Assimilation of the GOES-16/17 Atmospheric Motion Vectors in the Hurricane Weather Forecasting (HWRF) model

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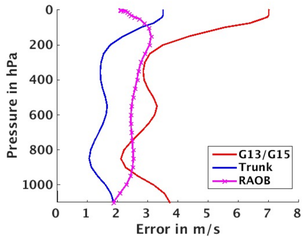
Objective: Evaluate GOES-16/17 AMVs for use in the HWRF to support a quick transition from the heritage AMVs of GOES-13/15 to the nested tracking GOES-16/17 AMVs.

1. Background

- Five different types of AMVs, Infrared (IR), cloud-top water vapor (CTWV), clear-air water vapor (CAWV), shortwave IR (SWIR) and visible (VIS), are produced from the Advanced Baseline Imager (ABI) onboard on the Geostationary Operational Environmental Satellite GOES-East and GOES-West.
- The AMVs derived using the GOES-R nested tracking algorithm (Bresky et al., 2012).
- Data frequencies are hourly (full-disk), 15-minute (CONUS) and 5-minute (mesoscale).
- The 2020 operational version of HWRF was used.
- HWRF has three domains: the parent domain at 13.5km, the intermediate domain at 4.5km and the innermost domain at 1.5-km. Observations were assimilated in the intermediate and innermost domain.
- HWRF Data Assimilation System (HDAS) uses a hybrid three-dimensional (3D) ensemble-variational data assimilation (EnVar) system implementation of the Gridpoint Statistical Interpolation (GSI).
- In the presence of Tail Doppler Radar (TDR) data and for priority storms,
  - Uses a 40-member HWRF ensemble to obtain information on the flow dependent background error covariance. Otherwise, the GFS ensemble is used.
  - Fully-cycled HWRF ensemble hybrid data assimilation.
- A merging procedure is applied after data assimilation to combine the HDAS analyses to the GDAS analysis, valid at the same time to produce the final analysis.
- HWRF has been configured to assimilates hourly IR, CTWV and CAWV GOES-16 and 17 AMVs operationally .

2. AMV error profile review



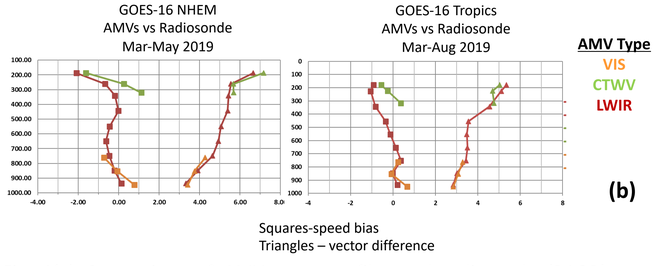


Fig. 1(a) Comparison of AMV error profiles and radiosonde (RAOB) error profiles used in HWRF. Trunk indicates operational HWRF. (b) AMVs verses radiosondes comparison derived by NESDIS.

- Current AMV profile too small compared to radiosondes and root-mean-square-error (rmse) derived by NESDIS.
- Revert to using the error profile use by GOES-13/15 to be more inline with radiosondes and NESDIS rmse

Acknowledgements
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References
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Holmlund, K, 1998: **The Utilization of Statistical Properties of Satellite-Derived Atmospheric Motion Vectors to Derive Quality Indicators**. Wea. Forecasting, 13, 1093-1104
Mozer, K., M. Seybold, D. Lindsey, R. Cox and T, Johnson, 2019: **GOES-17 Saturation Prediction Reference Tools**. GOES-17 Saturation Prediction Reference Tools, https://www.goes-r.gov/downloads/users/abiPerformance/GOES-17ABISaturationPredictionReferenceTools.pdf

3. Quality Control (QC) Procedure

Old QCs	New QCs
Gross check ratio of 1.3 for IR, CTWV and 2.5 for CAWV, SWIR and VIS	Gross check ratio of 3.5 for IR, CTWV, CAWV, SWIR and VIS
Q1>80%	No QI check
0.04<PCT1<0.5 for IR, CTWV, VIS and SWIR AMVs.	PCT1<0.5 for IR, CTWV. VIS and SIWR AMVs
Blacklisting of IR AMVs changed 400 - 800 hPa.	Blacklisting of IR AMVs changed 400 -600 hPa.

Table 1 Changes in the QCs

- Relax gross check to allow observations with higher windspeeds and larger vector difference for tropical cyclones.
- Density plots of speed and vector departures verses QI or PCT1 shows rejected observations have similar characteristics as accepted ones.
  - QI (Holmlund 1998) - calculated by estimating direction consistency, speed consistency, vector consistency and spatial consistency. Values are low if lack of "buddy" AMV.
  - PCT1 - GOES-R nested tracking parameter, a measure of the standard deviation of the tracked cluster / distance the cluster travelled.
- GOES-16 retrieved more AMVs between 600-800 hPa.
- 20-40% increase in AMVs assimilated (Fig 2).

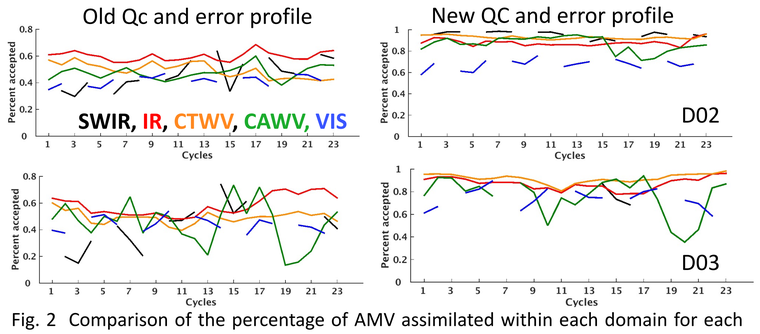
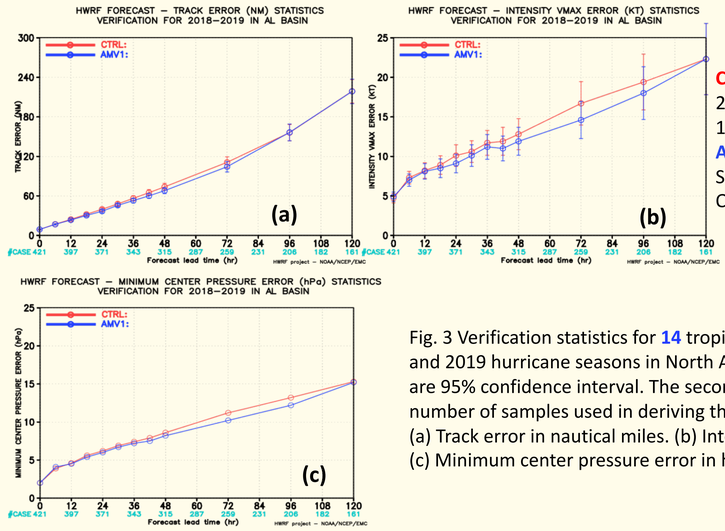


Fig. 2 Comparison of the percentage of AMV assimilated within each domain for each AMV wind type between the old and new configurations.

- Assimilation statistics show
  - improved normalized wind speed bias.
  - slight increase in standard deviation of normalized vector difference. This is expected due to inclusion of more AMVs and with larger vector differences.
  - histograms of innovations and analysis error are Gaussian and have very small bias.

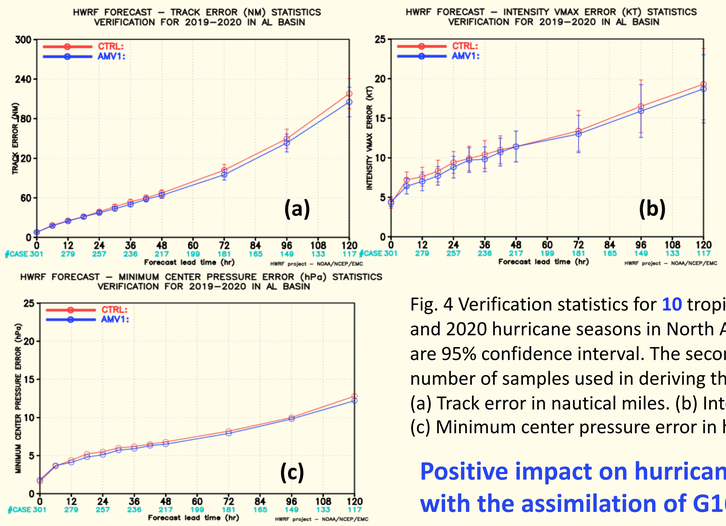
4. Forecast Impact assessment for G16 hourly AMVs



CTRL - operational version of 2020 HWRF with hourly GOES-16 IR, CTWV and CAWV AMVs .
AMV1 – CTRL + **hourly** GOES-16 SWIR and VIS AMVs and new QCs and error profiles.

Fig. 3 Verification statistics for **14** tropical cyclones from 2018 and 2019 hurricane seasons in North Atlantic basin. Error bars are 95% confidence interval. The secondary x-axis shows the number of samples used in deriving these statistics.
(a) Track error in nautical miles. (b) Intensity error in knots.
(c) Minimum center pressure error in hPa.

5. Forecast Impact assessment for G16 hourly and 15-min AMVs



CTRL - operational version of 2020 HWRF with hourly GOES-16 IR, CTWV and CAWV AMVs .
AMV1 – CTRL + all GOES-16 **hourly and 15 min** wind AMVs with new QCs and error profiles.

Fig. 4 Verification statistics for **10** tropical cyclones from 2019 and 2020 hurricane seasons in North Atlantic basin. Error bars are 95% confidence interval. The secondary x-axis shows the number of samples used in deriving these statistics.
(a) Track error in nautical miles. (b) Intensity error in knots.
(c) Minimum center pressure error in hPa.

Positive impact on hurricane forecast metrics with the assimilation of G16 AMVs.

6. Review of G17 hourly and 15-min AMVs

- The instrument cooling issue for GOES-17 has impacted the retrieval of AMVs.
- The cooling issue occurs at certain times of the year and affects the infrared channels (Mozer et al, 2019).
- The data provider retrieves AMVs whenever the tracking algorithm is capable. The QCs applied to the AMVs are independent of status of the instrument.
- The GOES-17 AMVs went into operational production in Nov 2019.
- The AMVs are evaluated within HWRF using 2020 Eastern Pacific (EP) storms.
- Evaluation of innovation and analysis error of normalized wind speed bias and standard deviation of normalized vector difference binned at 50hPa (Fig.5) and histograms show the AMVs assimilated do not degrade the analyses.
- Forecast verification shows track error improvement but degradation in the intensity forecasts.

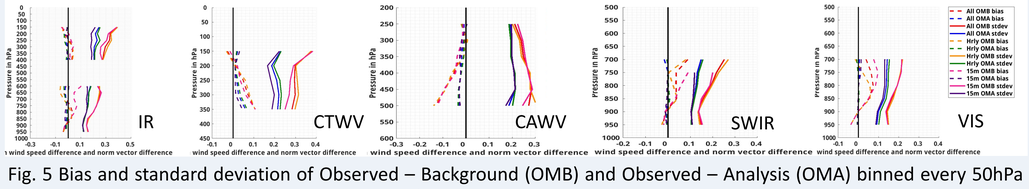


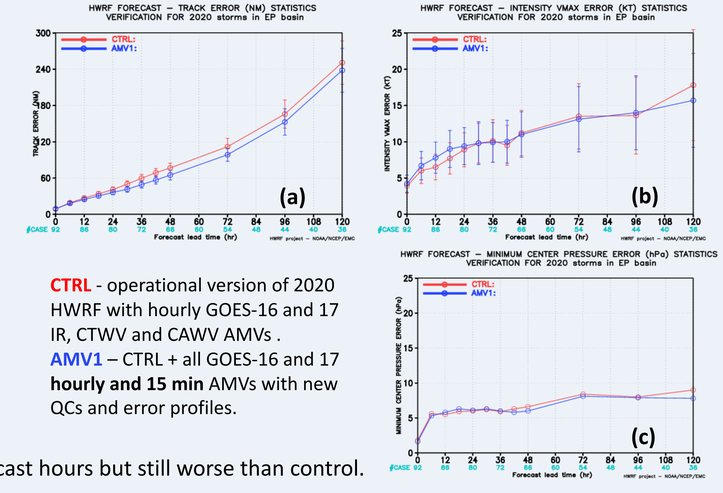
Fig. 5 Bias and standard deviation of Observed – Background (OMB) and Observed – Analysis (OMA) binned every 50hPa of all G17 AMV wind types for Hurricane Douglas. The statistics are reviewed for hourly AMVs, 15-minute AMVs and hourly+15-minute AMVs.

Investigations on poor intensity forecast conducted using Hurricane Marie :

1. Removal of 15-minute AMVs – Improved intensity error and minimum center pressure for the first 30 forecast hours but still worse than control.
2. Tighten the wind speeds of IR, CTWV and CAWV AMVs – Neutral on intensity error.

The above two changes only affect intensity error and minimum center pressure forecast. Other forecast metrics are neutral to these changes.

Fig. 6 Verification statistics for **4** tropical cyclones from 2020 hurricane seasons in EP basin. Error bars are 95% confidence interval. The secondary x-axis shows the number of samples used in deriving these statistics.
(a) Track error in nautical miles. (b) Intensity error in knots.
(c) Minimum center pressure error in hPa.



CTRL - operational version of 2020 HWRF with hourly GOES-16 and 17 IR, CTWV and CAWV AMVs .
AMV1 – CTRL + all GOES-16 and 17 **hourly and 15 min** AMVs with new QCs and error profiles.