CAPS Real-time Storm-scale Ensemble System for the NOAA HWT Spring Experiment

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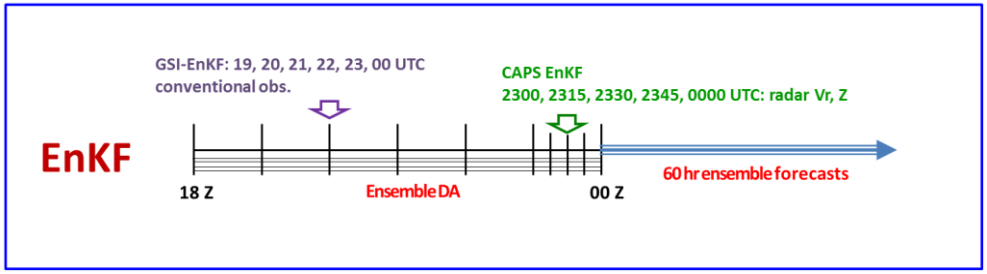
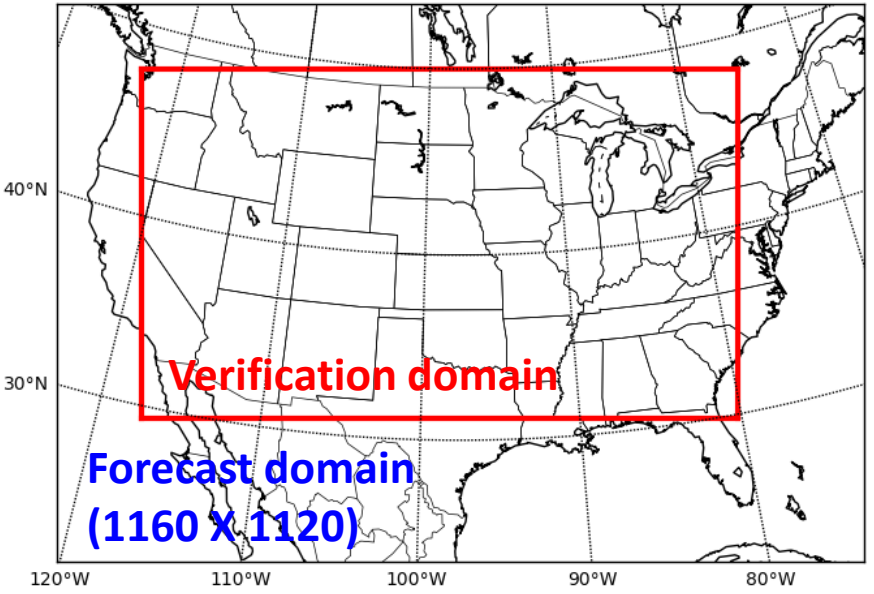
Background

- CAPS/OU has been producing 3-km (previously 4-km) CONUS-domain ensemble forecasts for evaluation at NOAA HWT since 2007.
- Goals: To determine the optimal design, configurations, and post-processing of storm-scale ensemble prediction and accelerate the R2O transfer of new tools
- Real-time experimental EnKF started in Spring 2013.
- A distinct feature of the CAPS SSEFs: the assimilation of full-volume radial velocity and reflectivity data from the WSR-88D network.
- To gain understanding to optimize and further calibrate a short-term probabilistic forecast system to support WoF.

2017 HWT Model and Configuration

- Forecast model: WRF-ARW v3.8.1 (2017)
- DA systems: GSI-EnKF, CAPS EnKF
- 3-km horizontal grid spacing, 51 vertical levels
- http://www.caps.ou.edu/~fkong/sub_atm/spring17-enkf.html





Physics

- Radiation (SW & LW): RRTMG
- unified Noah land-surface model
- No cumulus parameterization
- Multi-PBL schemes: MYJ, YSU, ACM2, MYNN
- Microphysics scheme during DA: Thompson with perturbed ρ_g (414 - 673 kgm^{-3})
- 10-member 60-h forecast: (Thompson, M-Y, Morrison, NSSL) + (MYJ, MYNN, YSU)

IC and BC

- 1800 UTC – 0000 UTC (DA)
  - Initial condition: 18Z NAM analysis + 15Z SREF perturbation
  - Boundary condition: 18Z NAM and 15Z SREF ensemble forecasts
- 0000 UTC – 1200 UTC (+ 2.5 days)
  - Initial condition: EnKF mean and ensemble analyses
  - Boundary condition: 00Z NAM and 21Z SREF ensemble forecasts

Data Assimilation System

- 40 members
- GSI-EnKF (100 nodes, 1400 cores, ~11 min)
  - surface (u/v, Ps, T, q)
  - sounding and profiler (u/v, Ps, T, q)
- CAPS EnSRF (1120 cores, ~4.7 min)
  - Vr (~0.17 M obs) and Z (~2.5 M obs)
  - Observation errors: 4 ms^{-1}/3 dBZ
  - Inflation: RTPS (95 %) and multiplicative (20 %)

Configurations

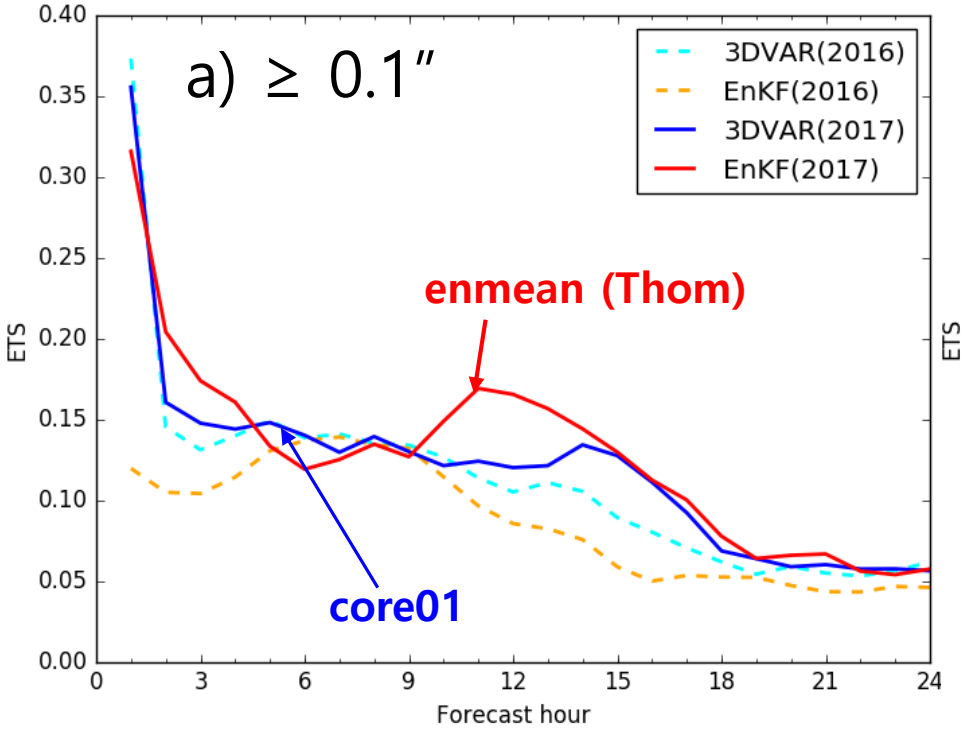
Member	IC	BC	Microphysics	PBL
enkf_m1	member1 analysis	00Z NAM forecast	Thompson	MYJ
enkf_m2	Member2 analysis	21Z SREF arw-p1	Morrison	YSU
enkf_m3	member15 analysis	21Z SREF arw-n1	MY	MYNN
enkf_m4	Member40 analysis	21Z SREF nmmb-p1	Morrison	MYJ
enkf_m5	Member8 analysis	21Z SREF nmmb-n1	Thompson	YSU
enkf_m6	Member36 analysis	21Z SREF arw-p2	MY	MYNN
enkf_m7	Member39 analysis	21Z SREF arw-n2	MY	YSU
enkf_m8	member17 analysis	21Z SREF nmmb-p2	NSSL	MYJ
enkf_m9	ensemble mean analysis	00Z NAM forecast	Thompson	MYJ
enkf_m10	ensemble mean analysis	00Z NAM forecast	NSSL	MYJ
noRadar	Same as enkf_m9 but without radar data	00Z NAM forecast	Thompson	MYJ
3DVAR	NAM 00Z analysis + 3DVAR/Could Analysis	00Z NAM forecast	Thompson	MYJ

QPF verification

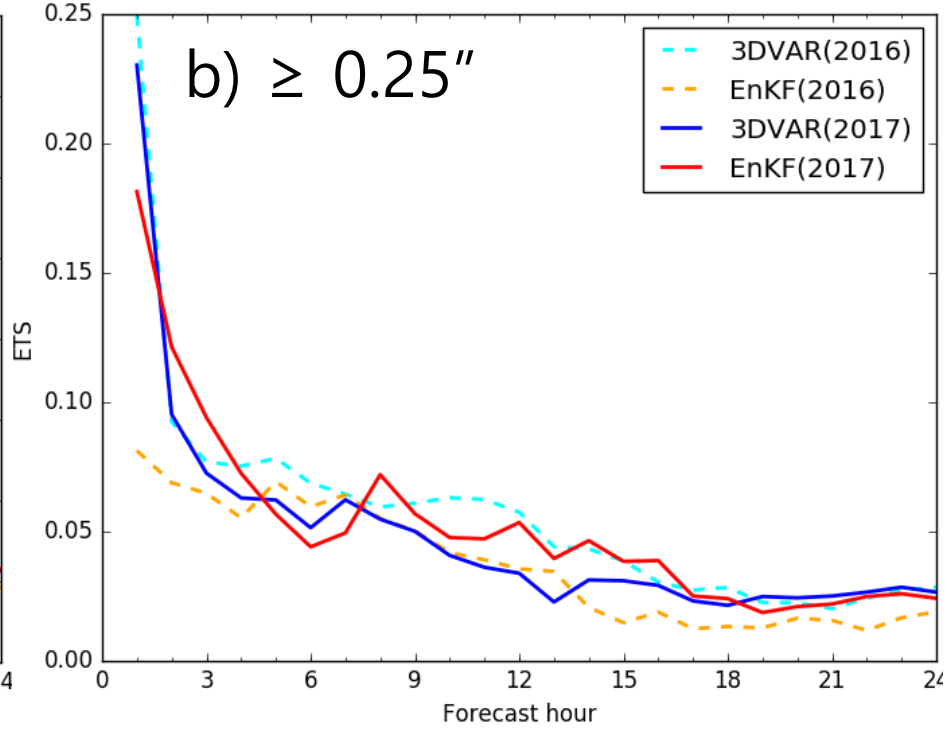
- Verification using data collected from 23 days during the 2017 HWT SFE.
- Ensemble products (mean, PM) for the EnKF ensemble were computed using available members, which varies day to day.

2016 vs 2017

ETS of 1-h accumulated Precipitation (≥ 0.1”)

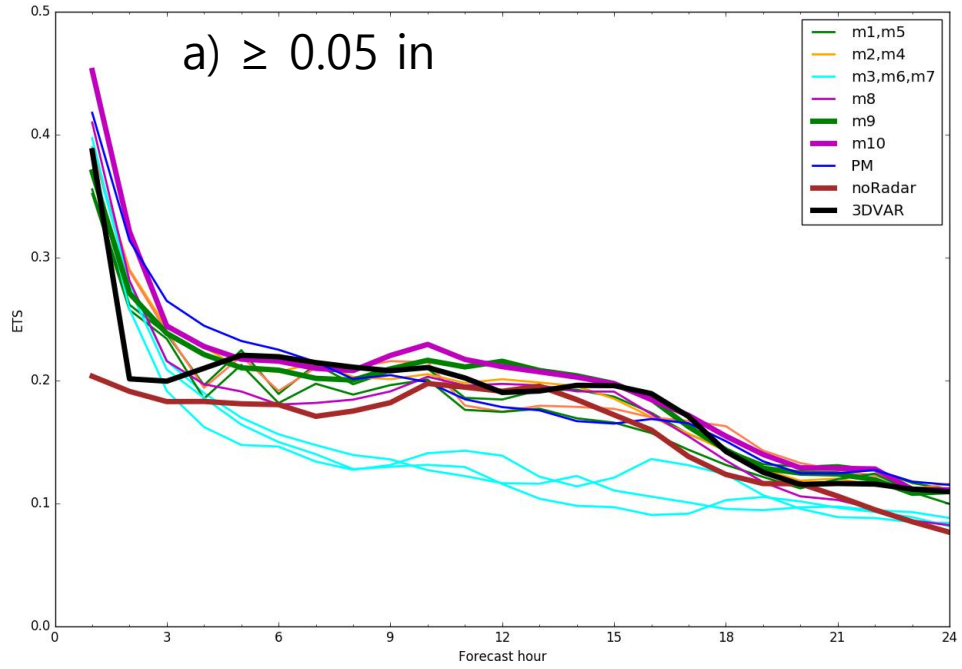


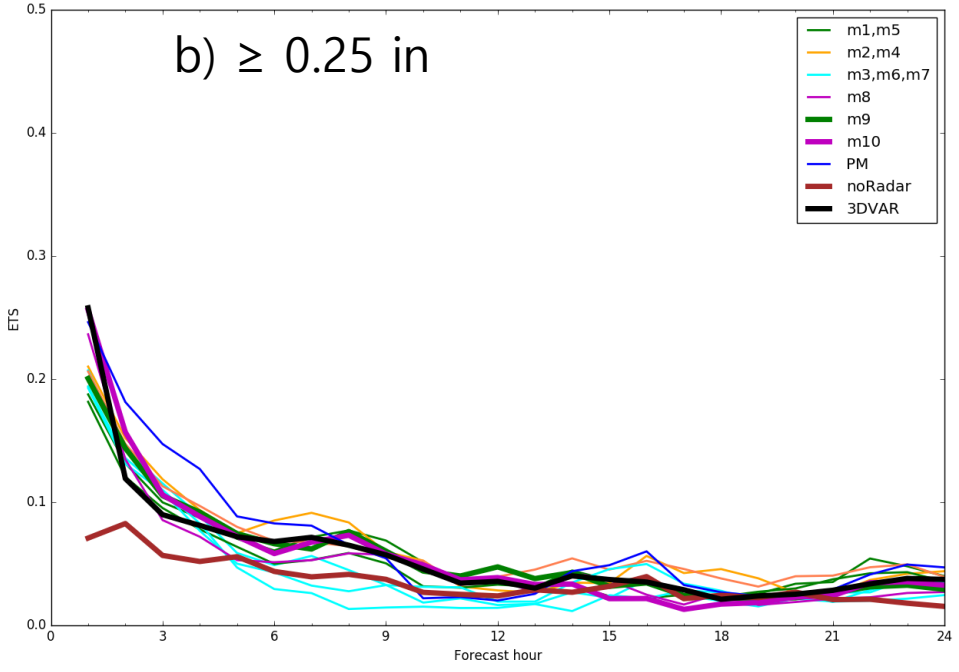
ETS of 1-h accumulated Precipitation (≥ 0.25”)



2016: average over 17 days
2017: average over 18 days

ETSs of 1-hour rainfall accumulations

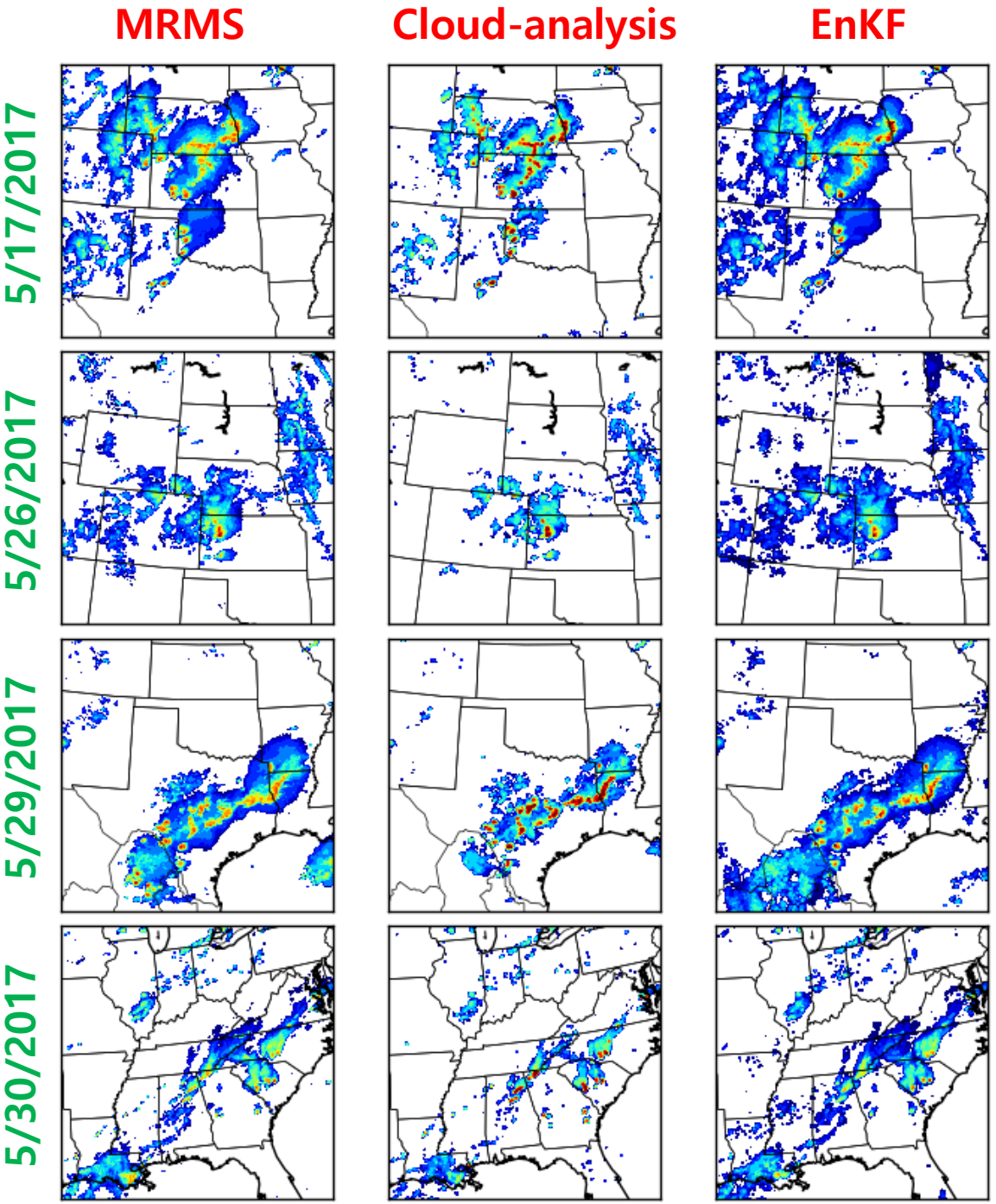




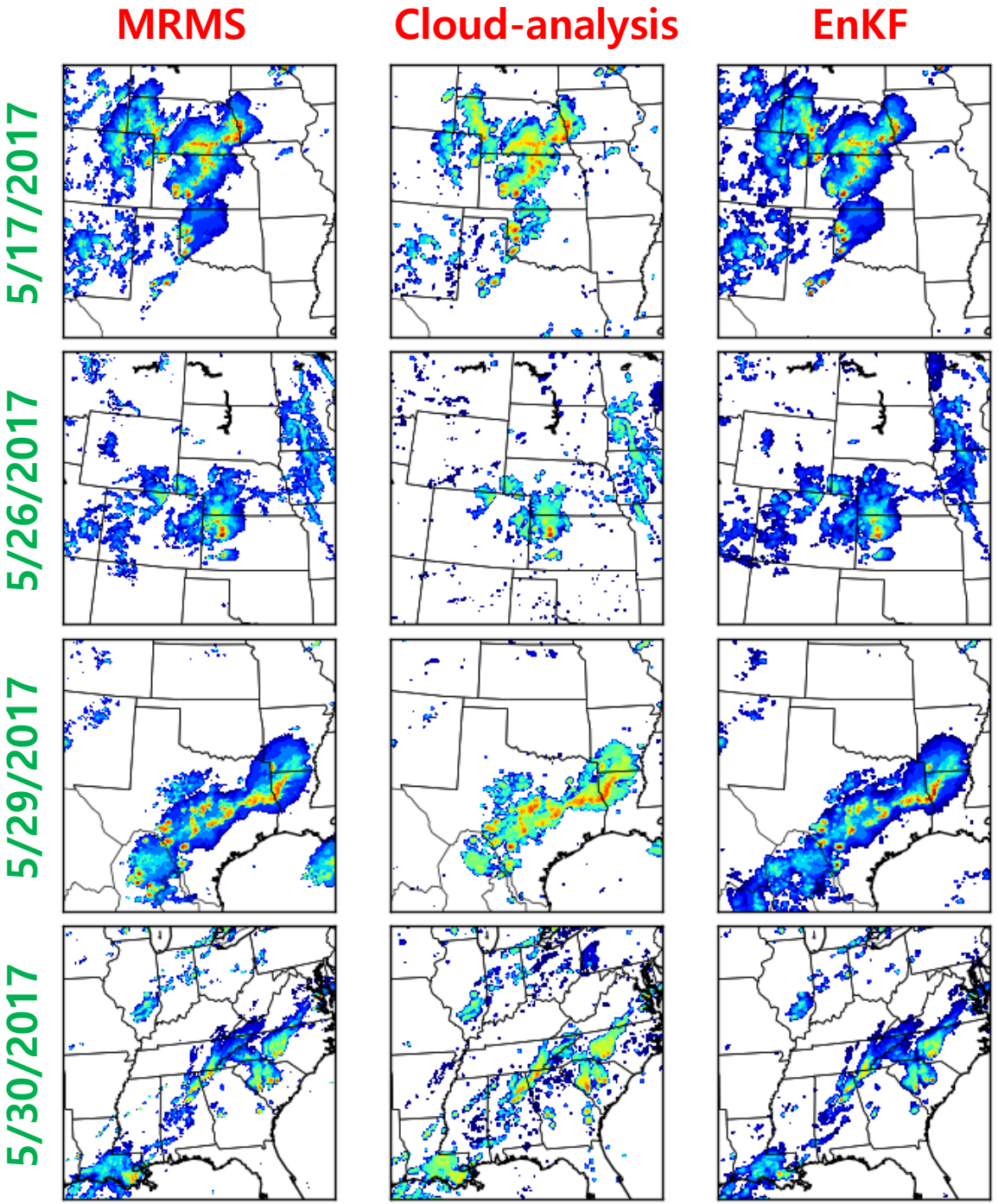
Green: Thompson (m1: 23, m5: 23, m9: 20 days)
Cyan: MY (m3: 16, m6: 16, m7: 18 days)
Orange: Morrison (m2: 22, m4: 23 days)
Purple: NSSL (m8: 20, m10: 20 days)

Black: 3DVAR (22 days)
Brown: noRadar (11 days)
Blue: PM (23 days)

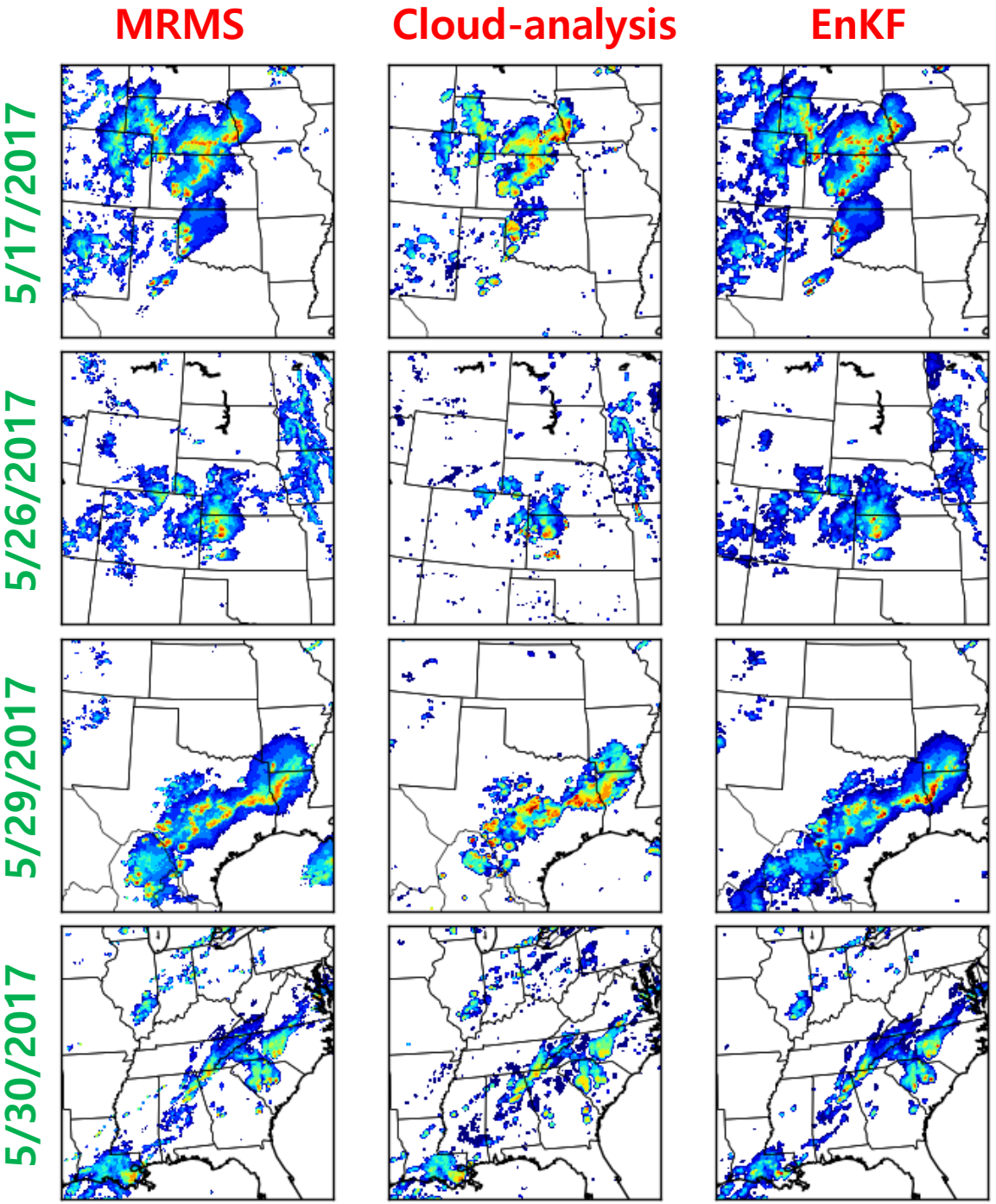
0000 UTC



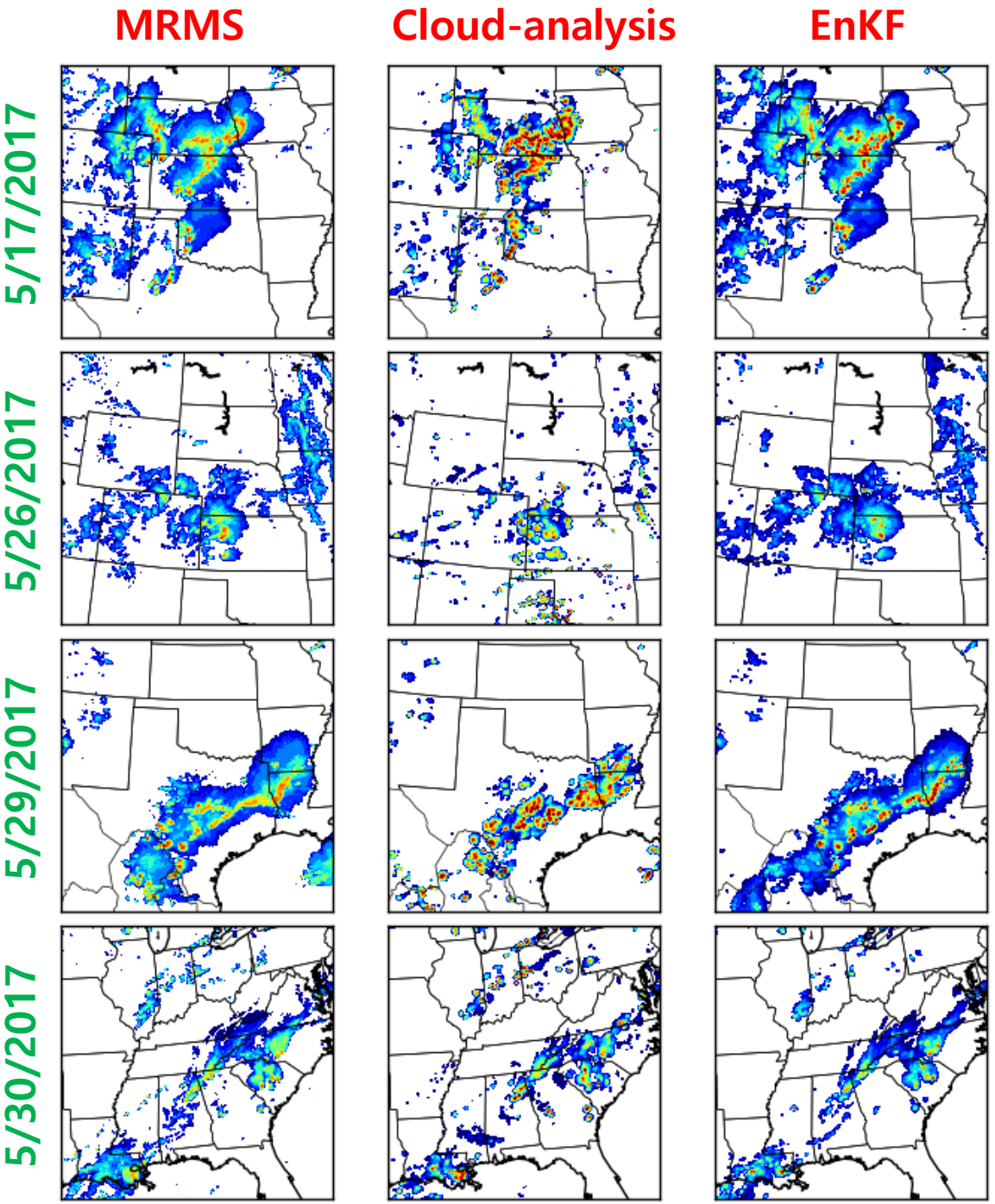
0006 UTC



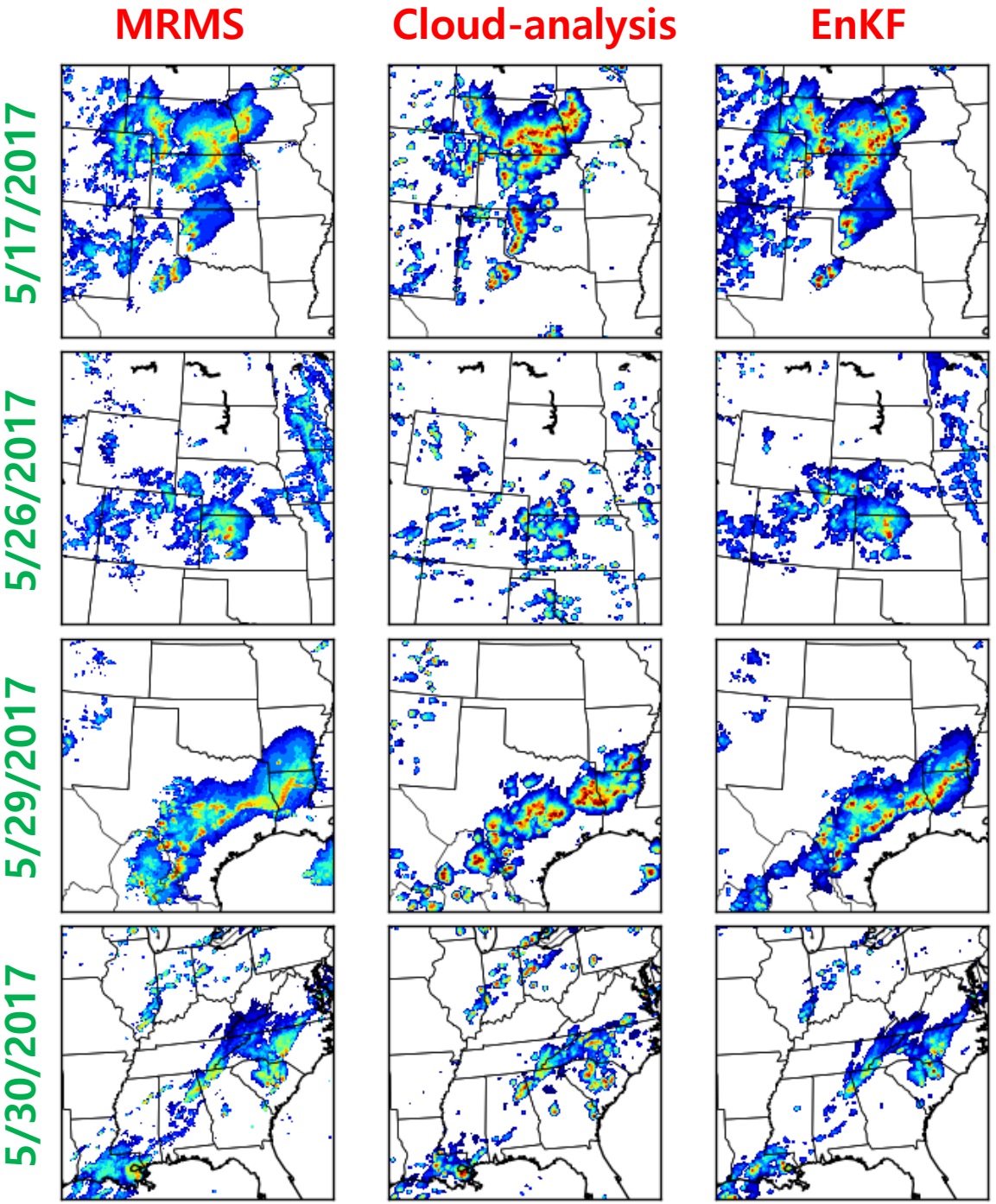
0012 UTC



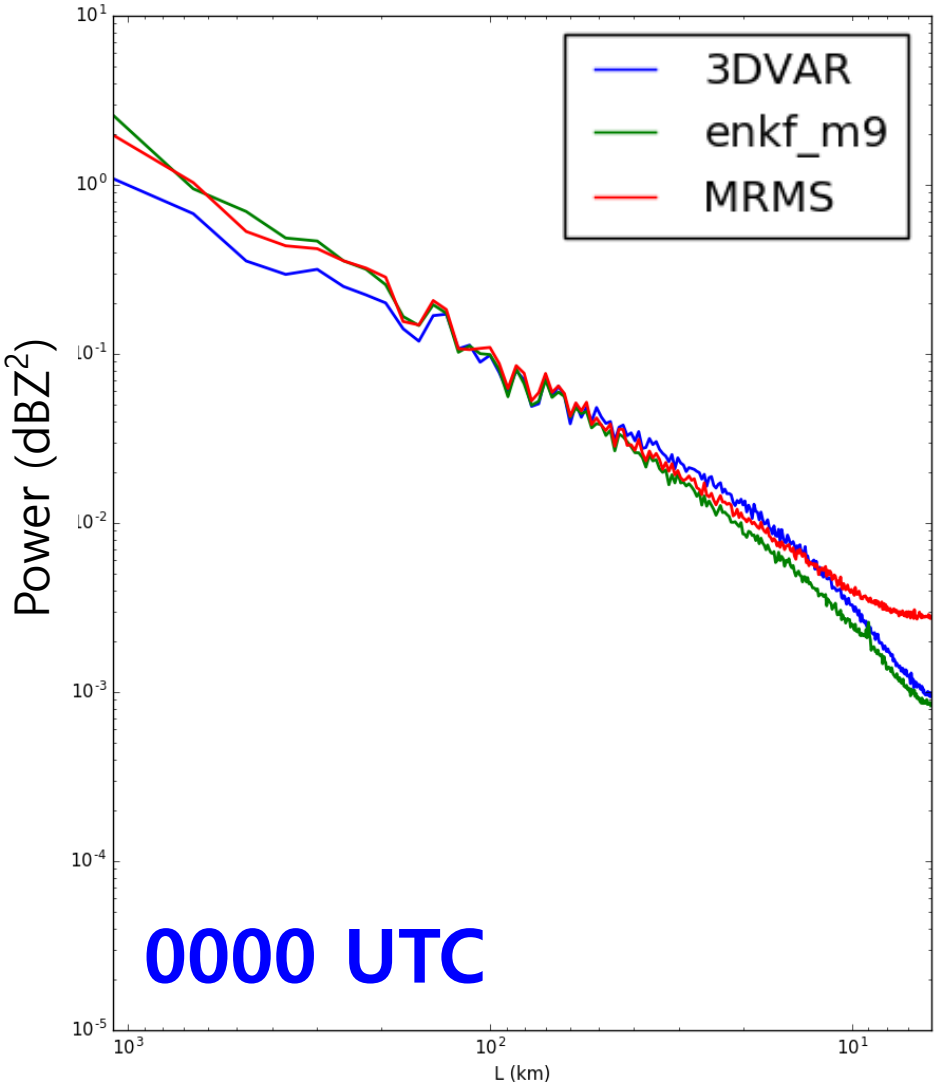
0030 UTC



0100 UTC



Reflectivity Spectra

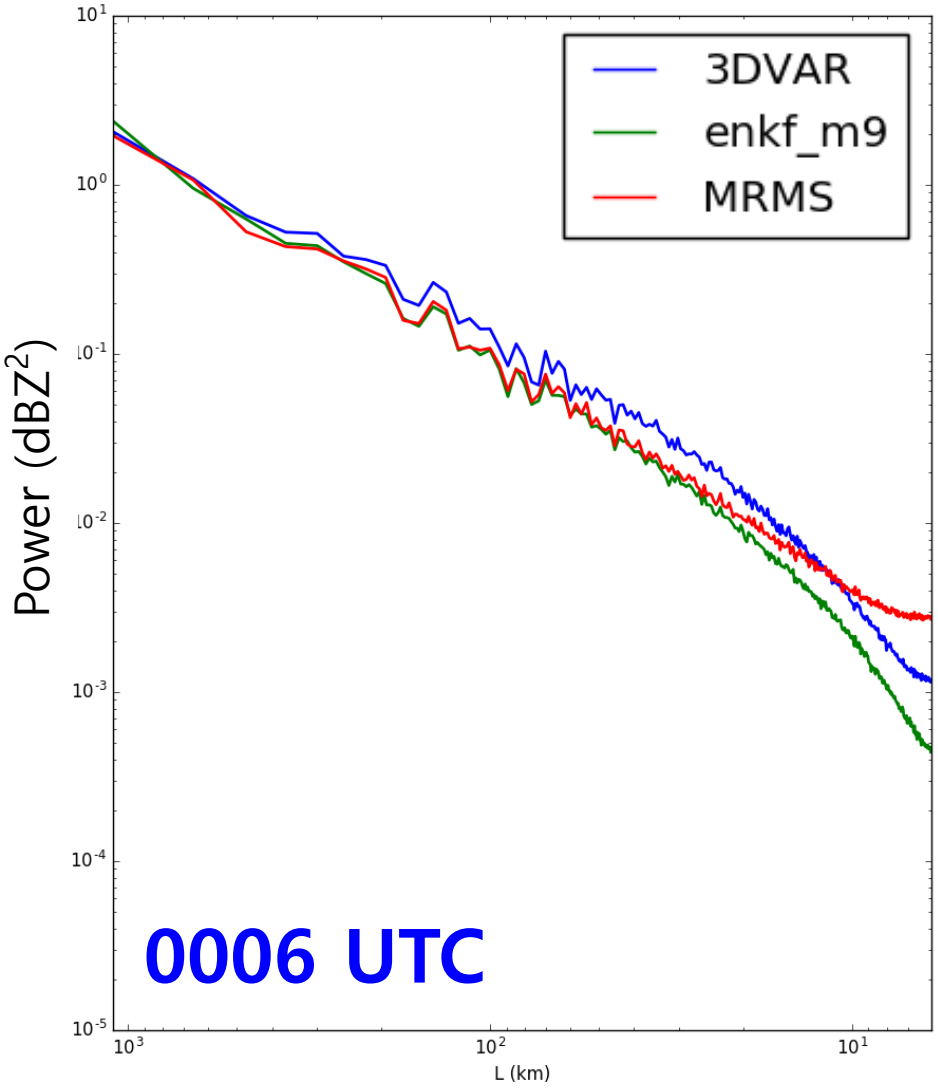


Discrete Cosine Transform (DCT)

Computed over a domain with 550 x 550 grid points where convection is most active each day.

Averaged over 14 days.

Reflectivity Spectra



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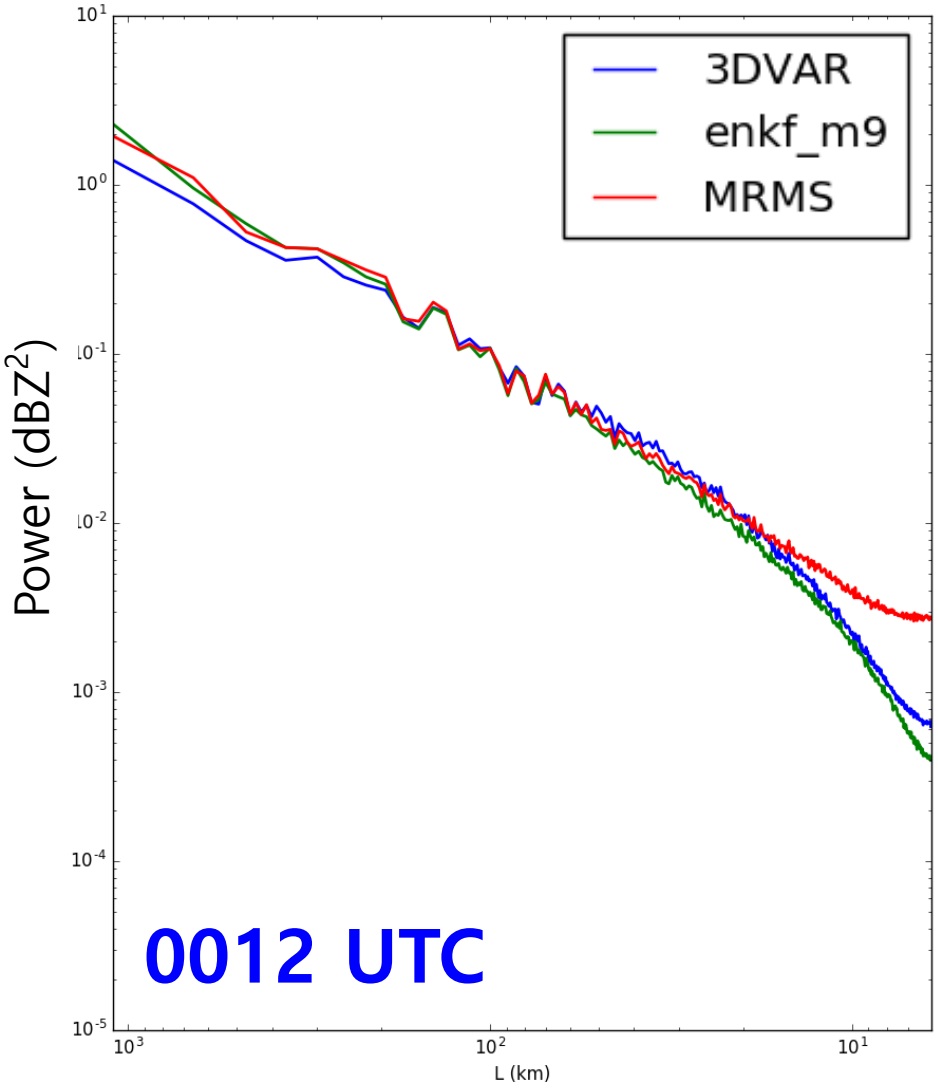

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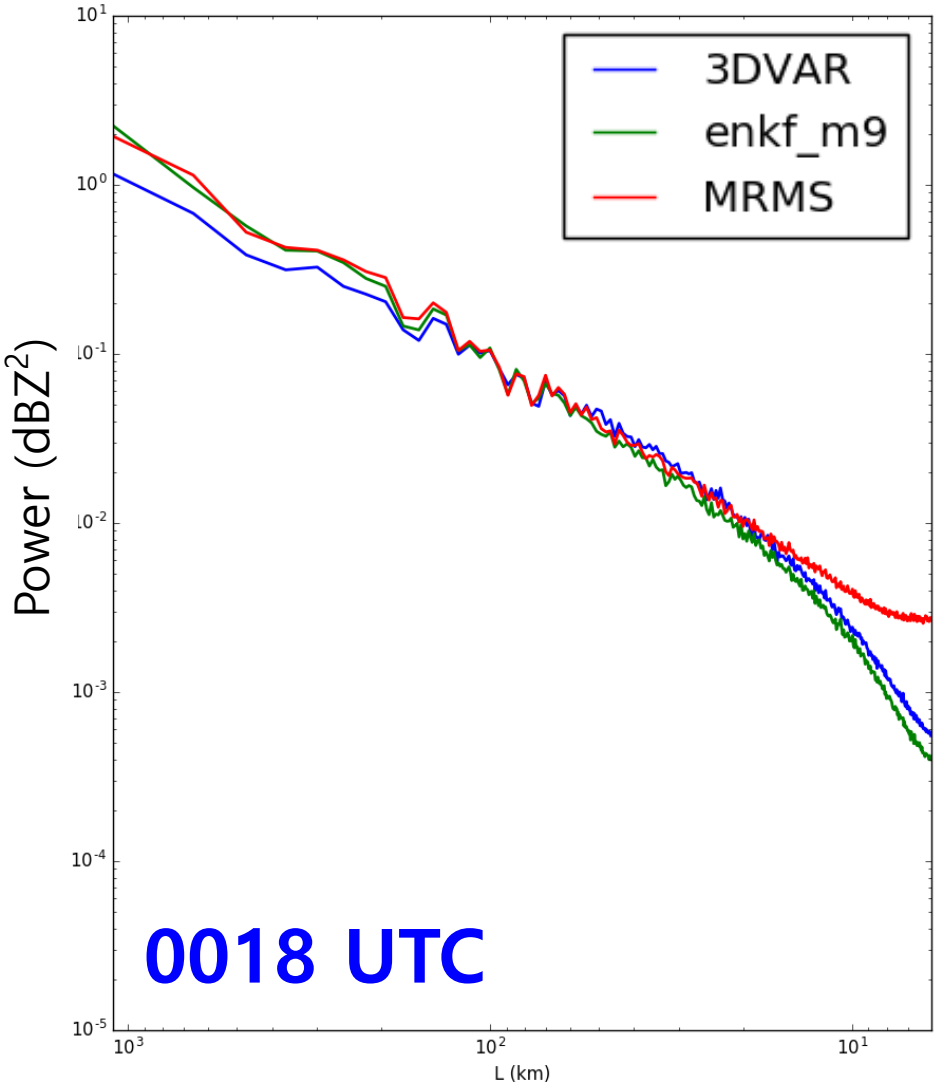

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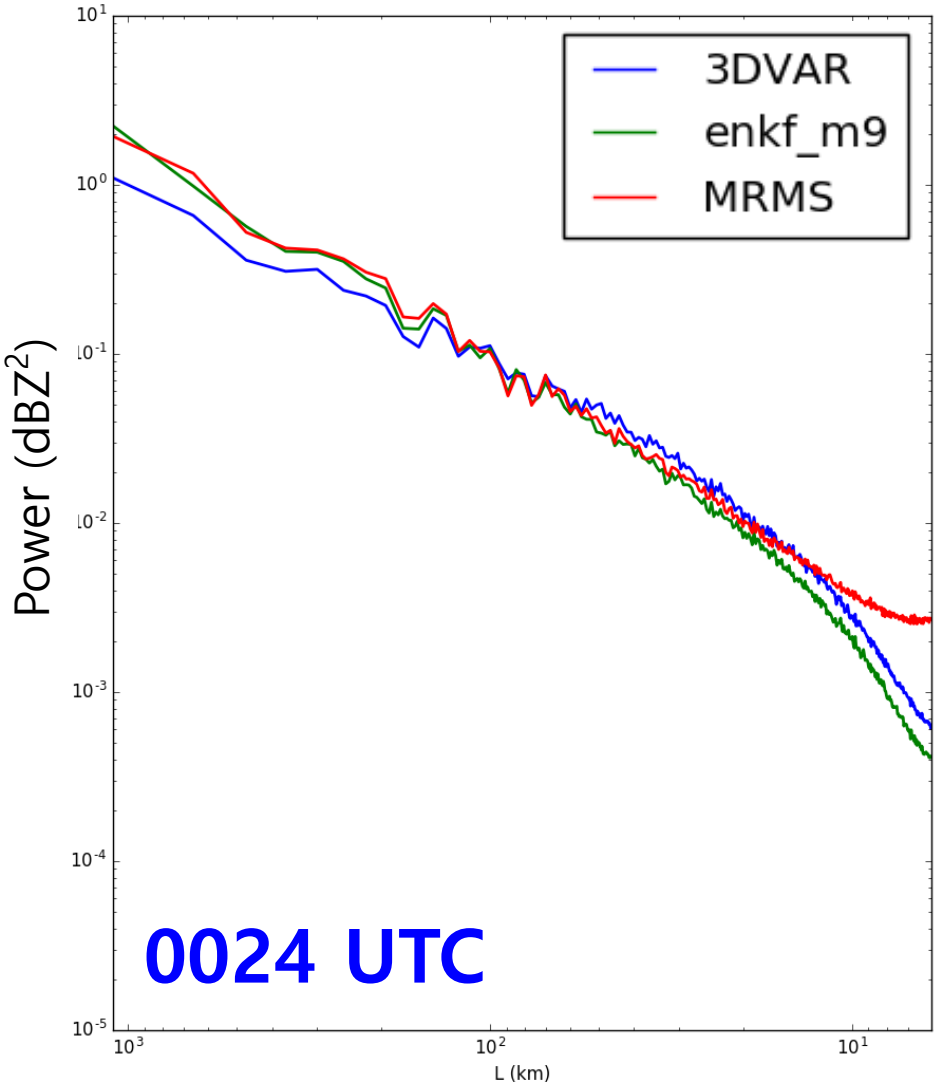

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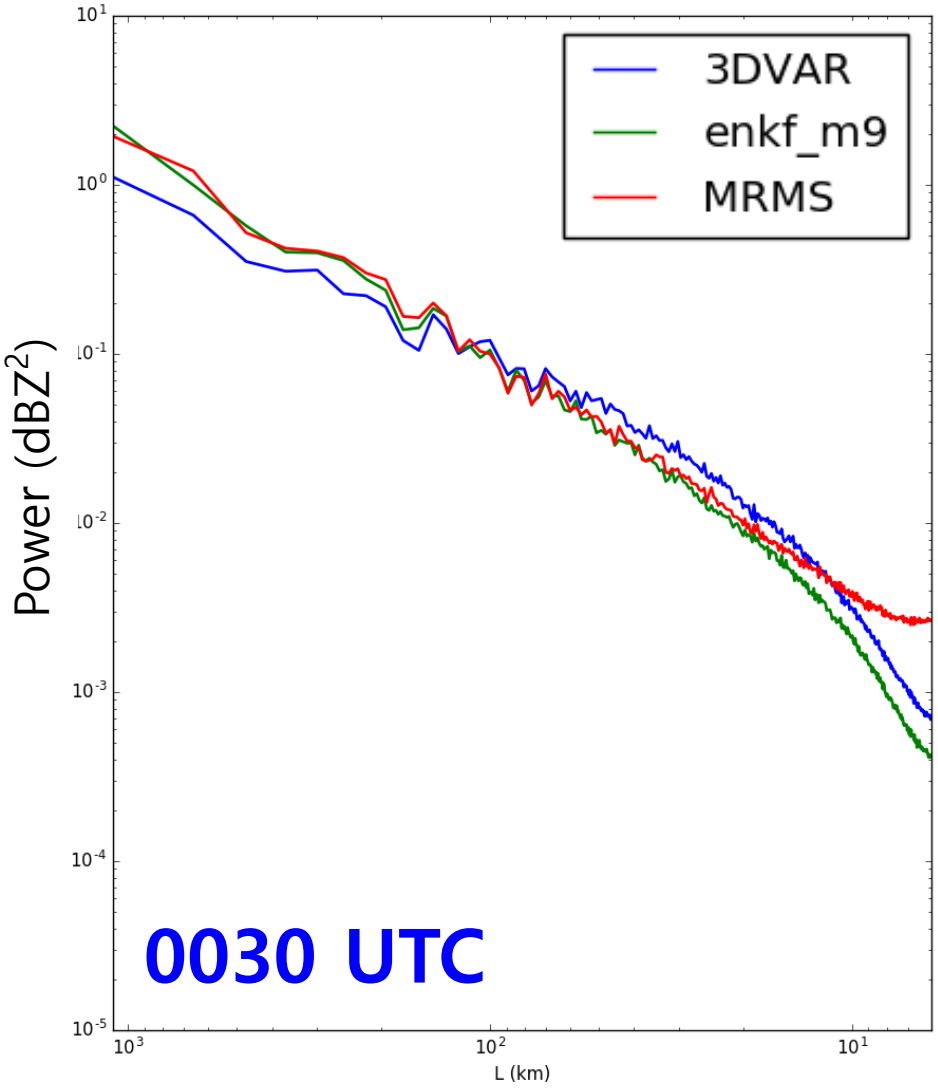

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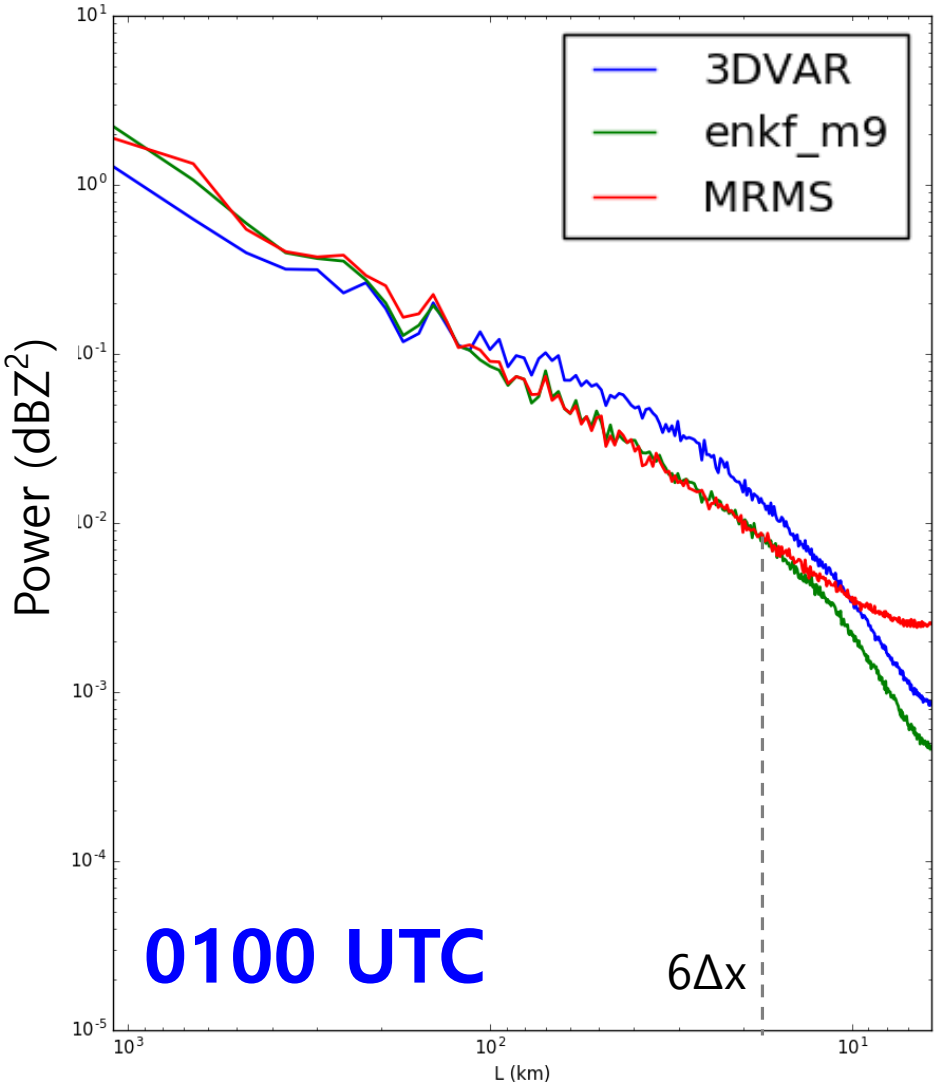
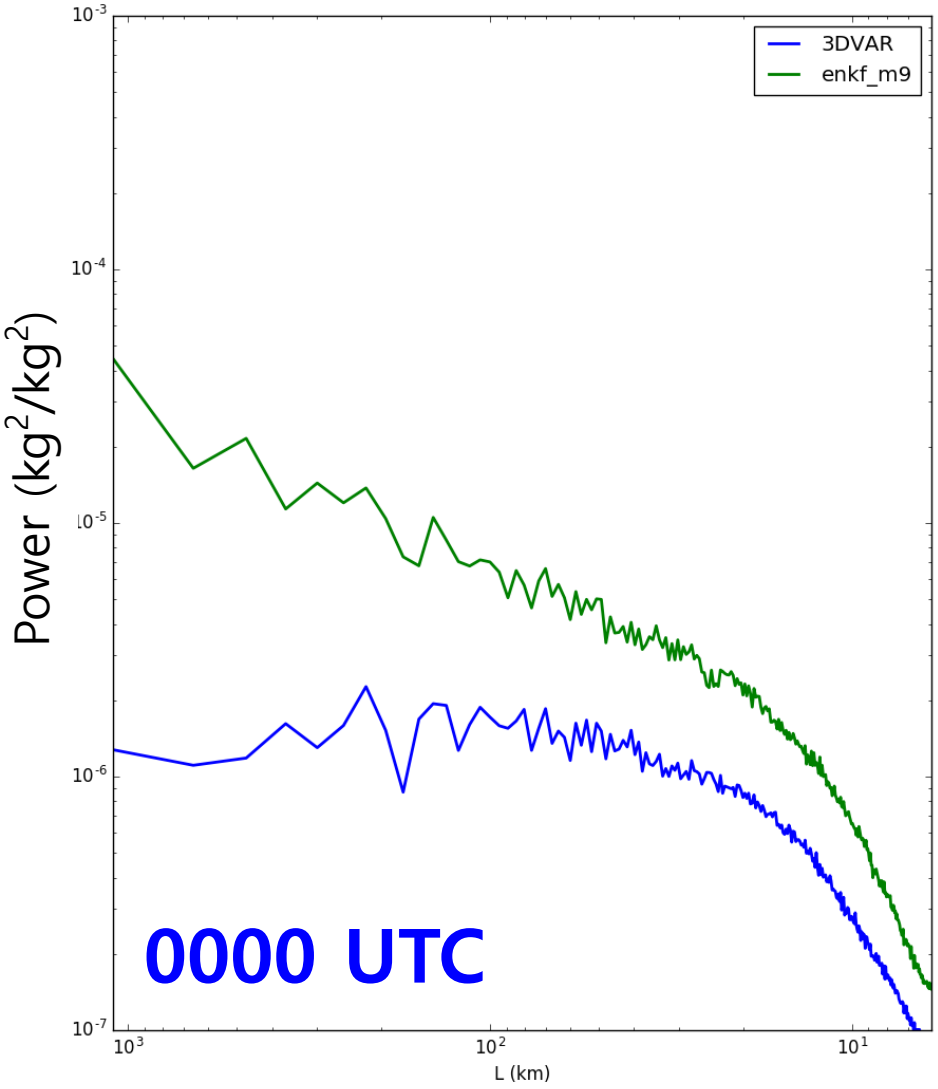


The reflectivity spectrum from EnKF forecast compares well with MRMS down to a wavelength of about 6Δx.

When the cloud analysis is used, the model under-predicts power at scales greater than 200 km while it gradually over-predicts power at the mesoscale.

Rainwater Mixing Ratio Spectra (k=1)



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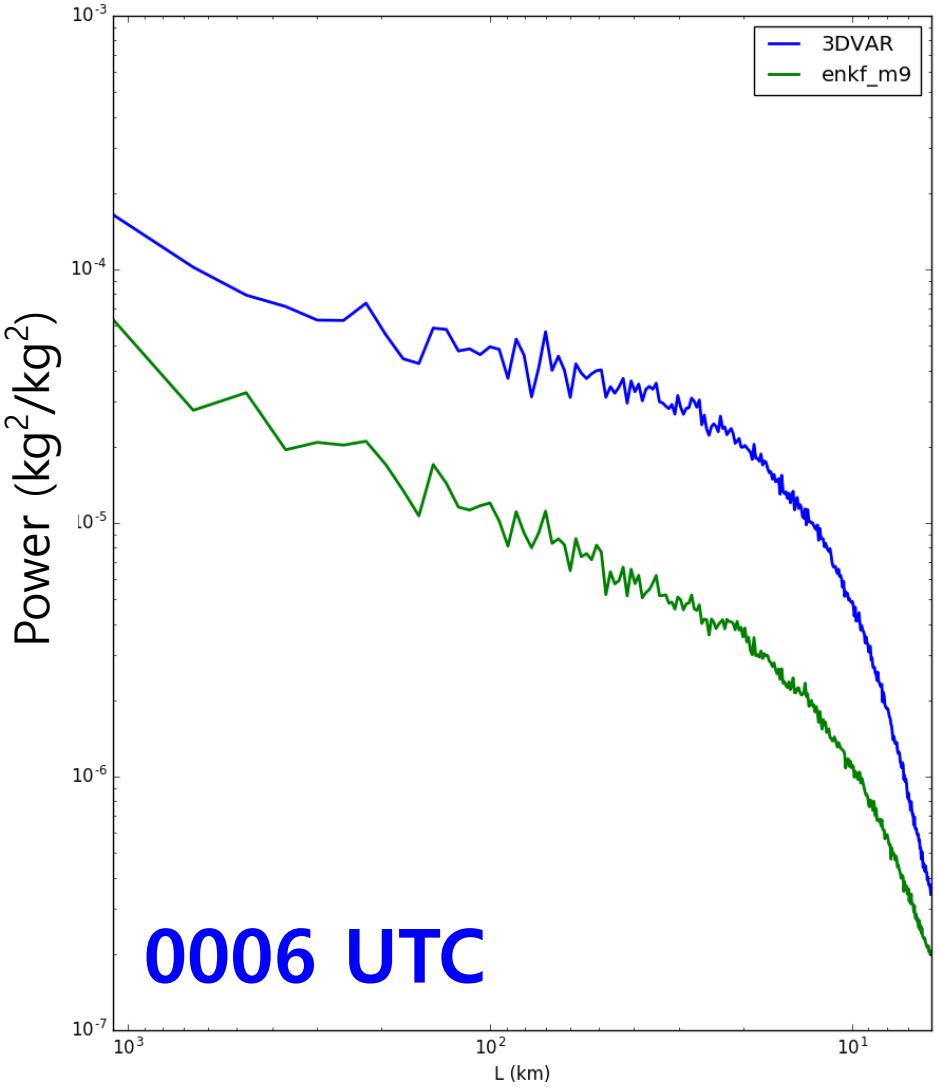

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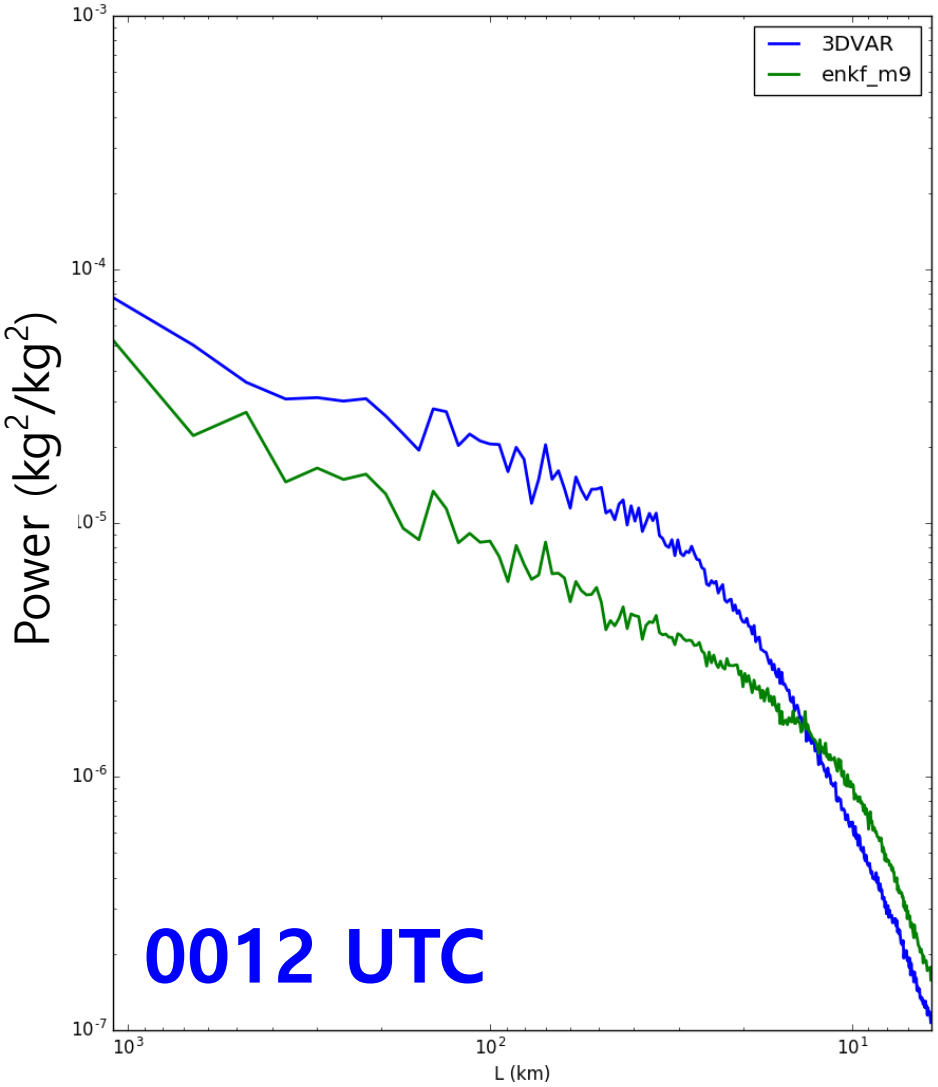

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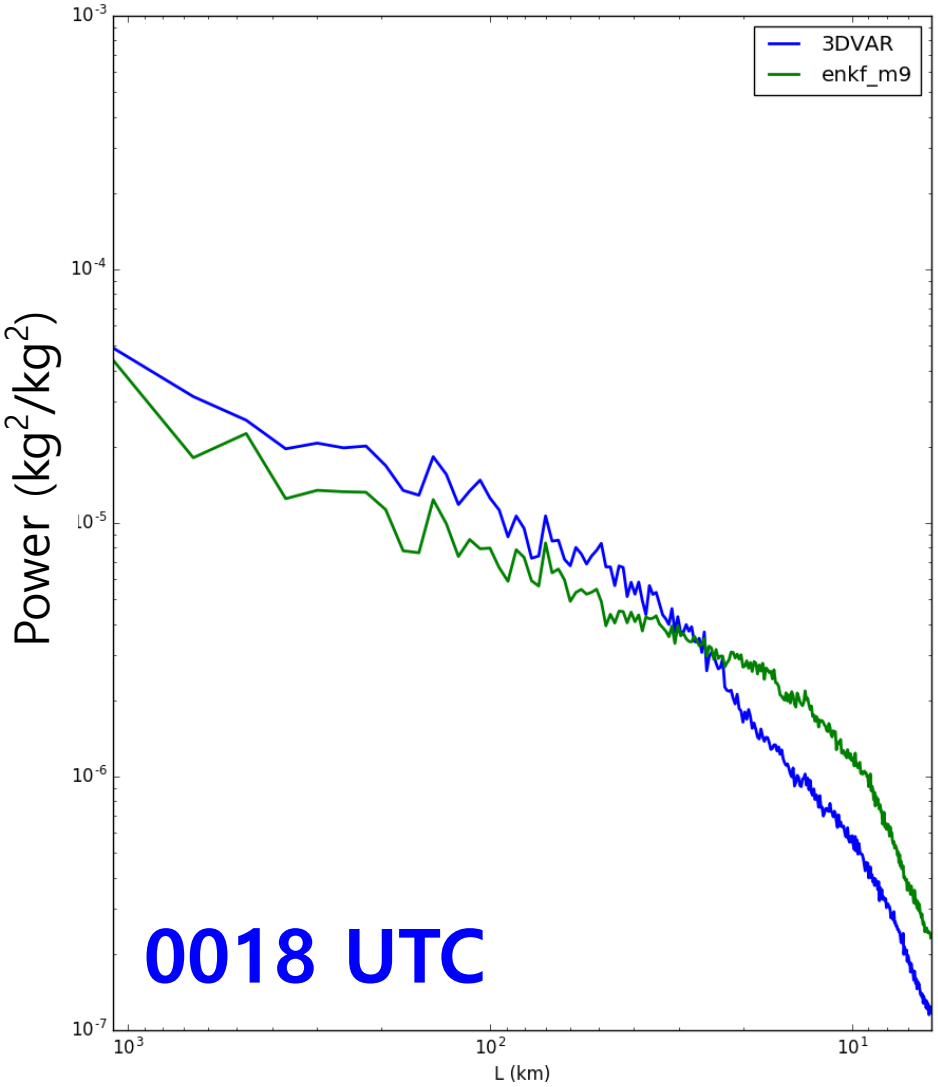

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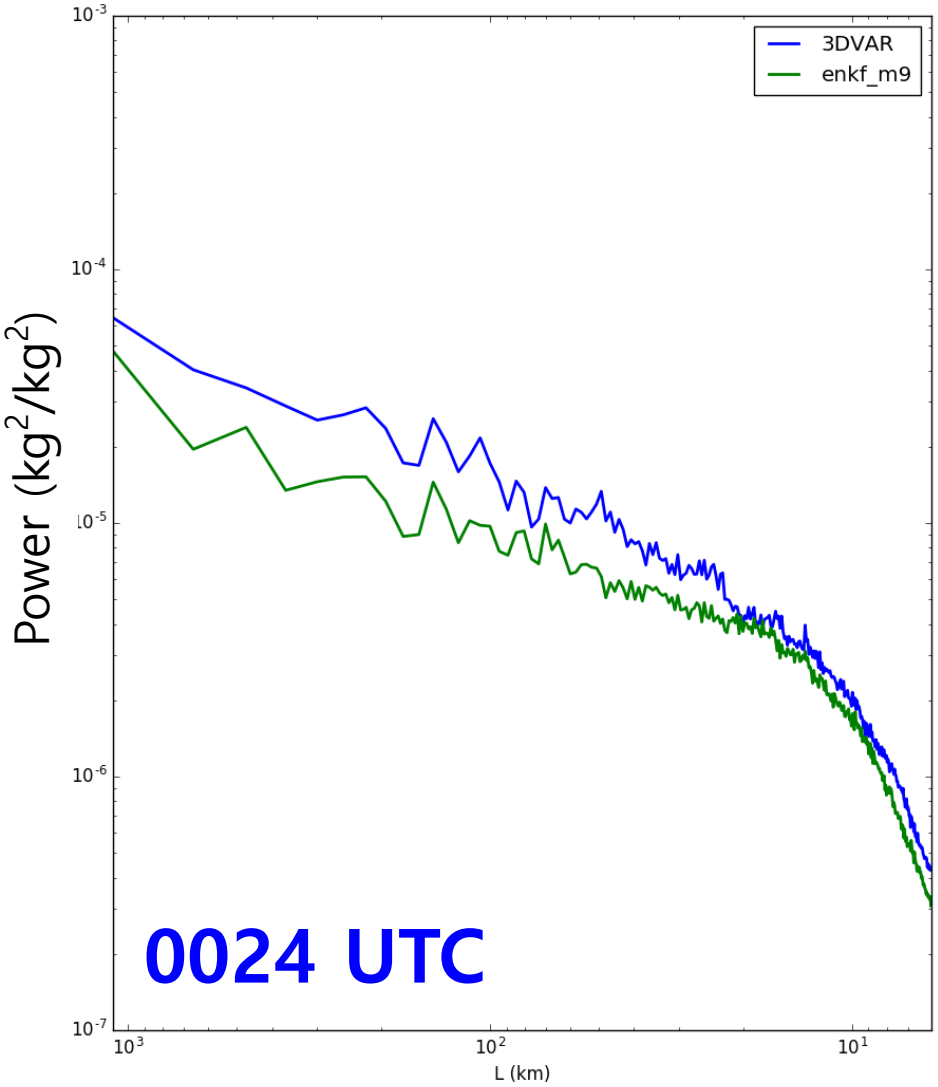

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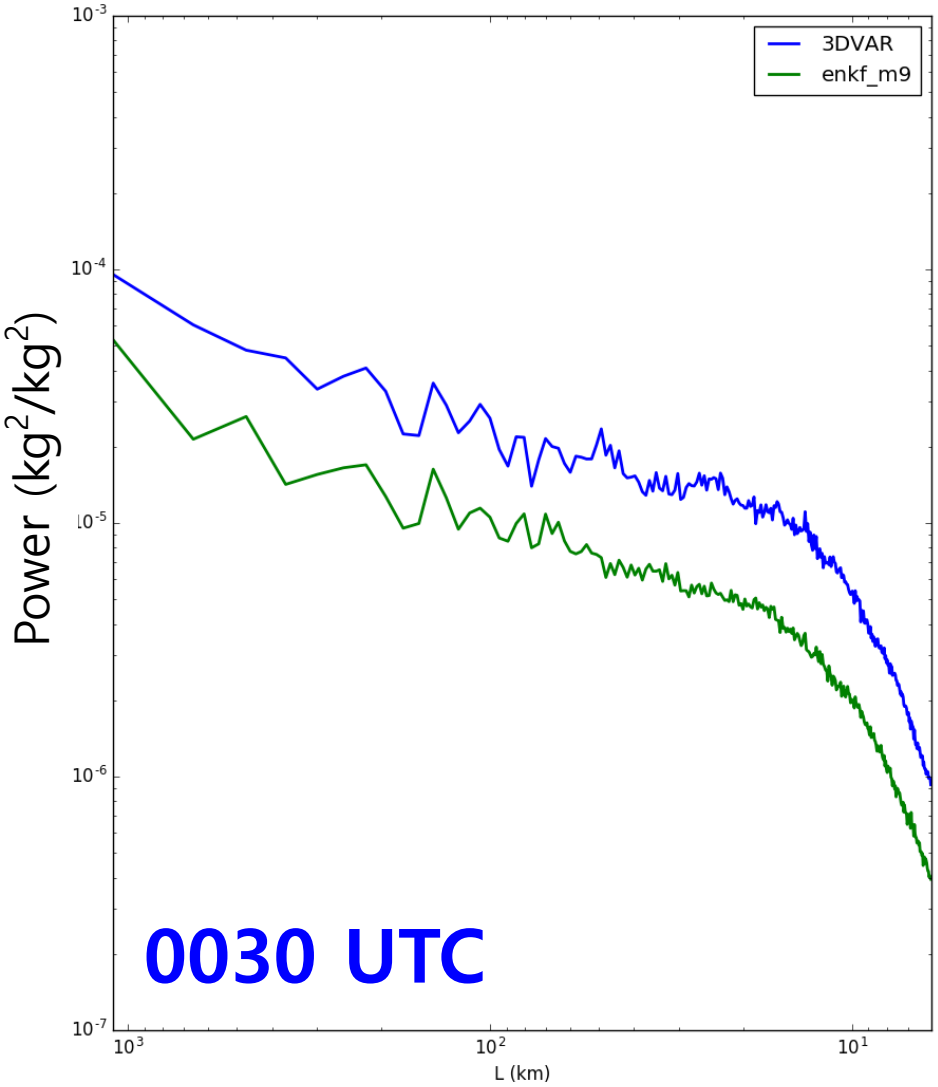

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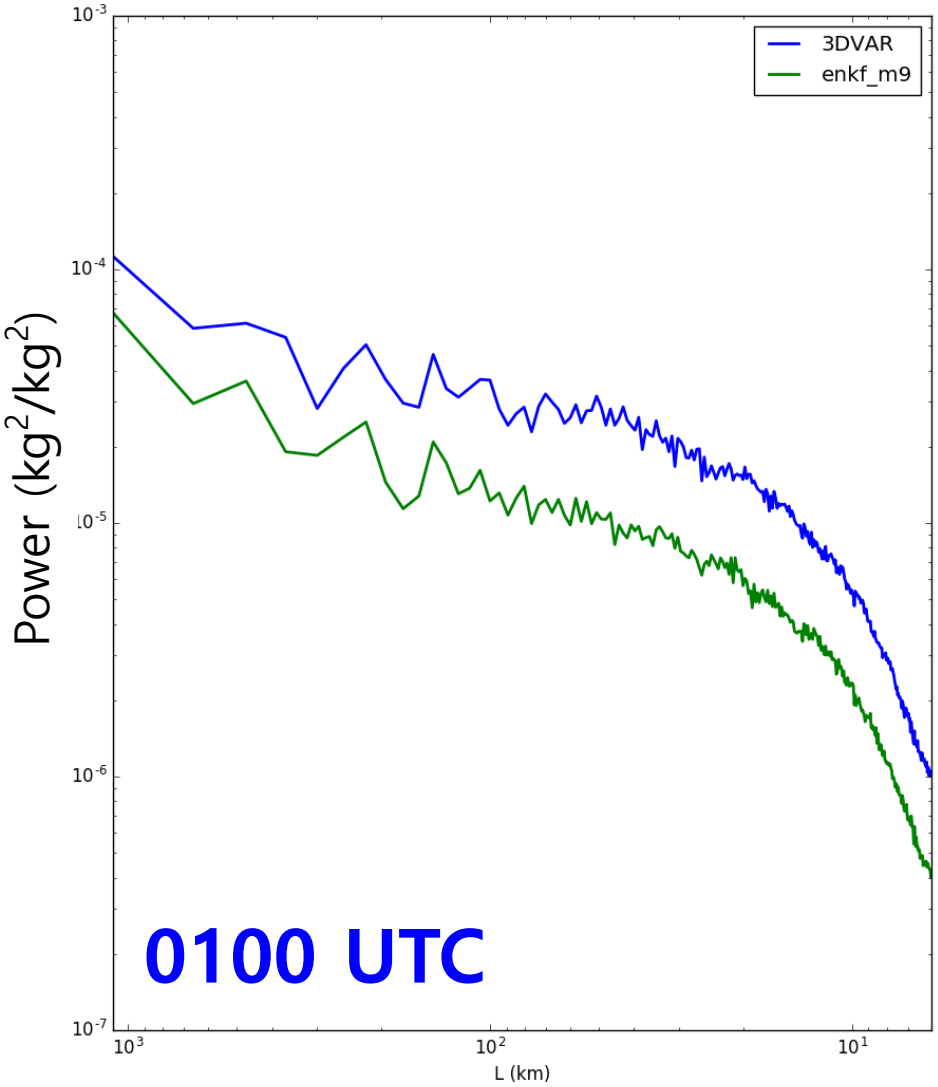
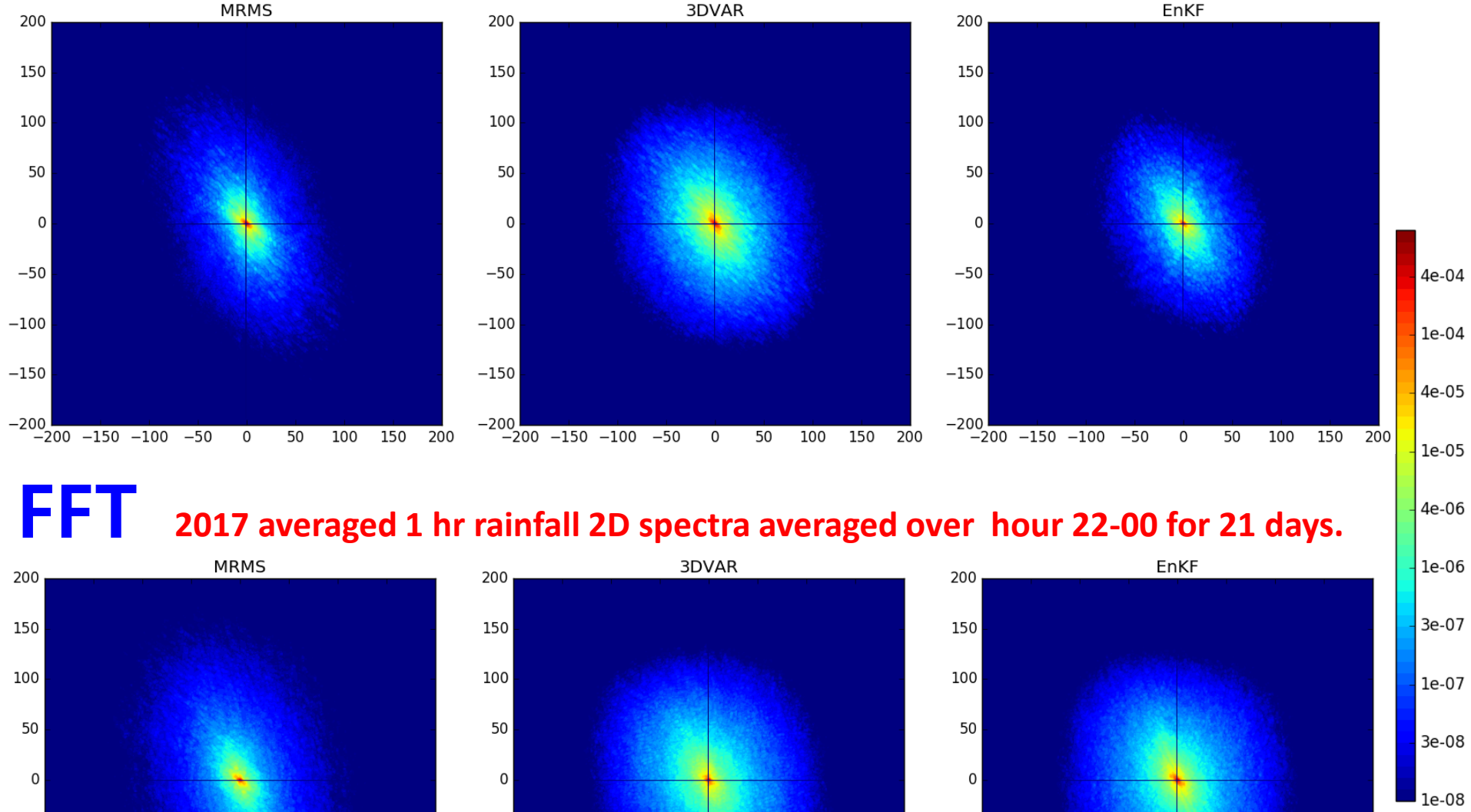


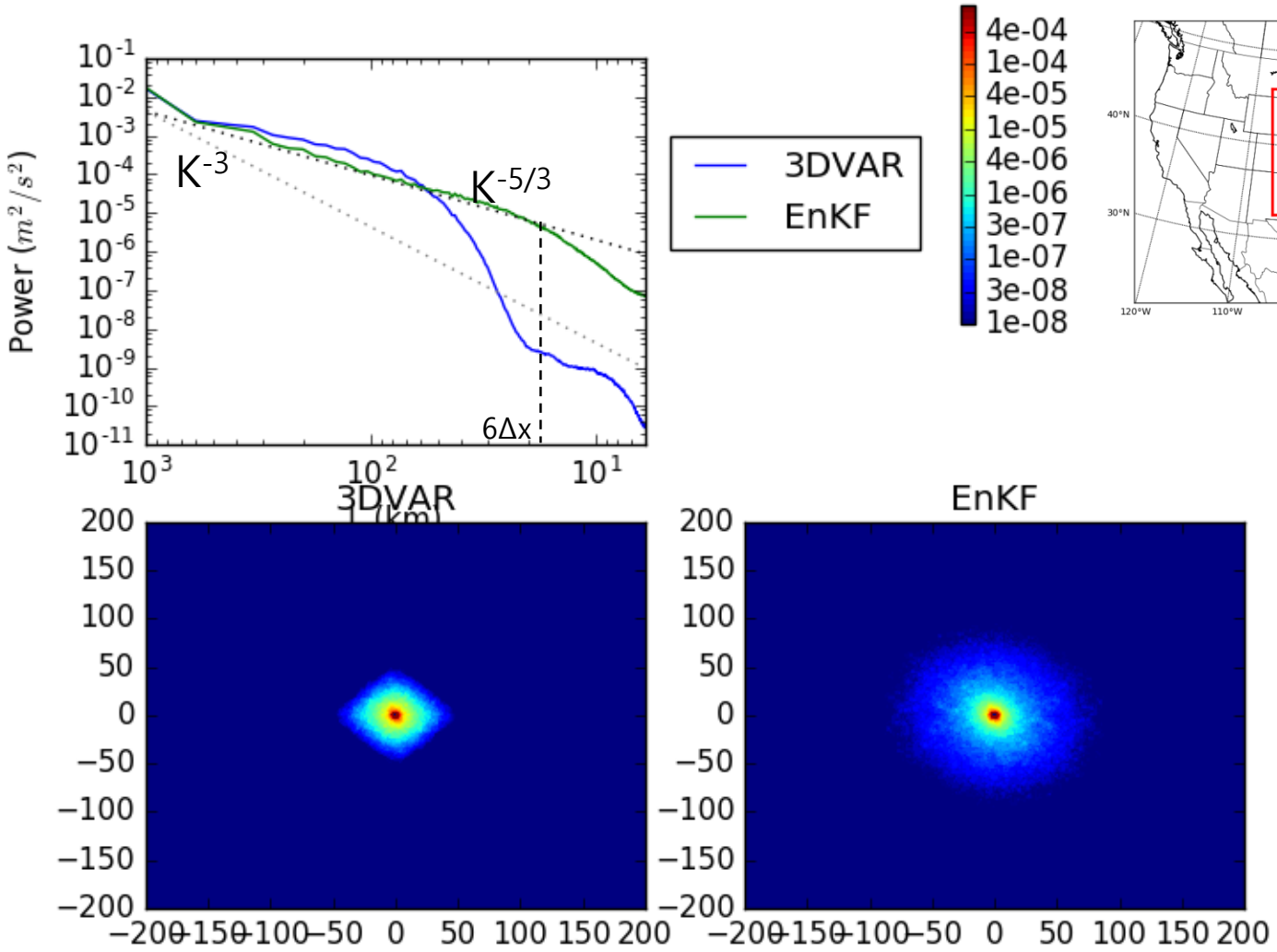
2017 averaged 1 hr rainfall 2D spectra averaged over hour 0-3 for 21 days.



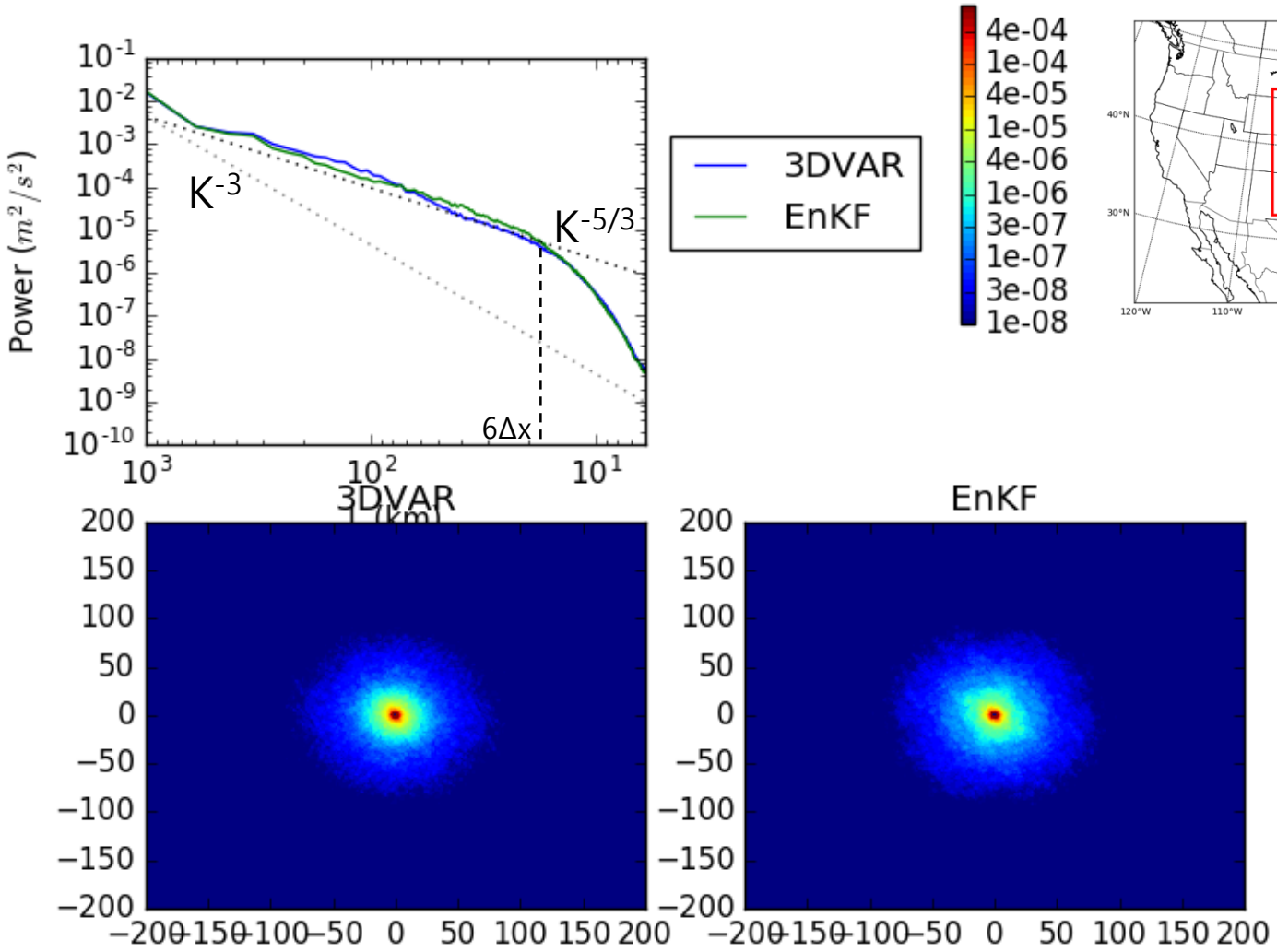
FFT

2017 averaged 1 hr rainfall 2D spectra averaged over hour 22-00 for 21 days.

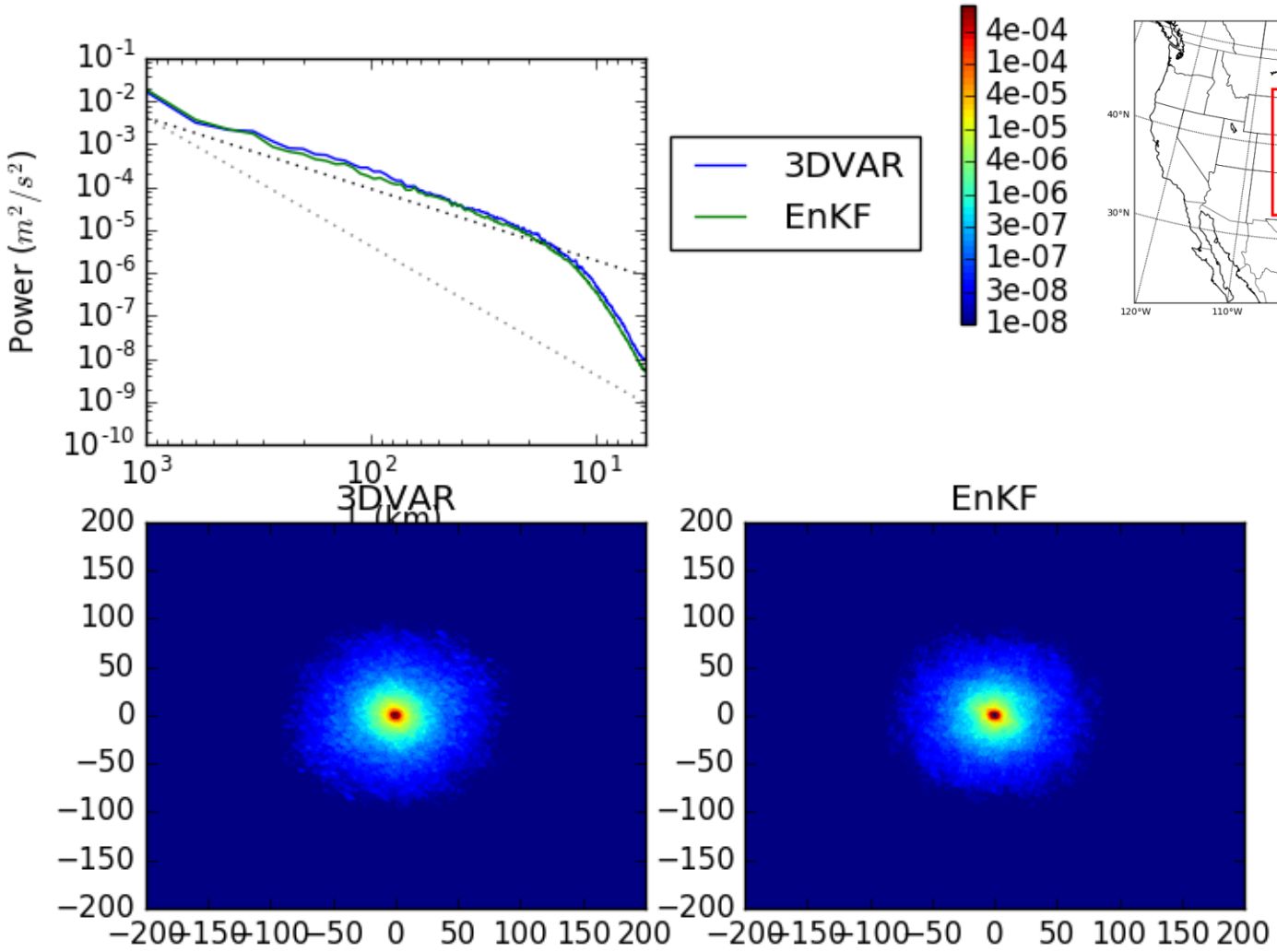
Horizontal Kinetic Energy
500 hPa, 0000 UTC



Horizontal Kinetic Energy
500 hPa, 0100 UTC



Horizontal Kinetic Energy
500 hPa, 0300 UTC



Summary

- Forecasts from the ensemble mean analysis outperforms individual ensemble members in general. The precipitation forecasts show large sensitivity to the choice of microphysics schemes.
- The EnKF forecasts are able to maintain the storm structure throughout the first forecast hour, suggesting that the EnKF analysis is well balanced. The system is able to develop reliable multivariate covariance among dynamic, thermodynamic, and microphysical variables and the prior estimates of radar observations.
- These results are preliminary and not a fair comparison. Mesonet, satellite, and aircraft data are not assimilated in the EnKF DA.
- The findings of this research will be used to optimize and further calibrate ensemble configurations to improve the prediction of convective-scale hazardous weather.
- An hybrid DA system based on this EnKF system and GSI-3DVAR is being developed and will be tested later.

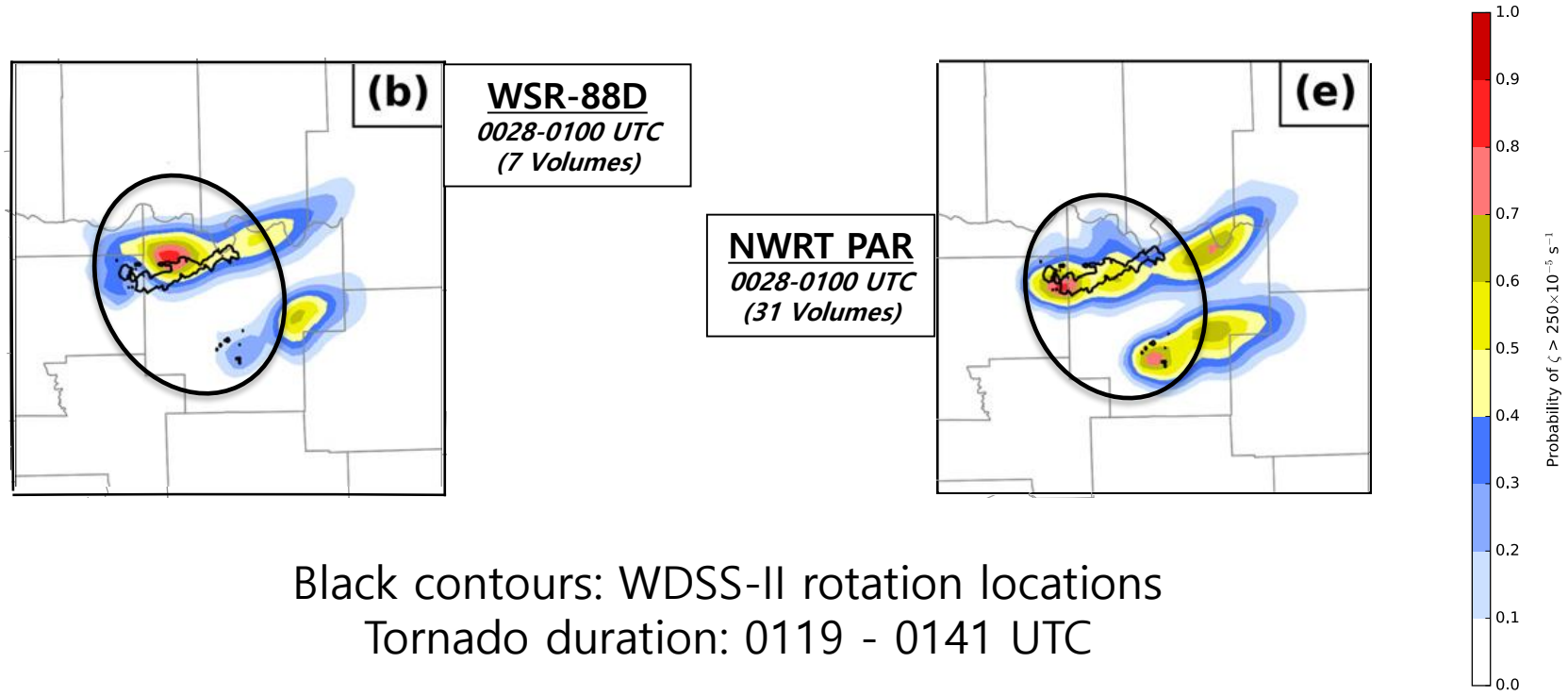
Relevant Projects

- Spectrum Efficient National Surveillance Radar Program (SENSR)
- Warn-on-Forecast (WoF)
- Key points:
  - Continuous rapid-update (≤ 5 min), cycled storm-scale ensemble DA and forecasts
  - WRF + GSI-EnKF
  - High-resolution (≤ 1 km) ensemble forecasts

Rapid-scan NWRT PAR

22 May 2011 Ada, OK

1-h forecast probability of vertical vorticity



Black contours: WDSS-II rotation locations
Tornado duration: 0119 - 0141 UTC

Supinie et al., 2017: "Comparison of the analysis and forecasts of a tornadic supercell storm from assimilating phased-array radar and WSR-88D observation, Wea. Forecasting, 32, 1379–1401.