WRF-EDAS for assimilation and downscaling of the GPM satellite precipitation information

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Knowledge to Go Places

Goals

- Develop an operation-ready system for downscaling and assimilating GPM precipitation-affected satellite radiances for improvement of rainfall estimates at high resolution suitable for hydrological modeling and prediction
- Assimilate conventional and satellite data to produce observation-constrained high-resolution precipitation analyses and short term forecasts, with uncertainties estimated from ensemble forecasts
- The following state-of-the art components are incorporated:
  - ✧ NASA Unified Weather Research and Forecasting (NU-WRF) model with NASA microphysics
  - ✧NCEP Gridpoint Statistical Interpolation (GSI) forward observation operators for conventional and cloud cleared satellite observations,
  - ✧ Goddard SDSU with Goddard all-sky Radiative Transfer Model as forward operator for precipitation sensitive satellite radiances
  - ✧ CSU Maximum Likelihood Ensemble Filter (MLEF) data assimilation method as a framework for addressing non-linear and discontinuous data assimilation problems (Zupanski 2005; Zupanski et al. 2008)
- Explore applications of the precipitation analyses and forecasts for improving hydrological forecasts
- Address the following problems: (1) insufficient rank of forecast error covariance in ensemble data assimilation, and (2) Radiance bias correction for precipitation-affected satellite radiances
- Algorithmic development of NU-WRF-EDAS as an operation-ready system

Hybrid forecast error covariance

✧ Ensemble error covariance is important since it is flow-dependent and describes complex cross-variable correlations.

✧ However, it has insufficient number of degrees of freedom, impacting the ability to assimilate all observations

✧ Include static (time-independent, variational) error covariance

✧ Create hybrid dynamic-static (i.e. ensemble-variational) error covariance

$$P_f^{1/2} = \left(\alpha P_{dyn}^{1/2} \quad (1-\alpha) P_{stat}^{1/2} \right) \qquad P_{stat}^{1/2} = P_{var}^{1/2} Q \qquad \alpha = 0.7$$

Addressing radiance bias correction

✧ Precipitation-sensitive microwave radiances are particularly susceptible to approximations and assumptions on physical properties of precipitation in radiative transfer calculations and model cloud physics schemes

✧ Radiance bias correction using parameter estimation with DPR observations (Zhang et al. 2014)

$$s_{opt} = \arg\min_{s} \left\| DFR_0 - DFR(s) \right\|^2 \qquad DFR = \frac{Z_{ku}}{Z_{ka}}$$

Assimilation of GMI all-sky radiance observations (May 15, 2014)

✧ Precipitation events over SE United States (IPHEx - May 1 – June 15, 2014)

✧ Assimilation of GMI all-sky satellite radiance at 89, 166, and 183+/-7 GHz over land surface

✧ Radiance bias correction using DPR reflectivity observations and parameter estimation

✧ NU-WRF at 9 km / 3km resolution, 31 vertical layers

✧ Control variables include dynamic and cloud variables: perturbation surface pressure, perturbation temperature, perturbation height, winds, specific humidity, cloud water, cloud rain, cloud ice, cloud snow, and graupel.

✧ 32 ensemble members

✧ 3 hour assimilation interval

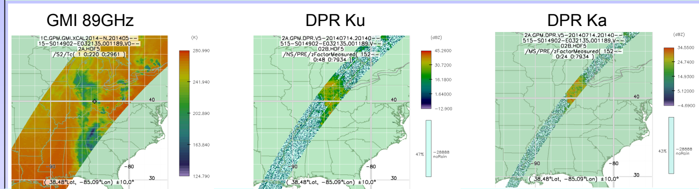

Figure 1. GPM observations on 15 May 2014 at 0000 UTC: all-sky GMI radiances, Ku and Ka DPR reflectivities. The DPR observations are used to estimate bias correction for GMI assimilation.

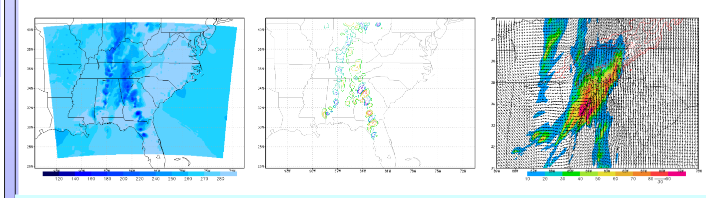

Figure 2. Assimilation of precipitation-affected GMI radiance observations: (a) simulated GMI radiance (left panel) valid 15 May 2014 at 0000 UTC, hydrometeor analysis increments (middle panel) valid 15 May 2014 at 0000 UTC, and verified using the accumulated 6-hour forecast (right panel) valid 15 May 2014 at 0600 UTC.

✧ Positive impact of GMI radiance assimilation on precipitation and near-surface wind.

✧ The accumulated precipitation forecast (0-6 h) is improved by 23% in RMSE verified using ground validation observations.

Additional, more detailed results with GMI all-sky radiance assimilation are presented on the poster #242 by Zhang et al.: **"*Dynamical Downscaling GPM data and MERRA2 global reanalysis using NU-WRF EnDA System: a case study of 2014 Thanksgiving Winter Storm*"**

Preparation for an operation-ready NU-WRF EDAS

✧ ***Speed***: Computational efficiency is required for real-time processing.

✧ ***Flexibility***: Algorithm structure that facilitates assimilation of new observation types, such as those from the GPM Ground Validation (GV) network

✧ ***Reliability***: Computational stability of the system and steady performance.

Algorithmic development of NU-WRF EDAS

✧ Unified data assimilation algorithm as a single program

✧ Separate shell scripts/executables for numerical model (e.g., NU-WRF) and for observations (e.g., NOAA GSI, NASA G-SDSU)

✧ Modular approach: Each component of data assimilation is a separate module: main data assimilation driver, minimization, error covariance localization, …

✧ Numerical model and observation operator included through a modular interfaces. Only the interface module contains variables relevant to the particular model or observation operator; they are converted into the data assimilation variables.

✧ User-friendly design of input namelist parameters

✧ MPI-based system for parallel processing

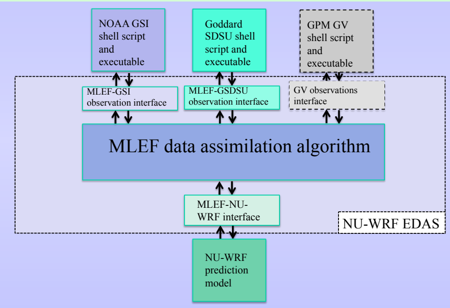

Figure 3. Flow-chart of NU-WRF EDAS. The current NU-WRF EDAS encompasses the MLEF data assimilation algorithm and interfaces with NU-WRF model and observations (GSI, GSDSU) observations. In the future we plan to add GPM Ground Validation (GV) observations.

Conclusions

❑ NU-WRF-EDAS successfully applied to assimilation of GMI all-sky radiances

❑ Other capabilities include assimilation of NOAA operational observations (GSI), radiance bias correction, and hybrid dynamic-static error covariance

❑ NU-WRF EDAS is a modular MPI algorithm

Future Work

✧ Upgrade system to assimilate GPM Ground Validation (GV) observations

✧ Further improve system's efficiency

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