Storm-Scale Ensemble Forecasting for the NOAA Hazardous Weather Testbed

Fanyou Kong, Ming Xue, Keith Brewster, Xuguang Wang,
Kevin Thomas, Yunheng Wang
(*Center for Analysis and Prediction of Storms/U. of Oklahoma*)
Steven J. Weiss (*NOAA/SPC*)
Adam Clark, John Kain, (*NOAA/NSSL*)

Collaboration with: DTC, HPC, SPC, NSSL, EMC

6th ECSS 2011 October 3-7, Palma de Mallorca, Spain

- History
- 2011 configuration highlight
- Product examples
- Objective evaluation

CAPS SSEF history

	2007	2008	2009	2010	2011
member	10	10	20	26	51
domain	2/3 CONUS (4 km)	3/4 CONUS (4 km)	3/4 CONUS (4 km)	Full CONUS (4 km)	Full CONUS (4 km)
forecast	33 h	30 h	30 h	30 h	36 h
model	WRF-ARW	WRF-ARW	WRF-ARW WRF-NMM ARPS	WRF-ARW WRF-NMM ARPS	WRF-ARW WRF-NMM ARPS
radar	No radar	Radial wind, reflectivity	Radial wind, reflectivity	Radial wind, reflectivity	Radial wind, reflectivity

Funded primarily by the NOAA CSTAR program, and leveraged by other NSF grants

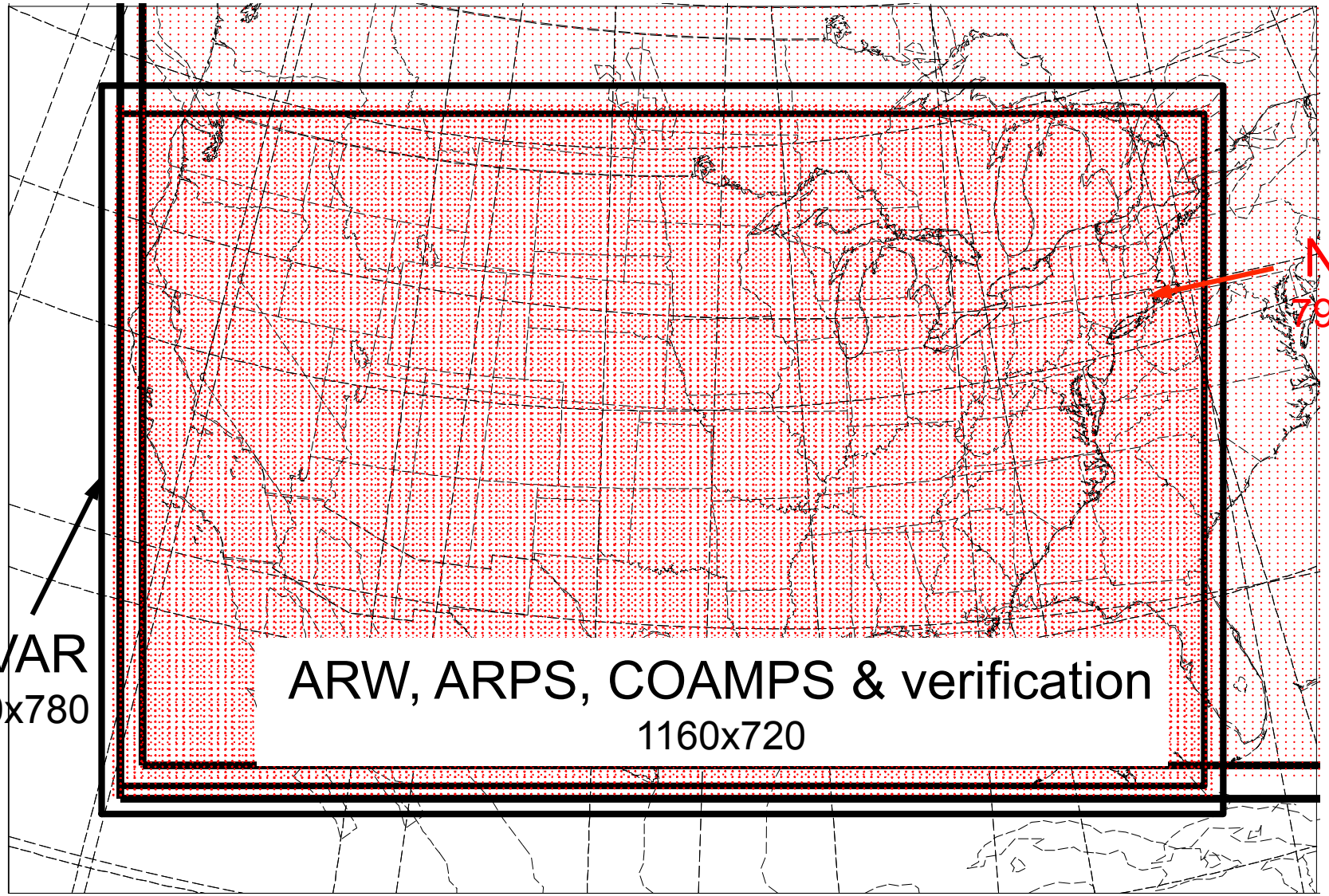
Highlight

- 4 km grid spacing – “convection allowing”
- Full continental US domain (CONUS)
- Multi-model ensemble
- IC/LBC perturbations (from NCEP SREF)
- Radar radial wind & reflectivity analysis
- 30-36 h forecast initiated at 00 UTC

2011 SSEF highlight

- 51 ensemble members (4-km grid spacing)
  - 41 WRF-ARW members
  - 5 WRF-NMM members
  - 4 ARPS member
  - 1 COAMPS member (experimental - partial dates, not available to HWT)
- 36h forecast, starting 00 UTC Mon-Fri
- April 25 – June 10 (HWT: May 9 – June 10)
- 9800 CPU cores on NICS Athena, 6 h/day

2010/2011 Spring Experiment Domains



51 vertical levels

2011 ARW member configuration (41)

	IC	BC	Radar data	Microphy	LSM	PBL
arw_cn	00Z ARPSa	00Z NAMf	yes	Thompson	Noah	MYJ
arw_c0 (18h)	00Z ARPSa	00Z NAMf	no	Thompson	Noah	MYJ
arw_cc (18h)	CYCLED	00Z NAMf	yes	Thompson	Noah	MYJ
arw_m4	arw_cn + em-p1_pert	21Z SREF em-p1	yes	Morrison	RUC	YSU
arw_m5	arw_cn + em-p2_pert	21Z SREF em-p2	yes	Thompson	Noah	QNSE
arw_m6	arw_cn – nmm-p1_pert	21Z SREF nmm-p1	yes	WSM6	RUC	QNSE
arw_m7	arw_cn + nmm-p2_pert	21Z SREF nmm-p2	yes	WDM6	Noah	MYNN
arw_m8	arw_cn + rsm-n1_pert	21Z SREF rsm-n1	yes	Ferrier	RUC	YSU
arw_m9	arw_cn – etaKF-n1_pert	21Z SREF etaKF-n1	yes	Ferrier	Noah	YSU
arw_m10	arw_cn + etaKF-p1_pert	21Z SREF etaKF-p1	yes	WDM6	Noah	QNSE
arw_m11	arw_cn – etaBMJ-n1_pert	21Z SREF etaBMJ-n1	yes	WSM6	RUC	MYNN
arw_m12	arw_cn + etaBMJ-p1_pert	21Z SREF etaBMJ-p1	yes	Thompson	RUC	MYNN
arw_m13	arw_cn + rsm-p1_pert	21Z SREF rsm-p1	yes	M-Y	Noah	MYJ
arw_m14	arw_cn + em-n1_pert	21Z SREF em-n1	yes	Ferrier+	Noah	YSU
arw_m15	arw_cn + em-n2_pert	21Z SREF em-n2	yes	WSM6	Noah	MYNN
arw_m16	arw_cn + nmm-n1_pert	21Z SREF nmm-n1	yes	Ferrier+	Noah	QNSE
arw_m17	arw_cn + nmm-n2_pert	21Z SREF nmm_n2	yes	Thompson	Noah	ACM2
arw_m18	arw_cn + rsm-p2_pert	21Z SREF rsm_p2	yes	WSM6	Noah	MYJ
arw_m19	arw_cn + rsm-n1_pert	21Z SREF rsm_n1	yes	M-Y	Noah	MYJ
arw_m20	arw_cn + rsm-n2_pert	21Z SREF rsm_n2	yes	M-Y	RUC	ACM2

For all ARW members: *ra_lw_physics*= RRTM; *ra_sw_physics*=Goddard; *cu_physics*=none

2011 ARW member configuration (continue)

arw_m21	00Z ARPSa	00Z NAMf	yes	Ferrier+	Noah	MYJ
arw_m22	00Z ARPSa	00Z NAMf	yes	Ferrier	Noah	MYJ
arw_m23	00Z ARPSa	00Z NAMf	yes	M-Y	Noah	MYJ
arw_m24	00Z ARPSa	00Z NAMf	yes	Morrison	Noah	MYJ
arw_m25	00Z ARPSa	00Z NAMf	yes	WDM6	Noah	MYJ
arw_m26	00Z ARPSa	00Z NAMf	yes	WSM6	Noah	MYJ
arw_m27	00Z ARPSa	00Z NAMf	yes	WSM6-M1	Noah	MYJ
arw_m28	00Z ARPSa	00Z NAMf	yes	WSM6-M2	Noah	MYJ
arw_m29	00Z ARPSa	00Z NAMf	yes	WSM6-M3	Noah	MYJ
arw_m30	00Z ARPSa	00Z NAMf	yes	WSM6-M4	Noah	MYJ
arw_m31	00Z ARPSa	00Z NAMf	yes	Thompson	Noah	QNSE
arw_m32	00Z ARPSa	00Z NAMf	yes	Thompson	Noah	MYNN
arw_m33	00Z ARPSa	00Z NAMf	Yes	Thompson	Noah	MYJ-P1
arw_m34	00Z ARPSa	00Z NAMf	Yes	Thompson	Noah	MYJ-P2
arw_m35	00Z ARPSa	00Z NAMf	Yes	Thompson	Noah	MYJ-P3
arw_m36	00Z ARPSa	00Z NAMf	Yes	Thompson	Noah	ACM2
arw_m37	00Z ARPSa	00Z NAMf	yes	Thompson	Noah	ACM2-A1
arw_m38	00Z ARPSa	00Z NAMf	yes	Thompson	Noah	ACM2-A2
arw_m39	00Z ARPSa	00Z NAMf	yes	Thompson-v31	Noah	MYJ
arw_m40	00Z ARPSa	00Z NAMf	yes	Thompson	Noah	YSU
arw_m41	00Z ARPSa	00Z NAMf	yes	Thompson	Noah	YSU-Thompson

2011 NMM member configuration (5)

member	IC	BC	Radar data	mp_phy	lw_phy	sw-phy	sf_phy
nmm_cn	00Z ARPSa	00Z NAMf	yes	Ferrier	GFDL	GFDL	Noah
nmm_m2	nmm_cn + em-n2_pert	21Z SREF em-n2	yes	Ferrier+	GFDL	GFDL	Noah
nmm_m3	nmm_cn + nmm-n1_pert	21Z SREF nmm-n1	yes	Thompson	RRTM	Dudhia	Noah
nmm_m4	nmm_cn + nmm-n2_pert	21Z SREF nmm-n2	yes	WSM 6-class	RRTM	Dudhia	RUC
nmm_m5	nmm_cn + em-n1_pert	21Z SREF em-n1	yes	Ferrier	GFDL	GFDL	RUC

For all NMM members: *pbl_physics*=MYJ; *cu_physics*=none

2011 ARPS member configuration (4)

member	IC	BC	Radar data	Microphy.	radiation	sf_phy
arps_cn	00Z ARPSa	00Z NAMf	yes	Lin	Chou/Suarez	Force-restore
arps_c0 (18h)	00Z ARPSa	00Z NAMf	no	Lin	Chou/Suarez	Force-restore
arps_c10 (18h)	10-min cycle ARPSa	00Z NAMf	yes	Lin	Chou/Suarez	Force-restore
arps_c30 (18h)	30-min cycle ARPSa	00Z NAMf	yes	Lin	Chou/Suarez	Force-restore

For all ARPS members: no cumulus parameterization

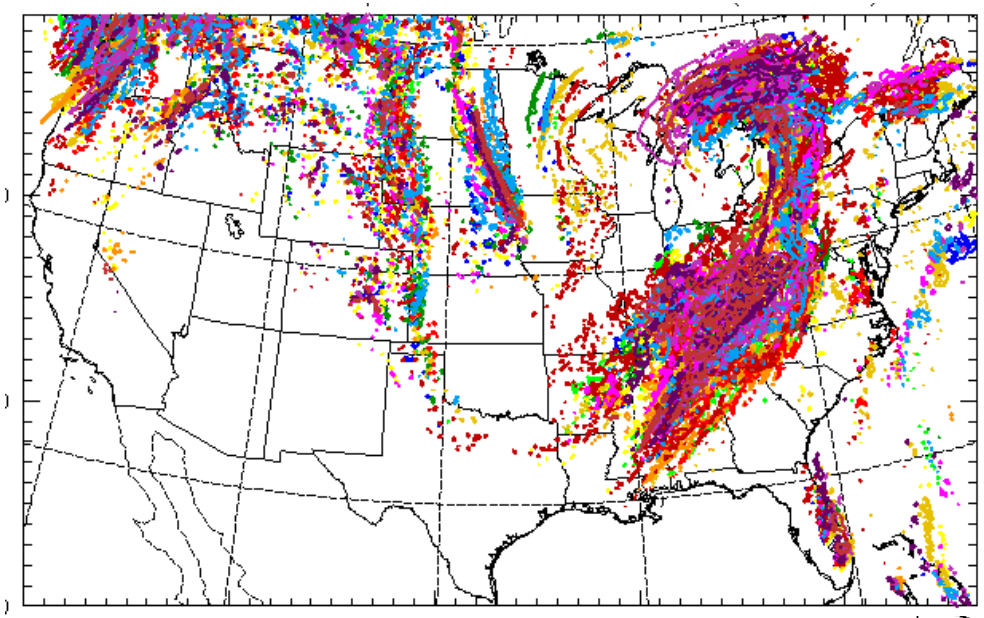
Members in red contribute to the **24-member** baseline ensemble for post-processing

Ensemble product

- Ensemble max, mean, spaghetti, postage-stamp chart
- Hourly- & 3-hourly max of certain variables (e.g., updraft helicity, surface wind speed, column integrated graupel)
- probability matching mean for reflectivity & QPF
- probability & neighborhood probability
- New in 2011 Spring Experiment, added two groups of experimental diagnosed products
  - Lightning threat (McCaul et al. 2009)
  - CI counts (NSSL - Jack Kain et al.)
  - and their probabilities
- Experimenting bias correction on QPF

CAPS SSEF product page

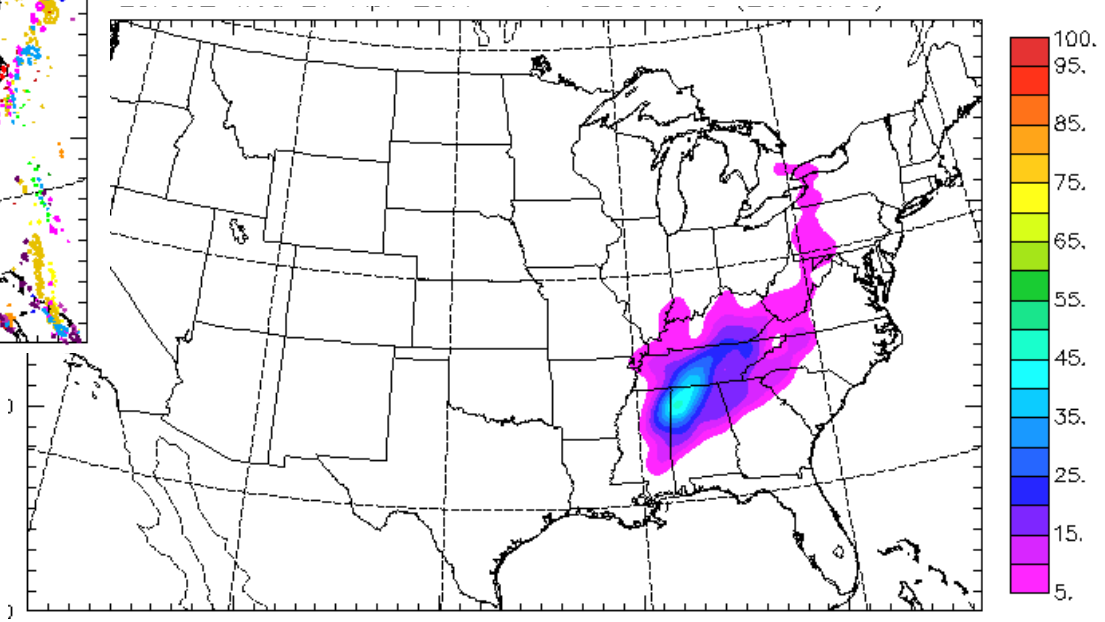
- http://forecast.caps.ou.edu
- http://www.caps.ou.edu/~fkong/sub_atm/spring11.html



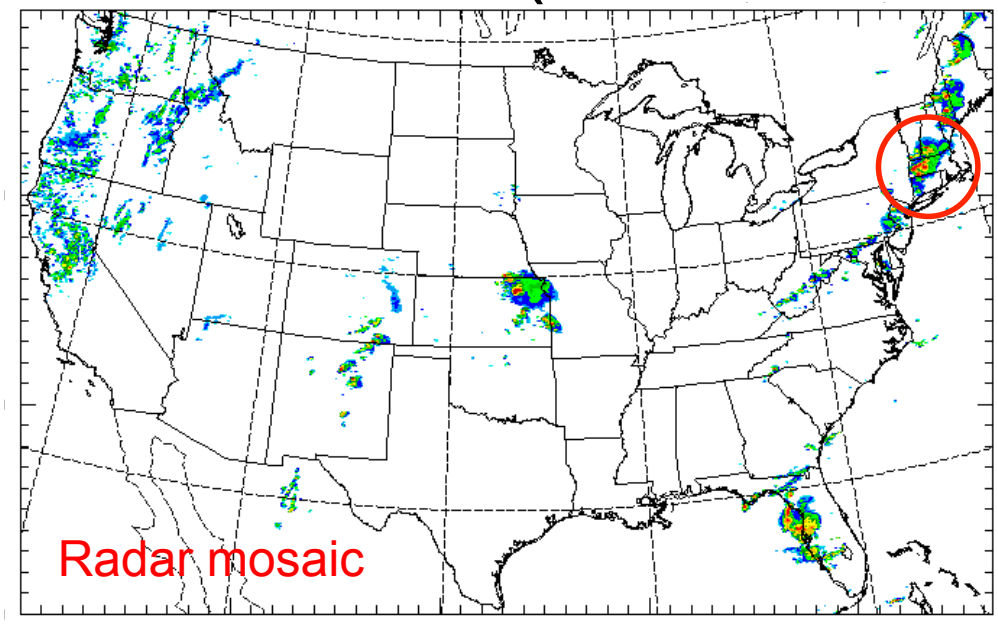
Spaghetti of cref = 35 dBZ

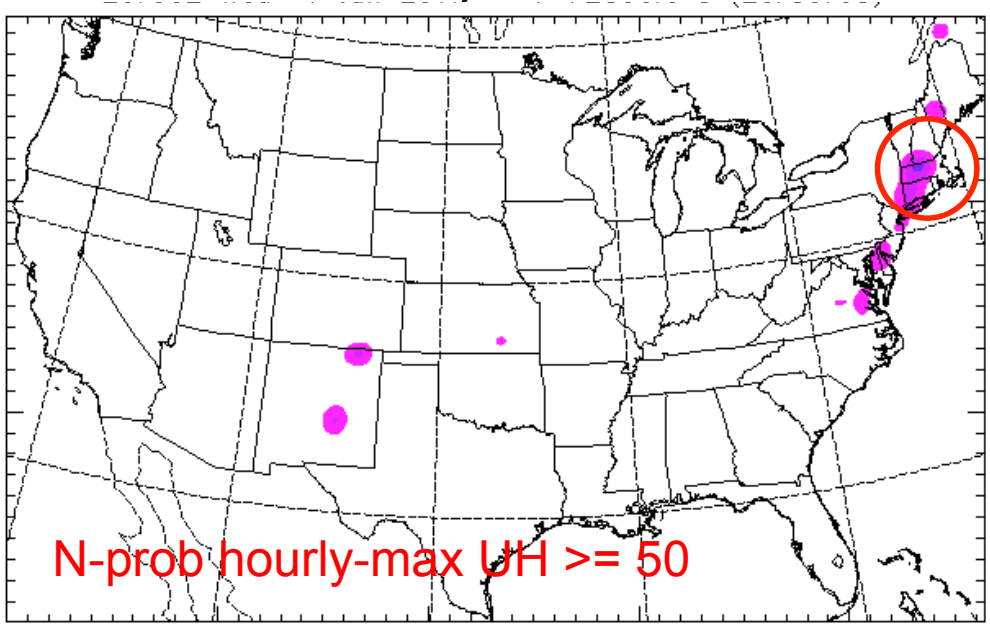
(23-h fcst, valid 23Z April 27)
Alabama tornado case

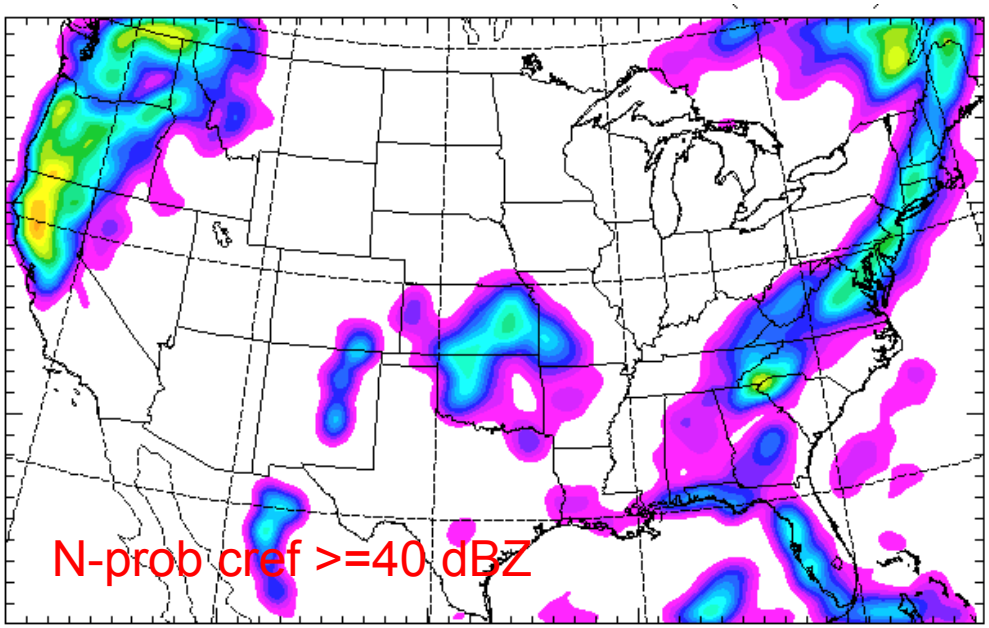
Neighborhood probability:
UH >= 50

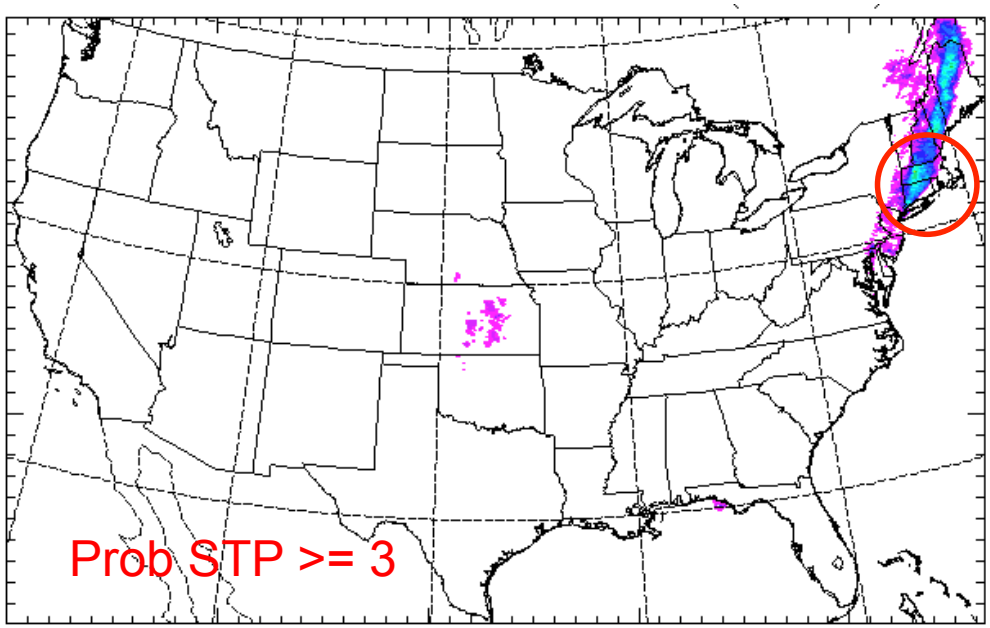


June 1 Massachusetts Tornado, 20h fcst
(valid 20 UTC June 1, 2011)

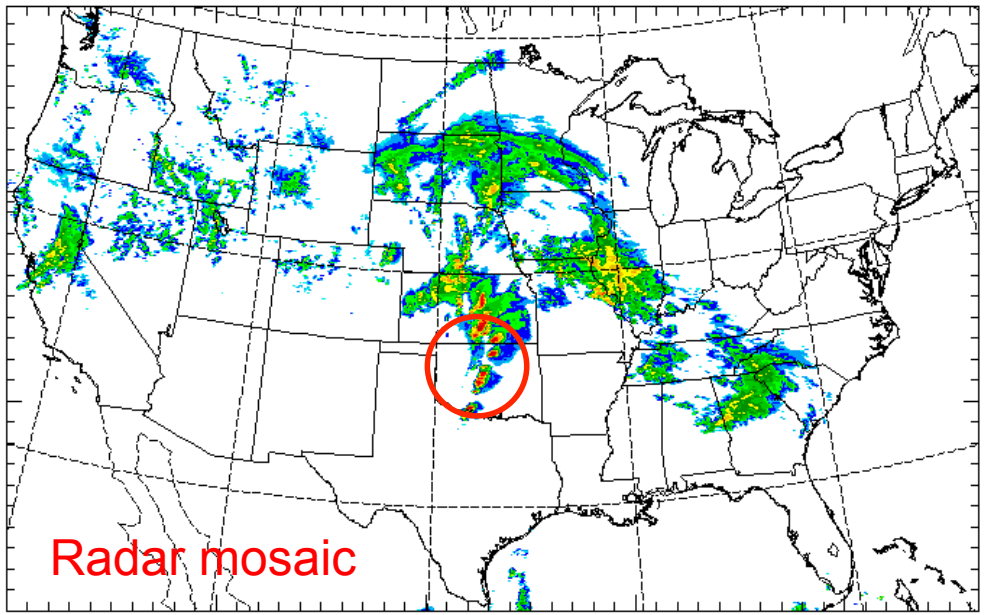


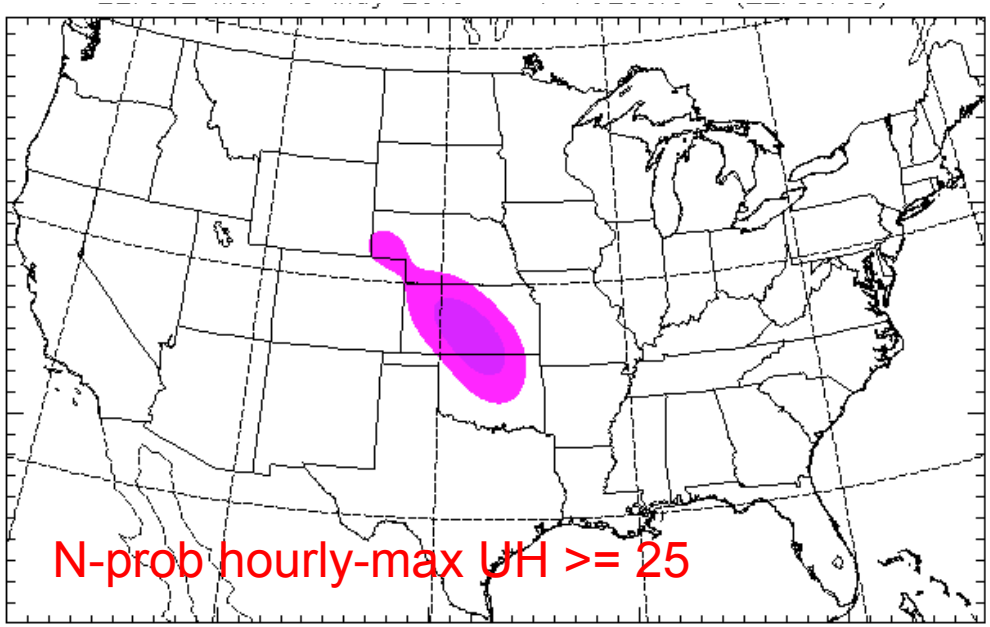


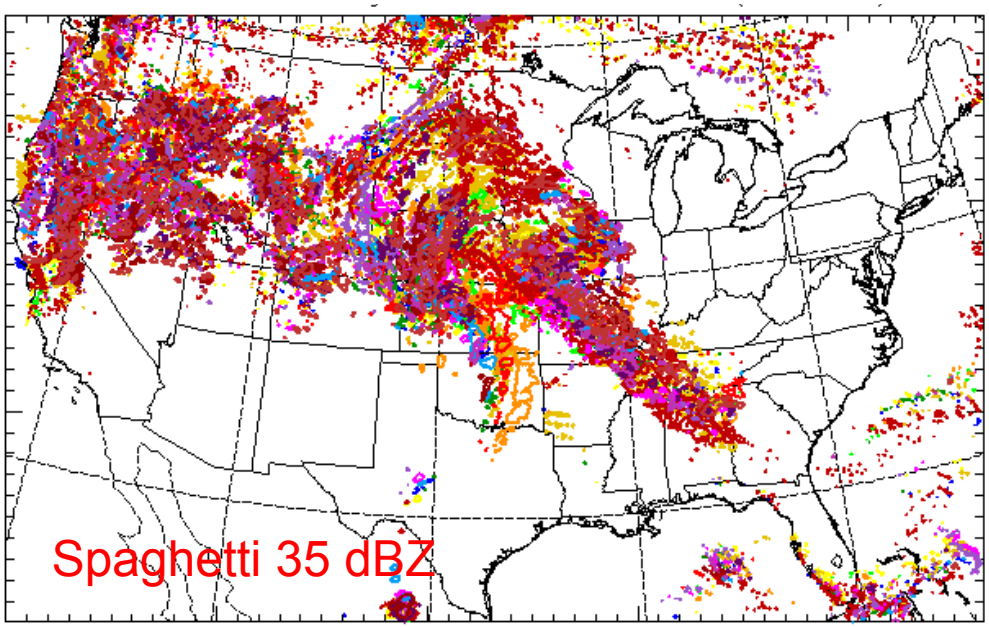


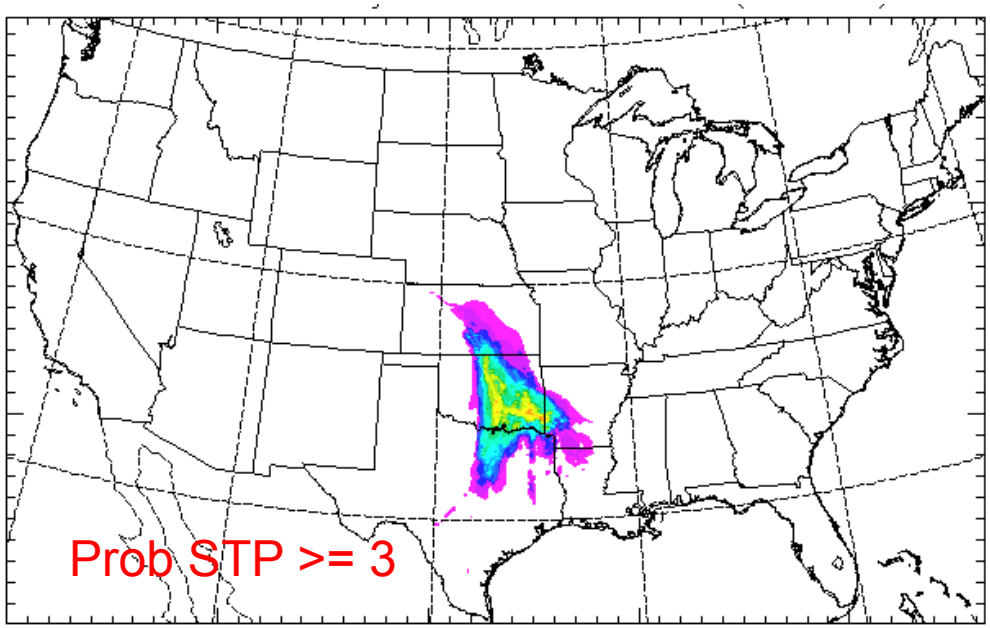


May 10 OKC Tornado, 22h fcst
(valid 22 UTC, May 10,2010)



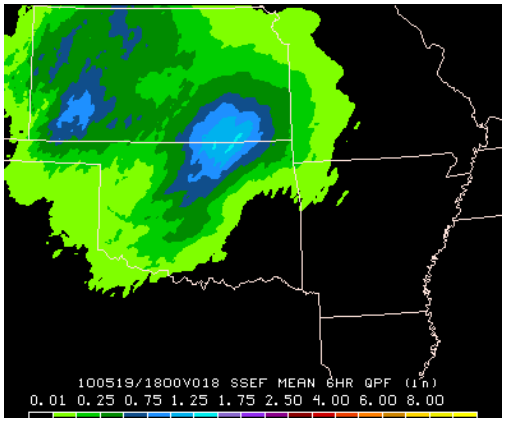




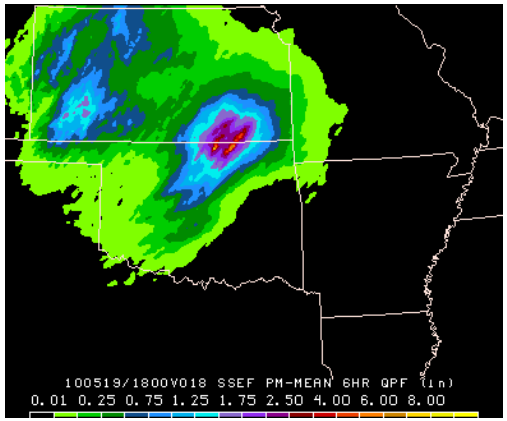


12–18Z accumulated precipitation: 18h (May 19, 2010)

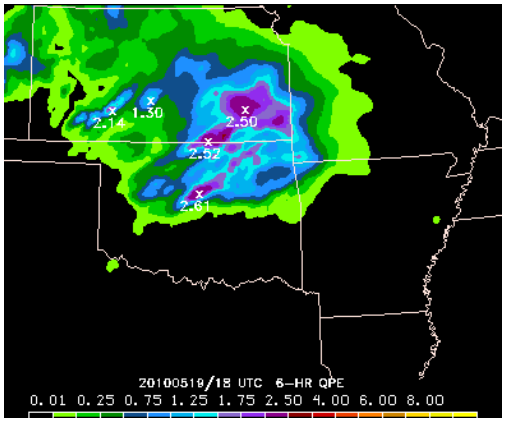
SSEF mean



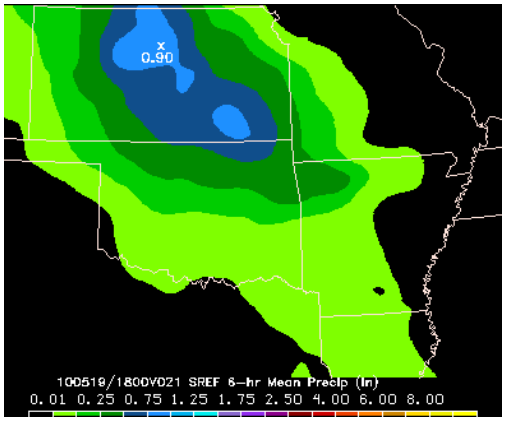
SSEF Prob match



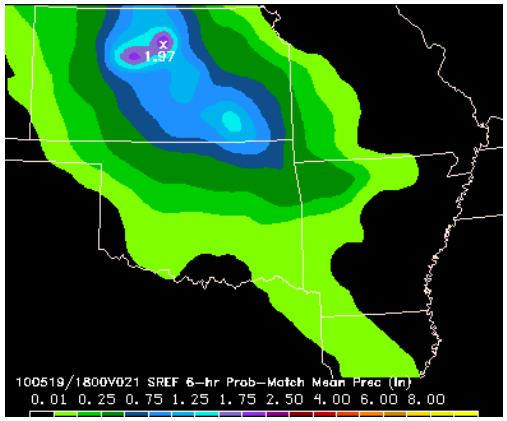
QPE



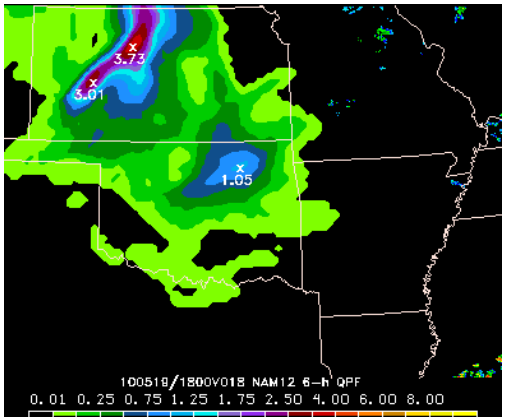
SREF mean



SREF Prob match



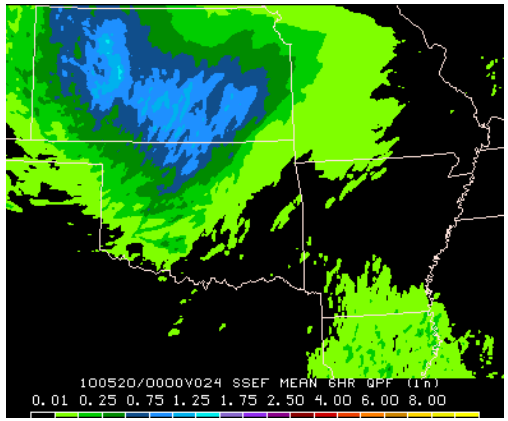
NAM



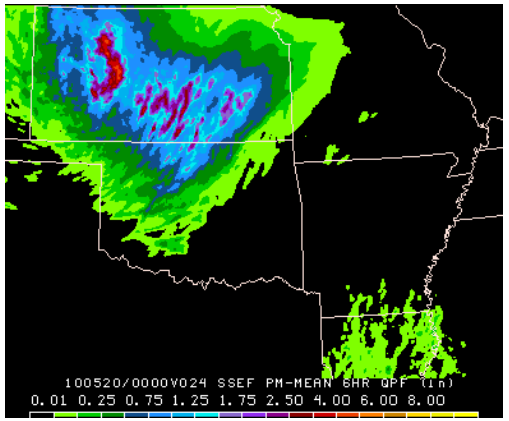
HWT images

18–0Z accumulated precipitation: 24h (May 19, 2010)

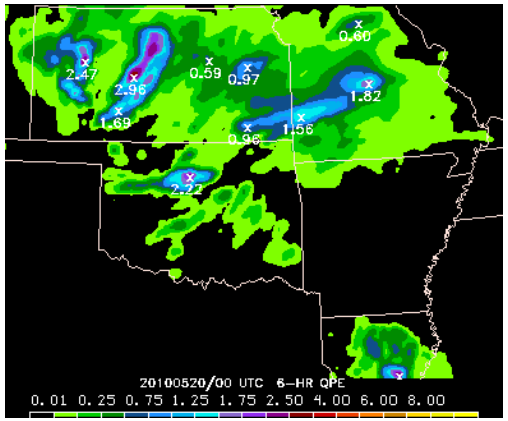
SSEF mean



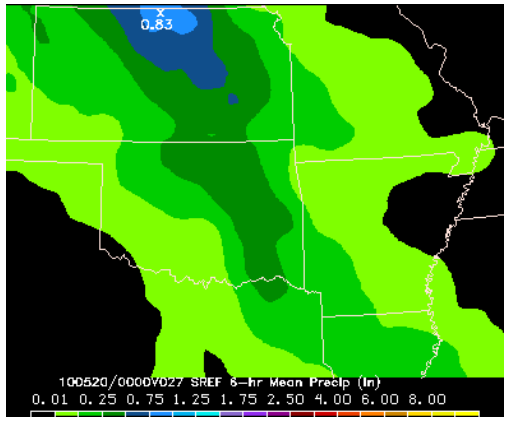
SSEF Prob match



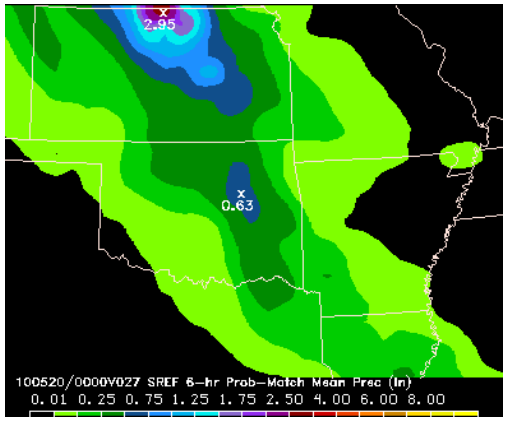
QPE



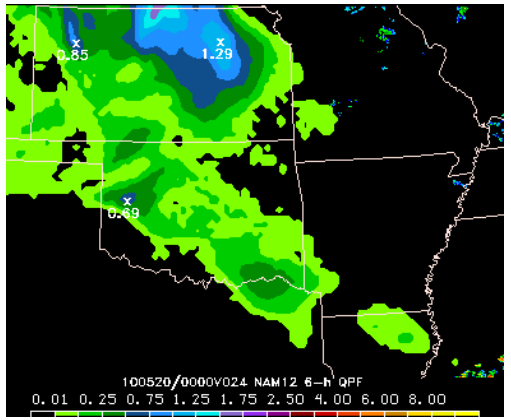
SREF mean



SREF Prob match

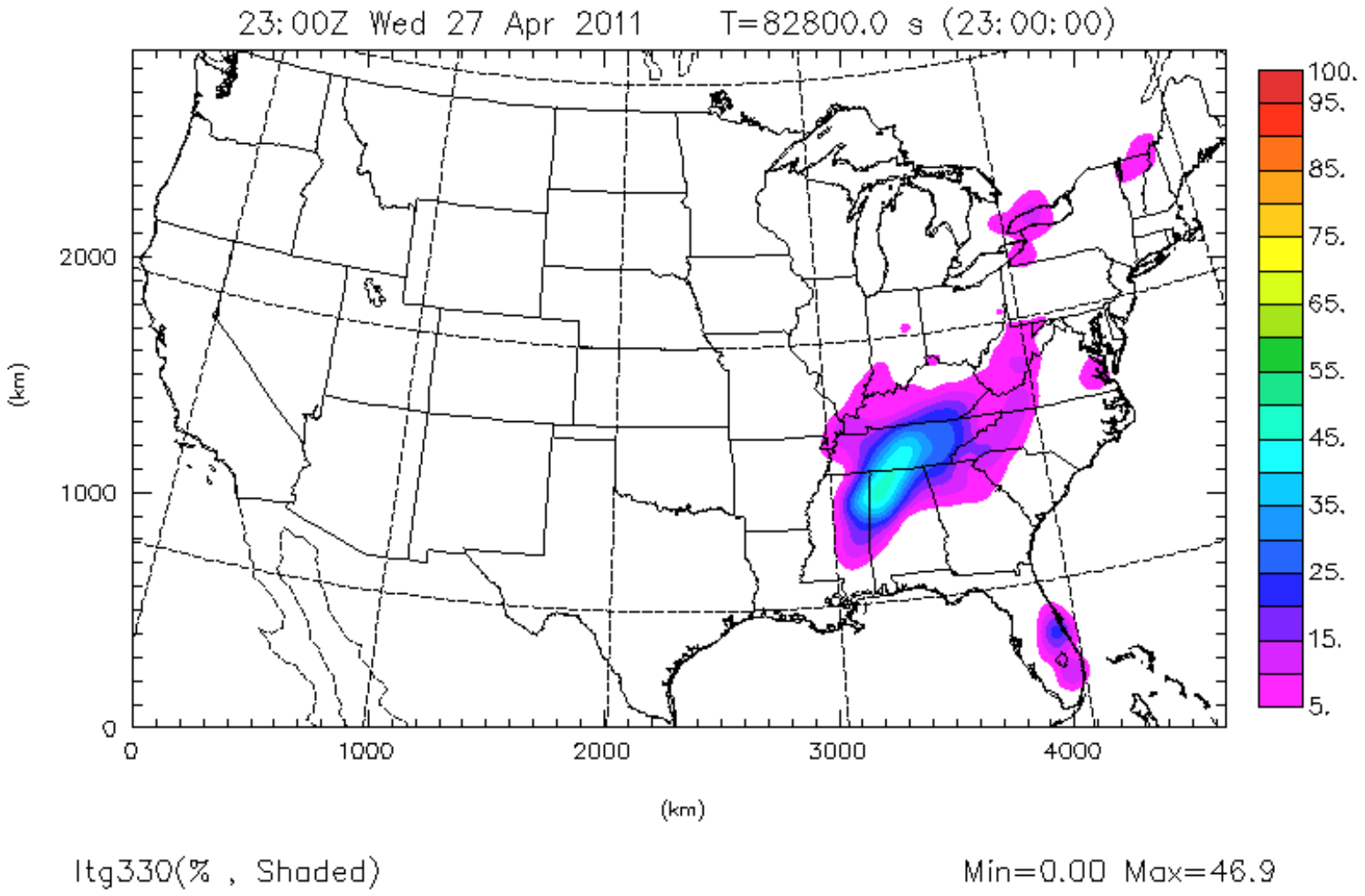


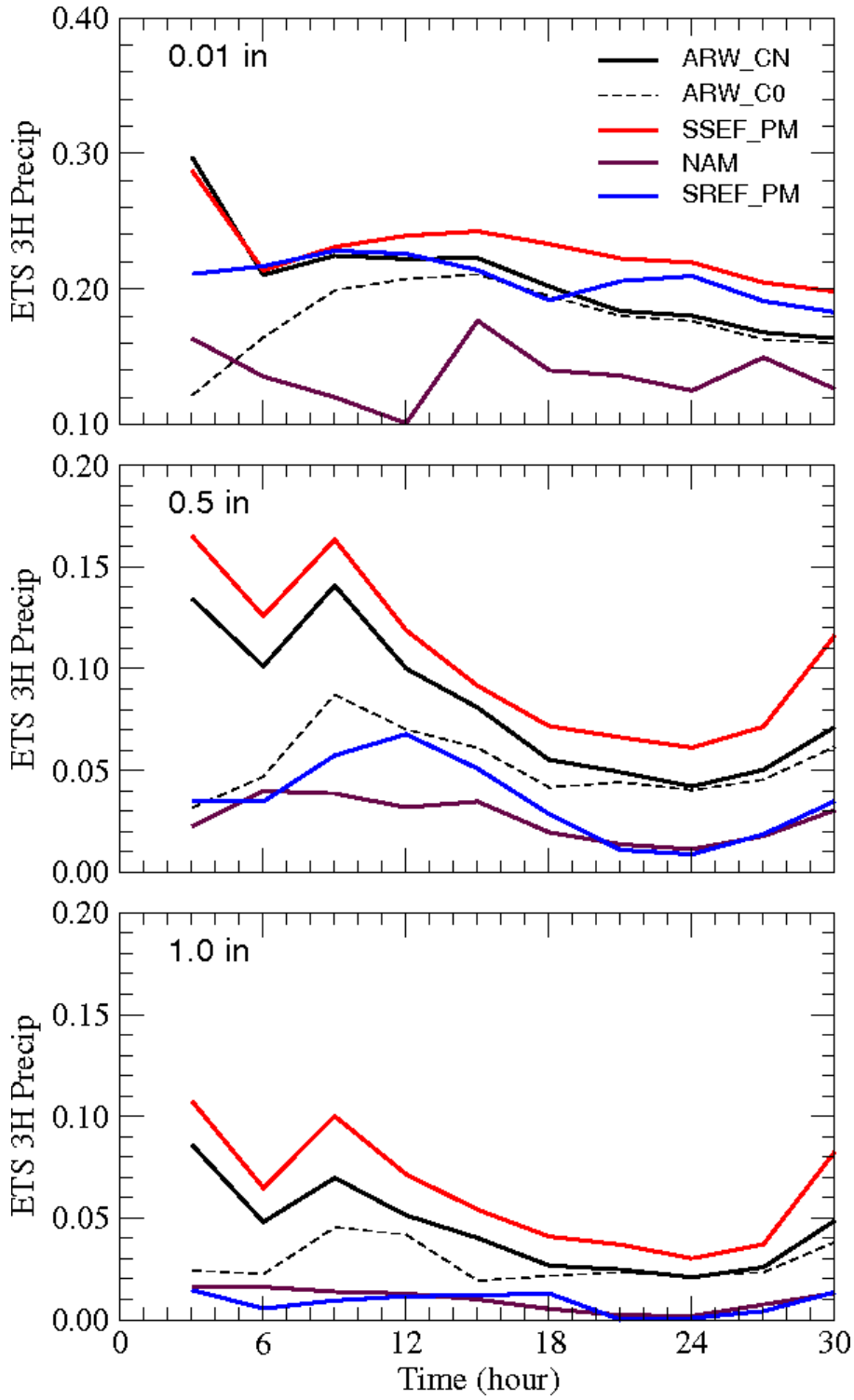
NAM



HWT images

Neighborhood probability of hourly-max Lightning Threat-3 ≥ 3.0 flashes/5min/km^2





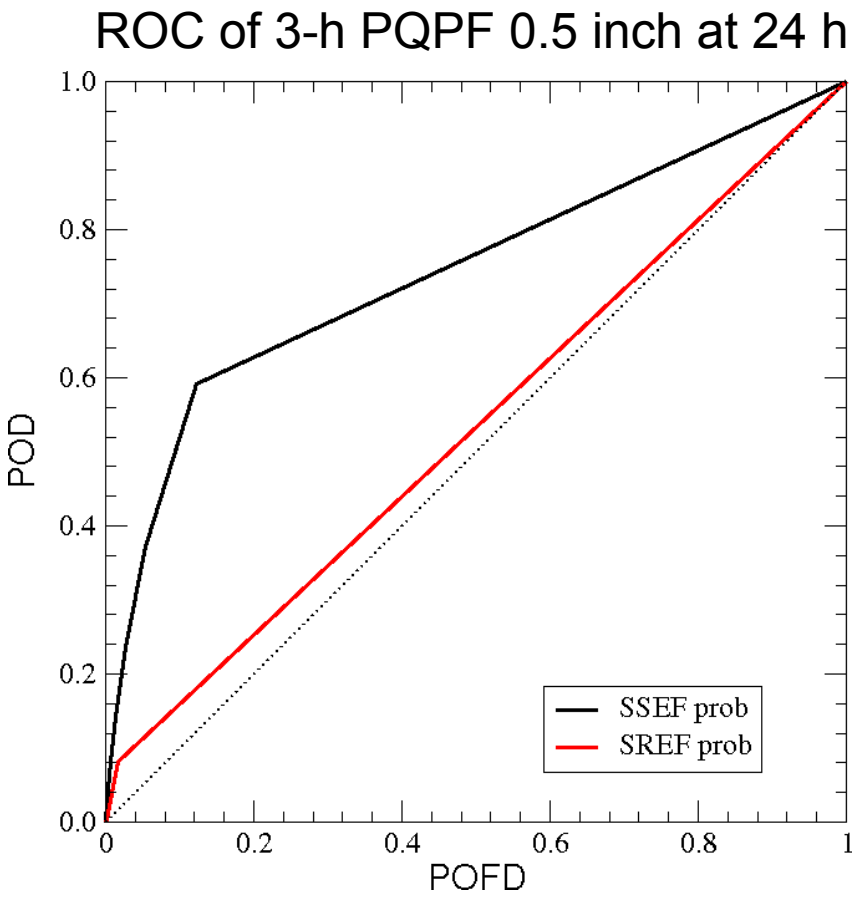
SSEF, NAM, SREF comparison

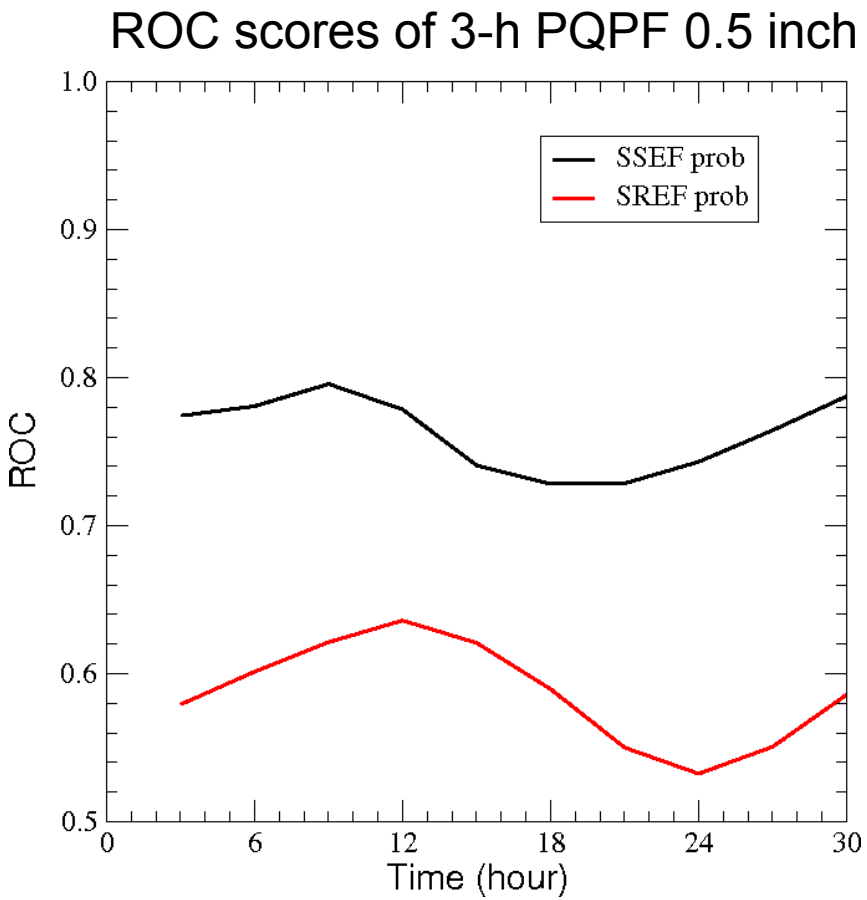
(2010 data)

ARW_C0: no radar data
ARW_CN: with radar

- SSEF_PM (4km) outperforms NAM and SREF
- ARW_CN (4km) outperforms NAM and SREF, except in light rain threshold where SREF_PM has higher ETS beyond 18 h
- Radar impact 0-30 h

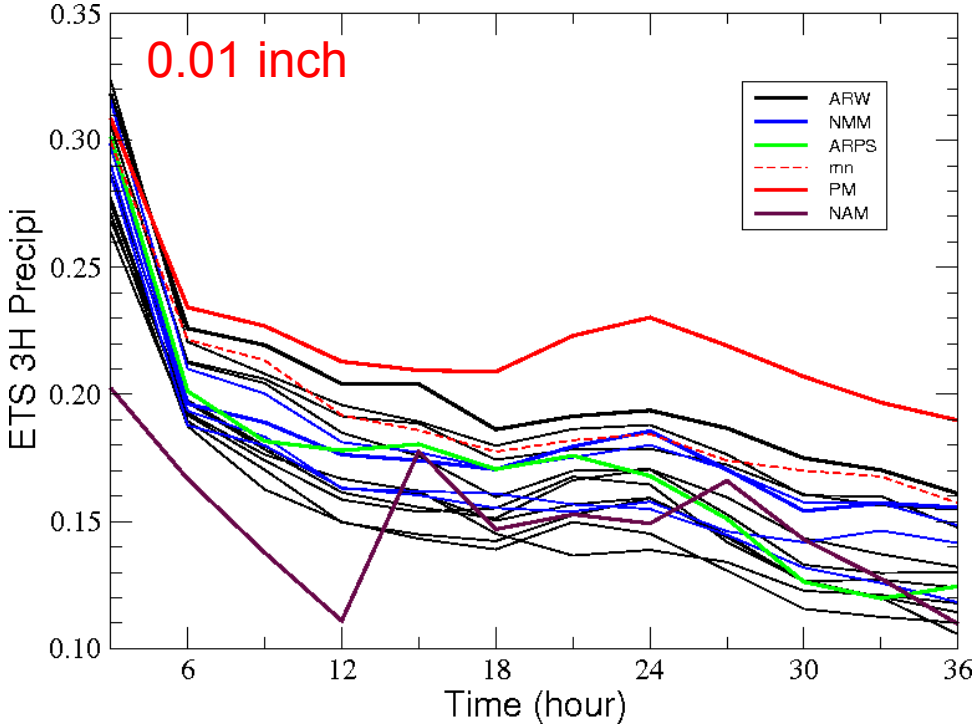
ROC: SSEF vs SREF

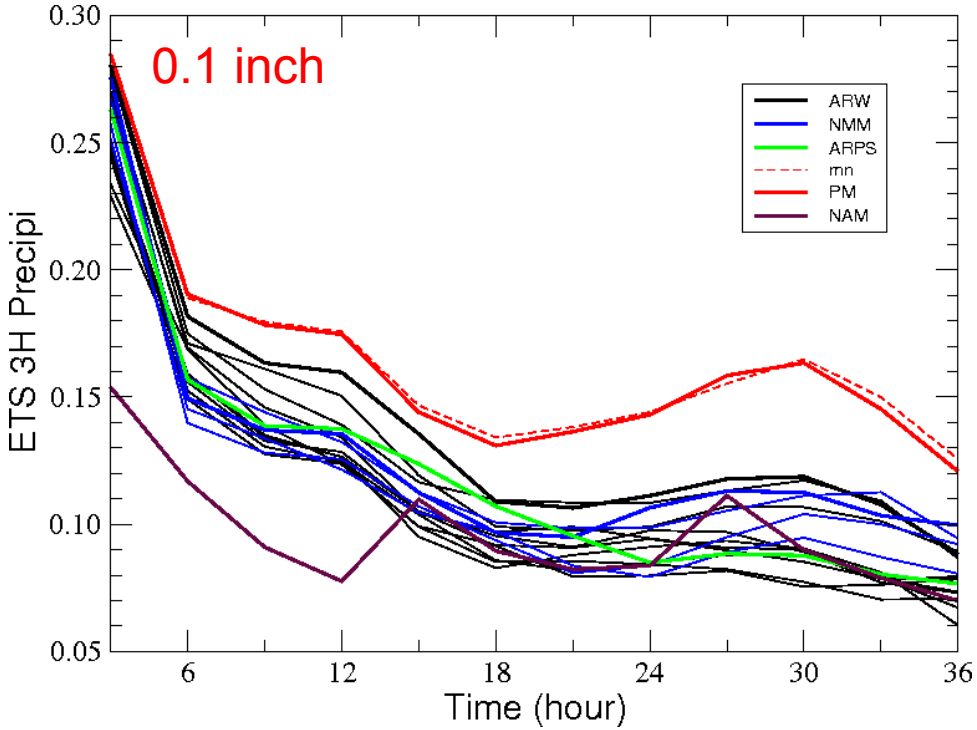


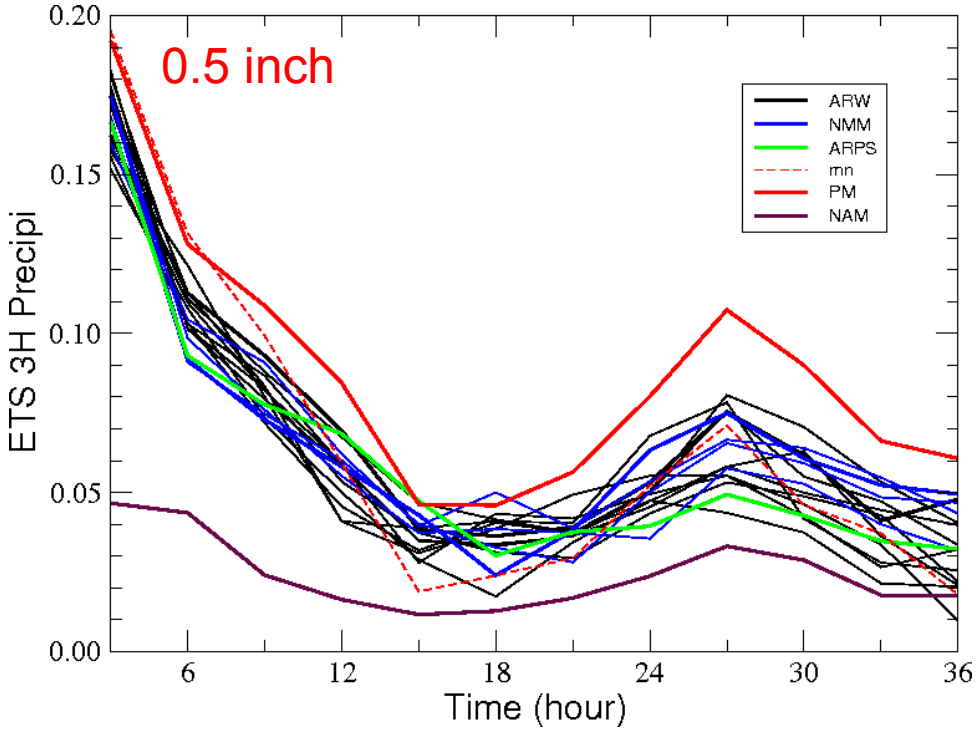


ETS for 3-h accumulated precipitation

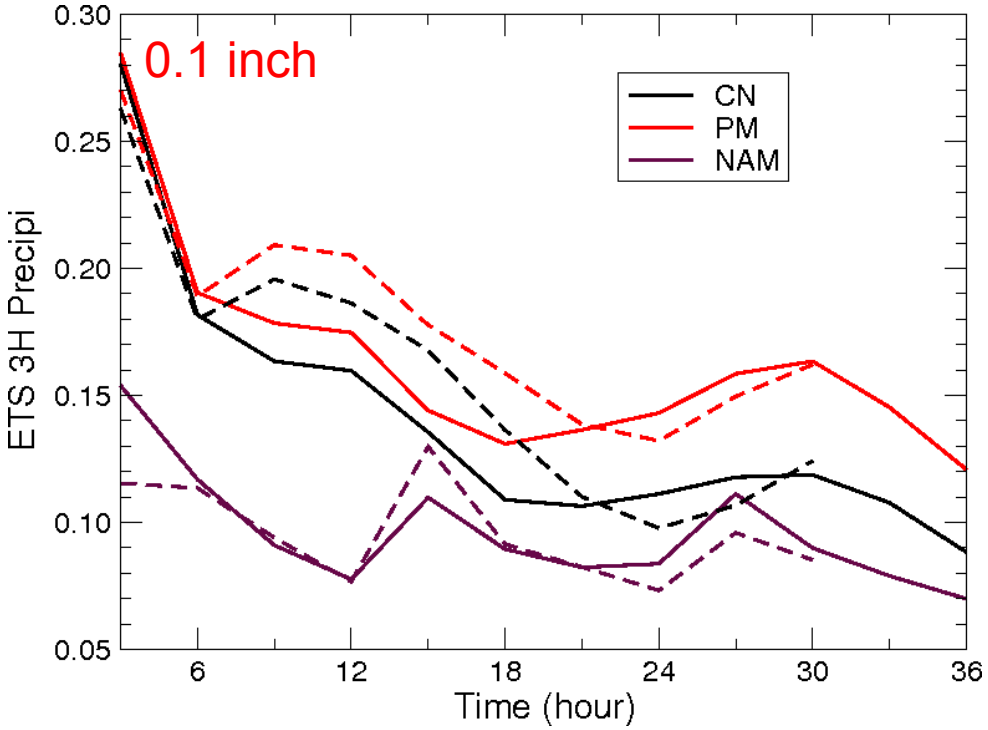
(2011data)

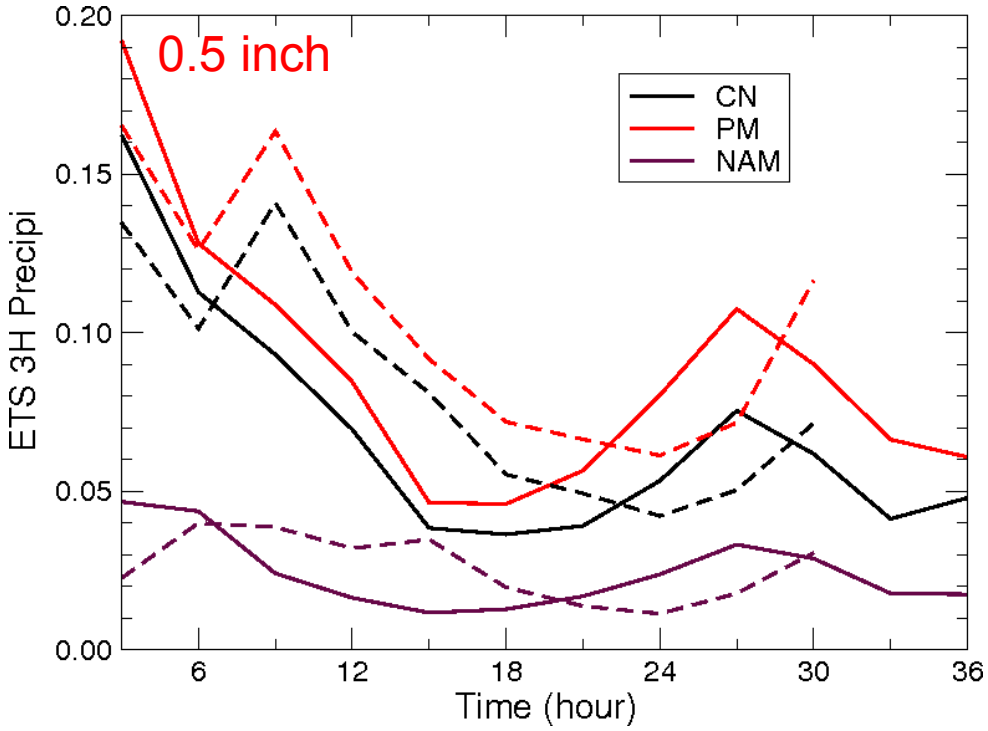






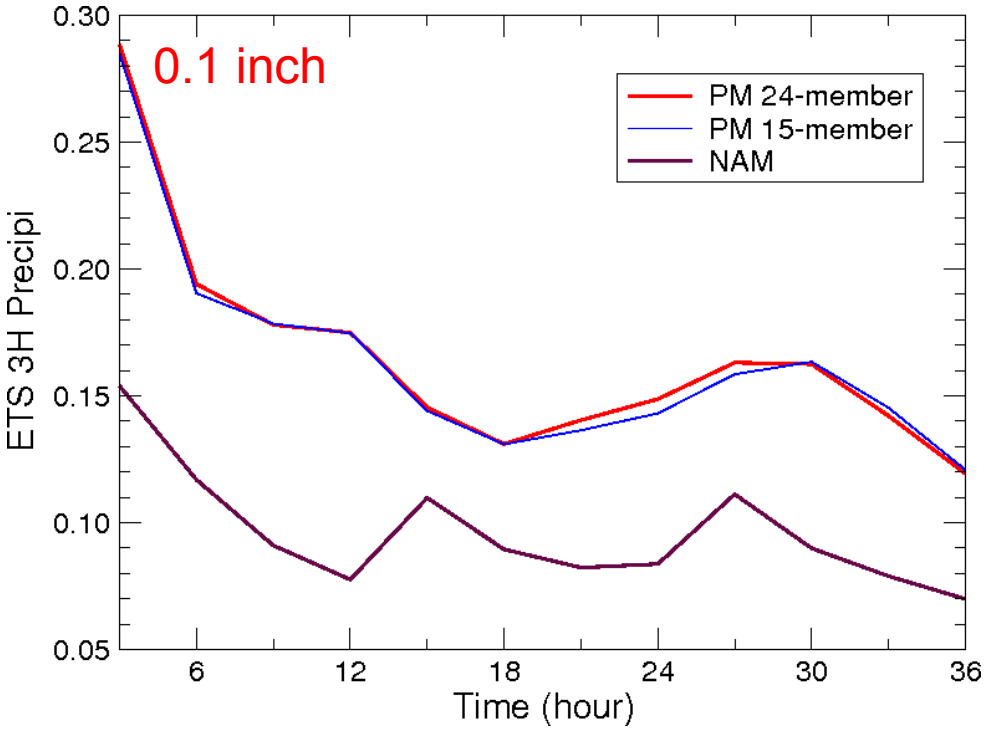
ETS for 3-h accumulated precipitation

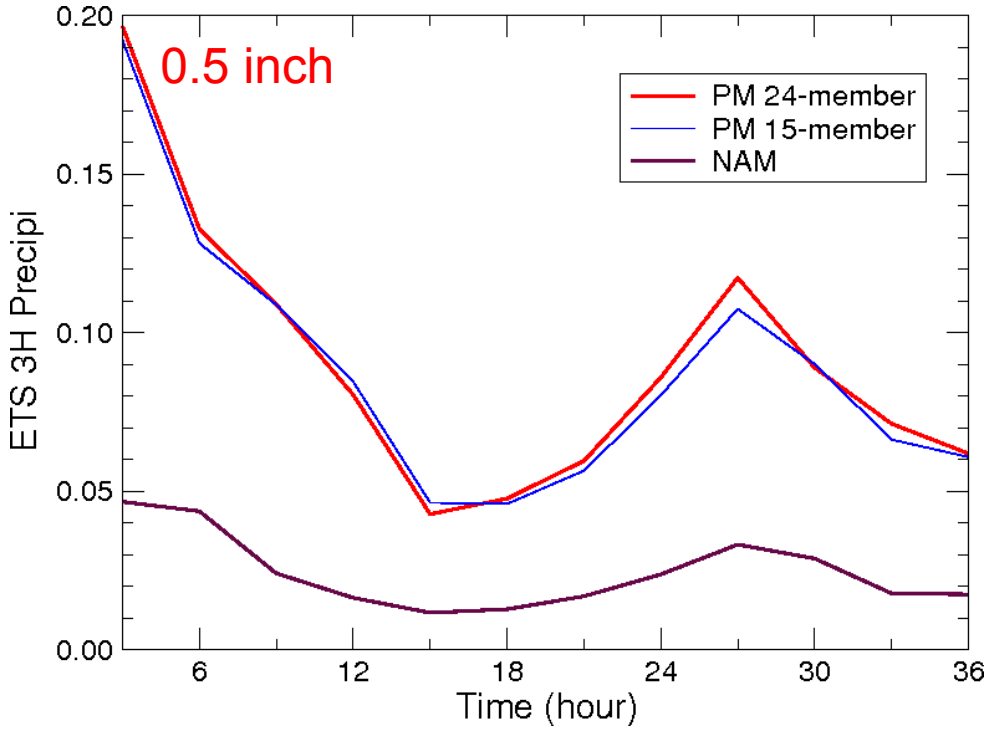




2010 - dash lines; 2011 – solid lines

ETS for 3-h accumulated precipitation





24-member and 15-member differ slightly

Summary

- Values we see …
  - SSEF outperforms SREF and 12 km NAM by a wide margin
  - Radar analysis is crucial for storm-scale QPF
  - Post-processed products (PM, N-prob) can add great value, BUT
- Big challenges ahead …
  - Develop good bias removal algorithm
  - Calibration, calibration, calibration

Thanks!

Tuscaloosa tornado

S4CN (1160x720x50, dx=4 km)

WRF Forecast starting at 00Z Wed 27 Apr 2011