pre-landfall environment of Typhoon Nangka (2015) observed by the Himawari-8 AHI, Asia-Pacific Journal of Atmospheric Sciences. DOI:10.1007/s13143-017-0046-z.

Conference presentations:

Lee et al., 2018: Validation of GOES-16 atmospheric precipitable water and instability indices products for operational applications, 98th American Meteorological Society Annual Meeting, 07 – 12 January 2018, Austin, TX.

Li et al., 2018: All-sky layered precipitable water products from ABI/AHI and their applications in nowcasting and forecasting the severe storms, 98th American Meteorological Society Annual Meeting, 07 – 12 January 2018, Austin, TX.

Li, J., et al., 2018: Value-added impact from geostationary hyperspectral infrared sounding on nowcasting and forecasting high-impact weather events, 98th American Meteorological Society Annual Meeting, 07 – 12 January 2018, Austin, TX.

Additional Information

1. Interaction with operational partners – telecom discussion with HWRF team on 02 February 2018.
2. Funding concerns – no.
3. Outside project publicity – CIMSS SDAT webpage, GOES-16 LAP validation tool webpage.
4. Journal articles – one article published, one is under review, see the above for the list.

Plans for the next Reporting Period

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- HWRF assimilation of LPW and AMV for initial results;
- Continue SDAT assimilation of GOES-16 AMVs and LPWs; conduct HWRF/S4, HWRF/Op and SDAT comparisons.

Key Graphics

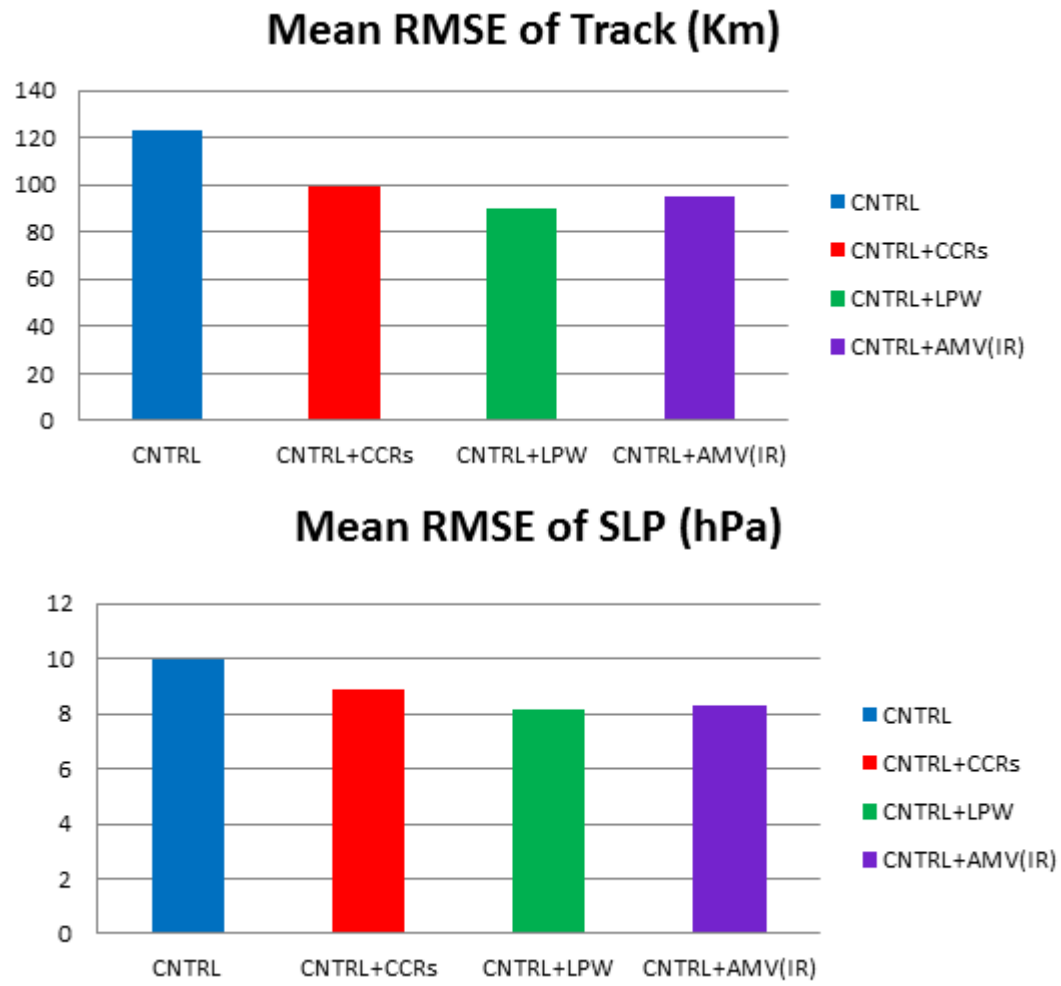

Figure 5. The mean HT (km) (upper) and SLP (hPa) (lower) RMSE from control run and the three assimilation experiments from SDAT for Hurricane Harvey (2017).