GOESR3 Periodic Reporting

Reporting Period: January 2018 – June 2018 (2nd half of FY17 funding cycle)

Team Lead: Dr. Ming Xue, CAPS, U. Oklahoma
Team Members: Dr. Rong Kong, CAPS, U. Oklahoma
Dr. Alex Fierro, NSSL
Dr. Edward Mansell, NSSL
Dr. Donald MacGorman, NSSL
Dr. Shun Liu, EMC/NCEP.

Project Title: Assimilation of High-Frequency GOES-R Geostationary Lightning Mapper (GLM) Flash Extent Density Data in GSI-Based EnKF and Hybrid for Improving Convective Scale Weather Predictions.

Project Number: 473

Executive Summary

This lighting data assimilation (DA) project is a collaboration project between three cooperative institutes: CAPS, NSSL, and EMC/NCEP. Through this project, direct assimilation capabilities for GOES-R GLM data within the operational GSI framework will be developed, implemented, and tested by using advanced ensemble Kalman filter (EnKF) and hybrid ensemble-variational (EnVar) methods. The capabilities developed will be first tested using selected, representative cases, then evaluated extensively in real time during the Hazard Weather Testbed (HWT) Spring Experiment. The impacts of assimilating additional GOES-R GLM data with and without operational radar data will also be addressed by comparing against parallel data assimilation and forecast members of the Storm-Scale Ensemble Forecasts to be run by CAPS during the HWT Spring Experiment. In addition, the data assimilation system will also be coupled with multi-moment microphysics schemes to evaluate their impact on the effectiveness of GOES-R GLM data assimilation. The major goal of this project is to accelerate the use of GOES-R GLM data in operational numerical weather prediction (NWP) models at NCEP, and thereby help meet the Weather Ready Nation objectives and realize the Warn-on-Forecast goals. Another goal is to develop and evaluate advanced DA techniques, such as EnKF and hybrid ensemble-variational (EnVar), utilizing the GLM Flesh Extend Density (FED) data, which could help to enhance the numerical weather prediction capability.

During this reporting period, we developed the adjoint code of GLM FED observation operator and implemented it within the GSI variational framework. The lighting DA capability was incorporated into the GSI-3DVar and hybrid En3DVar. The GLM data are preprocessed to produce accurate estimates of flash extent densities (FED). In the last report, the FED data are calculated based on the number of flashes that occur within the 8-km grid pixel, for which the locations of the flashes are represented by the longitudes and latitudes of the flashes centroid (mean constituent event latitude weighted by their energies). In this case, each flash is assumed to be contained within one pixel, which significantly

underestimates the actual FED. Considering the parent-child relationships among specific flashes, groups, and events, we tracked the event id for different groups and the group ids for different flashes, account for the possibility of flashes passing through multiple pixels. The longitudes and latitudes of the events instead of the flash centroids are directly used, so that the intensity and spatial distribution of the FED calculation are more representative of the actual rates. Further, the FED observations are converted to the BUFR format, which is the format used by GSI.

Two high-impact cases that happened on October 22, 2017 and July 13, 2018, respectively, were used to test the performance of FED DA using GSI-3DVar and EnKF. The grid size used is 300 × 300 with a 3-km horizontal grid spacing. The original GLM data are accumulated based on an assumed 8-km grid box and averaged within a 5-minute interval to produce the FED rate data (units: $min^{-1}pixel^{-1}$) for assimilation. The initial perturbations for the EnKF are derived from the operational Short-Range Ensemble Forecast (SREF) system. Deviations of 20 SREF ensemble analyses or forecasts from the control run (NAM analysis or forecast) are calculated, and their negative version is used to double the number of ensemble perturbations to 40 as positive and negative pairs. The perturbations are further inflated by a factor of 1.5. Additional smaller-scale smoothed Gaussian random perturbations are added to horizontal velocity, potential temperature and humidity fields to further increase the spread of the initial ensembles at small scales. The initial ensembles are then advanced two or three hours using the WRF ARW model to spin up the model states. Different surface layer and PBL schemes are used. The Thompson microphysics scheme is used in all members but with different parameter intercept parameter and graupel density values. FED observations are assimilated every 15-min for 1 hour using GSI EnKF or 3DVar. In EnKF, adaptive inflation is used to help maintain ensemble spread.

Preliminary results for the October 2017 case are shown in Figure 1. Relative to observations, the intensity of the simulated FED from forecast of the control run (ensemble mean forecast without assimilating FED observations) is much weaker. The forecast squall line is behind (westward of) the observed location. After the FED DA, both EnKF and 3DVar are able to significantly alleviate and correct this location error of the squall line. The locations and rates of the simulated FED centers for EnKF and 3DVar are in better agreement with the observations in both the analyses and forecasts relative to the control run. There are, however, some spurious FED forecasts in the 3DVar cycles (especially in the last two cycles), which are well suppressed in EnKF cycles due to the use of the ensemble covariance.

Results for the 2018 case are shown in Figure 2. After EnKF DA, the intensity and locations of high FED centers are again much more consistent with observations in both the analyses and forecasts relative to the control run. The analyzed or forecast FED rates from 3DVar are overall larger than for the EnKF DA and agree better with the observations. Similar to the first case, the 3DVar cycles produce notably more spurious FED areas than the EnKF.

Progress toward FY17 Milestones

1. Developed the adjoint of the FED observation operator, and added FED DA capability into GSI-3DVar and GSI-En3DVar.

2. Reprocessed GLM data by tracking the flash and group ids.
3. Converted the FED observations to BUFR format to be consistent with the GSI observation format.
4. Conducted initial experiments assimilating FED using GSI EnKF and 3DVar and obtained encouraging results.

Plans for Next Reporting Period

1. Further tuning of the GSI EnKF and GSI 3DVar FED DA capabilities, and obtained better and more complete results for the two cases, and report and results in a manuscript for publication.
2. Establish, test and evaluate FED DA capability using GSI-En3DVar method, and compare with EnKF and 3DVar.

Additional Information

1. Interaction with operational partners –
2. Conference/workshop participation –
3. Outside project publicity –
4. Journal articles –

Key Graphics

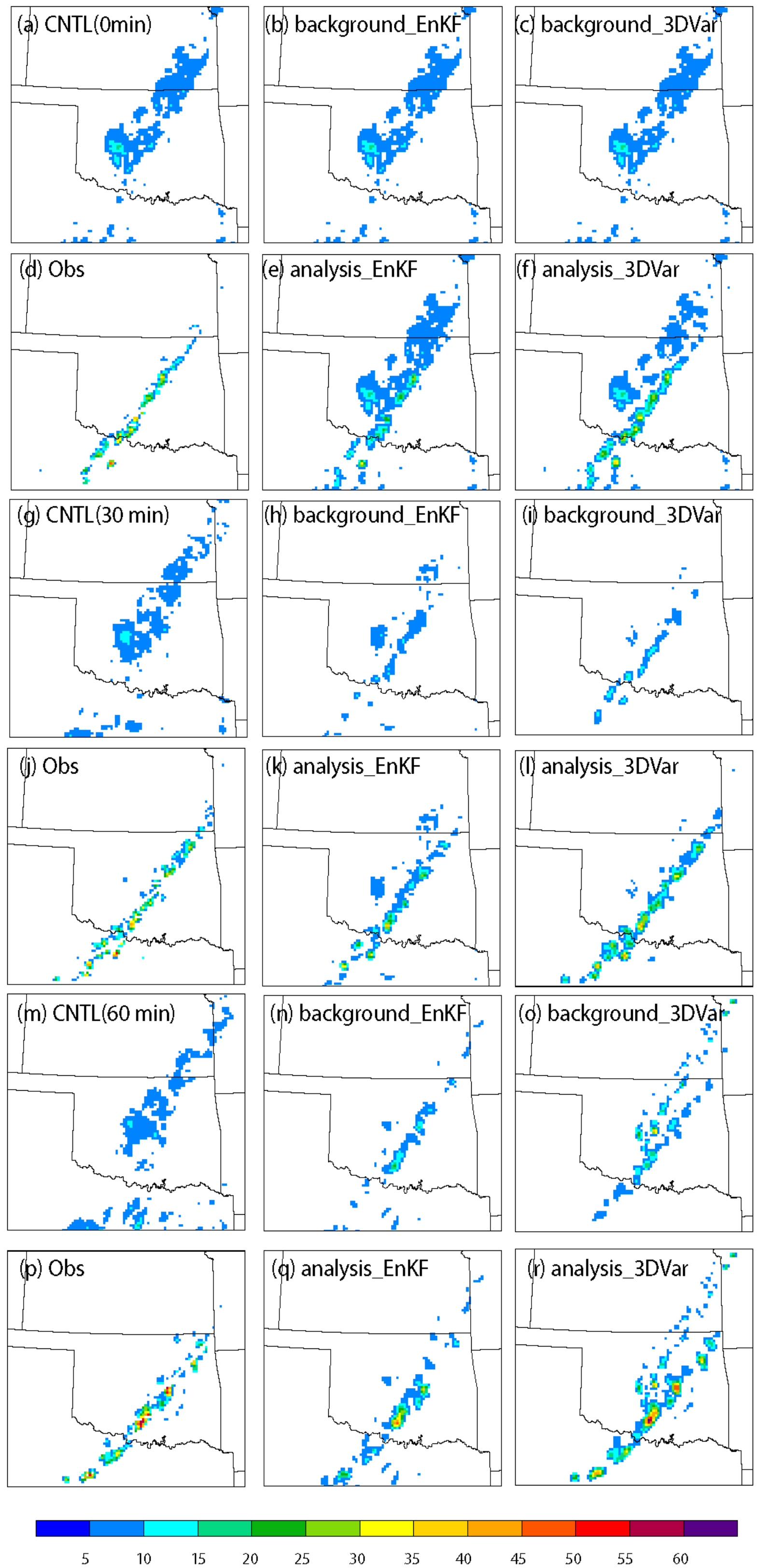

Figure 1. Comparisons of simulated FED for control forecast (ensemble mean without FED DA, a, g, m), observations (d, j, p), background forecasts (b, h, n) and analyses (e, k, q) for EnKF, background forecasts (c, i, o) and analyses (f, l, r) for 3DVar for October 22, 2017 case. Figures are shown for cycles at 0 min (a ~f), 30 min (g~l), and 60 min (m~r) respectively (unit: pixel^{-1}min^{-1}).

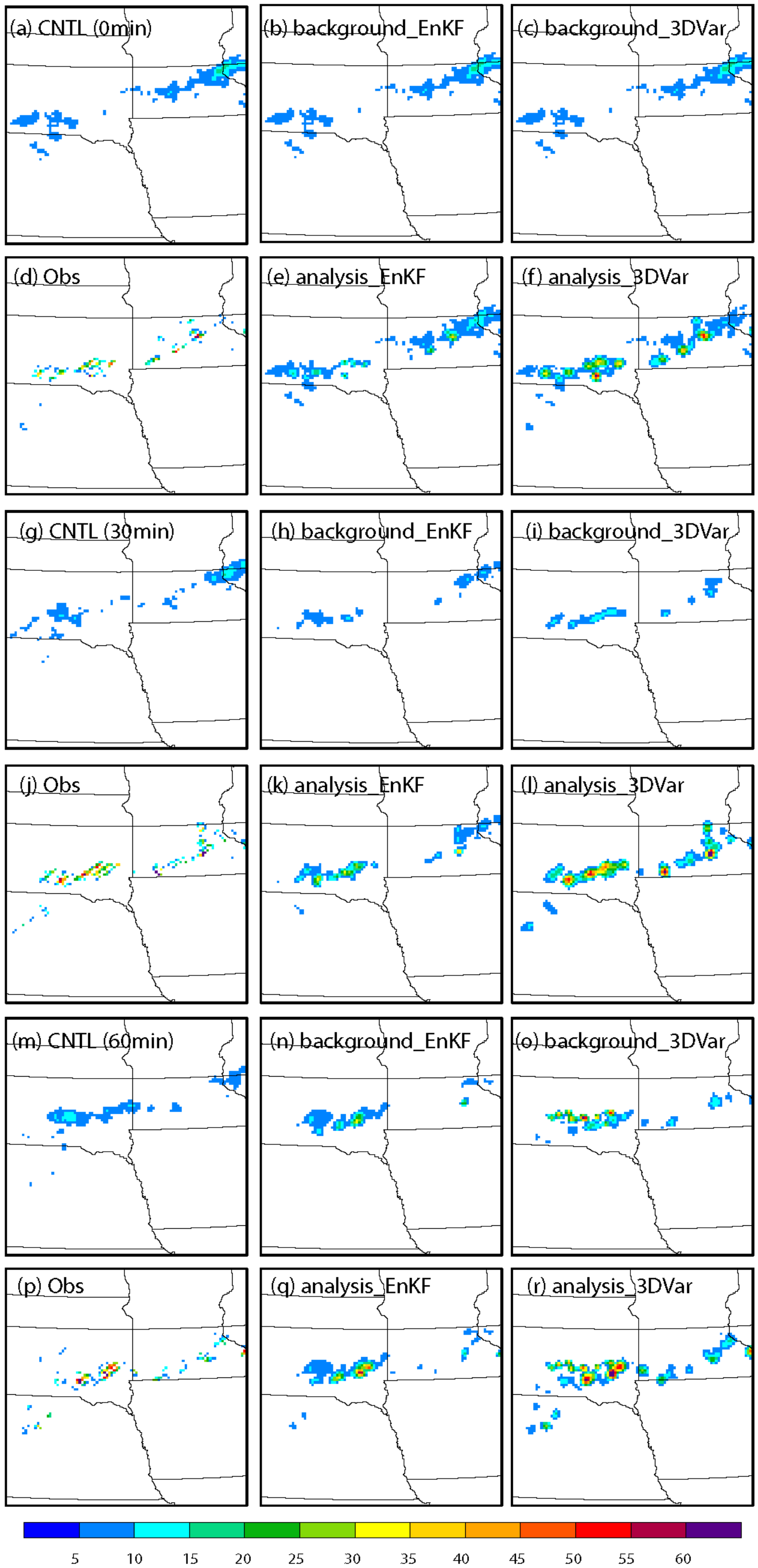

Figure 2. Comparisons of simulated FED for control forecast (ensemble mean without FED DA, a, g, m), observations (d, j, p), background forecasts (b, h, n) and analyses (e, k, q) for EnKF, background forecasts (c, i, o) and analyses (f, l, r) for 3DVar for July 13, 2018 case. Figures are shown for cycles at 0 min (a ~f), 30 min (g~l), and 60 min (m~r) respectively (unit: $pixel^{-1}min^{-1}$).