Evaluating FV3 Model for Convection-Permitting Forecasting over CONUS in the 2017 HWT Spring Experiment and HMT FFaIR Experiment

Presented by Ming Xue
Center for Analysis and Prediction of Storms and School of Meteorology
University of Oklahoma

CAPS Team: Tim Supinie, Chunxi Zhang, Fanyou Kong, Youngsun Jung, Kevin Thomas, Keith Brewster, Nathan Snook

With inputs from Corey Potvin and Adam Clark of NSSL
Lucas Harris and SJ Lin of GFDL

April 10, 2018
TBPG Workshop, Kansas City, MO

mxue@ou.edu

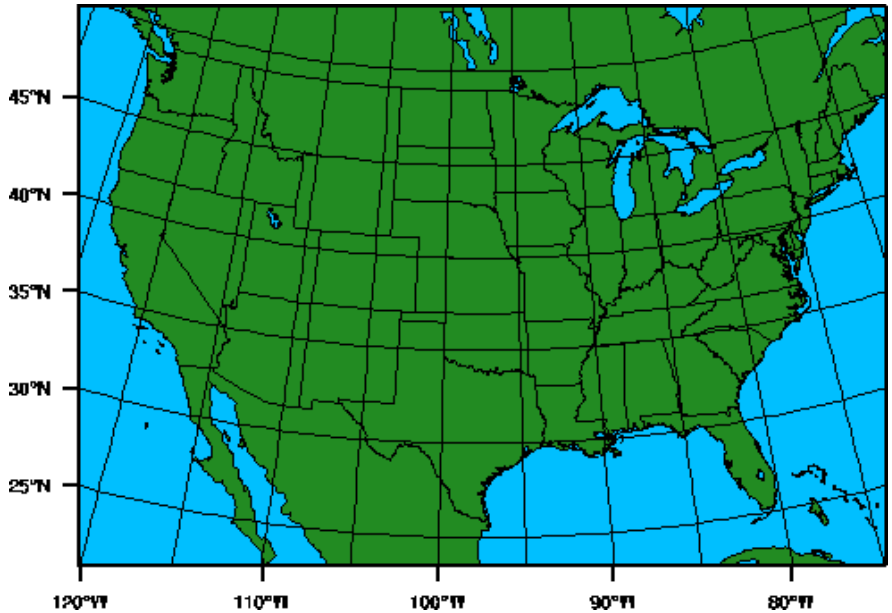
ARPS Simulated Tornado

Background

- **The Center for Analysis and Prediction of Storms (CAPS) at the University of Oklahoma is supported by the CSTAR, HWT and HMT Programs to contribute to the HWT Spring Forecast Experiment (SFE) and HMT Flash-Flood and Intense Rainfall (FFaIR) Experiment**
  - In 2017, 34 WRF-ARW ensemble forecasts (SSEF) on 3-km CONUS grid with 60-hr forecasts from 00Z
  - Multi-physics/single physics/stochastic physics
  - 3DVAR/cloud analysis and EnKF DA
- **With NGGPS Program support, 120hr FV3 convection-allowing forecasts are added in 2017**
  - ~3 km over CONUS, two-way nested within simultaneous global run
  - Thompson microphysics (added by CAPS)
  - GFDL ran another version with Lin-like microphysics

2017 CAPS 3km SSEF and FV3 Domains (run for 2017 HWT SFE and HMT FFaIR Experiments)

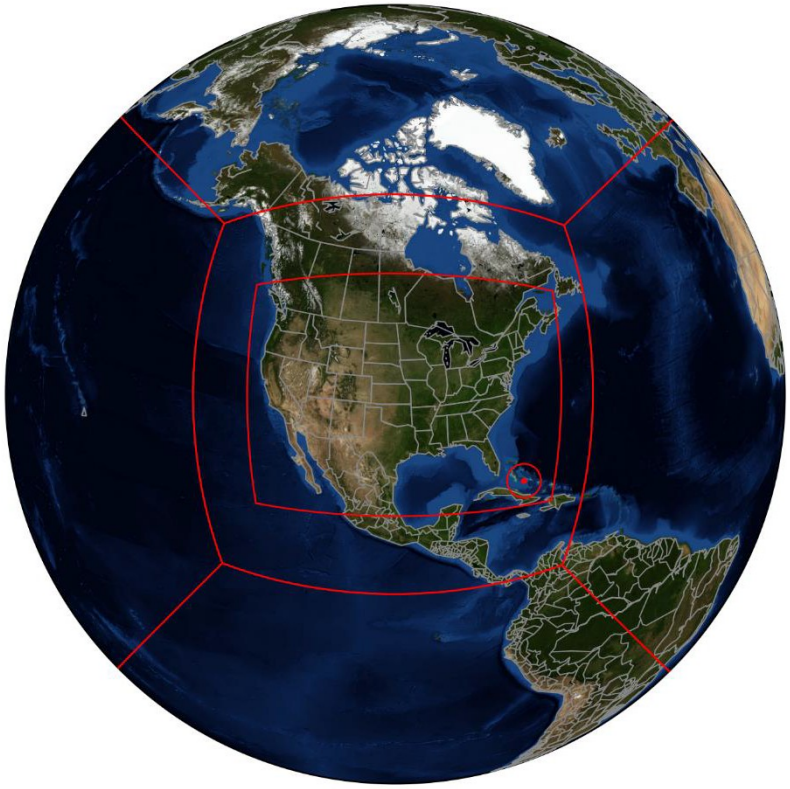
HWT: 5 weeks in May and early June. HMT: 4 weeks in June and July



3 km WRF Grid 1620x1120

Shared with other CLUE members

Once a day starting from 00 UTC

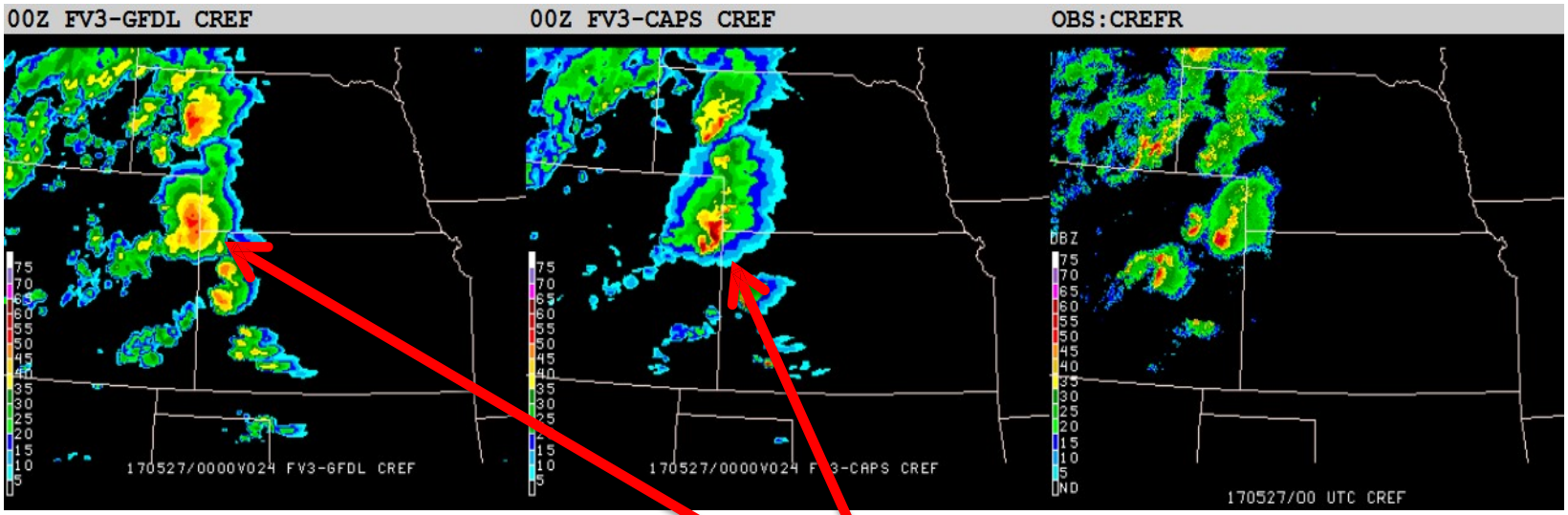


Nested FV3 Grid ~ 3 km over CONUS stretched global grid with average 13 km grid spacing Coordinated with GFDL run

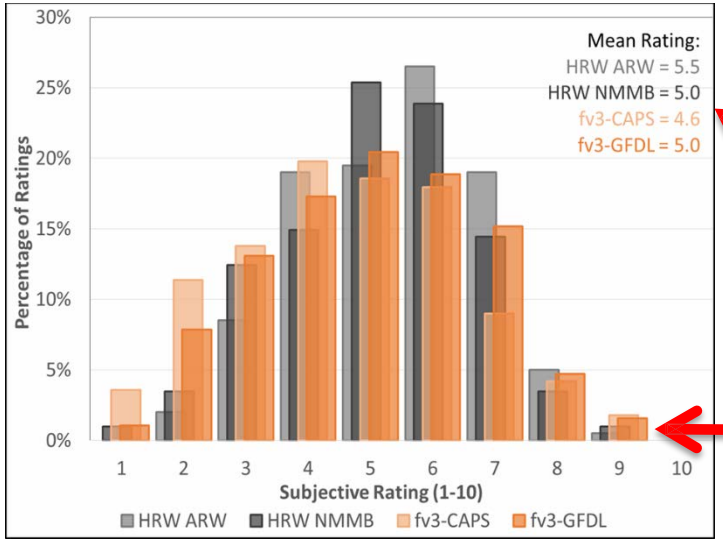
FV3 Configurations for 2017 HWT SFE and HMT FFaIR

- Microphysics
  - FV3_CAPS: Thompson MP
  - FV3_GFDL: GFDL MP (based on WSM-6)
- Cumulus
  - Scale-aware SAS (Global), None (Nest)
- PBL
  - MRF (from GFS)
- Radiation
  - RRTM
- Land surface model
  - NOAH
- Initial condition
  - Cold-started from 00Z GFS T1534 analysis every day
- LBC: two-way nested within global grid

FV3 in HWT 2017 – Subjective Evaluations



Example of subjective comparison plots used for rating CAM performance at convective scales.
24-h forecast of composite reflectivity of FV3-GFDL (left), FV3-CAPS (middle) and , observed (right) at 0000 UTC on 27 May 2017.



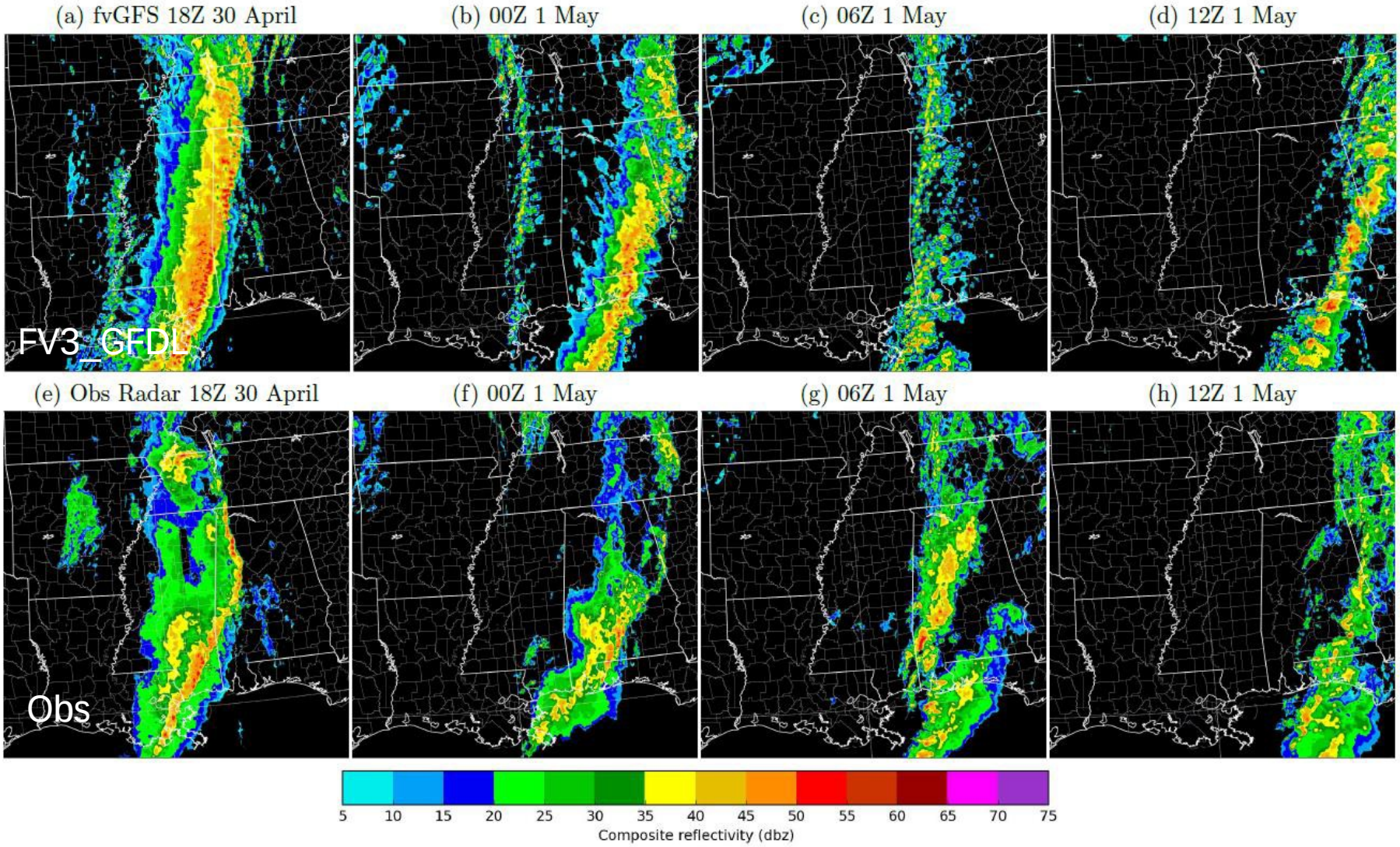
Note the different character in simulated reflectivity – left uses GFDL microphysics, right uses Thompson.

According to SFE participant ratings, FV3 is competitive with operational CAMs

FV3 obtained more 9 ratings than others

(from Adam Clark of NSSL)

FV3_GFDL forecast (upper) and observed composite reflectivity from 00 Z April 30



t = 18 h t = 24 h t = 30h t = 36 h

Figure 12. Composite reflectivity from fvGFS forecast initialized 00Z 30 April 2017 (top row, a–d) and observations (bottom row, e–h). Henceforth, all 3-km model output depicts shaded unsmoothed native nested-grid cells, unless otherwise stated.

From Harris et al. (2018 JGR Submitted)

FV3_GFDL forecast (upper) and observed composite reflectivity from 00 Z May 27
A severe derecho case

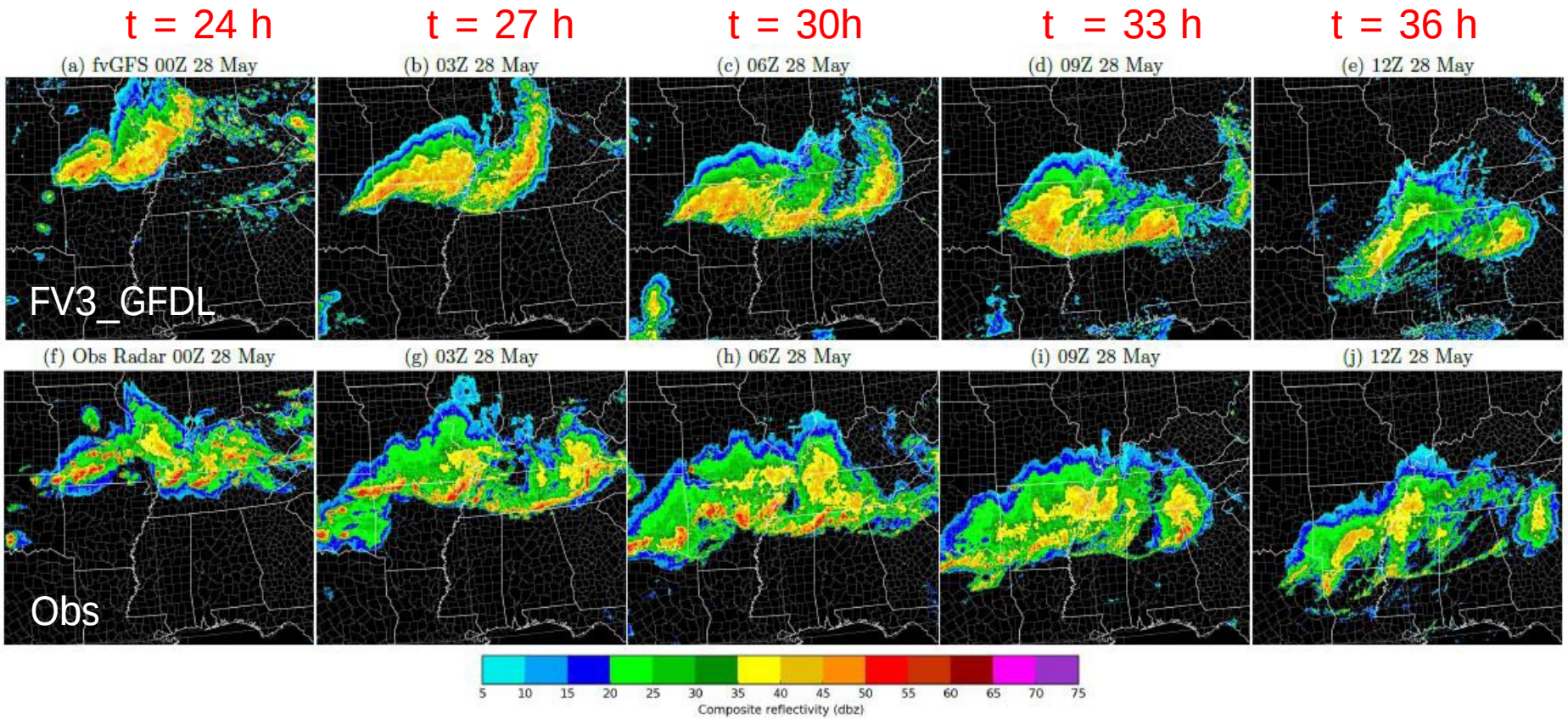
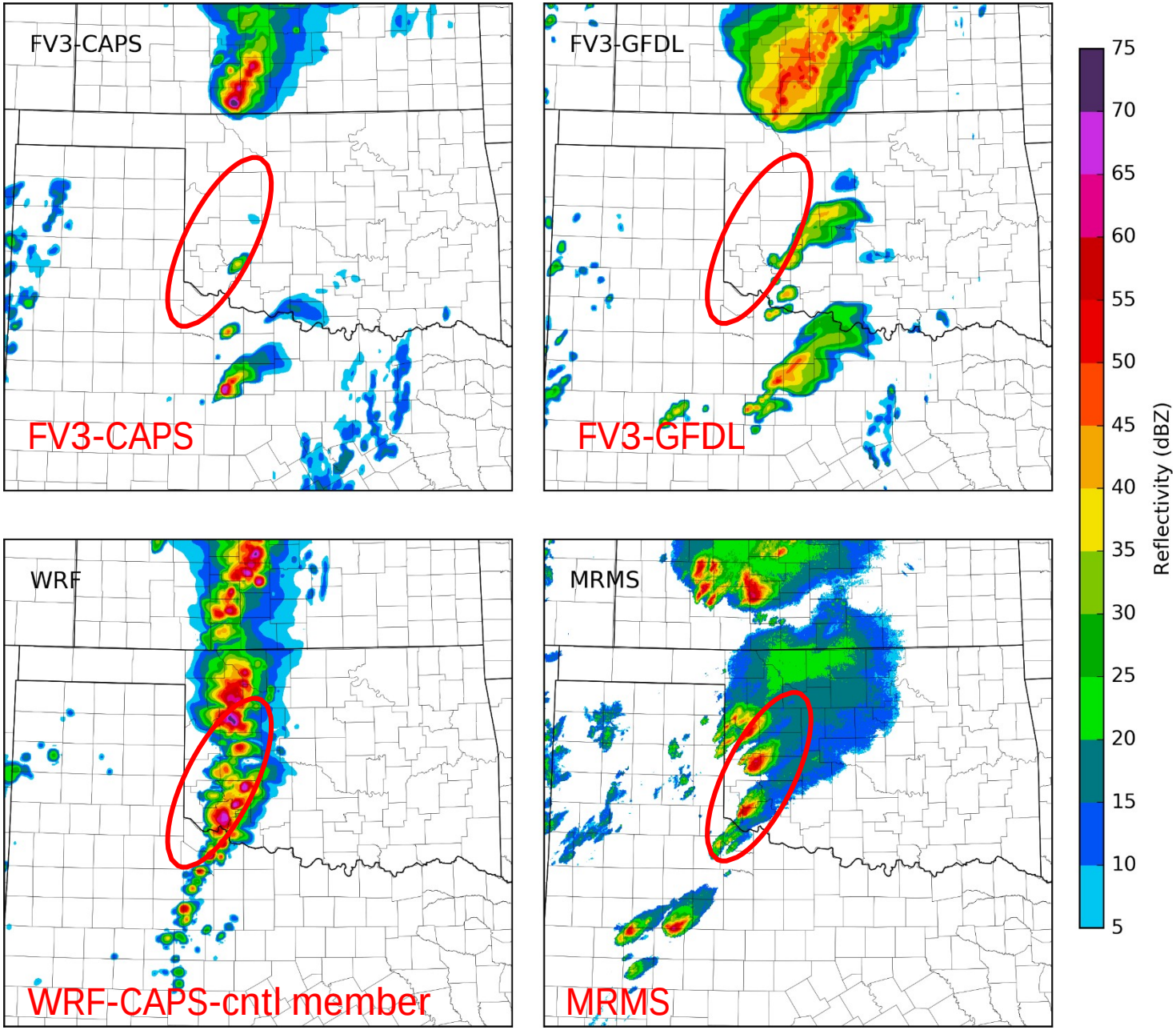


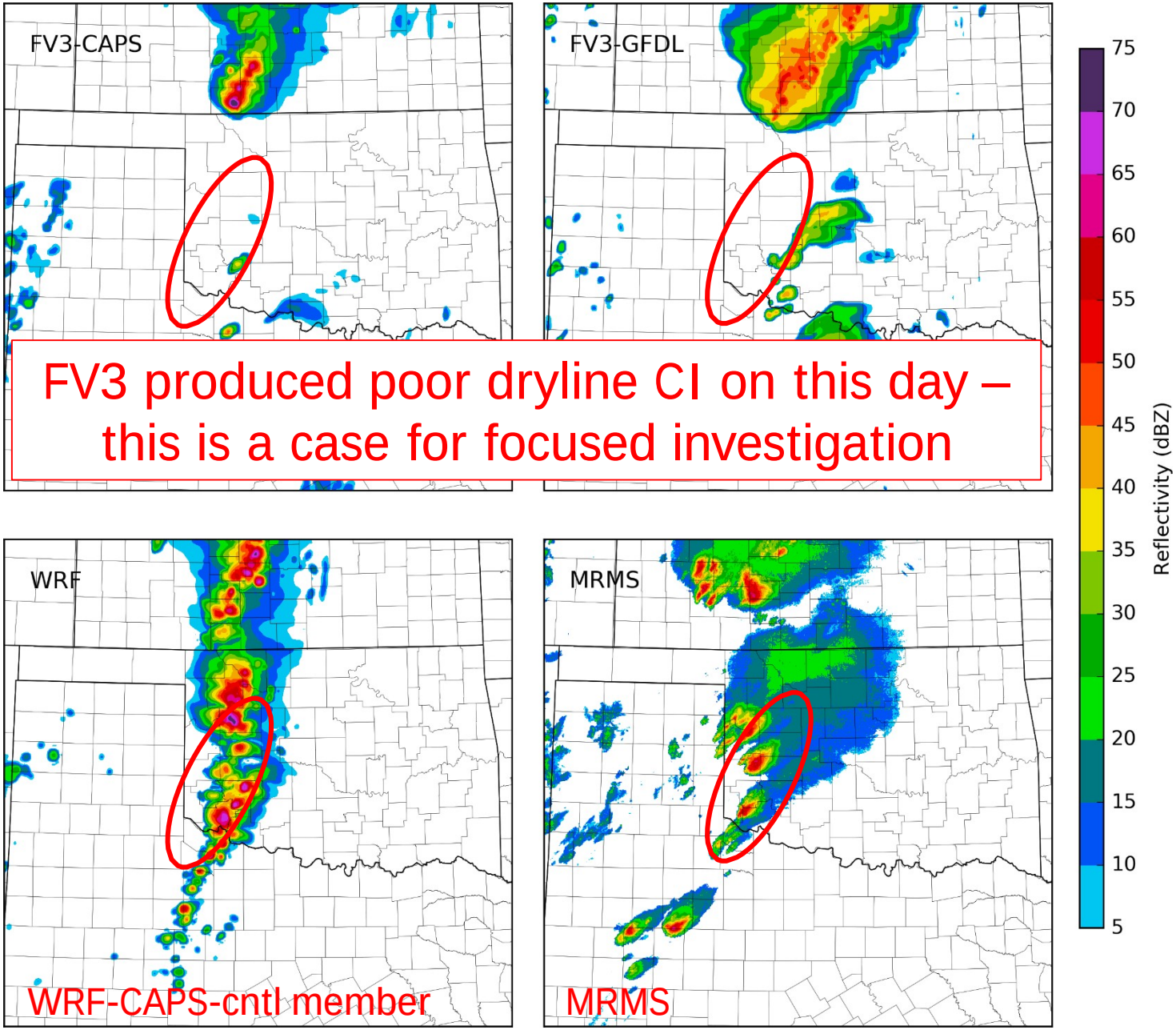
Figure 19. As in Figure 12, but for the forecast initialized 00Z 27 May 17.

From Harris et al. (2018 JGR Submitted)

Composite Reflectivity (+24h @00Z 17 May 2017)

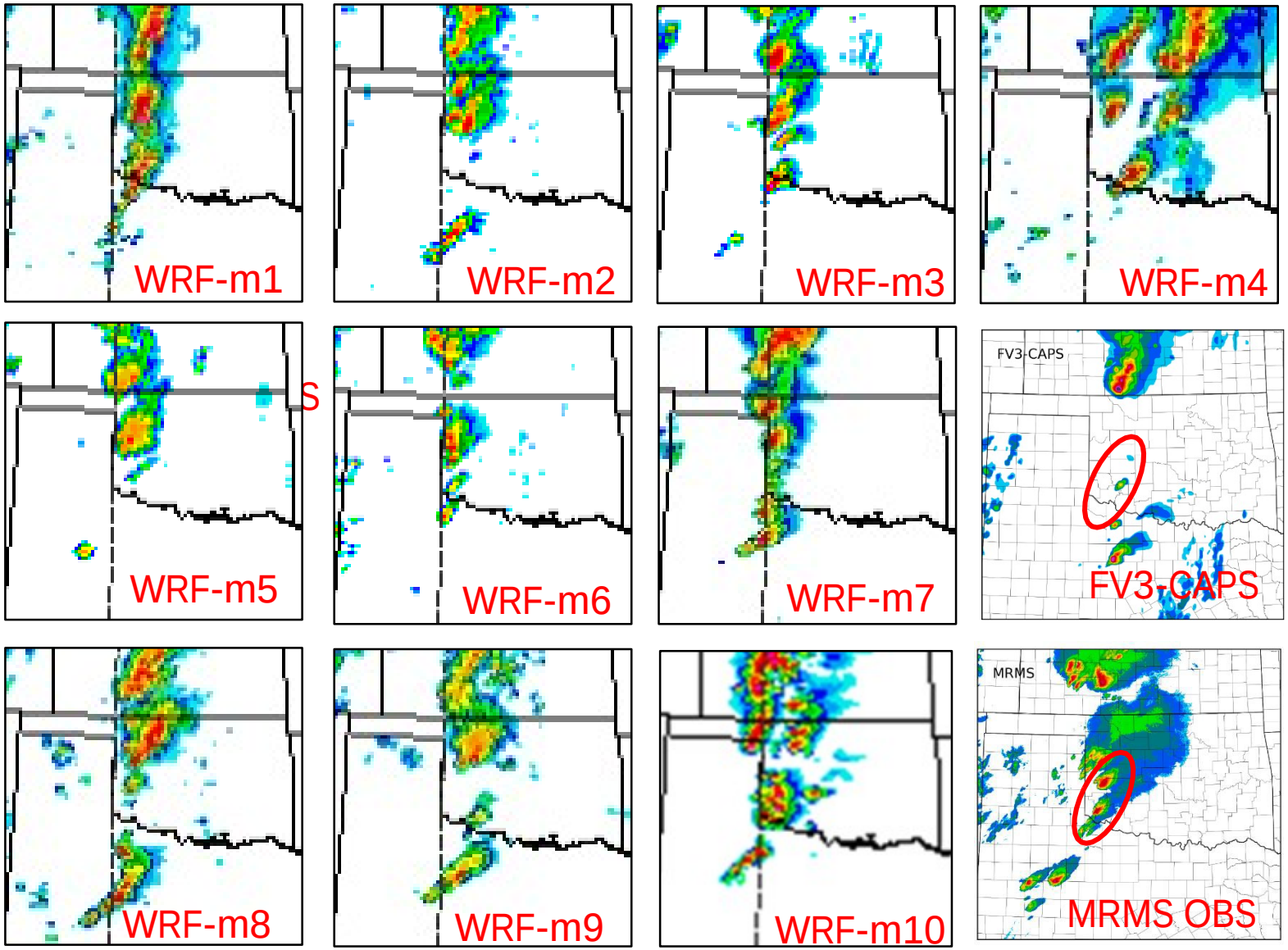


Composite Reflectivity (+24h @00Z 17 May 2017)



FV3 produced poor dryline CI on this day – this is a case for focused investigation

16 May 2017 Composite Reflectivity (00Z 17 May)

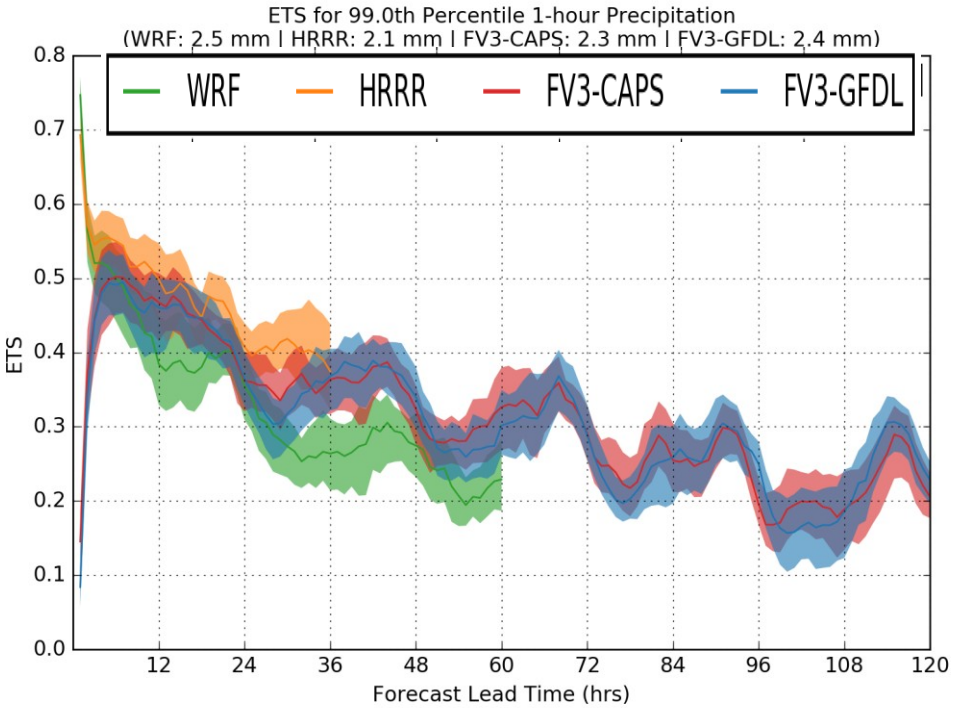


t = 24h

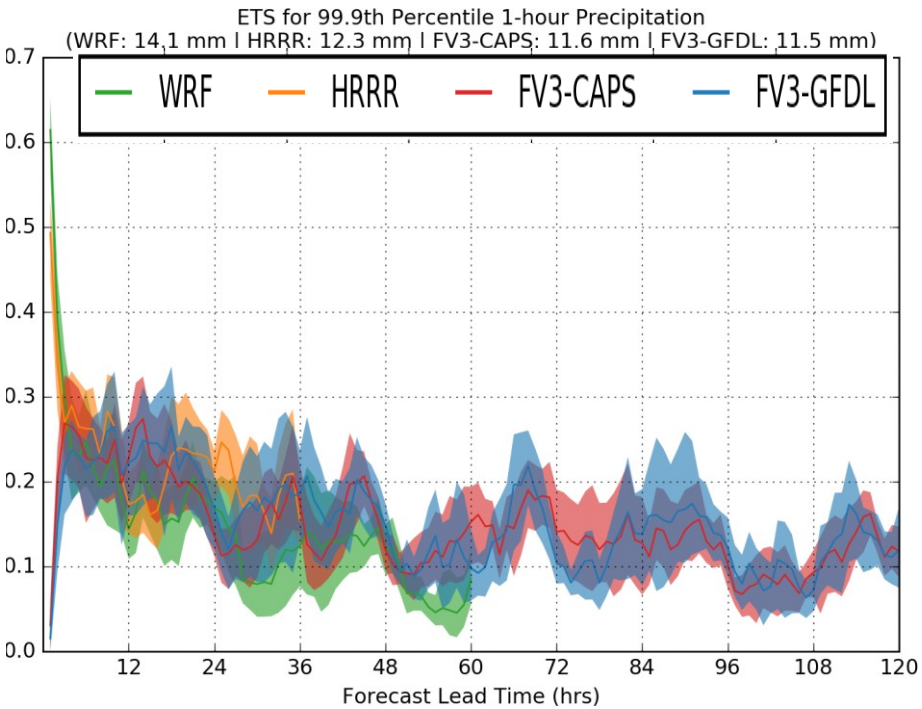
Large Variability among WRF multi-physics ensemble forecasts of CAPS

Neighborhood Hourly Precip ETS (HWT) – 19days

99th Percentile (~2.4 mm/s)



99.9th Percentile (~11 mm/s)

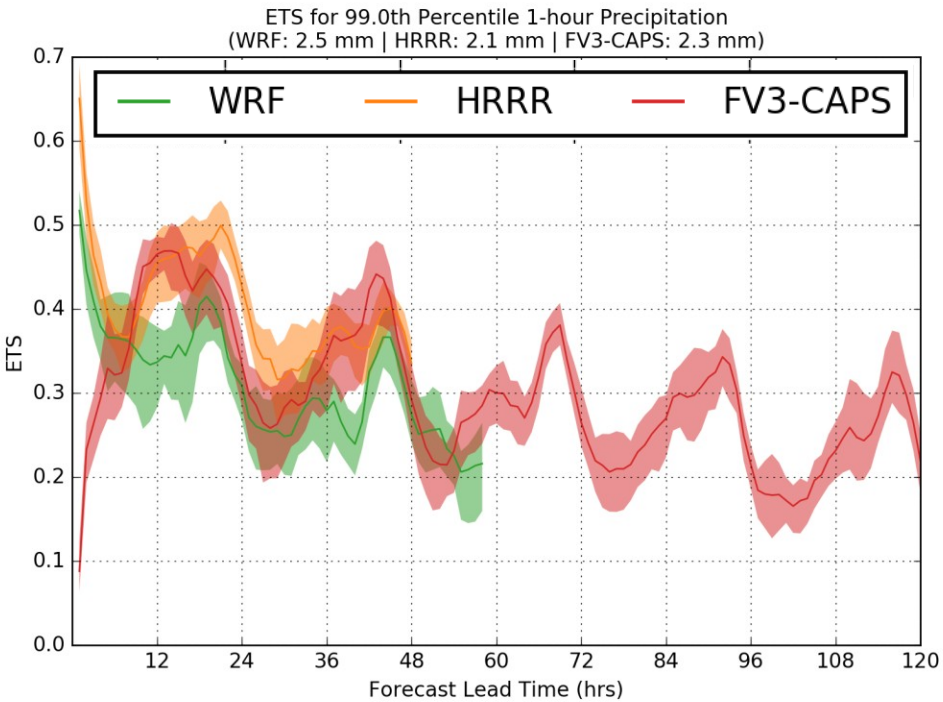


R=45 km

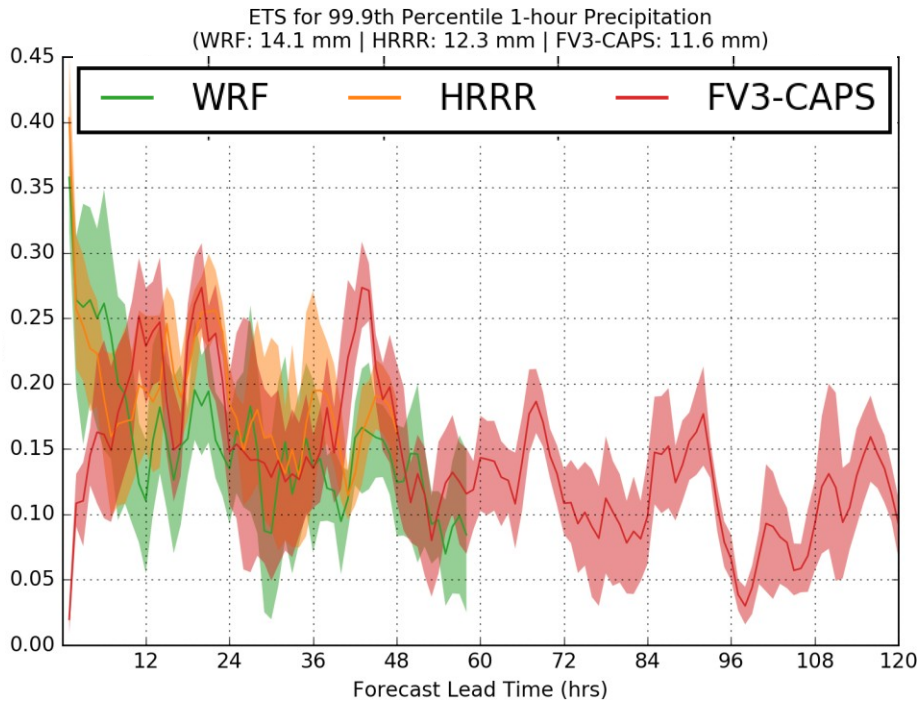
Shading is 90% confidence interval on bootstrap resampled (10000 times) set of forecasts

Neighborhood Hourly Precip ETS (HMT) – 10days

99th Percentile Intense (~2.4 mm/s) precip



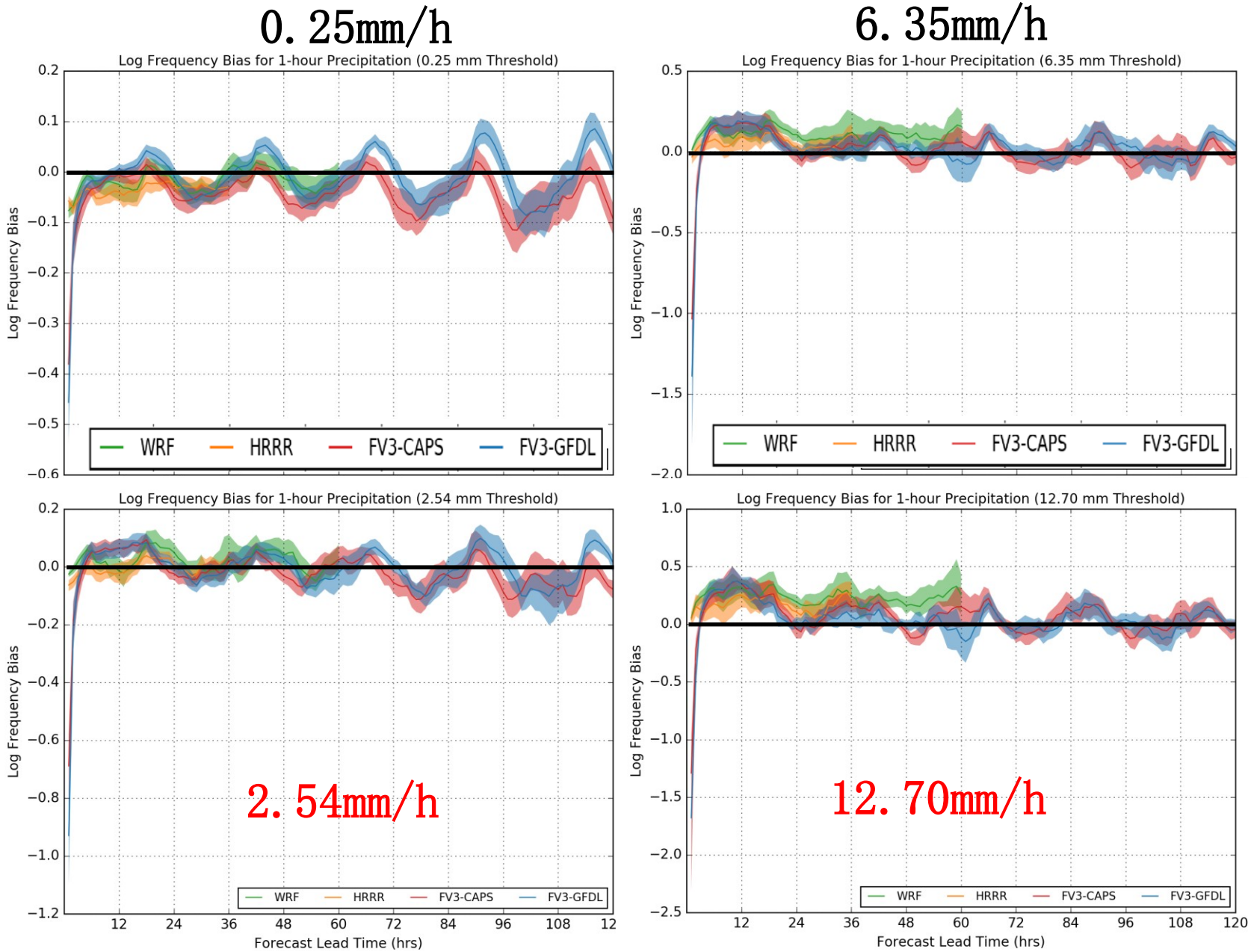
99.9th Percentile (~11 mm/s) precip



R=45 km

Shading is 90% confidence interval on bootstrap resampled (10000 times) set of forecasts

Log Frequency Bias (HWT)



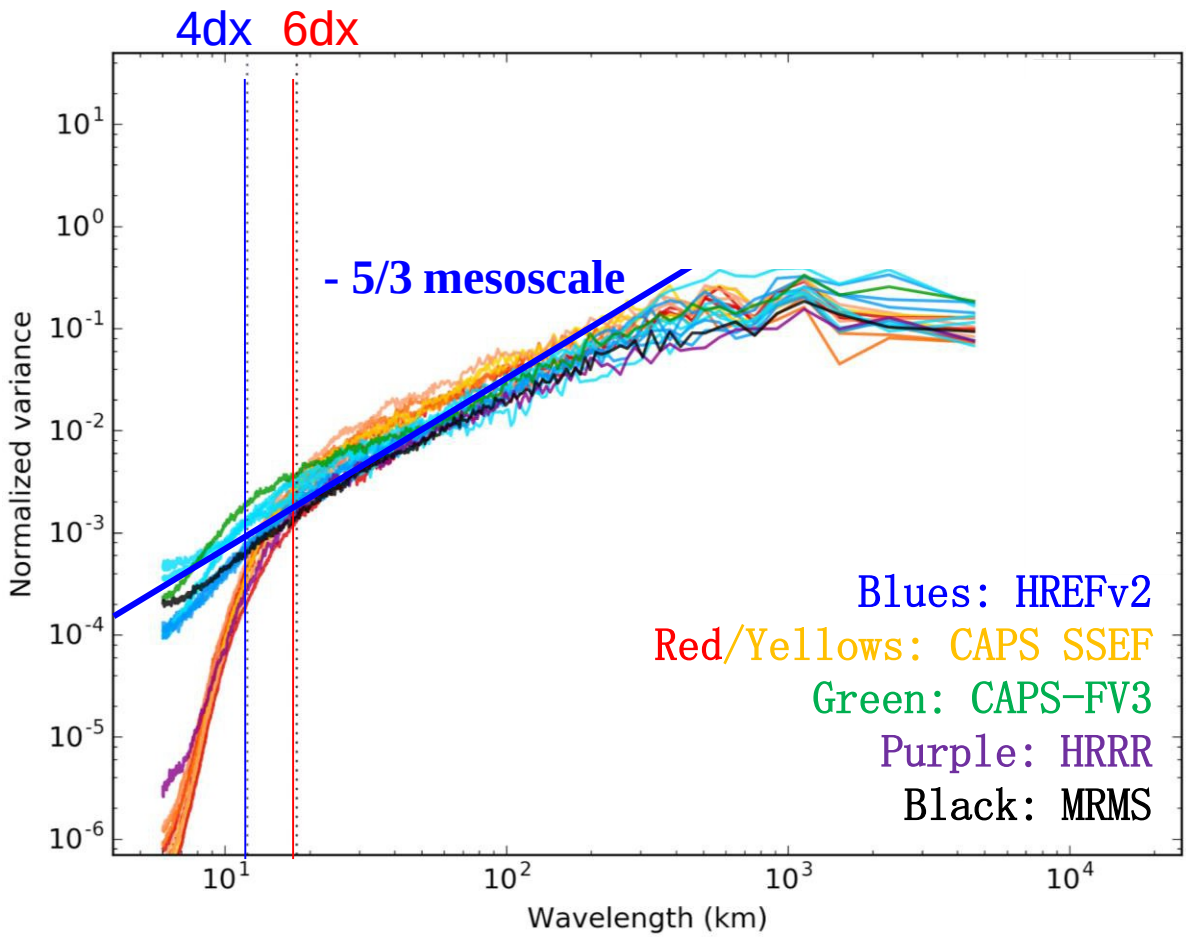
Power Spectra (3-Hourly Precipitation)

Surcel et al. (2014)

12-hour forecasts

Average of 4 cases during the FFaIR Experiment

Radically different behavior between FV3 and HRRR/SSEF

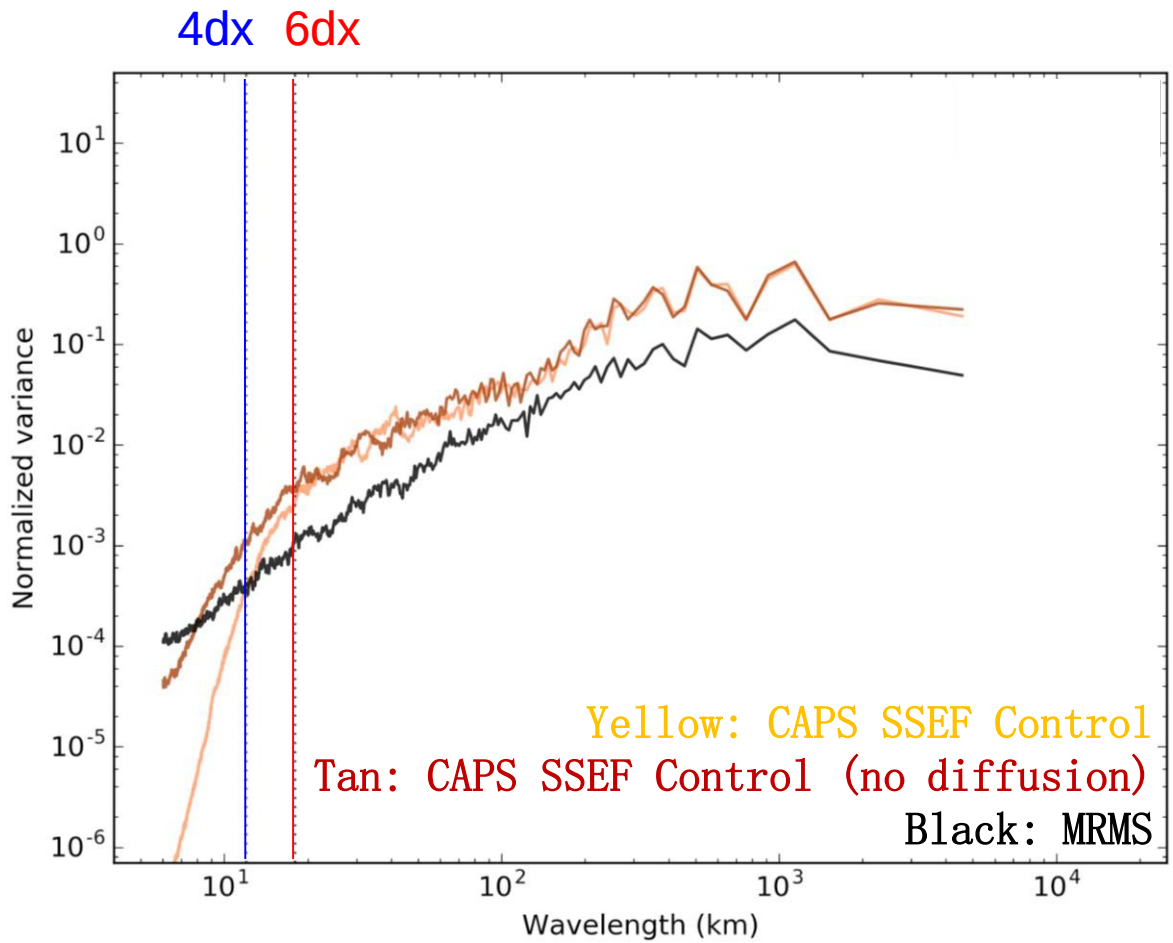


Plot by Nate Snook

Power Spectra (3-Hourly Precipitation)

Try with 6th order diffusion off (one test case)

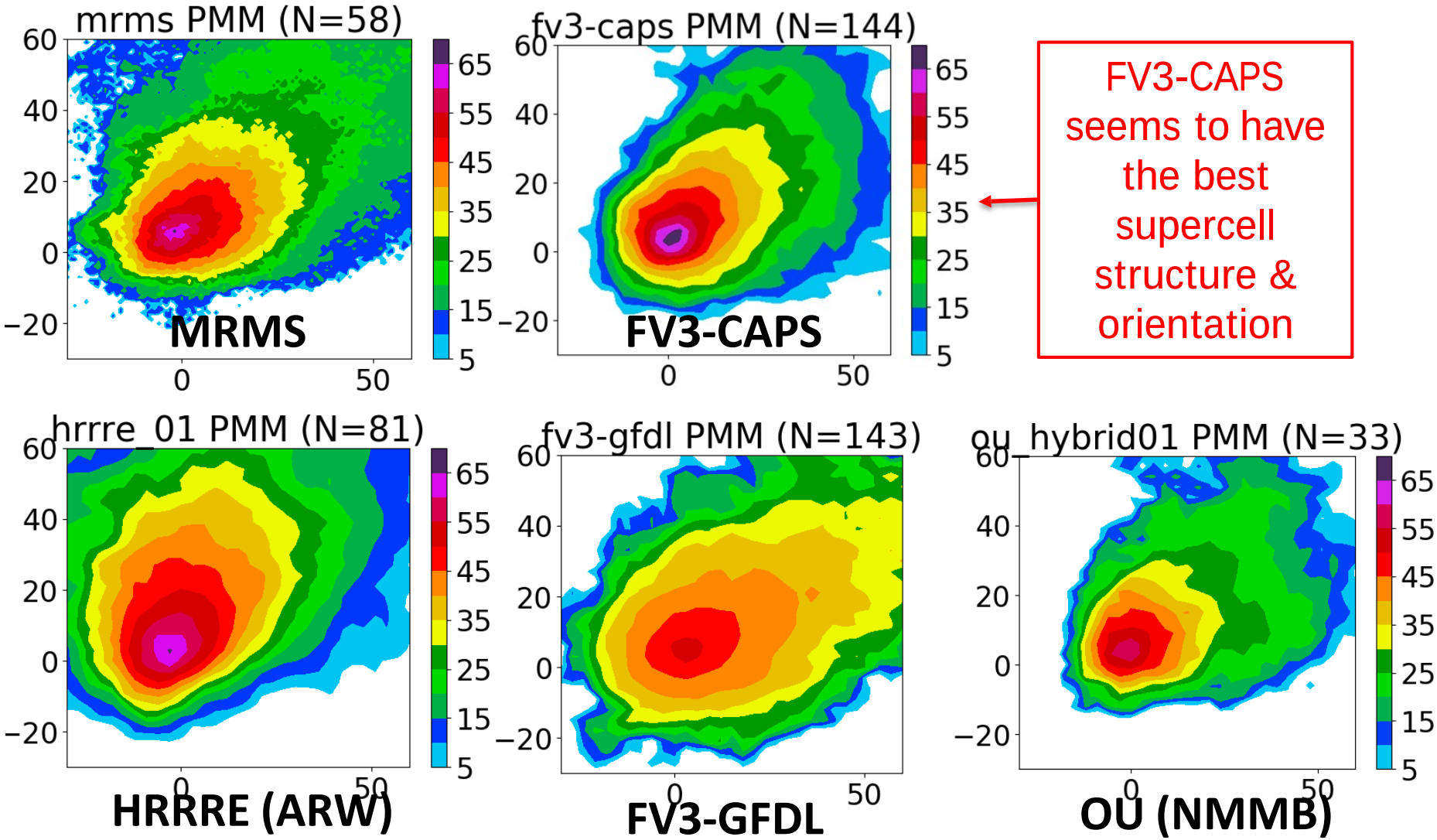
Aggressive diffusion leads to drop in power at scales smaller than ~6Δx



Plot by Nate Snook

Supercell Composite dBZ

break down well by dynamical core



FV3-CAPS seems to have the best supercell structure & orientation

Orientation too northward

From Corey Potvin/NSSL

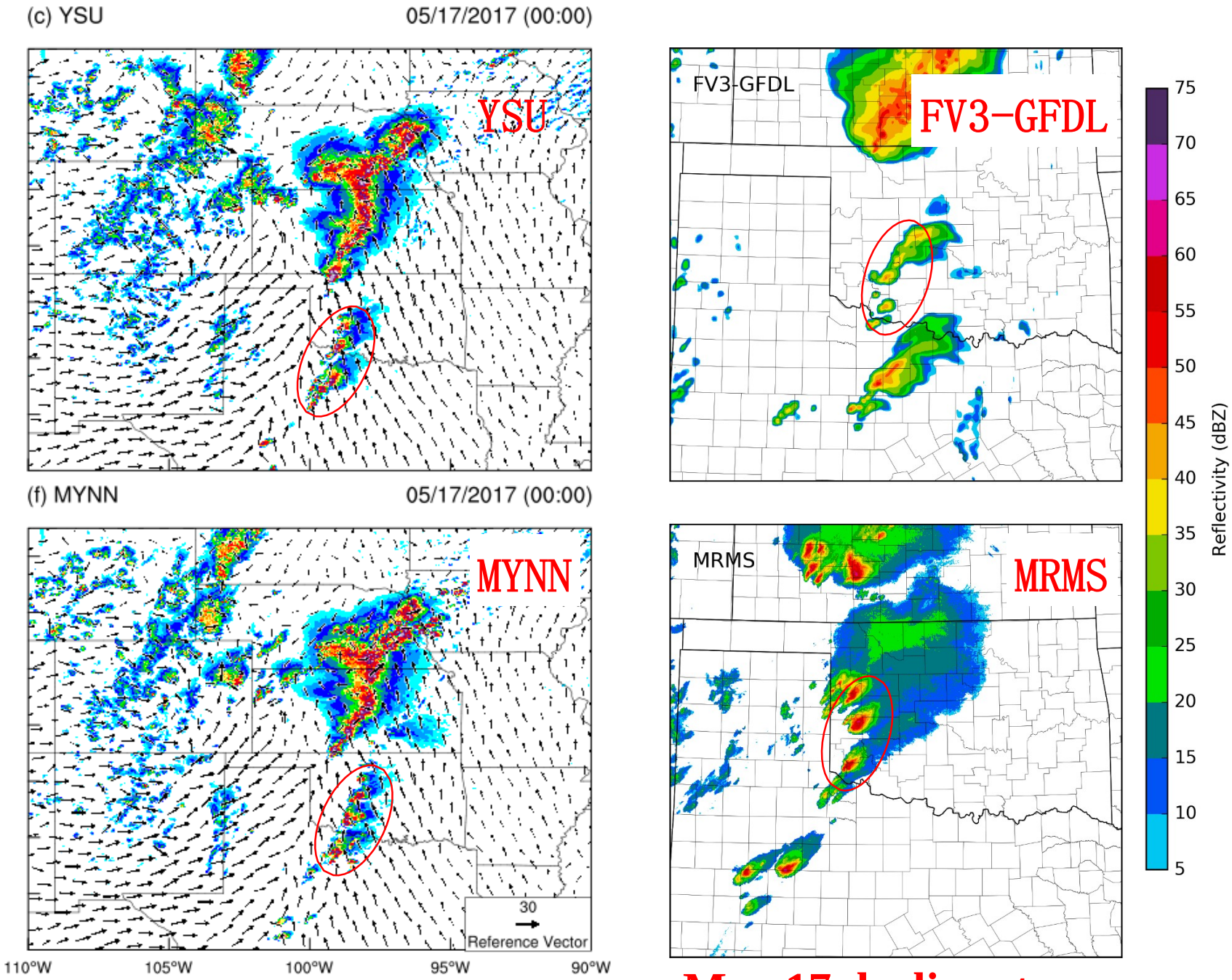
Summary on HWT and HMT Results

- FV3 HWT and HMT forecasts appear generally comparable with WRF-based (CAPS SSEF and HRRR) forecasts;
  - The difference between FV3 and WRF forecasts appear within the variability/uncertainty of WRF ensemble members;
  - The models do show different precipitation biases
- At longer forecast ranges, FV3 performed better than CAPS WRF control member;
- FV3 and WRF have similar precipitation power spectra when numerical diffusion is minimized;
- FV3_CAPS seems to produce the best composite supercell structures and orientation.

Physics Schemes CAPS Implemented in FV3 since 2017 HWT/HMT Experiments

(based on the most recent version of FV3 from GFDL)

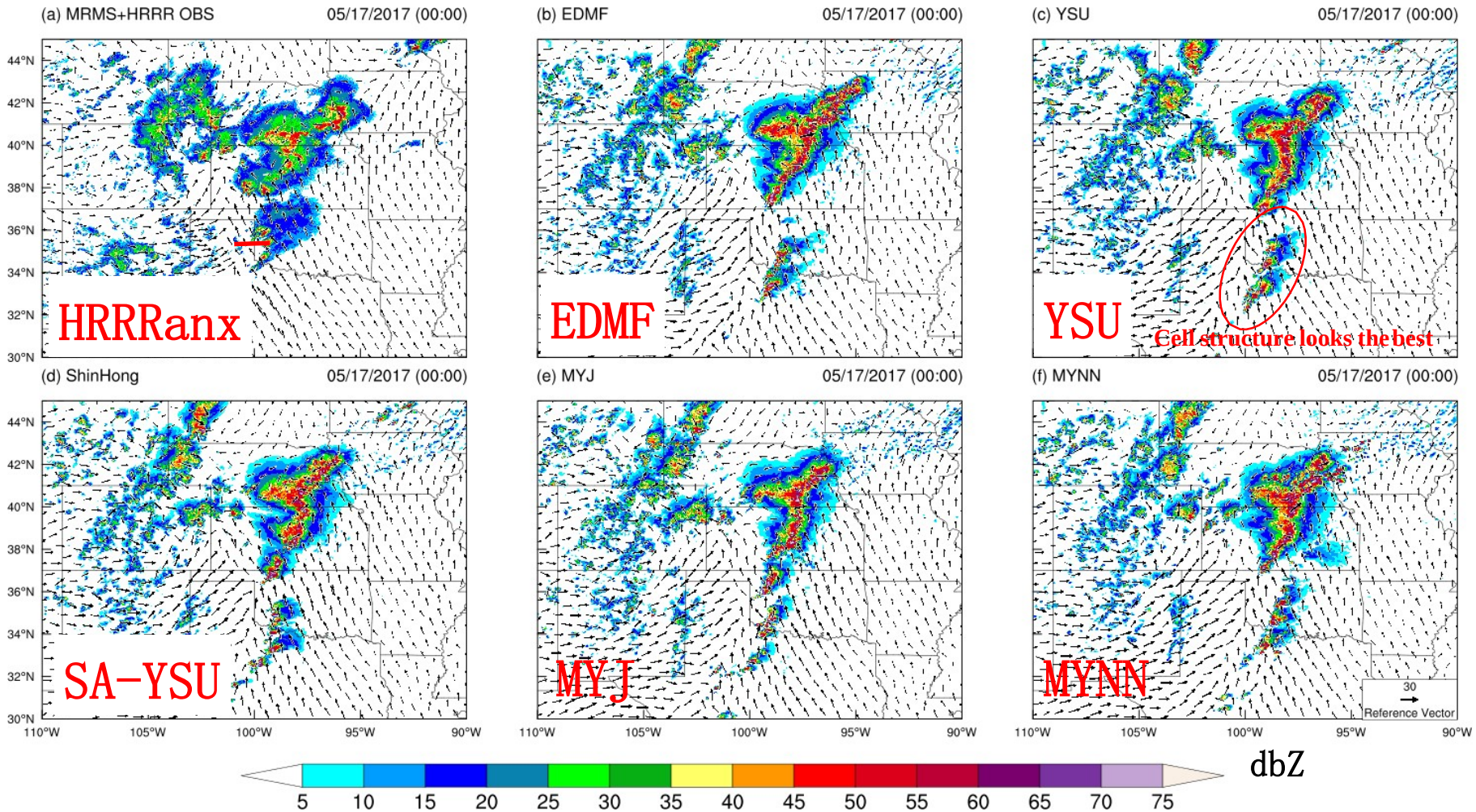
- **5 Microphysics Scheme**: Thompson, NSSL, MY, and Morrison two-moment schemes
- **5 PBL Schemes**: YSU, Scale-aware YSU, MYJ, MYNN, scale-aware MYNN, and E-epsilon
- **1 Cumulus Scheme**: New Tiedtke with both deep and shallow convection.



May 17 dryline storm case

Composite Reflectivity & Surface Wind Vectors (HRRR anx+MRMS and FV3 Forecasts)

t=24h



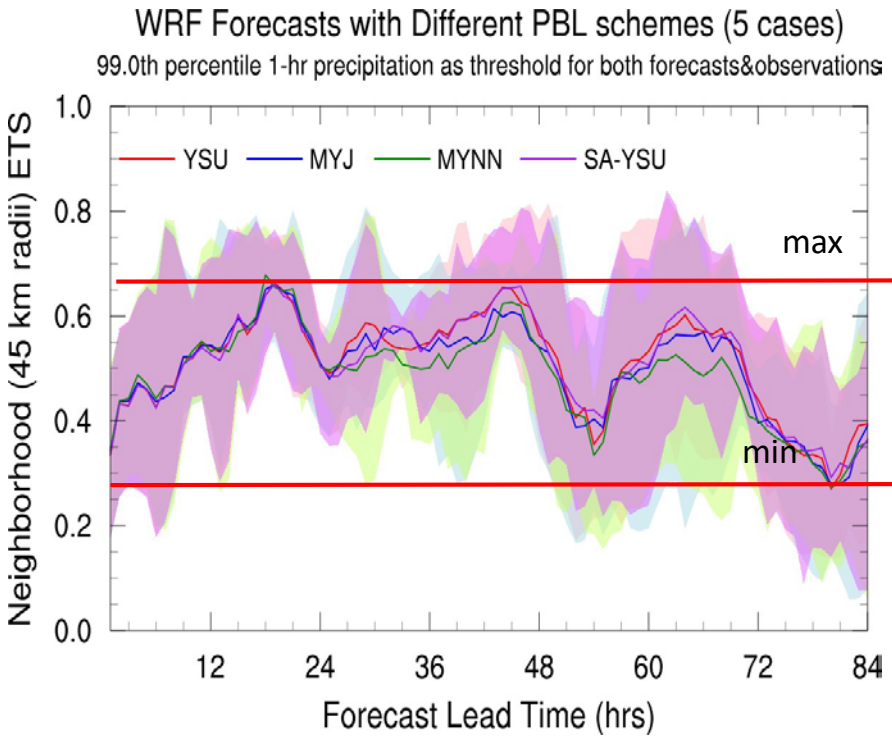
YSU and MYNN produced better supercell forecasts than others but still positioned too far east

Comparison of WRF and FV3 with different PBL Schemes with same GFS IC and Thompson MP

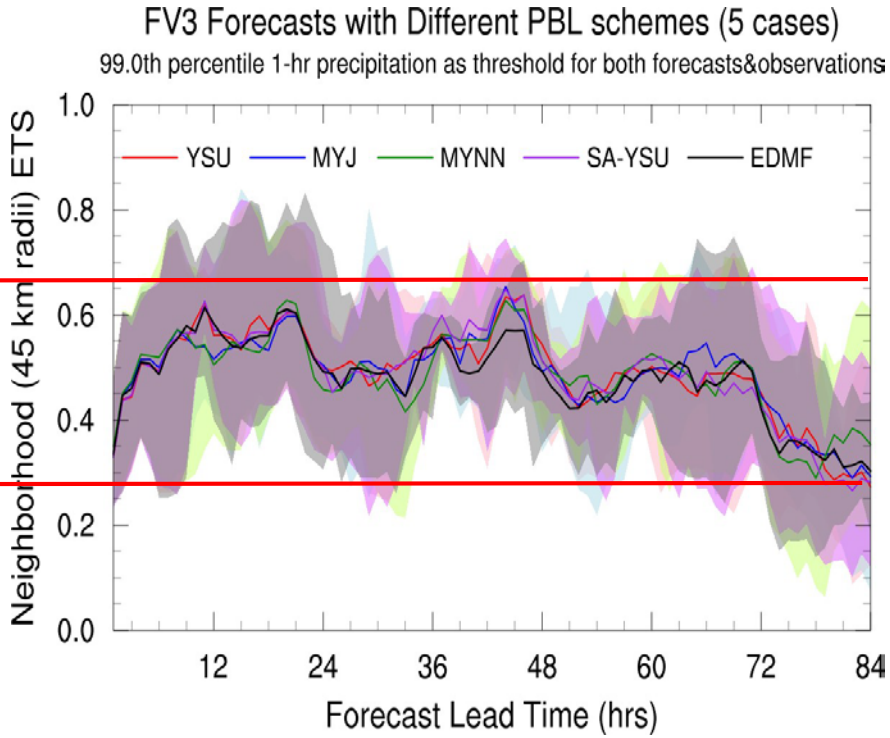
Five cases (3 from 2017 HWT, 2 from 2017 HMT) May 12, 16, 19 and July 14, 19 2017

99 Percentile Neighborhood ETS (45 km radii)

WRF



FV3

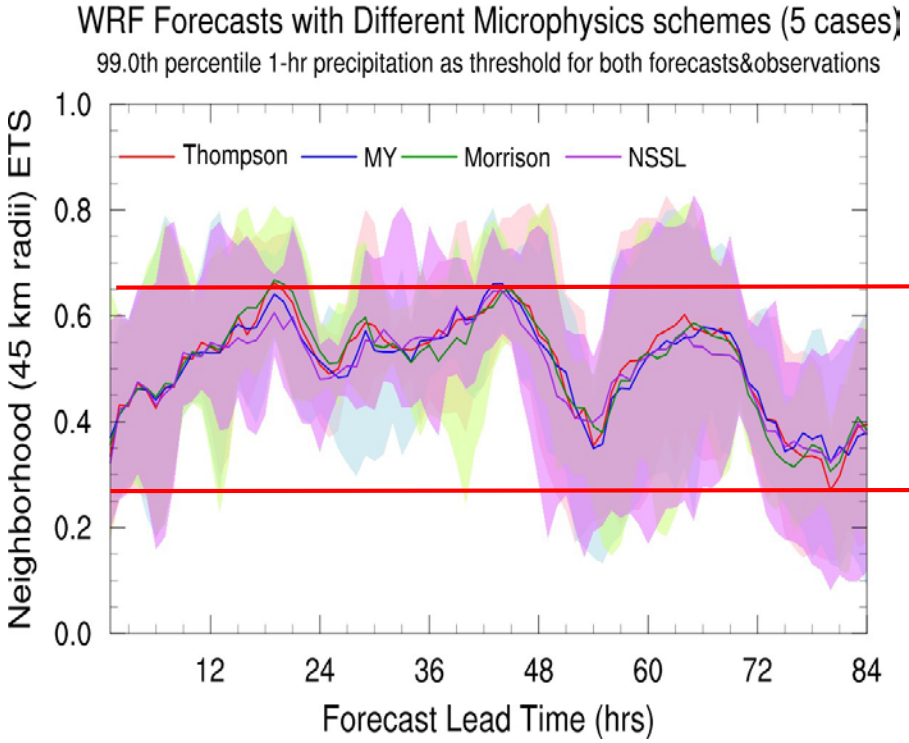


Comparison of WRF and FV3 with different microphysics Schemes with same GFS IC and EDMF PBL

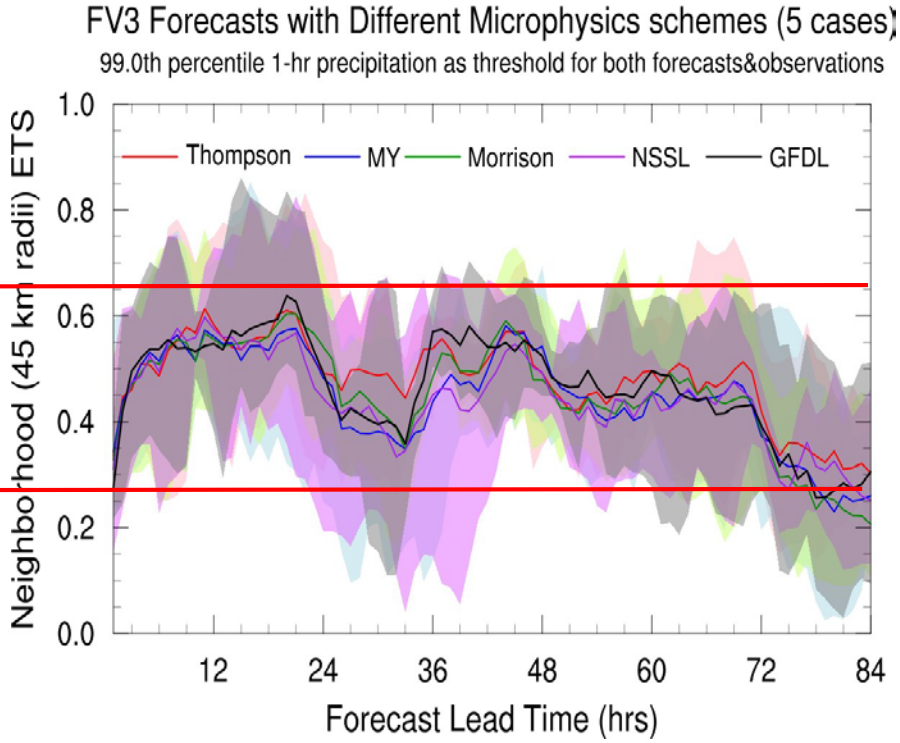
Five cases (3 from 2017 HWT, 2 from 2017 HMT)
May 12, 16, 19 and July 14, 19 2017

99 Percentile Neighborhood ETS (45 km radii)

WRF



FV3

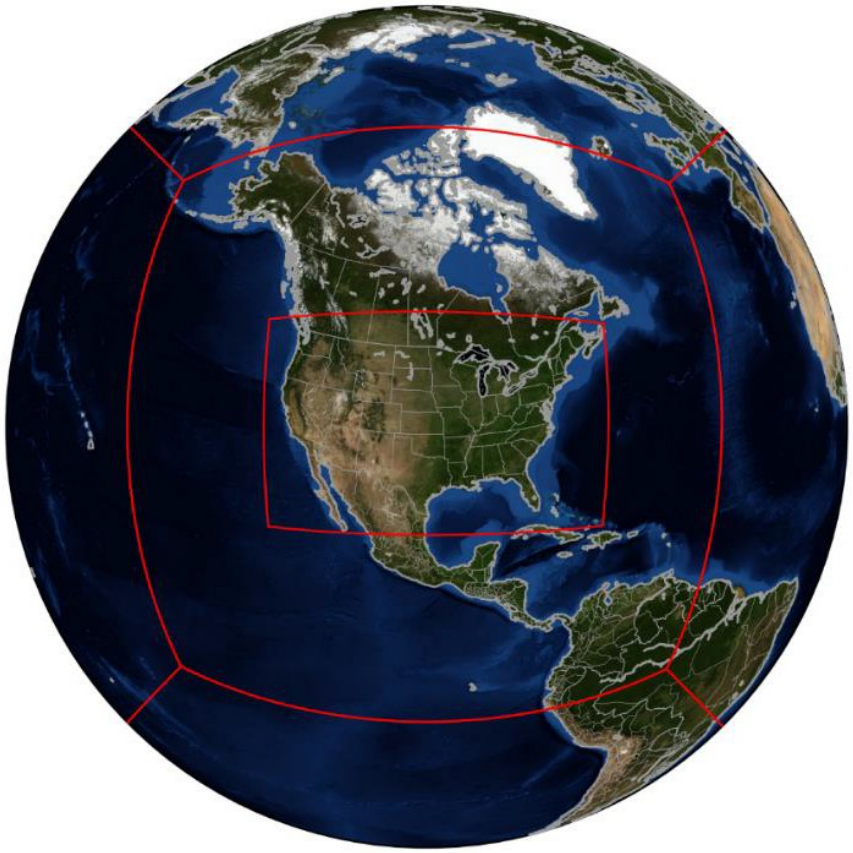


Summary on Physics Testing

- The May 16-17 dryline tornado case was improved using YSU or MYNN PBL scheme;
- For the 5 HWT/HMT cases, no clear separation of hourly precipitation ETSs using different PBL or MP schemes, or between WRF and FV3;
- FV3 showed larger sensitivity to MP scheme than WRF (FV3 calls MP at 60-90s time intervals);
- More systematic evaluations will occur during 2018 HWT and HMT forecast experiments.

Plan for 2018 HWT/HMT Experiments

- ~3.5 km grid nested inside uniform 13 km grid;
- Assimilate radar Z data on top of GFS analysis
- Run 11 forecasts with different PBL and MP combinations
- 1 uses Tiedtke cumulus scheme



Planned CAPS FV3 Ensemble for 2018

Ens Members	IC	Microphysics	LSM	PBL	Cumulus
fv3-01	GFS+radar DA	Thompson	NOAH	MYNN-SA	Tiedtke
fv3-02	GFS+radar DA	Thompson	NOAH	MYNN	Tiedtke
fv3-03	GFS+radar DA	Thompson	NOAH	YSU-SA	Tiedtke
fv3-04	GFS+radar DA	Thompson	NOAH	YSU	Tiedtke
fv3-05	GFS+radar DA	Thompson	NOAH	EDMF	Tiedtke
fv3-06	GFS+radar DA	NSSL	NOAH	MYNN-SA	Tiedtke
fv3-07	GFS+radar DA	NSSL	NOAH	MYNN	Tiedtke
fv3-08	GFS+radar DA	NSSL	NOAH	YSU-SA	Tiedtke
fv3-09	GFS+radar DA	NSSL	NOAH	YSU	Tiedtke
fv3-10	GFS+radar DA	NSSL	NOAH	EDMF	Tiedtke
fv3-11	GFS+radar DA	Thompson	NOAH	MYNN-SA	SA-SAS

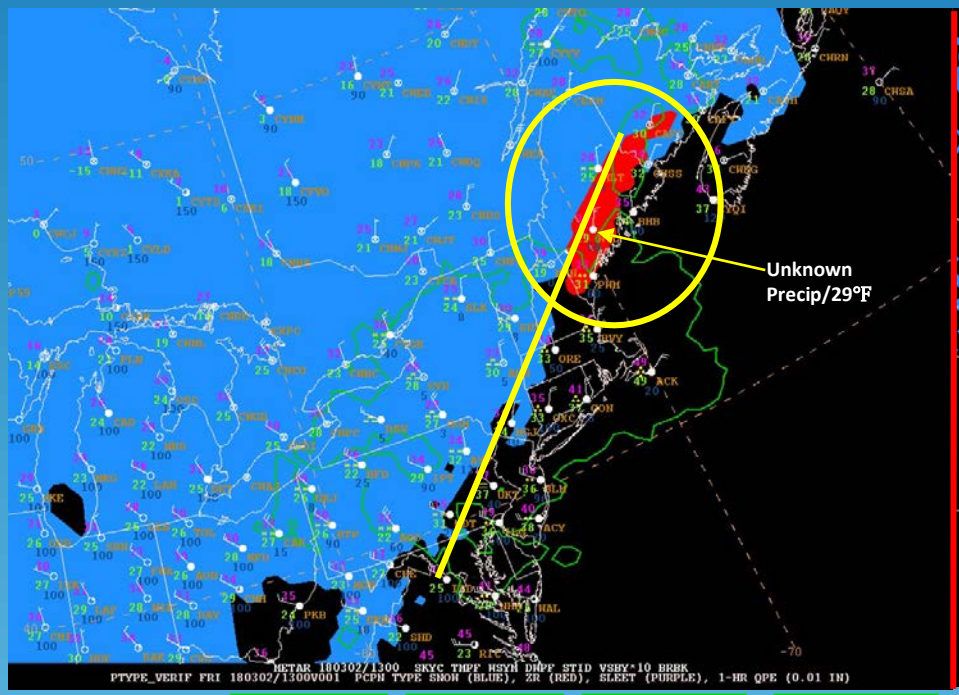
CAPS FV3 Forecasts for HMT Winter Experiment

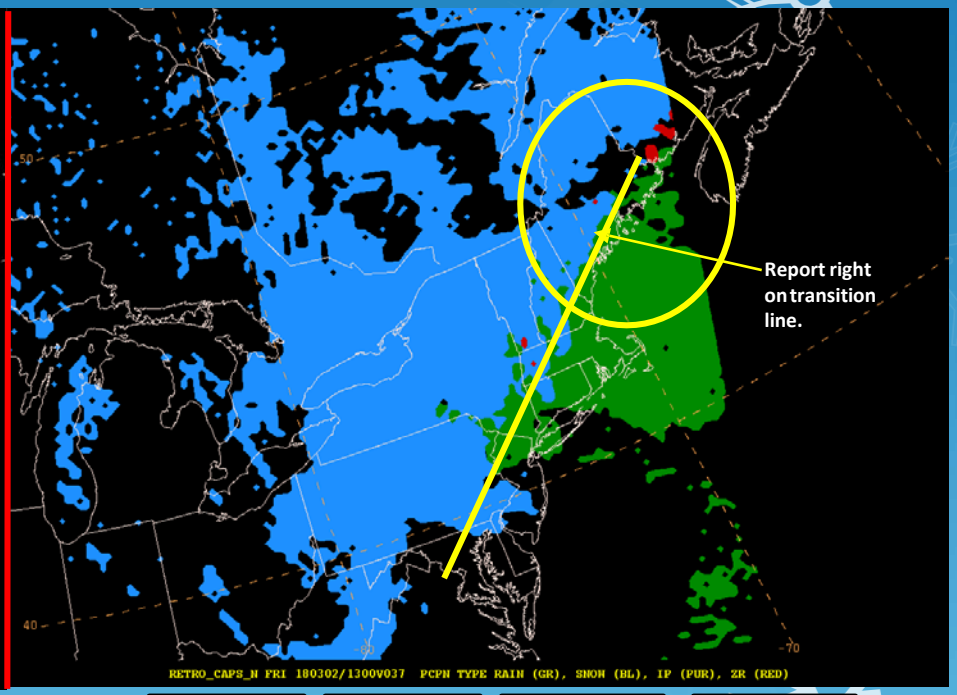
- In 2/12 – 3/9/2018 (4 weeks), CAPS ran two 84 h FV3 forecasts from 00 UTC for the HWT Winter Experiment on weekdays, using Thompson and NSSL microphysics, and MYNN PBL.

- Precip type was the main product evaluated.

March 2-3 Nor'Easter -- 13Z 3/2/18

00Z cycle, CAPS-FV3 NSSL 37 Hour Forecast





KEY: Where Ptype/QPE overlap

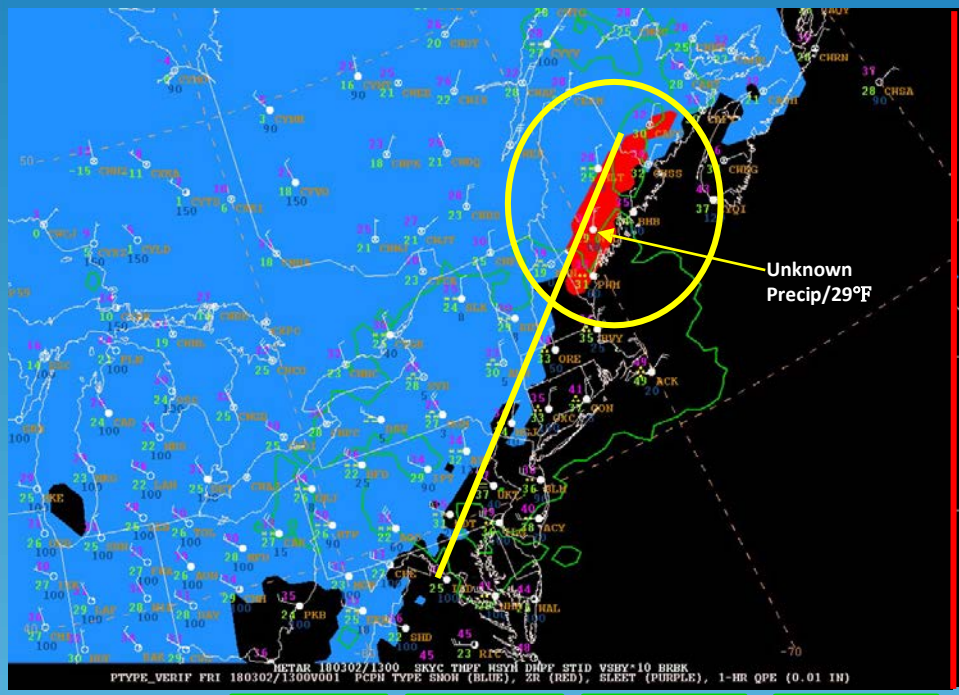
SNOW | SLEET | FREEZING RAIN | RAIN

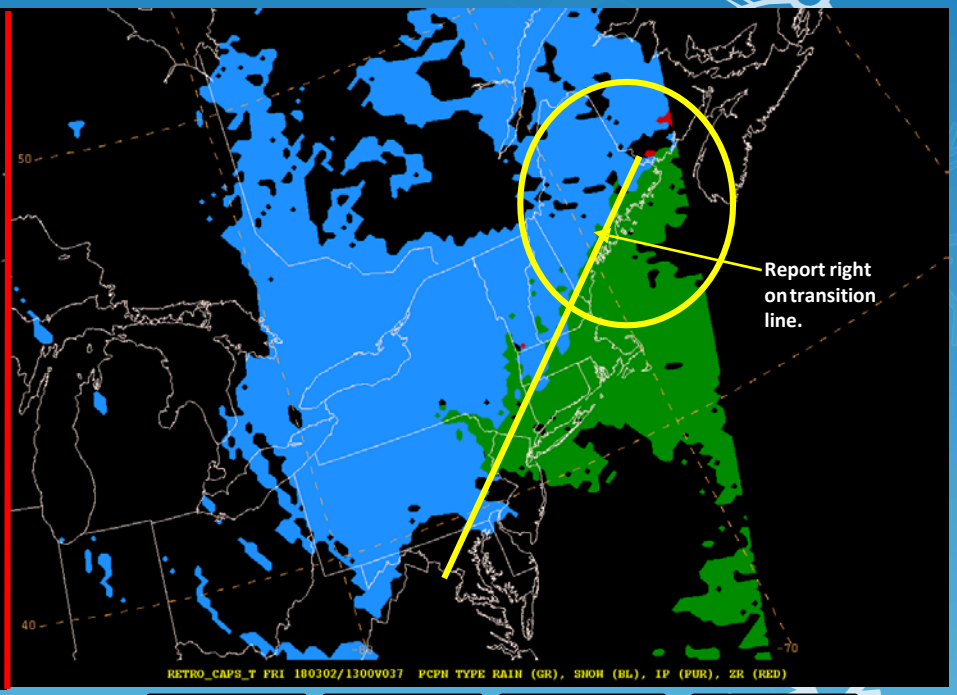
SNOW | SLEET | FREEZING RAIN | RAIN

From Ben Albright and Sara Perfater of WPC

March 2-3 Nor'Easter -- 13Z 3/2/18

00Z cycle, CAPS-FV3 Thompson 37 Hour Forecast





KEY: Where Ptype/QPE overlap

SNOW | SLEET | FREEZING RAIN | RAIN

SNOW | SLEET | FREEZING RAIN | RAIN

From Ben Albright and Sara Perfater of WPC

Transition to Operations

- CAM-ensemble-based forecast products/post-processing algorithms → SPC, WPC, EMC
- Data assimilation capabilities, specially for radar DA → EMC
- Enhancements to FV3 model (added and tested physics packages) → EMC
- RL5 to RL6/7