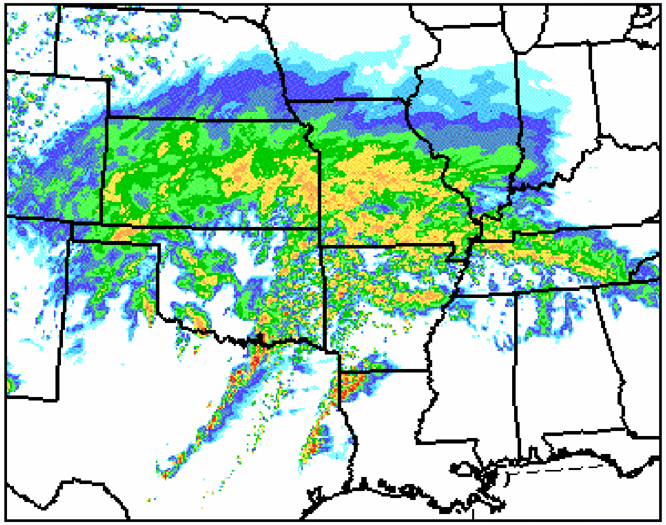
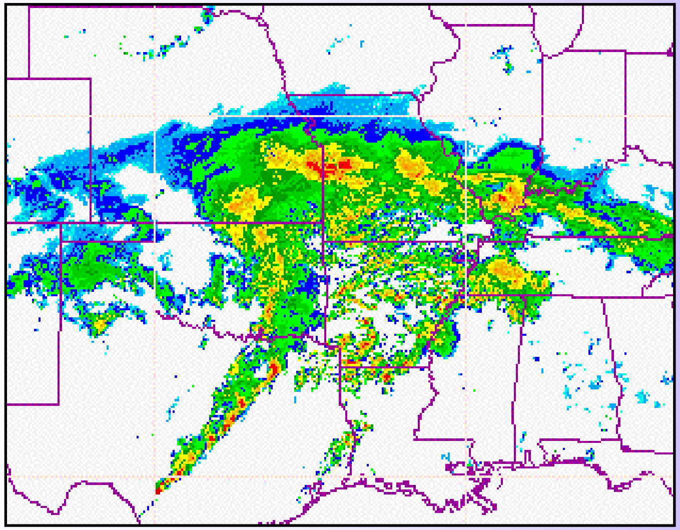
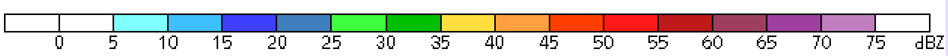
Progress in Convection-Resolving Forecasting with WRF

25 h WRF/ARW 3 km forecast



01 UTC 4/14/07 NOWRAD Mosaic

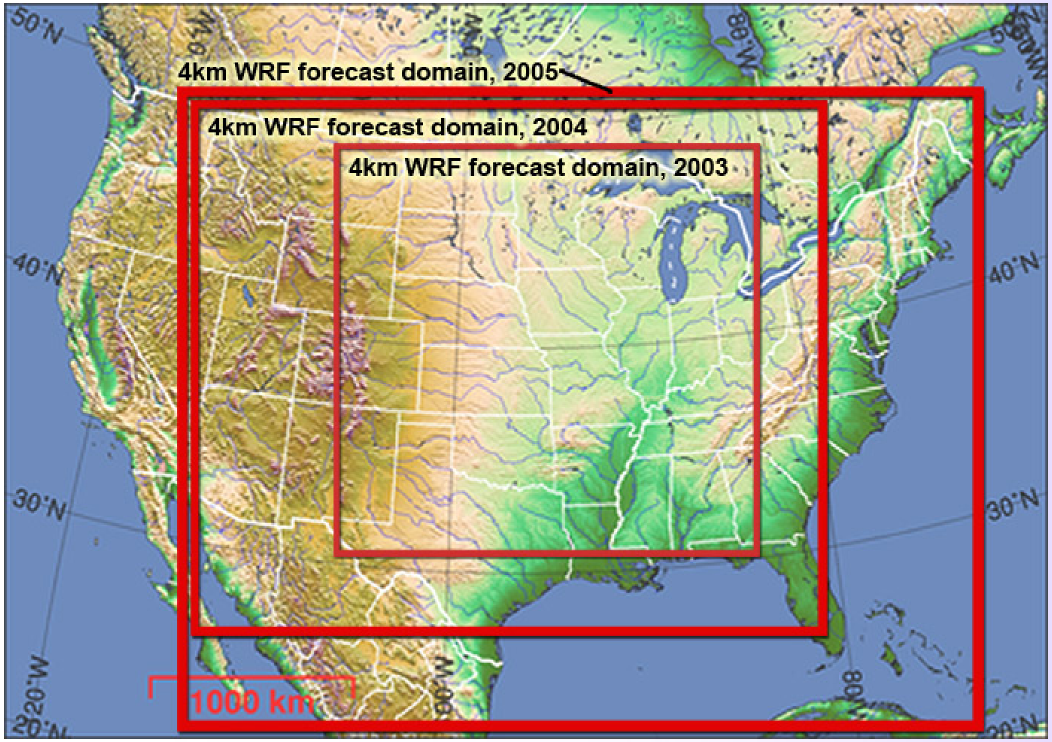




Joe Klemp

National Center for Atmospheric Research
Boulder, Colorado, USA

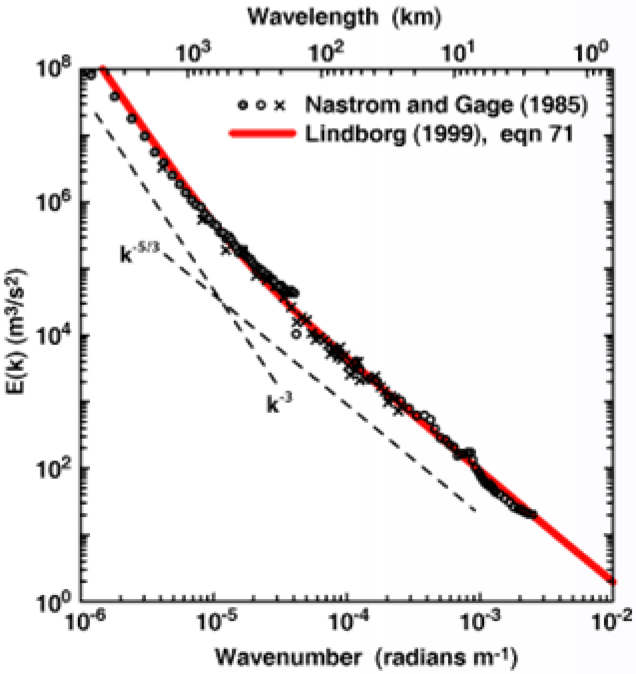
WRF-ARW Real-Time Convective Forecasts



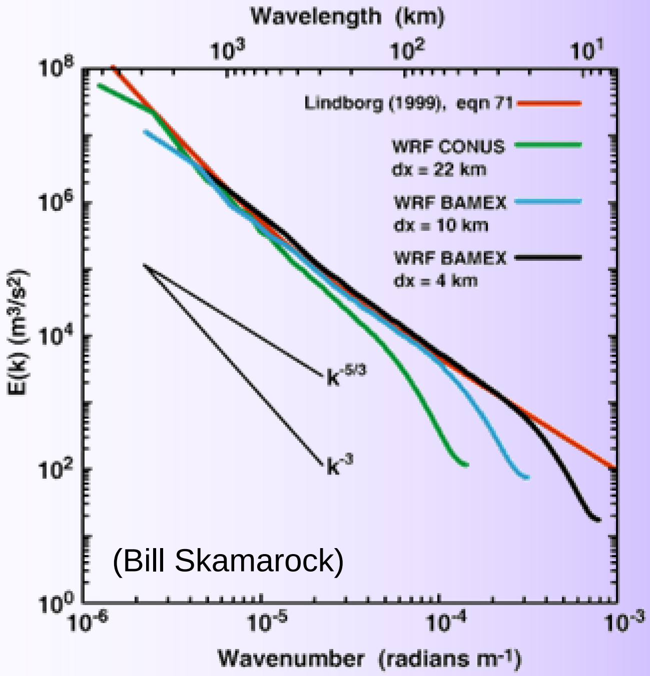
Year	Horizontal Grid	Domain	PBL	Microphysics	Land-Surface
2003	4 km	2000 x 2000 km	YSU	Lin (5 cat)	OSU
2004	4 km	2800 x 2600 km	YSU	Lin (5 cat)	OSU
2005	4 km	3900 x 3000 km	YSU	WSM6 (6 cat)	Noah
2006	4 km	3900 x 3000 km	MYJ	WSM6 (6 cat)	Noah
2007	3 km	3330 x 2760 km	MYJ	Thompson (6 cat)	Noah

WRF-ARW Dynamic Core

- Terrain-following hydrostatic pressure vertical coordinate
- Arakawa C-grid
- 3rd order Runge-Kutta split-explicit time differencing, 5th or 6th order differencing for advection
- Conserves mass, momentum, dry entropy, and scalars using flux form prognostic equations
- Minimal additional computational damping



Observed Kinetic Energy Spectra

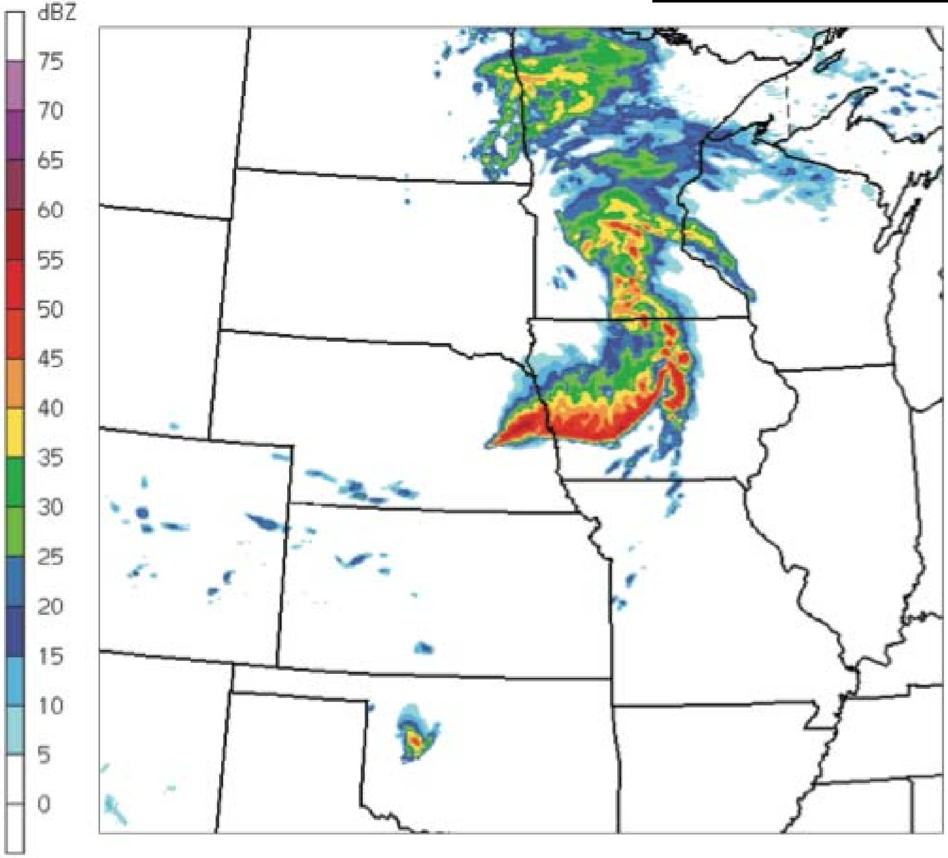


WRF-ARW Kinetic Energy Spectra

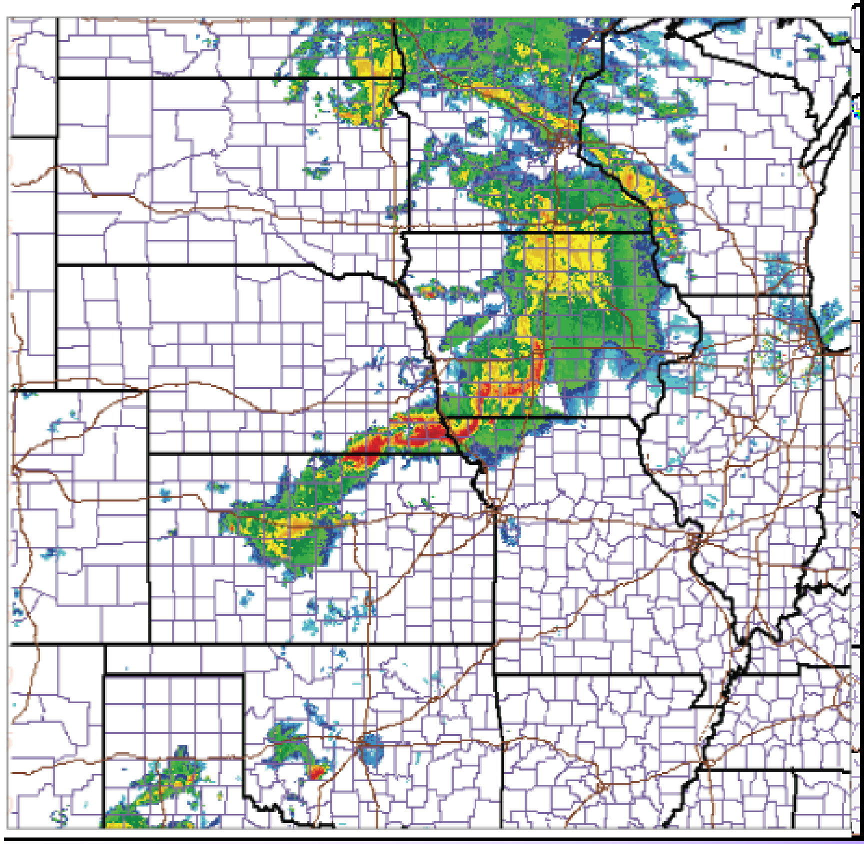
4 km WRF-ARW BAMEX Forecast

Initialized 00 UTC 9 June 03

30 h forecast 06 UTC 9 June 03

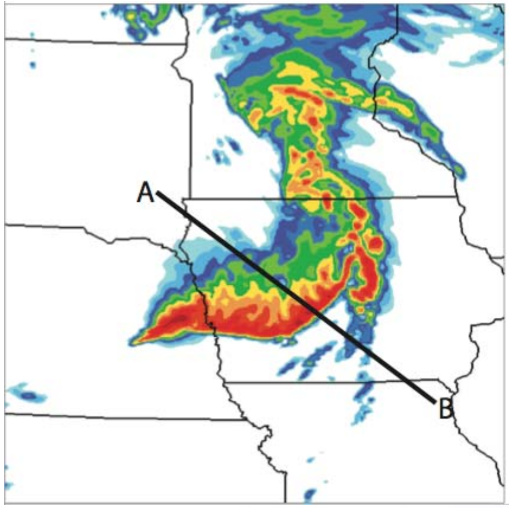


Reflectivity forecast

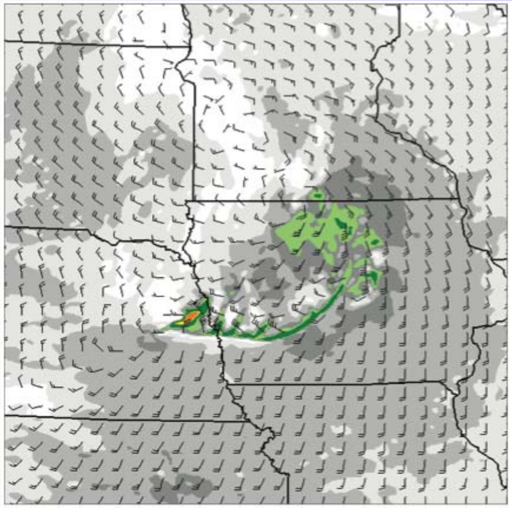


Composite NEXRAD Radar

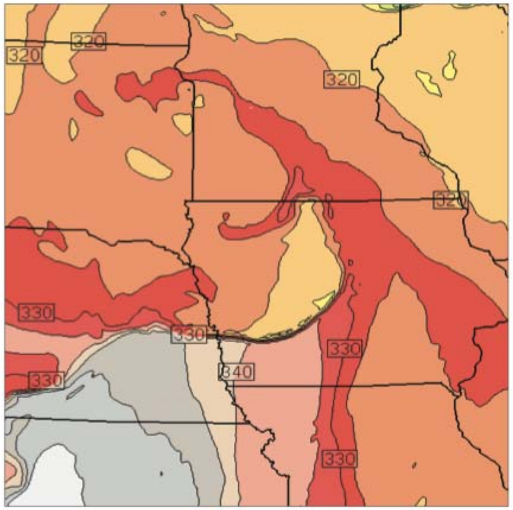
30 h ARW Forecast valid 6/10/03 06 UTC



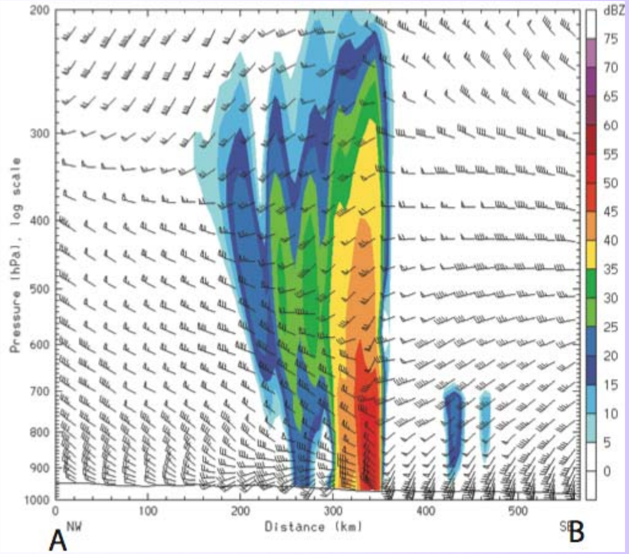
Reflectivity



Surface flow field



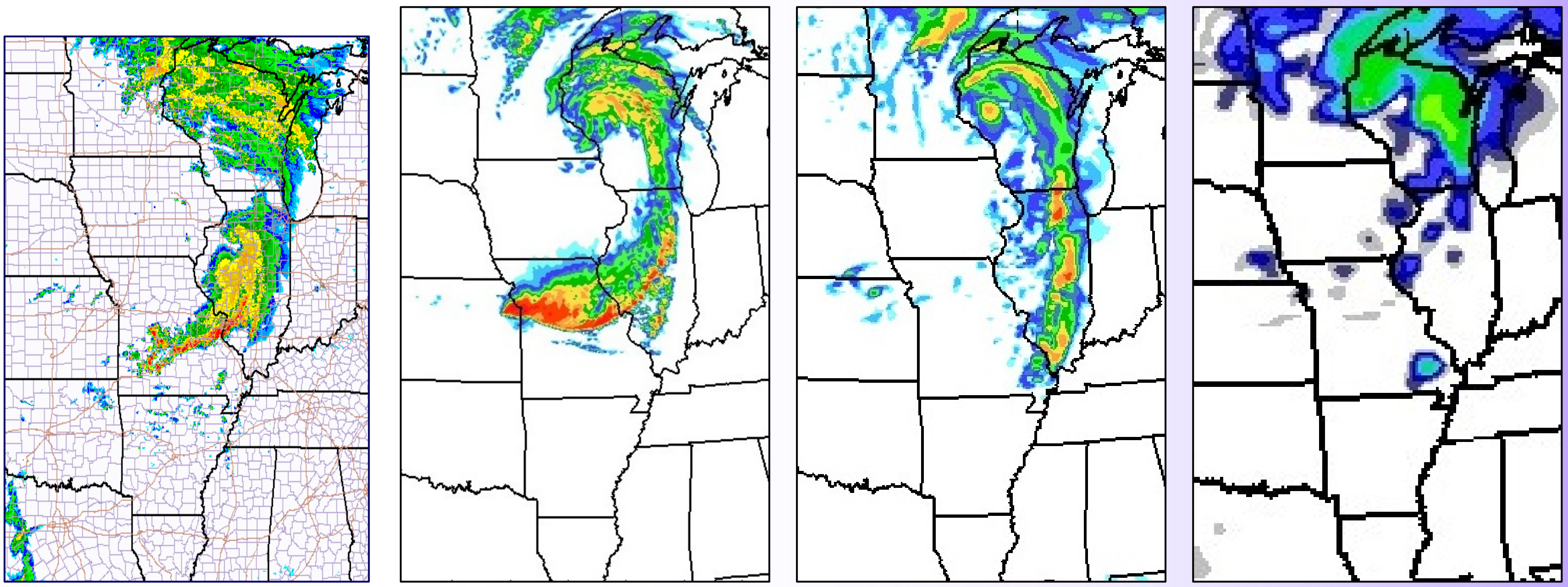
Surface theta-E



Reflectivity & relative wind

Real-time 36 h WRF Reflectivity Forecast

Valid 6/10/03 12Z



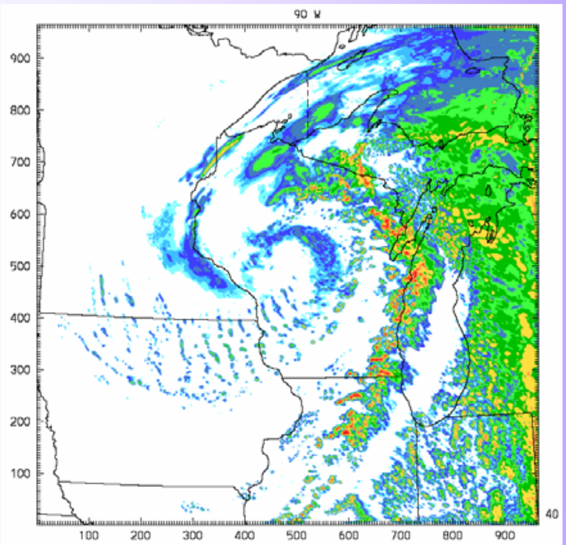
Composite NEXRAD Radar | **4 km BAMEX forecast** | **10 km BAMEX forecast** | **22 km CONUS forecast**

Real-time WRF BAMEX Forecast

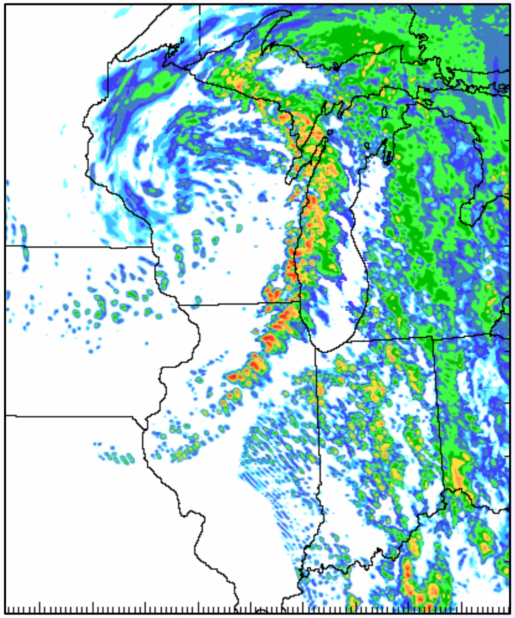
23 h Reflectivity Forecast

Valid 5/30/03 23 UTC

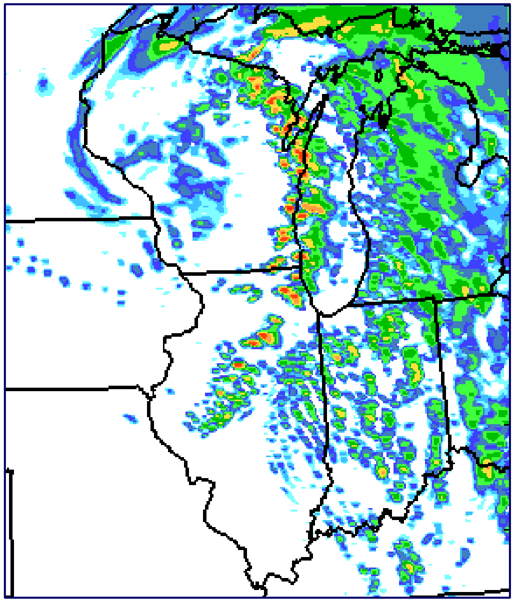
1 km



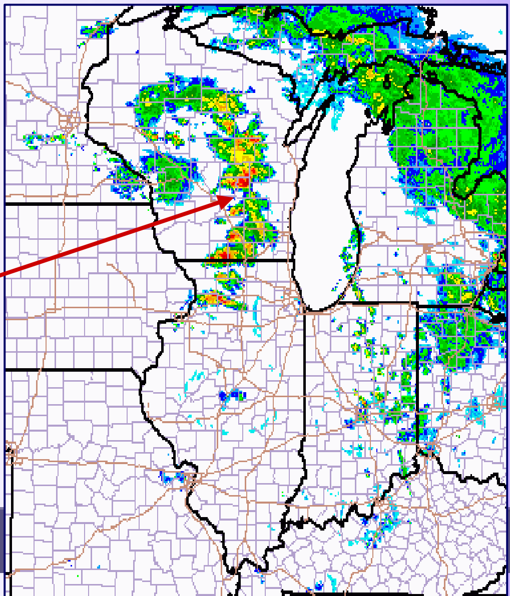
2 km



4 km



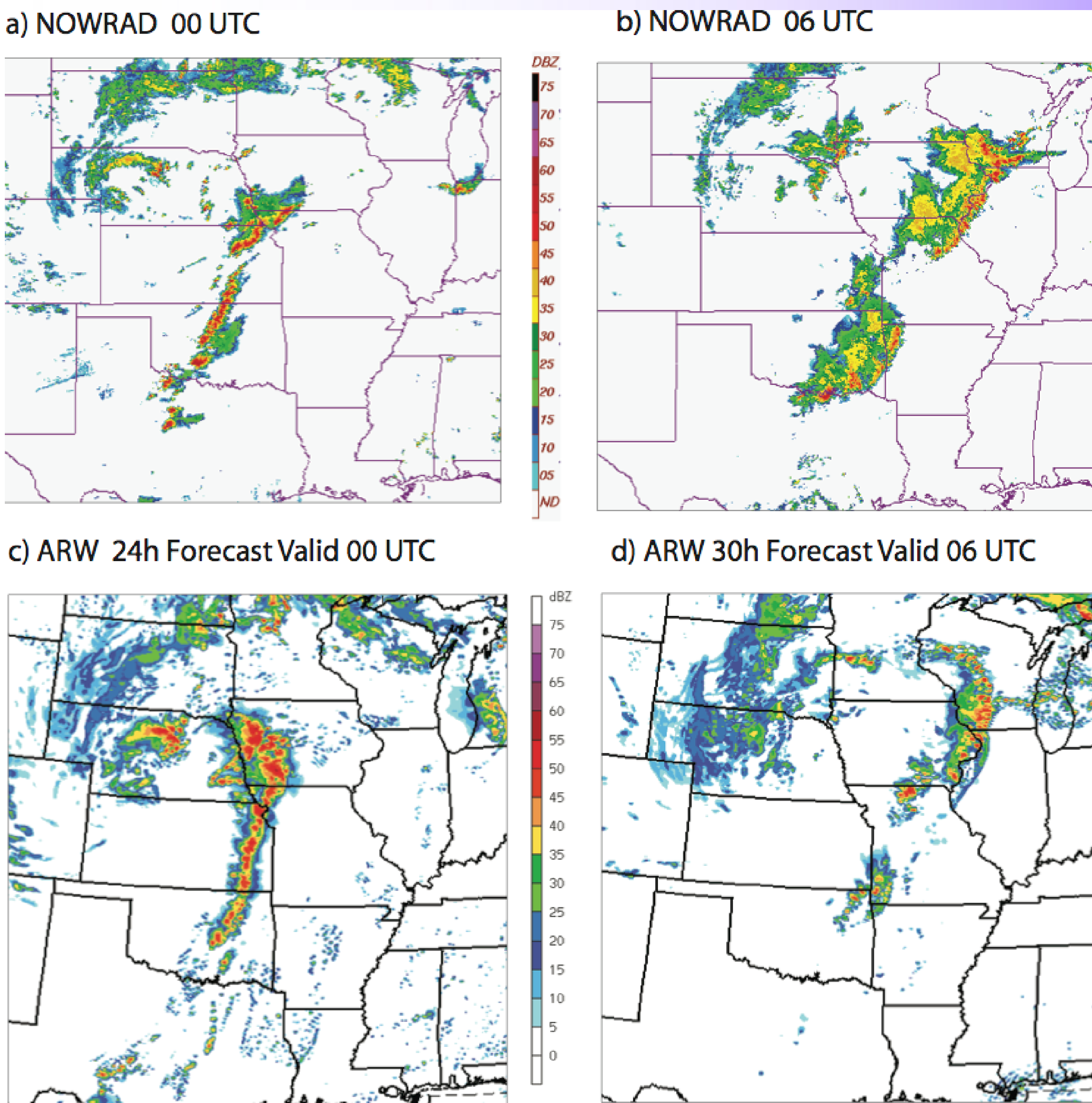
Composite NEXRAD Radar



Line of Supercells

4 km WRF-ARW Reflectivity Forecast

Initialized
00 UTC
04 June 2005



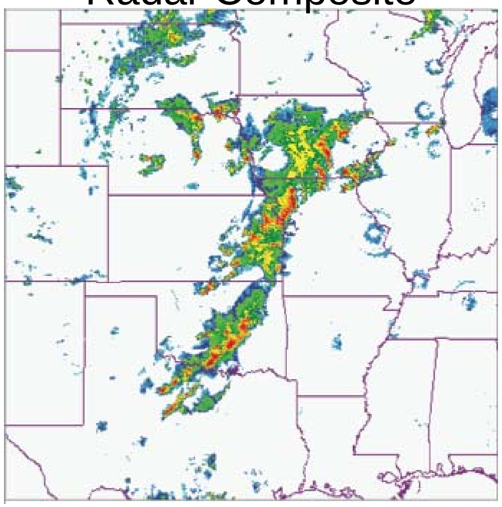
Common reasons for forecast failures:

- erroneous early convection
- misrepresented mesoscale/ larger-scale forcing
- insufficient convective spin-up

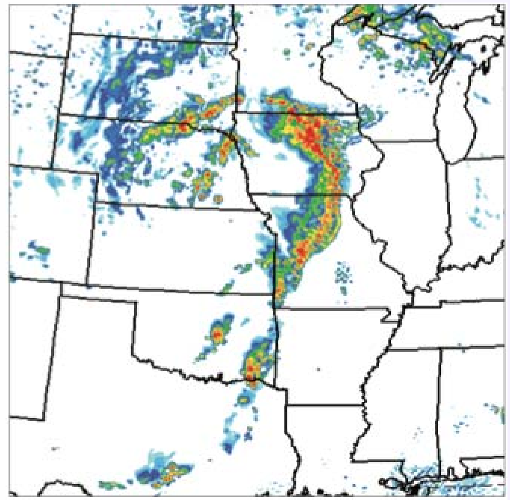
27 h WRF-ARW Sensitivity Forecasts

Valid 0300 UTC
05 June 2005

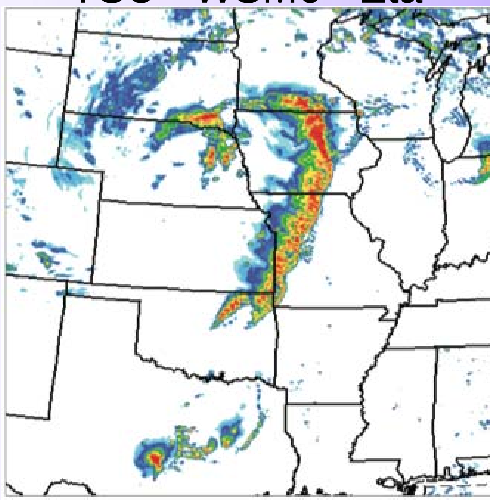
Radar Composite



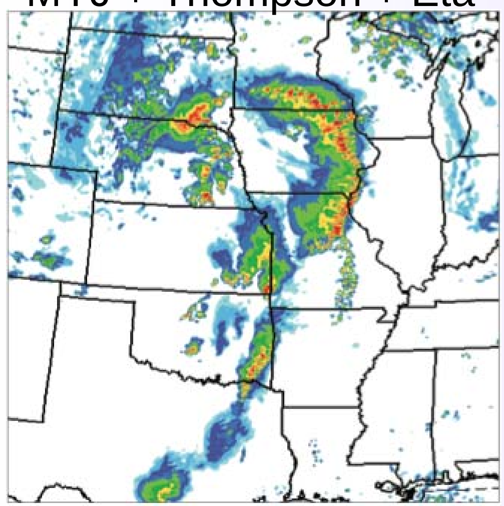
MYJ + WSM6 + Eta



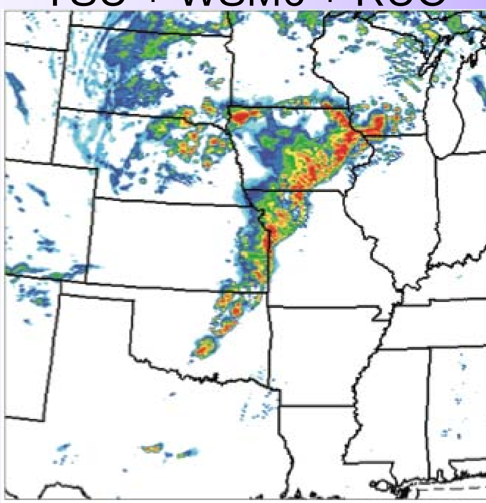
YSU +WSM6 +Eta



MYJ + Thompson + Eta



YSU + WSM6 + RUC

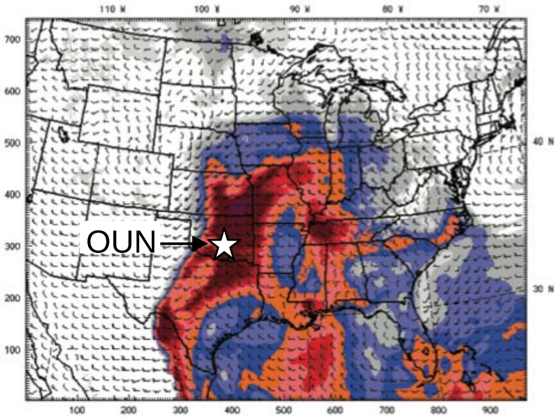


(Morris Weisman)

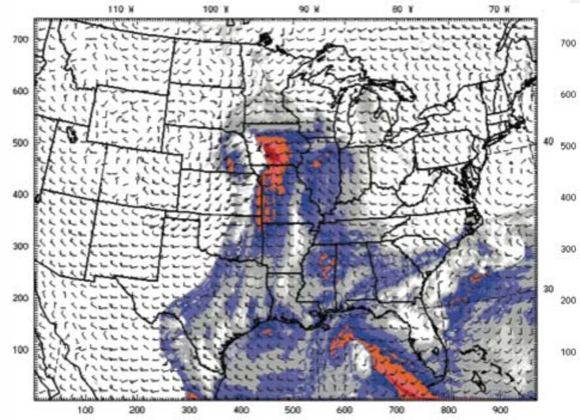
24 h CAPE and Oklahoma City Sounding Forecast

Valid 00 UTC 05 June 2005

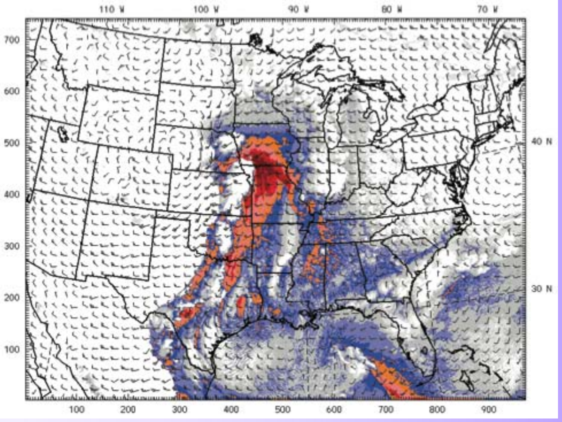
00 UTC ETA Analysis



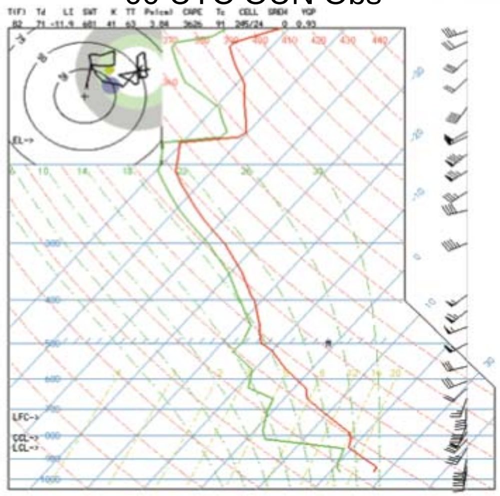
24 h ARW-YSU forecast



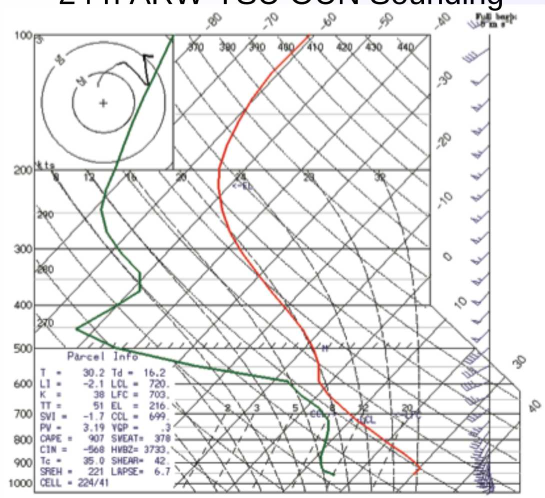
24 h ARW-MYJ forecast



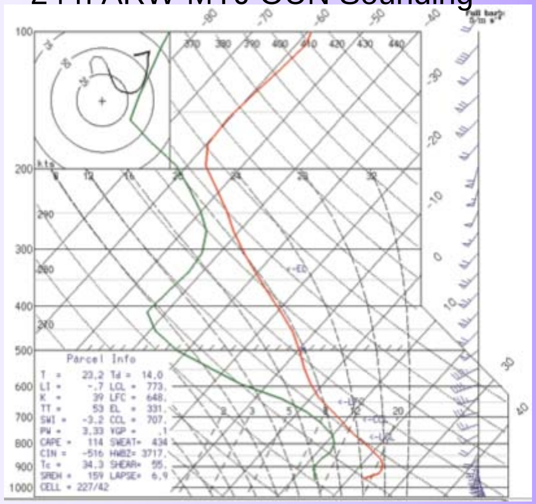
00 UTC OUN Obs



24 h ARW-YSU OUN Sounding



24 h ARW-MYJ OUN Sounding



(Morris Weisman)

Characteristic YSU and MYJ PBL Behavior

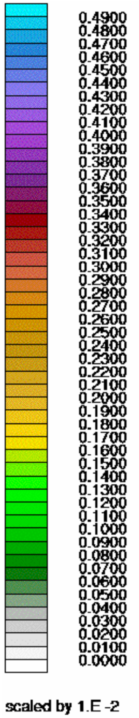
YSU PBL:

- Diagnoses BL depth and mixes instantaneously through entire BL
- Entrainment across BL top computed as a separate step
- Tends to produce deeper, drier BL, aggressive in eliminating capped inversions

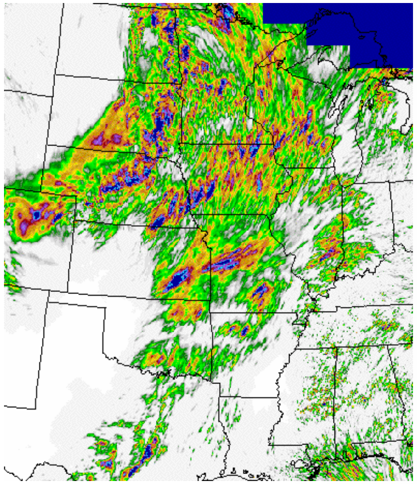
MYJ PBL

- Builds BL via direct mixing with adjacent model levels
- BL mixing based on turbulence energy calculations
- Tends to produce cooler moister BL, with more strongly capped inversions

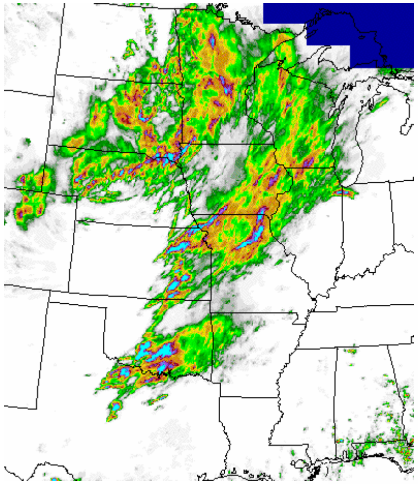
Ongoing Problem:High Precipitation Bias



Initialized 00 UTC 04 June 2005

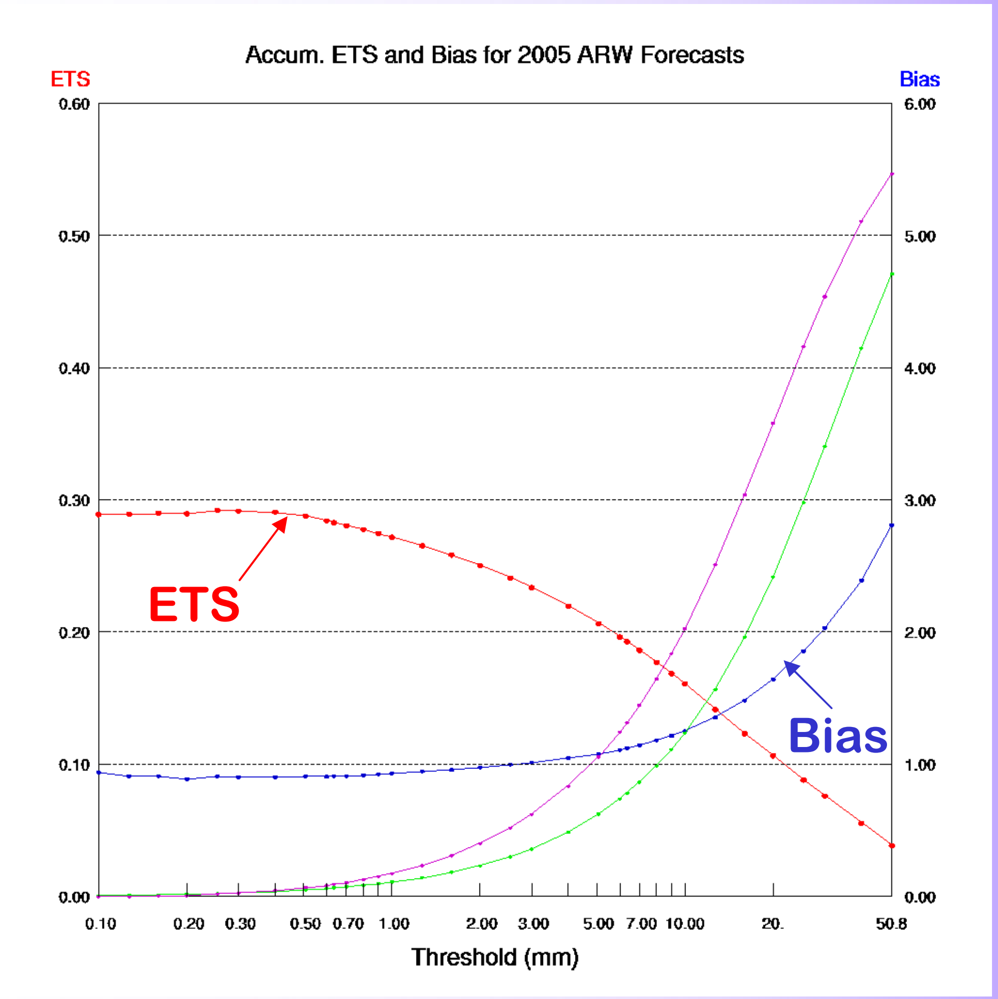


ARW 12-36 h Forecast Precip



24 h Observed (ST4) Precip

2005 ARW 4 km Forecasts:



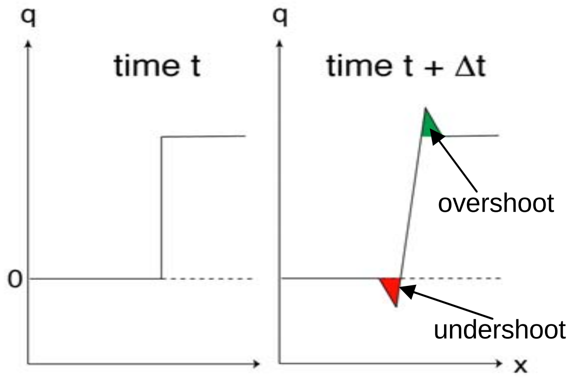
Mesoscale & Microscale Meteorology Division

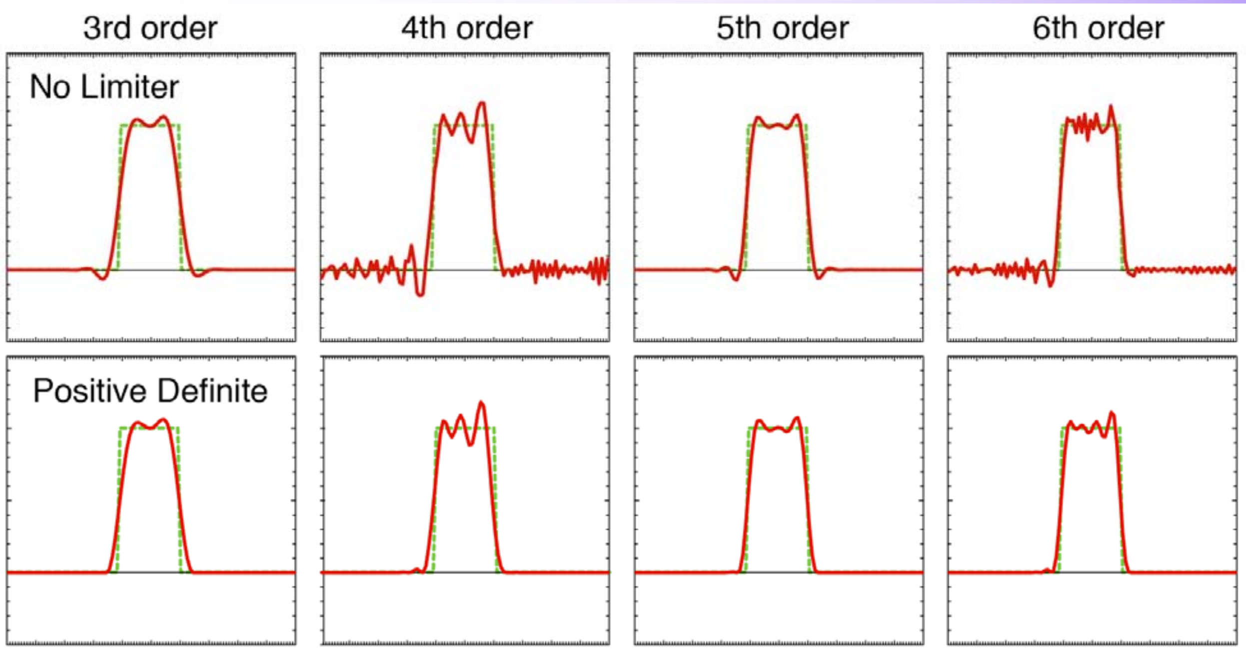
NCAR

Moisture Transport in WRF/ARW

Advection of Top-Hat Profile with PD Limiter

1D advection





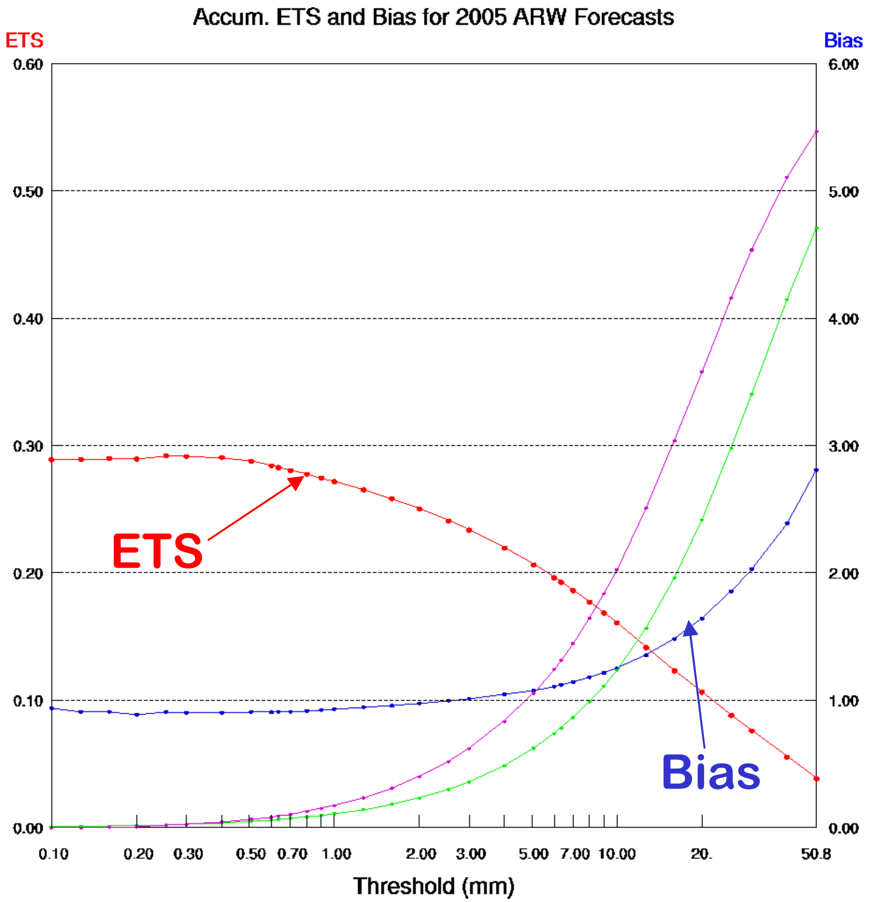
ARW scheme is conservative, but not positive definite nor monotonic. Removal of negative q ■ results in spurious source of q ■.

Cr = 0.5, 1 revolution (200 steps)

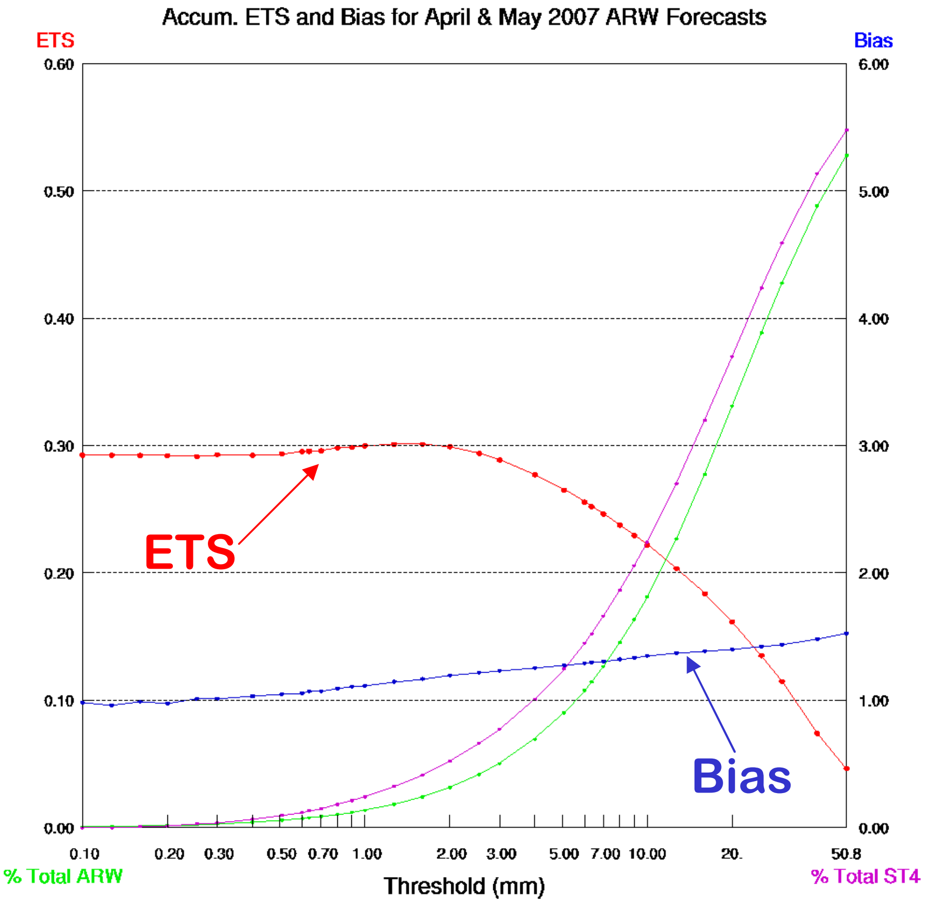
(Bill Skamarock)

Accumulated ETS and BIAS: 2005, 2007

2005: Standard advection

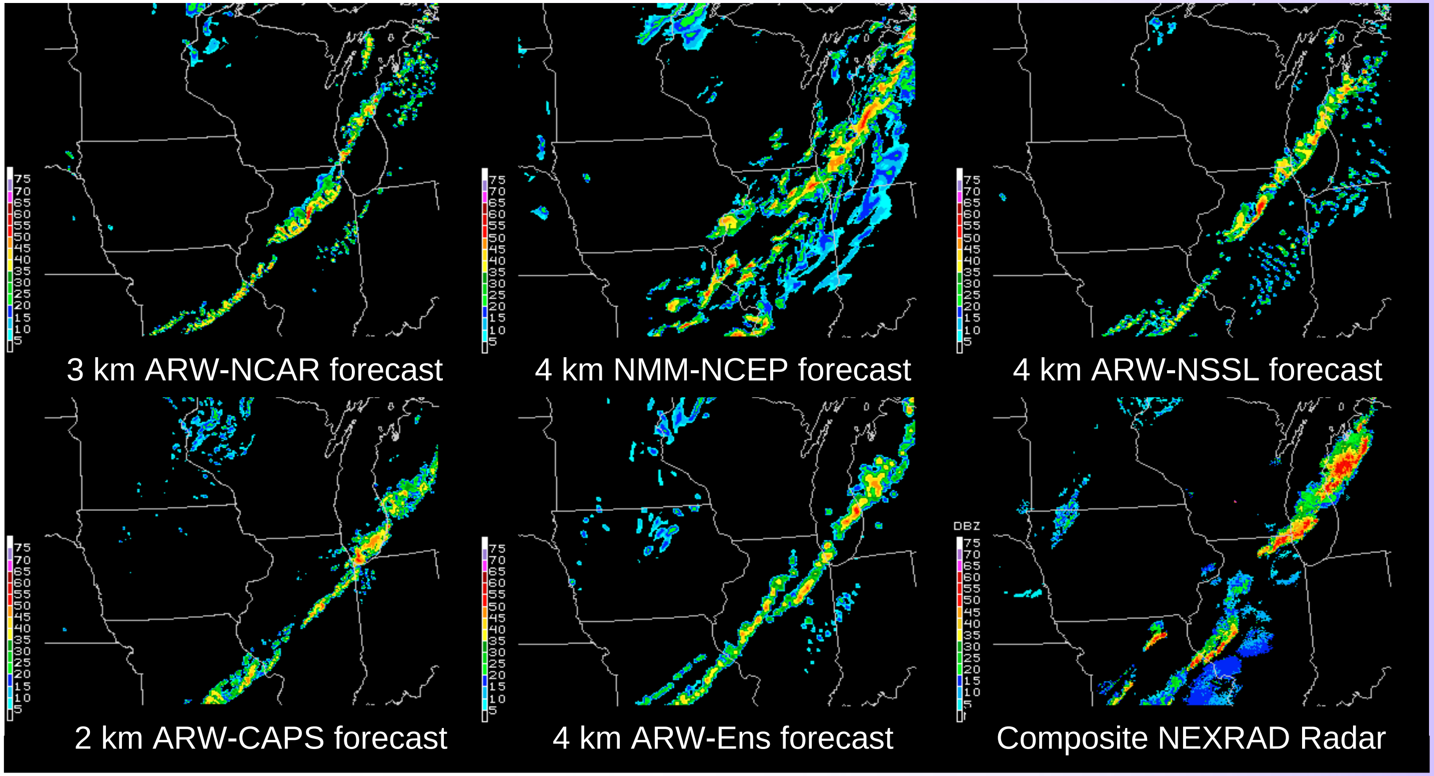


2007: Positive-definite advection



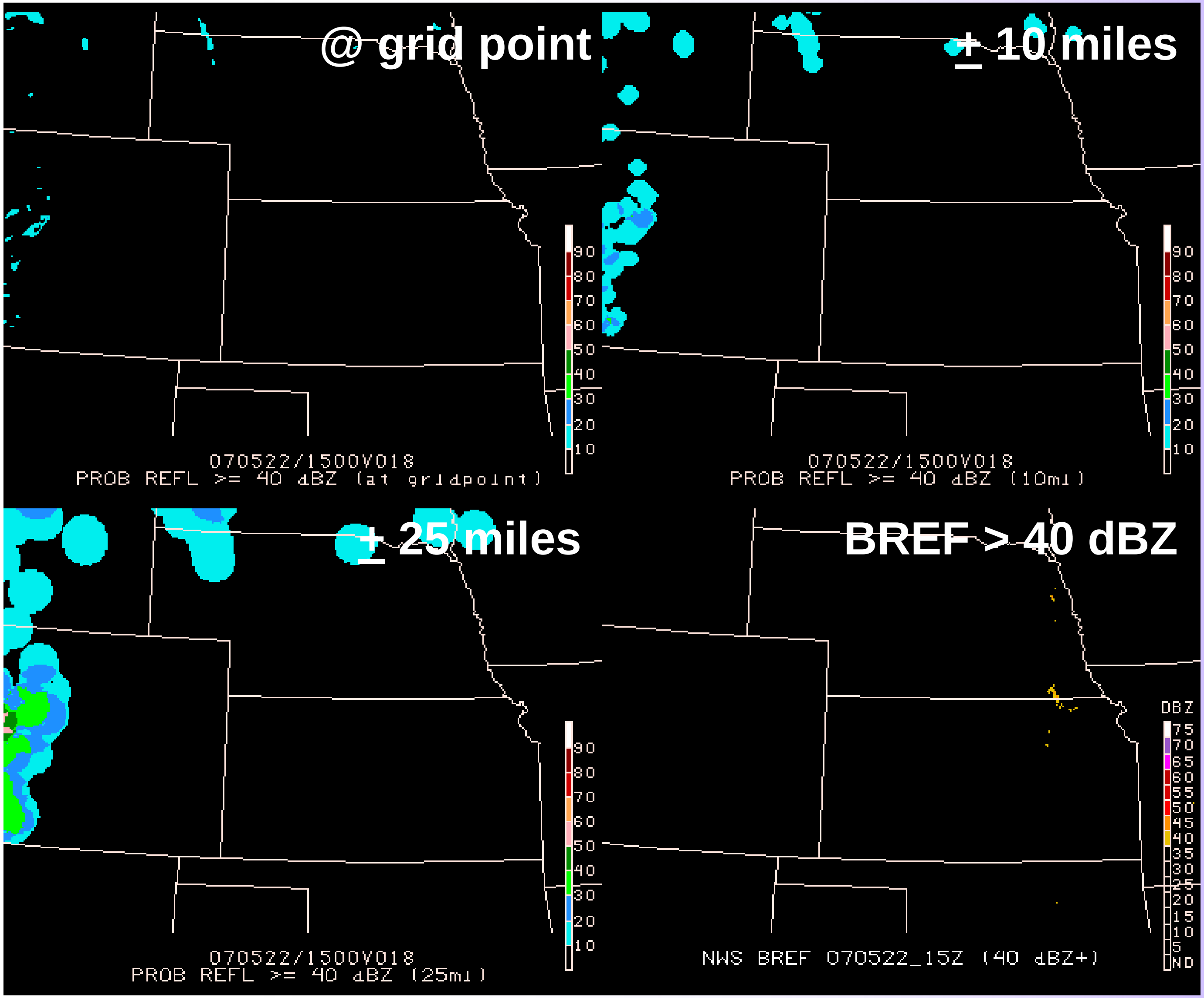
NOAA Hazardous Weather Testbed 2007 Spring Experiment

- Directed by SPC, NSSL, and the Norman WFO
- Convection allowing forecasts provided by OU/CAPS, NCAR, NCEP, and NSSL
- Daily 36 h forecasts over ~2/3 CONUS from 23 April - 8 June 2007



30 h WRF Reflectivity Forecasts Valid 6/08/07 06 UTC

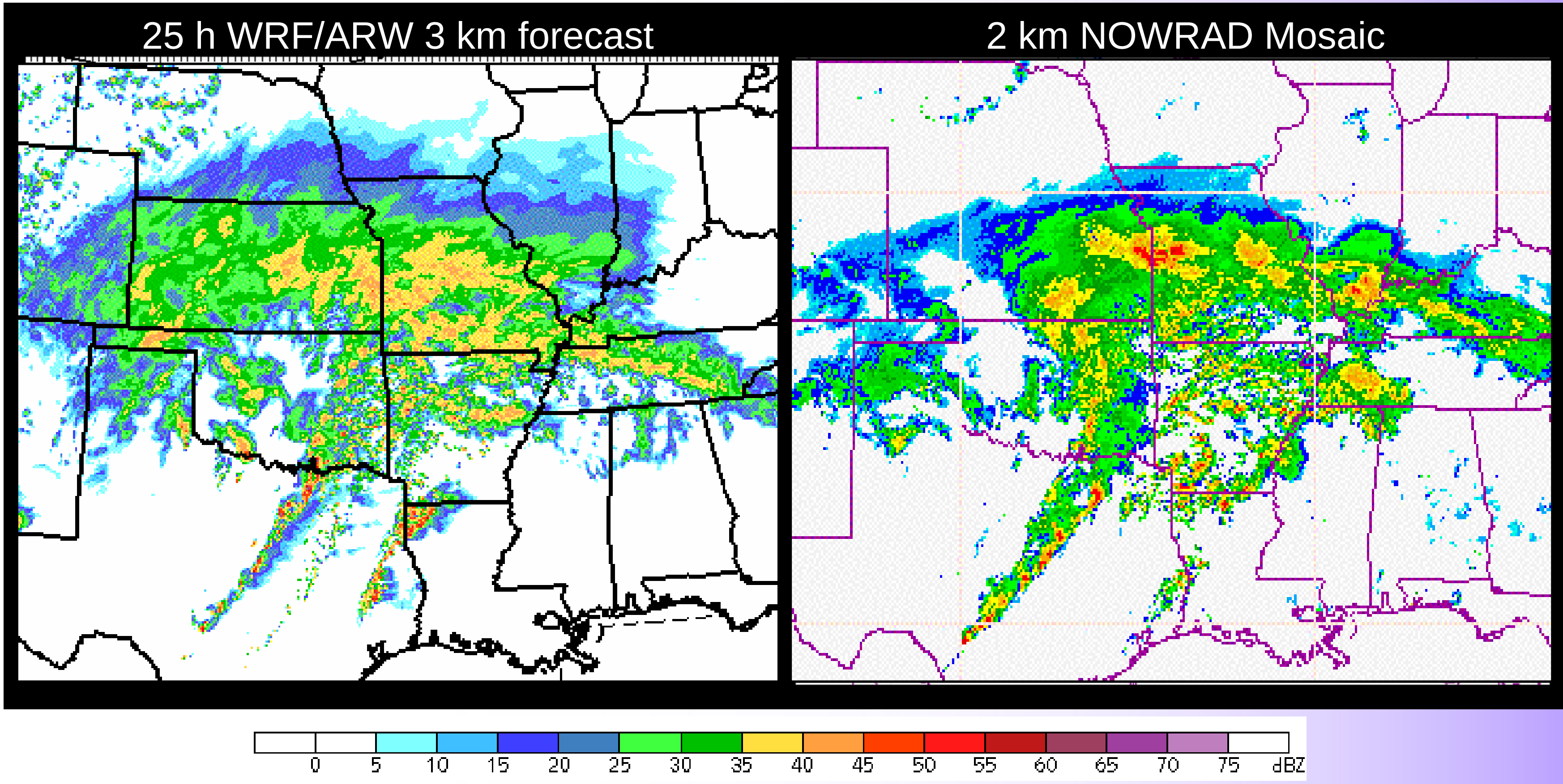
Probability of Reflectivity > 40 dBZ within a radius



(Mike Coniglio, NSSL)

3 km WRF-ARW Forecast
2007 NOAA HWT Spring Experiment

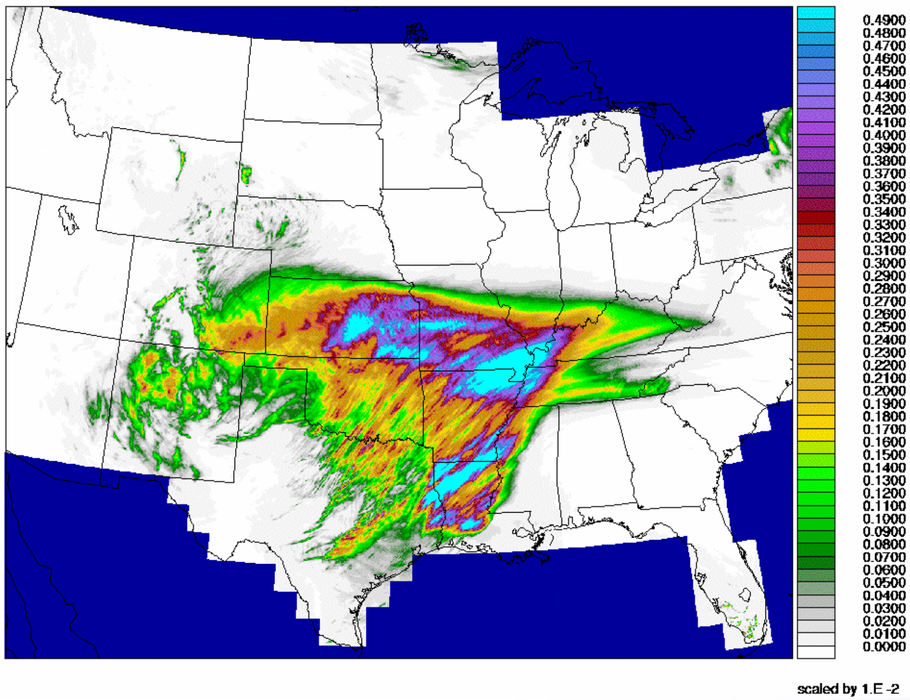
Forecast and composite radar reflectivity for tornadic squall line at 01 UTC 4/14/07



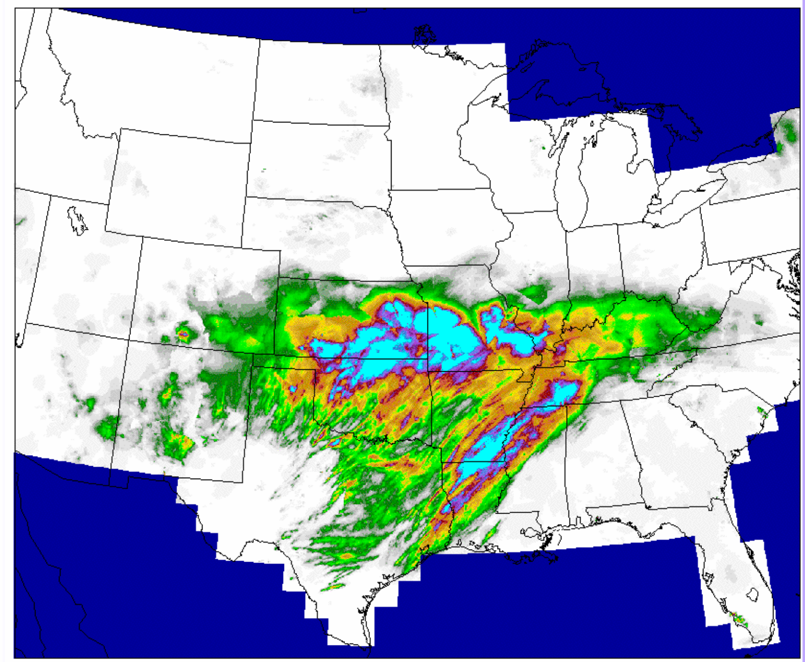
12-36 h Accumulated Precipitation

Forecast initialized at 00 UTC 13 April 2007

3 km ARW Forecast

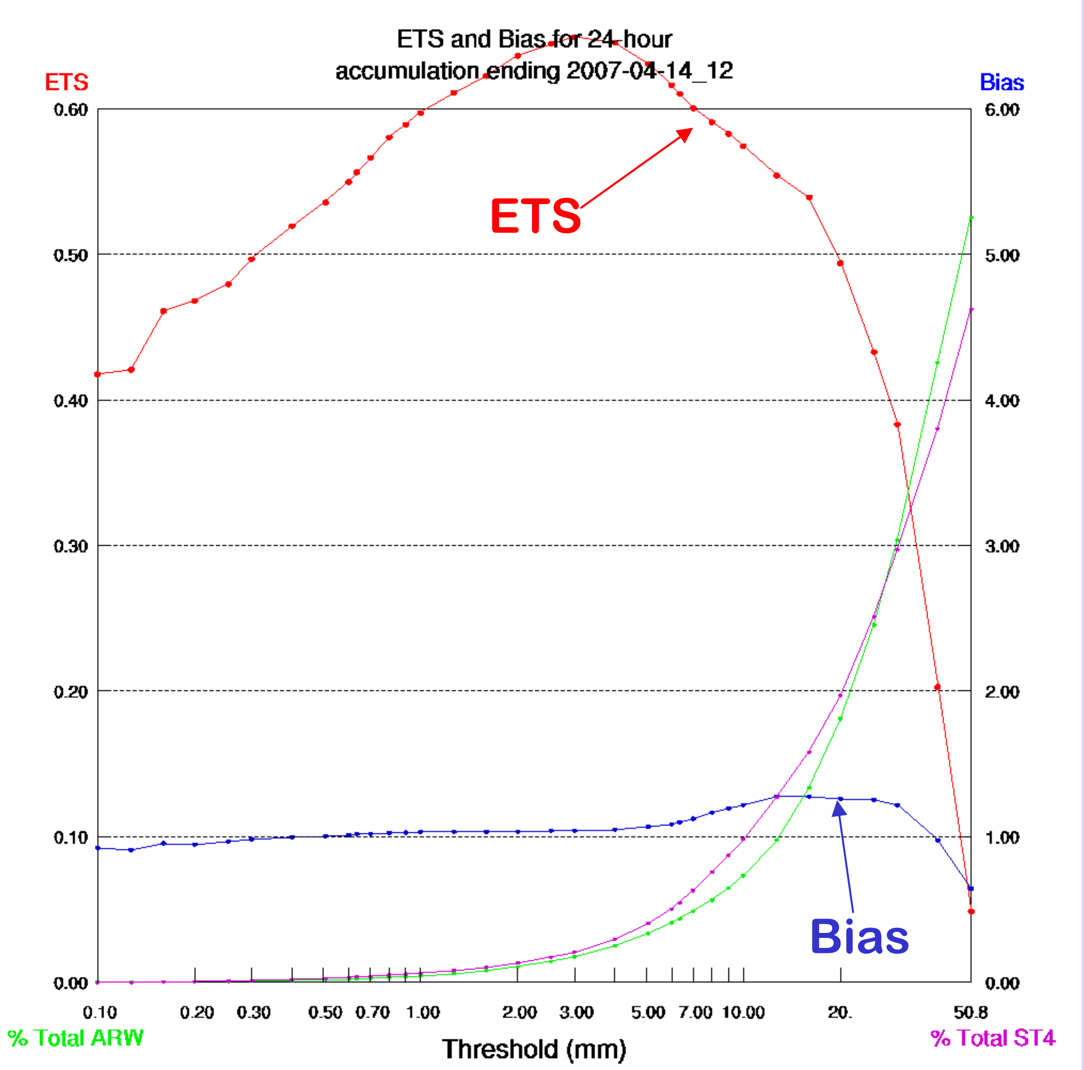


ST4 Precipitation Analysis



24 h ETS and BIAS: 04/14/07

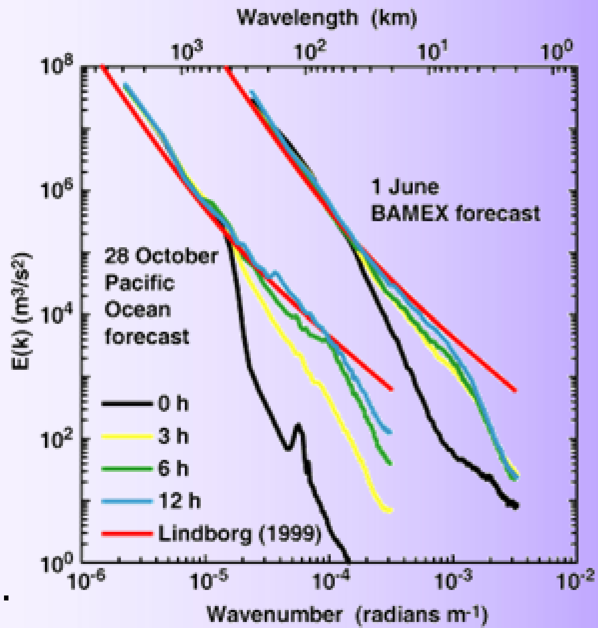
Forecast initialized at 00 UTC 13 April 2007



Summary of Explicit Convective Forecasts

Progress:

- Encouraging ability to forecast mesoscale convective systems (MCS) out to 36 h
- Demonstrated skill at depicting MCS mode (bow echoes, mesoscale convective vortices, supercell lines)
- Spin-up of convective systems within 3-4 h from a cold start.
- Convective systems well-forecast when closely tied to well-resolved larger-scale forcing features.

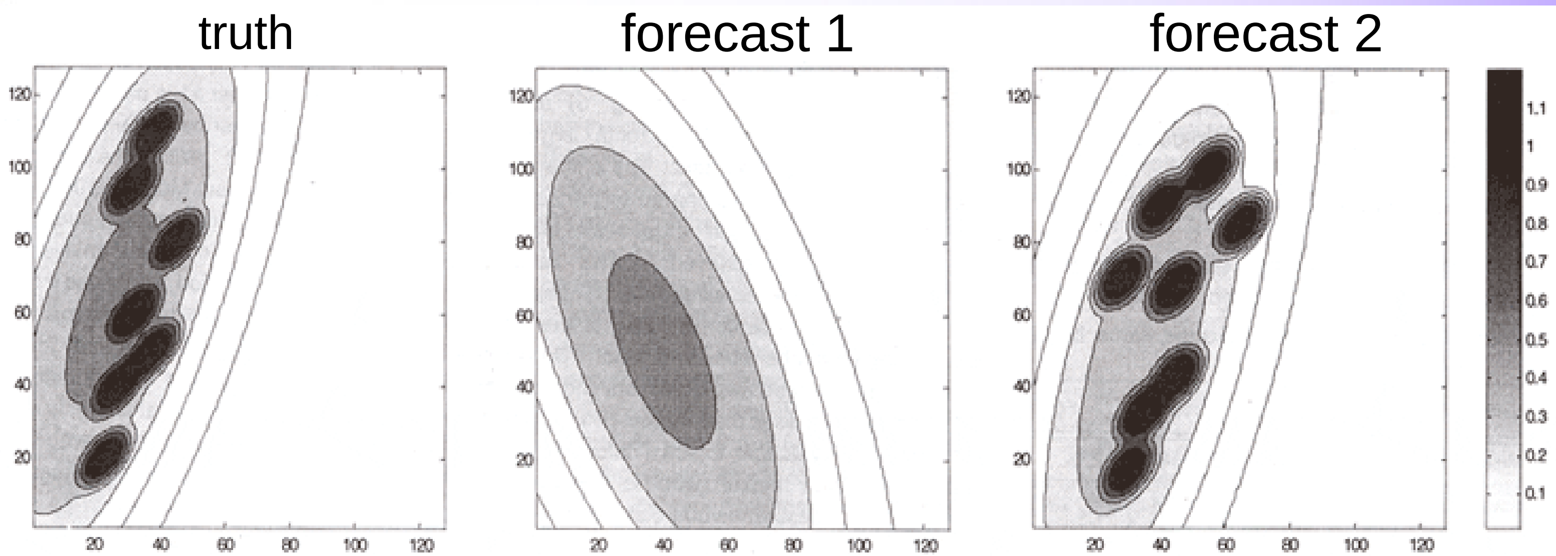


(Skamarock, MWR 2004)

Challenges:

- Convective systems not well forecast when building upscale from isolated cells and/or within weakly-forced regions.
- Forecast deficiencies generally not remedied by modifications to model physics, resolution…..more sensitivity to variations in initial conditions.
- Better representation of meso/ sub-synoptic scale features in the initial state may be critical for further forecast improvements.
- New verification techniques needed for high-resolution forecasts.

Problems with Traditional Verification Schemes



Verification measure	Forecast #1	Forecast #2
Mean absolute error	0.157	0.159
RMS error	0.254	0.309
Bias	0.98	0.98
Threat score	0.214	0.161
Equitable threat score	0.170	0.102

Issue: the obviously poorer forecast has better skill scores

From Mike Baldwin
NOAA/NSSL