GLM Flash Extent Density Assimilation for Operational NWP

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NOAA GSL
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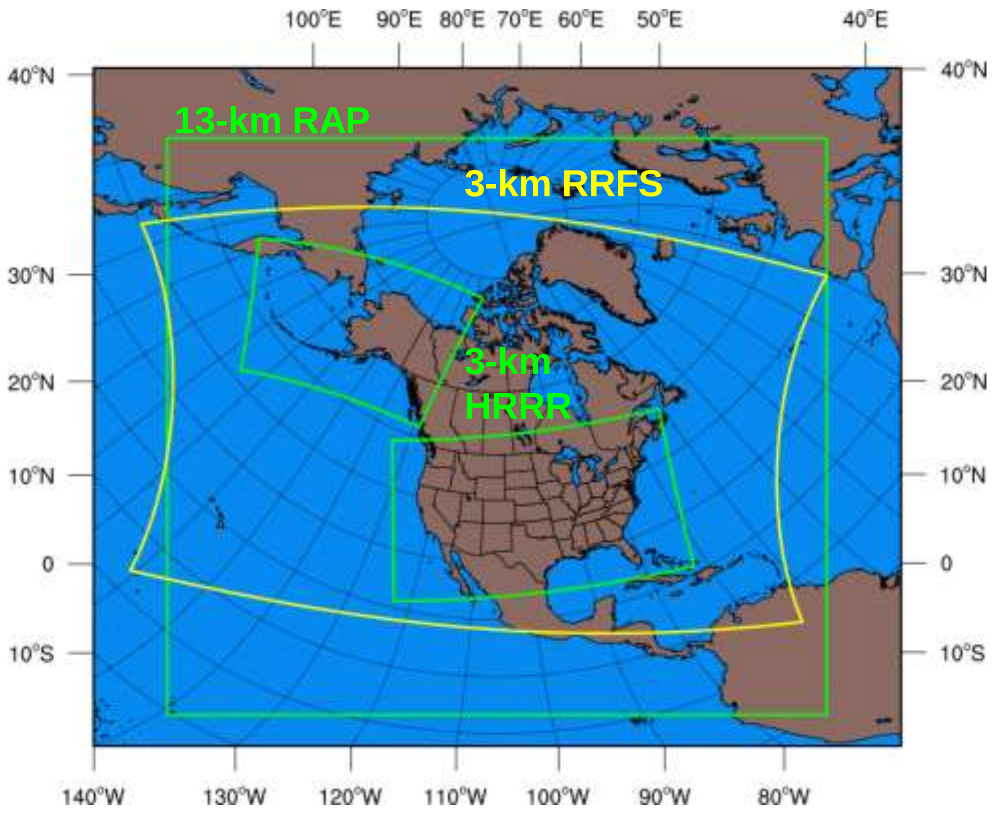
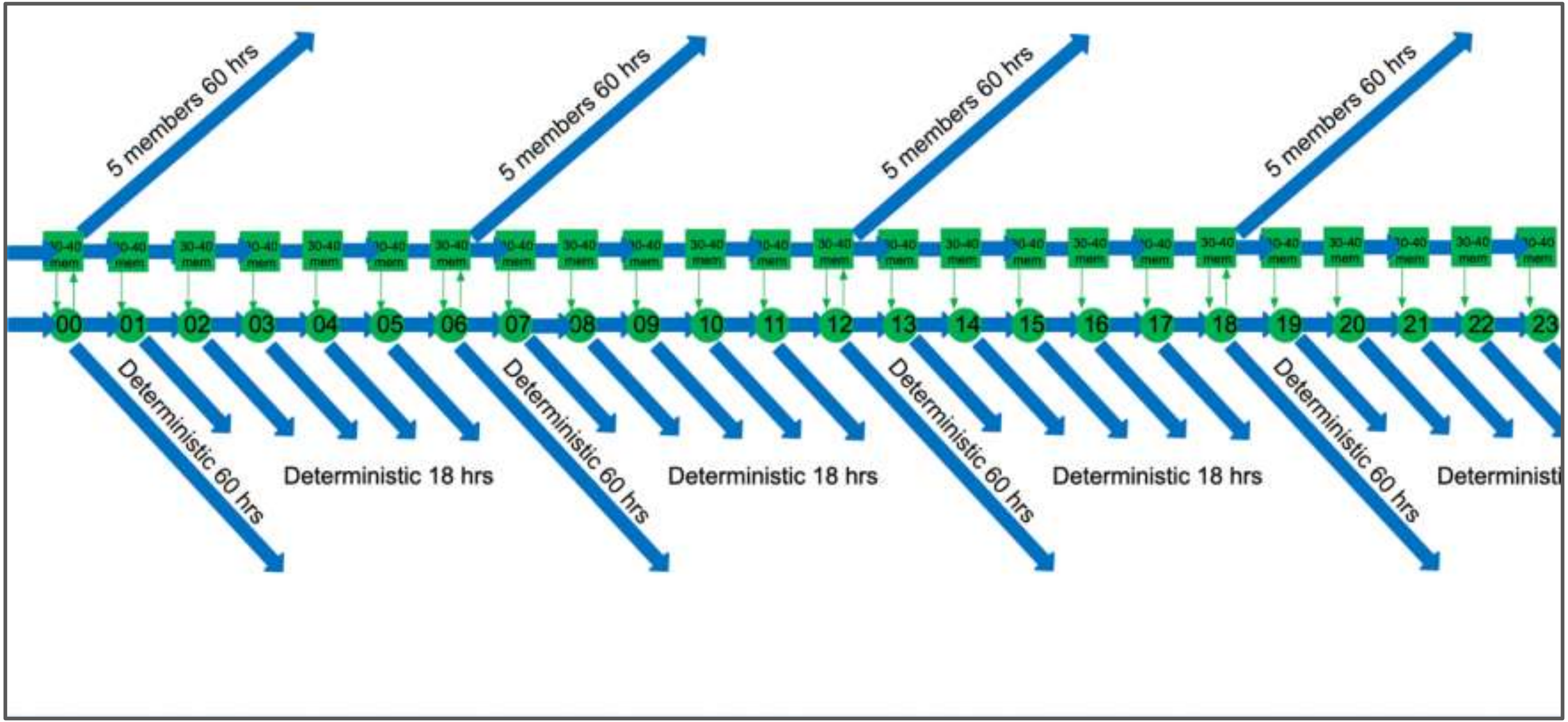
Rapid Refresh Analysis and Forecast Systems



- Hourly updating numerical weather prediction systems
- RAPv5/HRRRv4, operational since Dec. 2020, ingest lightning from ground based detecting networks
- RRFSv1, implementation expected early 2025, has convection-allowing resolution on much larger domain and will benefit from use of satellite observations

RRFS Cycling and Forecast Cadence

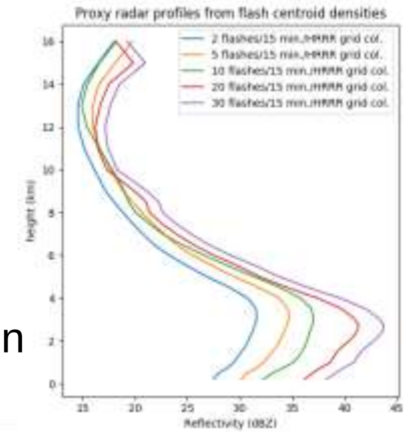


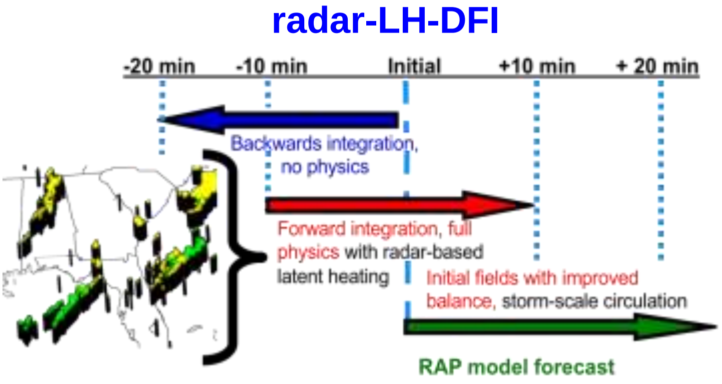
Indirect LTG assimilation in RAP and HRRR

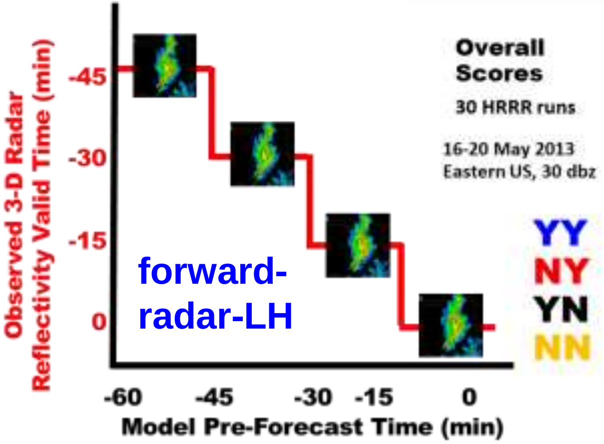
RAP (13 km North America domain) and HRRR (3 km CONUS, Alaska)

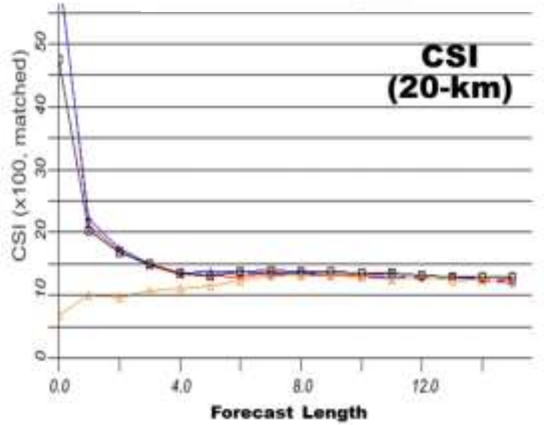
CG flash centroid densities converted to radar reflectivity profiles

Together specify temperature tendency profile applied at model initialization









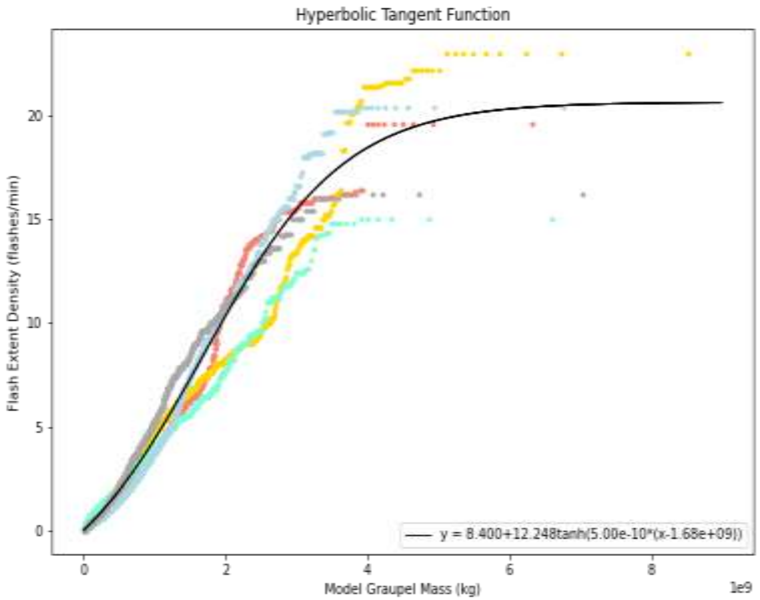
Weygandt et al., 2022: "Radar Reflectivity-based Model Initialization using Specified Latent Heating (Radar-LHI) within a Diabatic Digital Filter or Pre-forecast Integration."

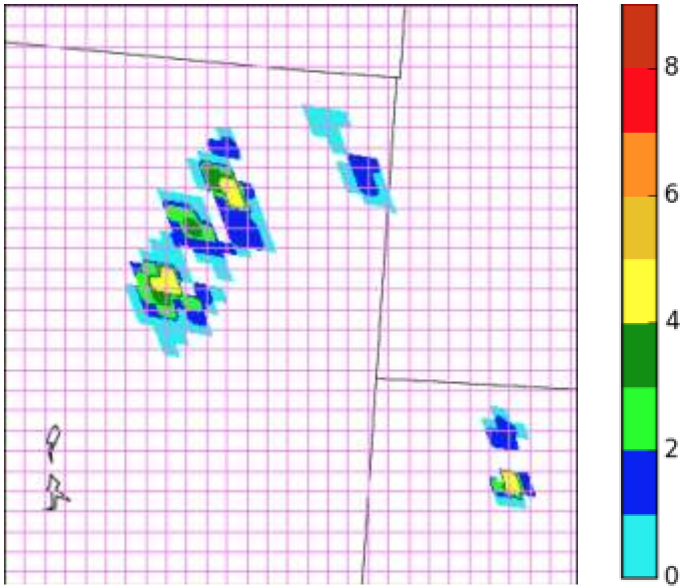
Direct assimilation of Flash Extent Density for CAM

using statistical relationship with graupel

- Mansell, 2014 "Storm-Scale Ensemble Kalman Filter Assimilation of Total Lightning Flash-Extent Data" pioneered GLM FED assimilation onto graupel volume in an OSSE
- Allen et al., 2016 "Assimilation of Pseudo-GLM Data Using the Ensemble Kalman Filter" assimilated pseudo-GLM (from LMA) onto graupel volume and graupel mass
- Kong et al., 2020 "Assimilation of GOES-R Geostationary Lightning Mapper flash extent density data in GSI EnKF for the analysis and short-term forecast of a mesoscale convective system" and
- Kong et al., 2022 "Development of New Observation Operators for Assimilating GOES-R Geostationary Lightning Mapper Flash Extent Density Data Using GSI EnKF: Tests with Two Convective Events over the United States" refined the ensemble techniques and introduce hybrid capability

Some remarks on the FED forward operator





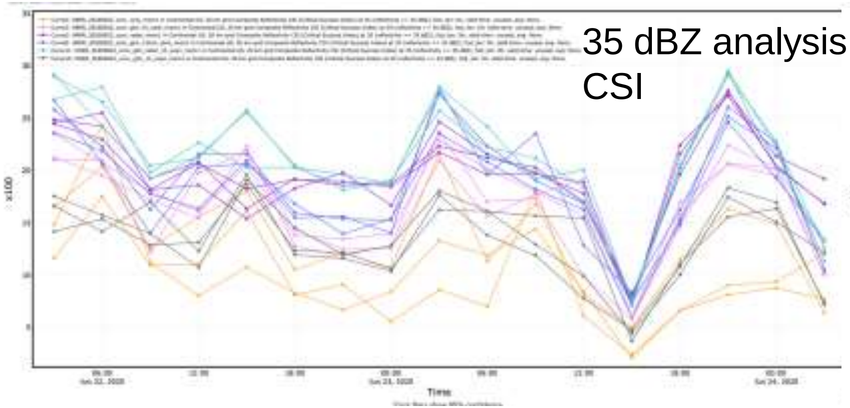
obs. flashes/ minute

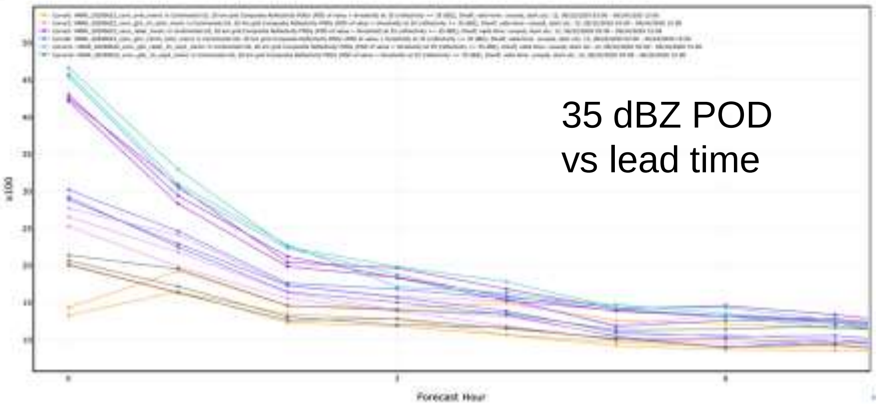
pink boxes=5 x 5 model grid columns

L: Calibration to the model on “successful” forecasts

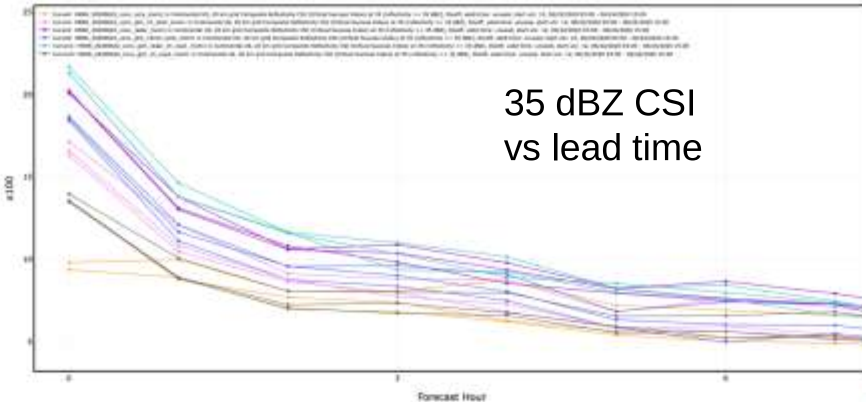
R: Model graupel is summed horizontally and vertically to mimic GLM pixel extent

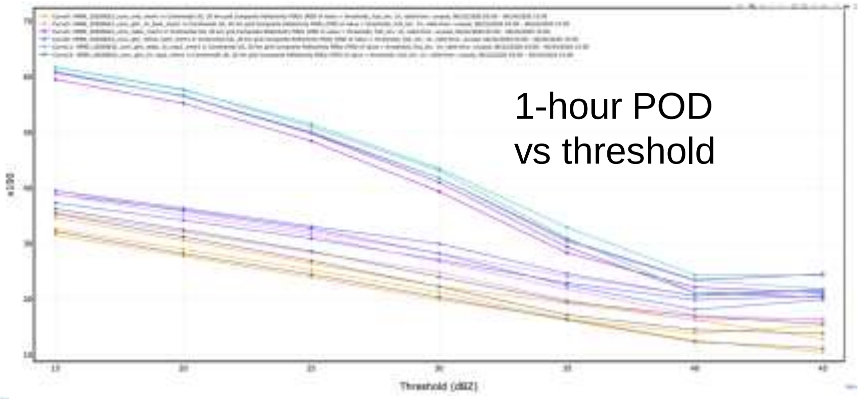
Test results - Ensemble assimilation in HRRR-E



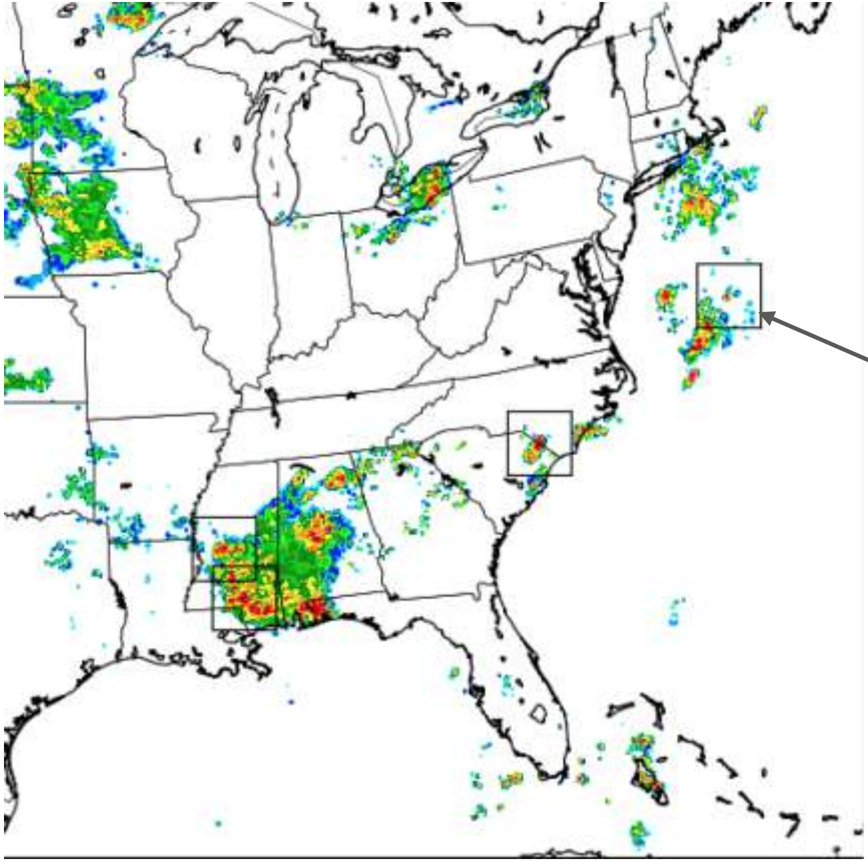


CONV ONLY - **CONV+GLM-linear** - **CONV+GLM-tanh**
CONV+GLM-tanh, 15-min - **CONV+RADAR** - **CONV+RADAR+GLM**





Test results - Ensemble assimilation in protype RRFS



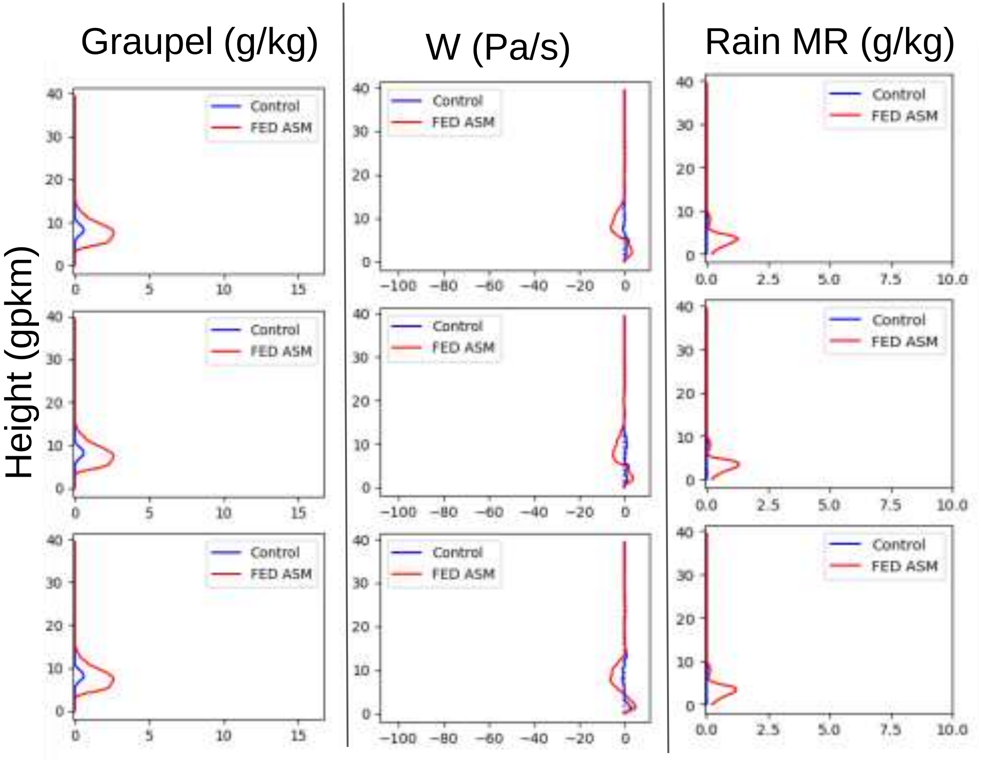
Examining first hour of multi-day cycled retro, boxes show locations of greatest graupel mass increments

Next slide details increment over ocean, outside radar range, for 3 members of 30-member ensemble.

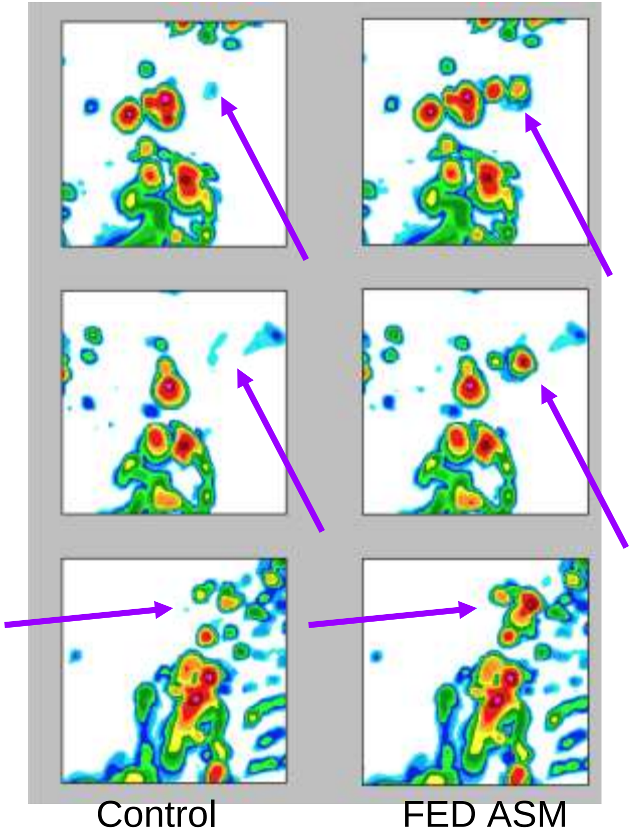
Control: usual data streams incl. radar

FED ASM: usual data streams incl. radar, as well as GLM FED

Test results - Ensemble assimilation in prototype RRFS

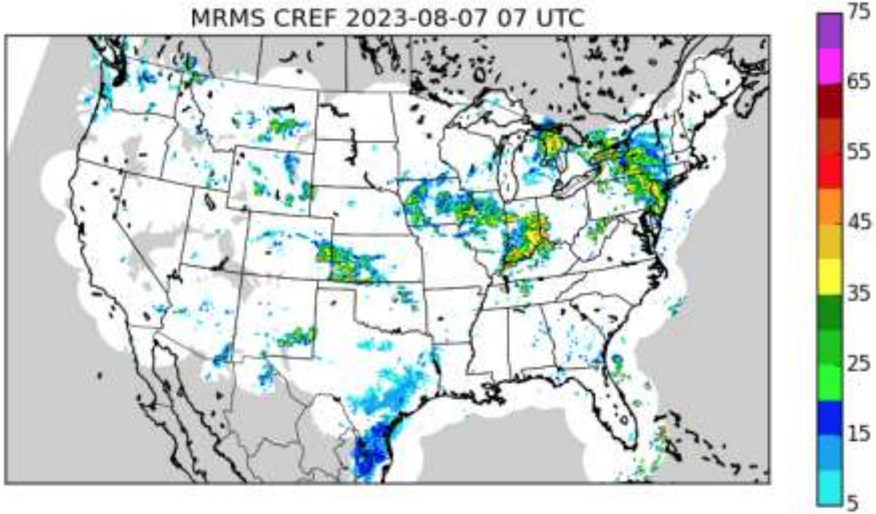


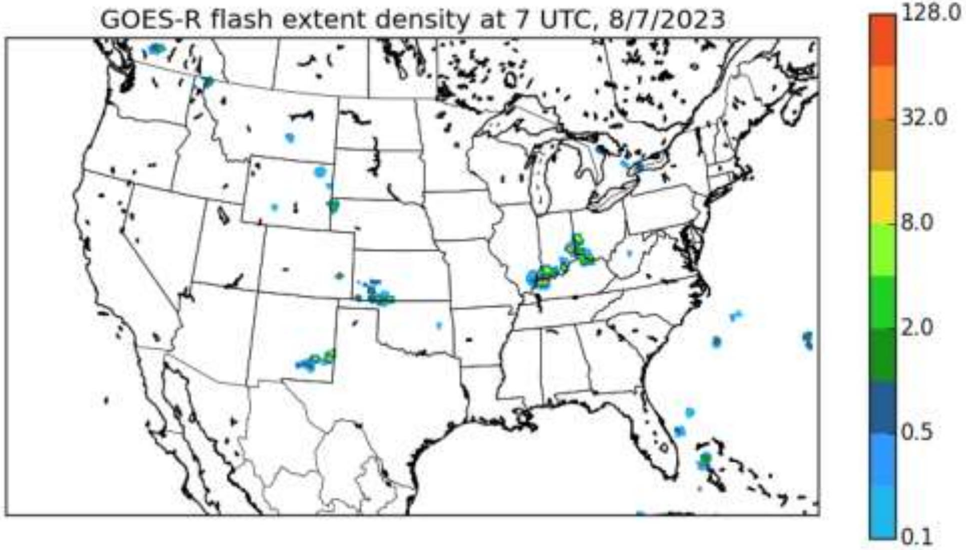
Expt. vs. Control analysis for 3 members



Same 3 members - 1 hour forecast column-max reflectivity

Test results - EnVar assimilation in prototype RRFS



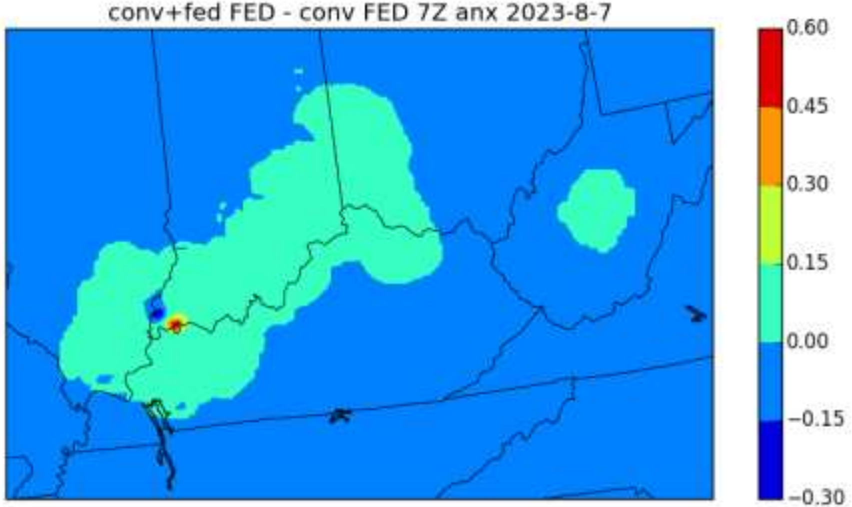


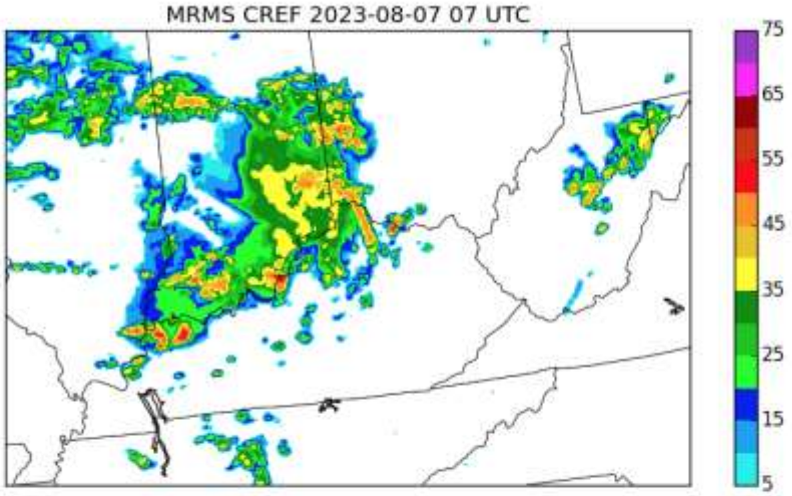
Reflectivity (L) and GOES-R FED observations for one hour of EnVar RRFS retrospective test

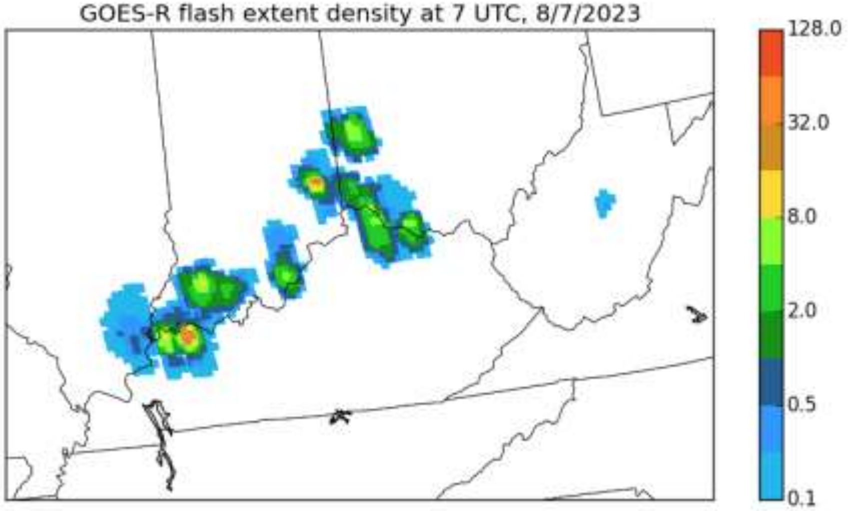
FED is assimilated both into ensembles and into the deterministic control member

All conventional data streams assimilated; no radar

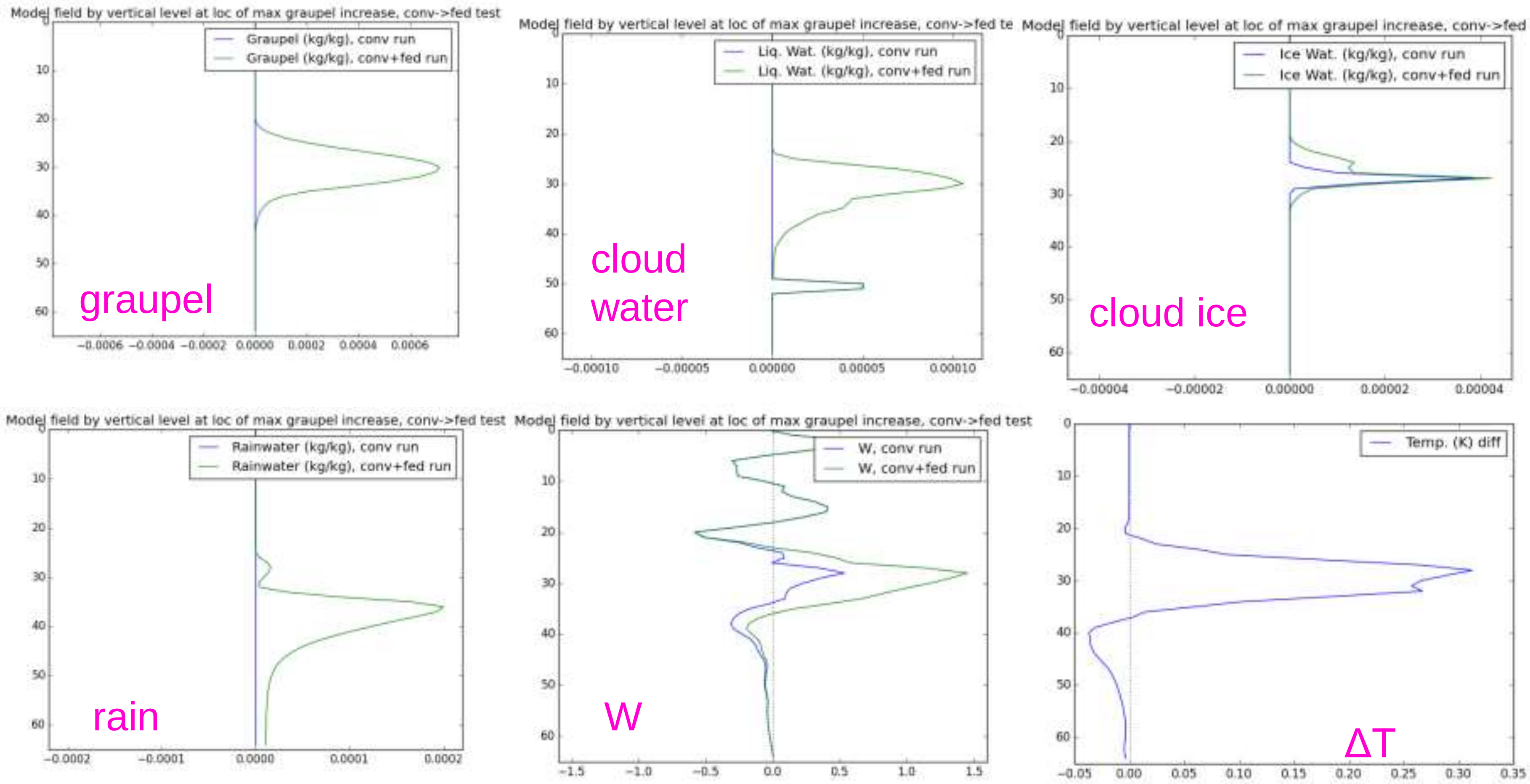
At 7Z, both the largest positive increment in model “FED” (graupel sum) and the largest negative increment are located in SW IN (increment shown at right)



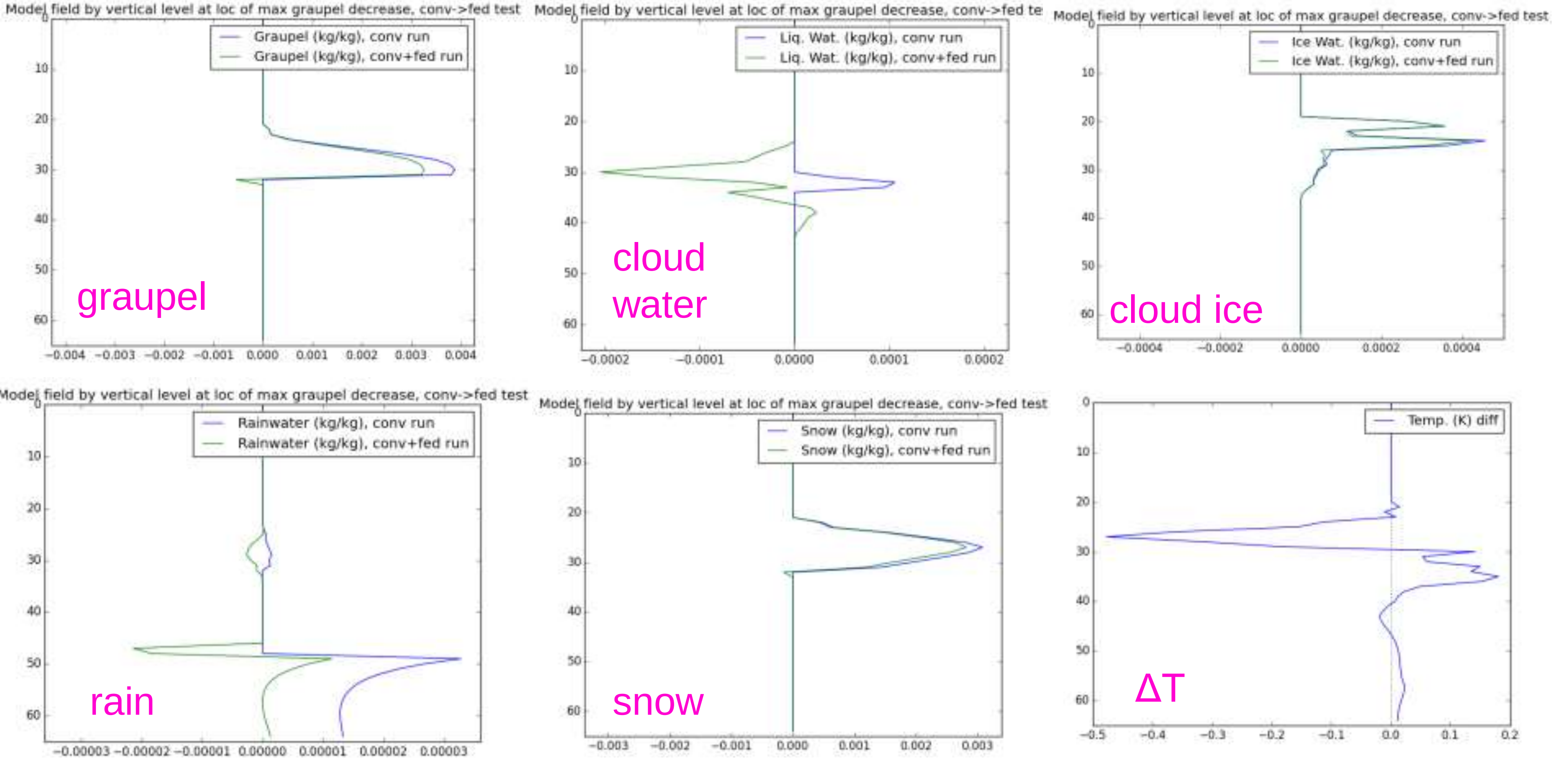




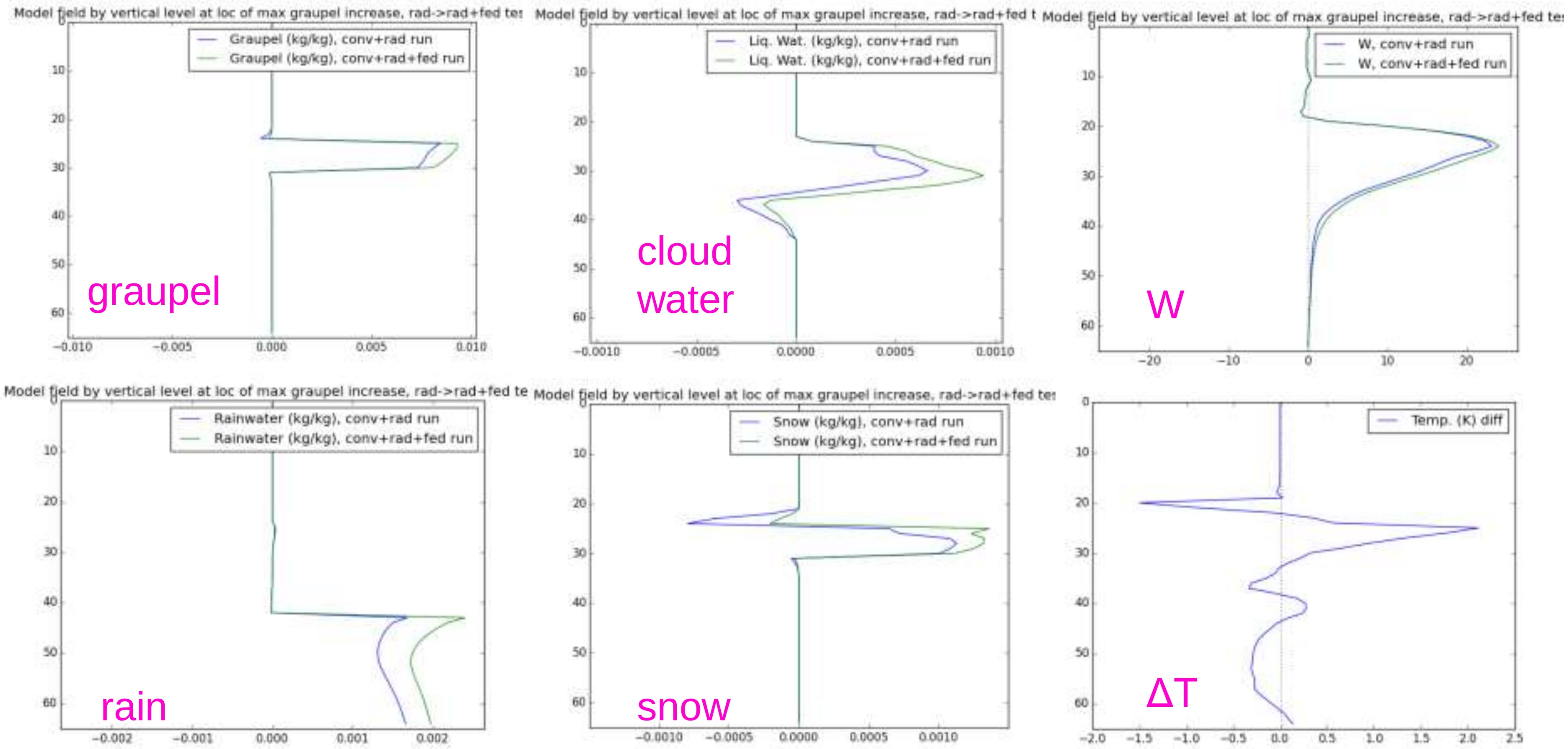
Model fields vs vertical level at loc. of most positive FED increment



Model fields vs vertical level at loc. of most negative FED increment



Model fields vs vertical level at loc. of most positive FED increase
when radar is also assimilated



Future work

- Finalize configuration for RRFSv1 over next few months
- Move testing and dev to JEDI data assimilation framework for RRFSv2+
- Integrate data from ground-based detecting networks
- Incorporate other microphysical and meteorological quantities (for example, Apodaca & Zupanski adaptation of the McCaul lightning diagnostic as a forward operator)
- Test use of model cloud height info in place of fixed ellipsoid to map GLM data to latitude/longitude for assimilation