A comparison of bulk microphysical schemes for cloud resolving NWP

Axel Seifert and Morris Weisman

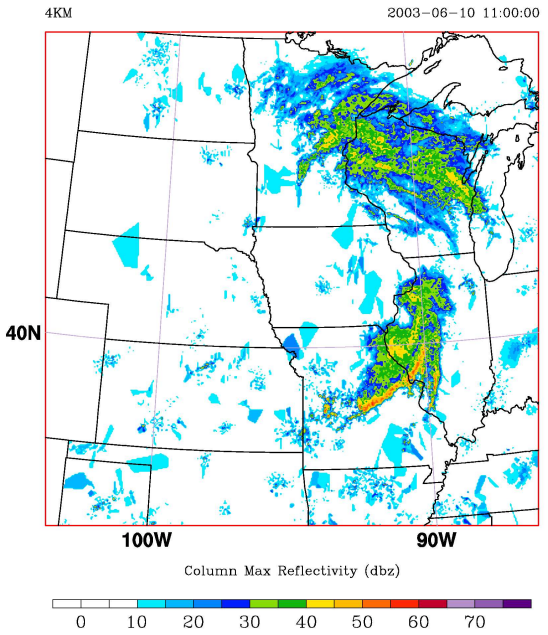
... with help from a lot of people at NCAR

National Center for Atmospheric Research, Boulder, CO

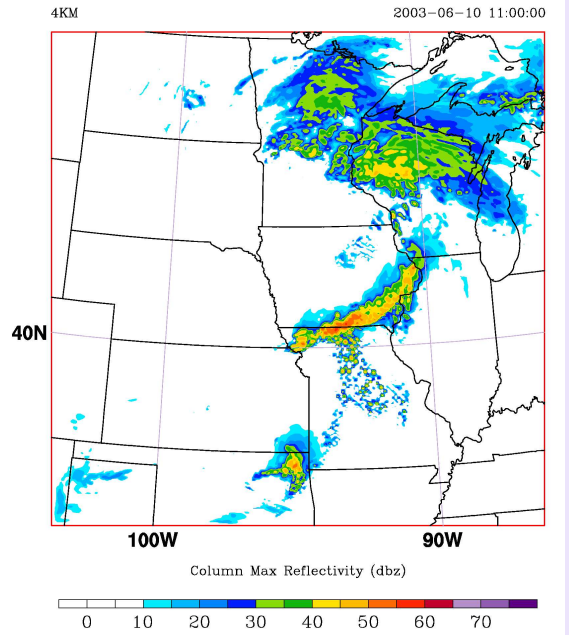
Motivation

BAMEX 2003, JUNE 10 - 00 UTC + 11 h, column max. reflectivity

a) NEXRAD Composite



b) LIN scheme



- Error in location of convective line
- Lack of trailing stratiform region (High refl. line at leading edge is too broad)
- Spurious convective cell in Oklahoma
- Overprediction of surface precipitation

WRF setup

- WRF 1.3 as used for BAMEX forecasts

WRF setup

- WRF 1.3 as used for BAMEX forecasts
- 1600 km $\times$ 1600 km domain over continental U.S. with 4 km resolution (400$\times$400$\times$30 grid points)

WRF setup

- WRF 1.3 as used for BAMEX forecasts
- 1600 km $\times$ 1600 km domain over continental U.S. with 4 km resolution (400$\times$400$\times$30 grid points)
- WRFSI initialization at 00 UTC and b.c. using ETA model forecast (no clouds)

WRF setup

- WRF 1.3 as used for BAMEX forecasts
- 1600 km $\times$ 1600 km domain over continental U.S. with 4 km resolution (400$\times$400$\times$30 grid points)
- WRFSI initialization at 00 UTC and b.c. using ETA model forecast (no clouds)
- YSU boundary layer scheme

WRF setup

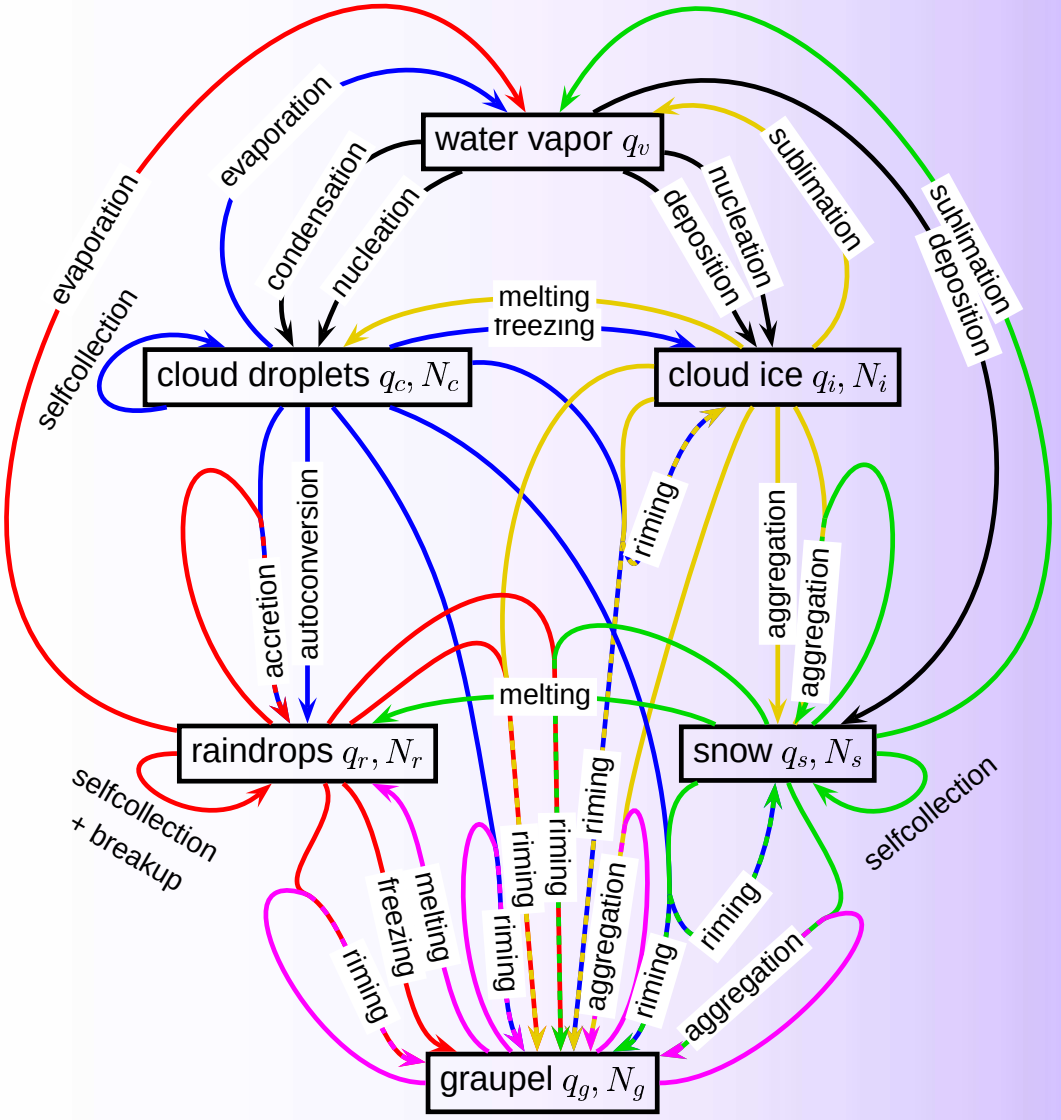
- WRF 1.3 as used for BAMEX forecasts
- 1600 km $\times$ 1600 km domain over continental U.S. with 4 km resolution (400$\times$400$\times$30 grid points)
- WRFSI initialization at 00 UTC and b.c. using ETA model forecast (no clouds)
- YSU boundary layer scheme
- No cumulus parameterization

WRF setup

- WRF 1.3 as used for BAMEX forecasts
- 1600 km $\times$ 1600 km domain over continental U.S. with 4 km resolution (400$\times$400$\times$30 grid points)
- WRFSI initialization at 00 UTC and b.c. using ETA model forecast (no clouds)
- YSU boundary layer scheme
- No cumulus parameterization
- Four microphysical schemes:
  - Purdue ’Lin et al.’ scheme
  - WRF single-moment scheme by Hong et al. (WSM-6)
  - Reisner scheme (Thompson et al. 2004)
  - Seifert&Beheng two-moment scheme

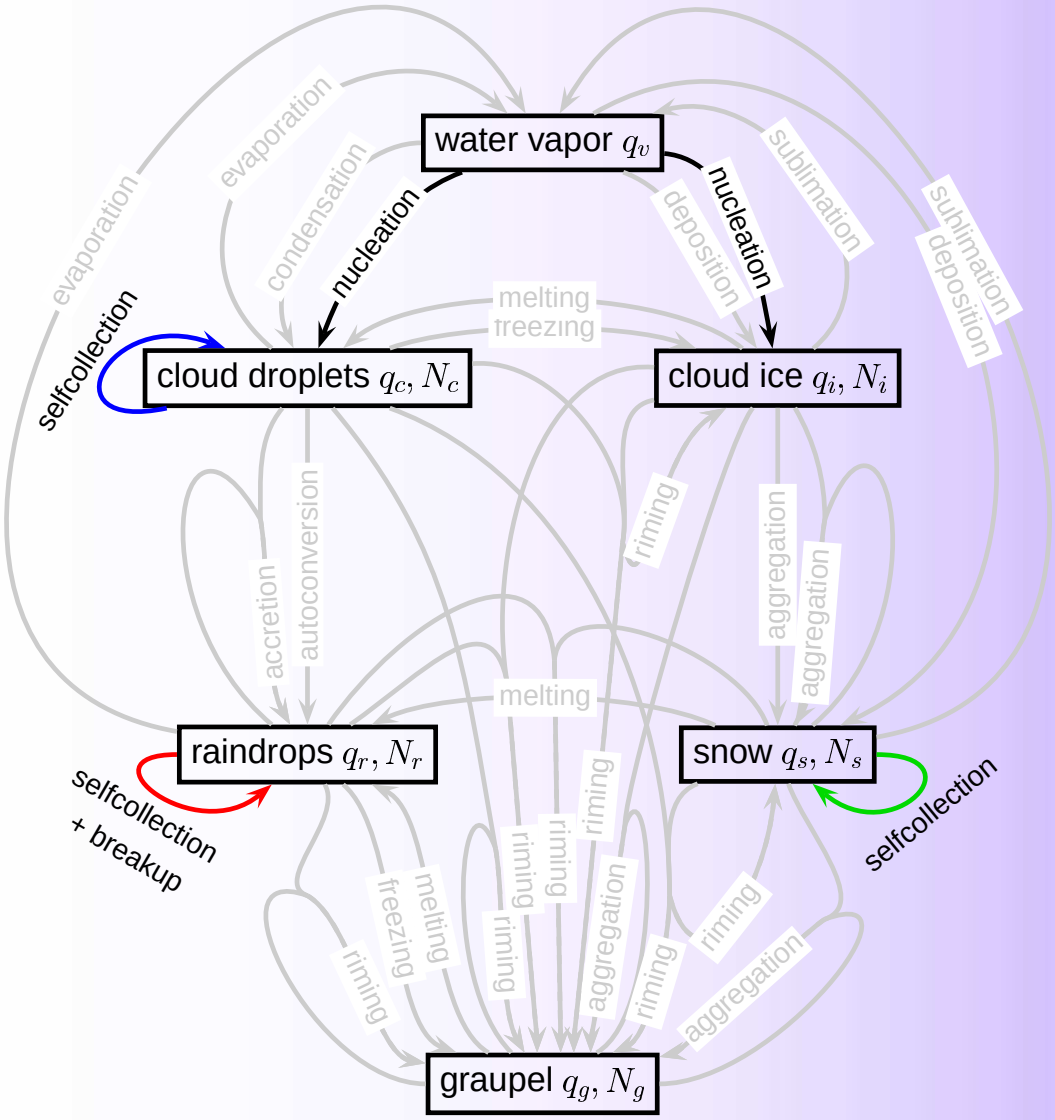
Seifert&Beheng two-moment microphysics

- mass and number concentrations
- cloud water, rain, cloud ice, snow, graupel
- S&B (2001) autoconversion
- snow = unrimed and slighty rimed aggregates
- graupel density increases from 0.2 to 0.8 g/cm^3, i.e. includes rimed aggregates, graupel and hail



Seifert&Beheng two-moment microphysics

- nucleation of droplets and ice
- selfcollection and breakup



Observations used for validation:

- NEXRAD column maximum reflectivity composite (available only for BAMEX domain)
- NCEP precipitation estimates (Stage II radar-only, Stage II gage-only, Stage IV)

Observations used for validation:

- NEXRAD column maximum reflectivity composite (available only for BAMEX domain)
- NCEP precipitation estimates (Stage II radar-only, Stage II gage-only, Stage IV)

Reflectivity calculation:

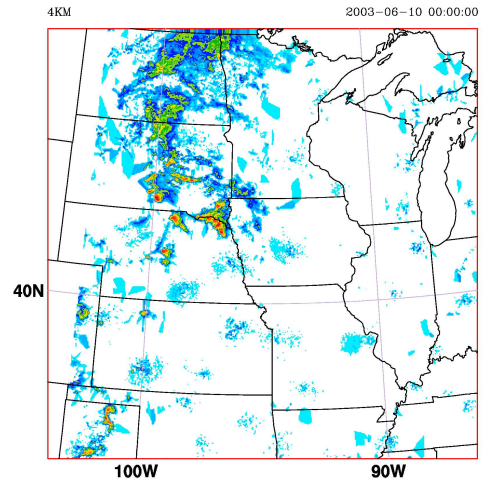
- Empirical approach not useful for comparison of microphysics schemes
- Use particle densities and size distributions as assumed in each microphysics scheme (two-moment schemes can use number conc.)
- Maxwell-Garnet approach to approximate dielectric function of ice particles
- Mie theory to calculate reflectivity using size bins

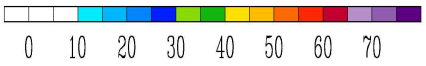
Test case 1:

JUNE 10 - Bow echo

JUNE 10 - 00 UTC + 00 h, microphysics schemes

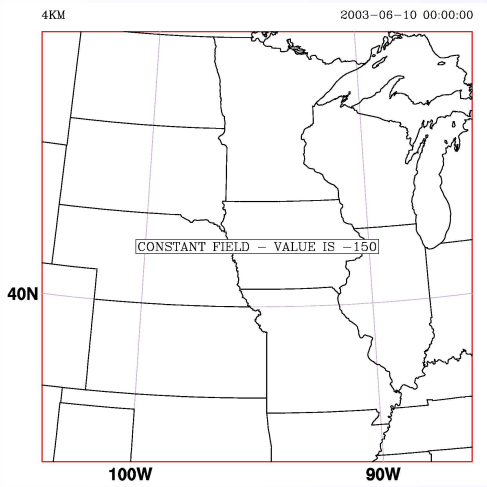
a) NEXRAD Composite



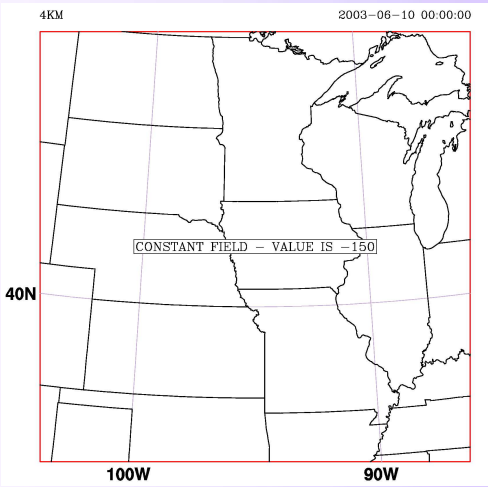


Column max. reflectivity (dBZ)

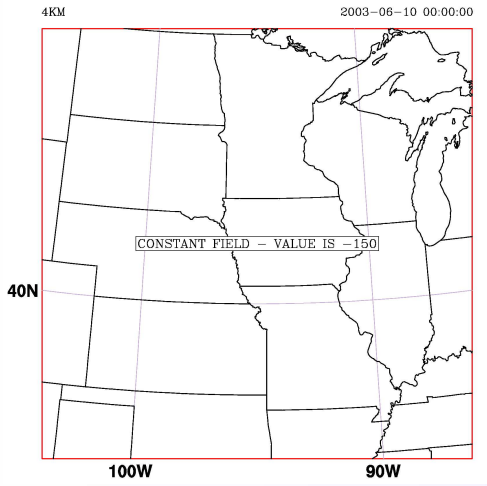
b) LIN scheme



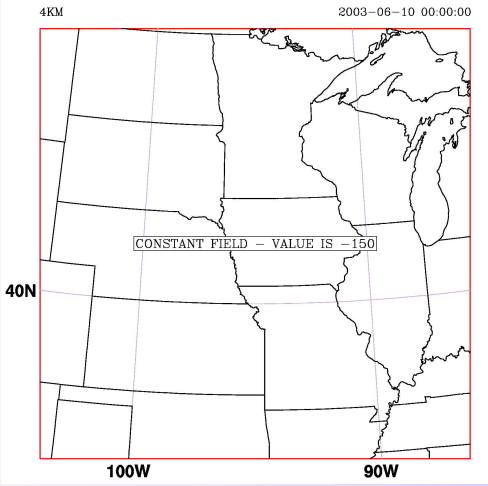
c) WSM-6 scheme



d) Reisner scheme

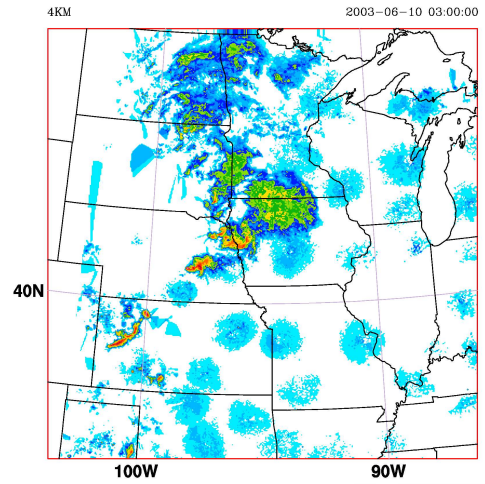


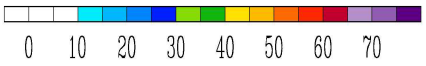
e) SB2004 scheme



JUNE 10 - 00 UTC + 03 h, microphysics schemes

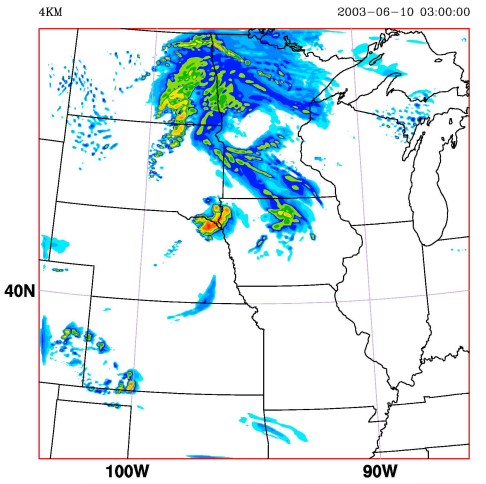
a) NEXRAD Composite



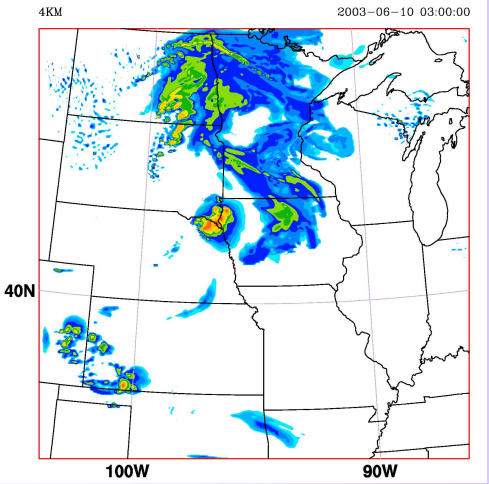


Column max. reflectivity (dBZ)

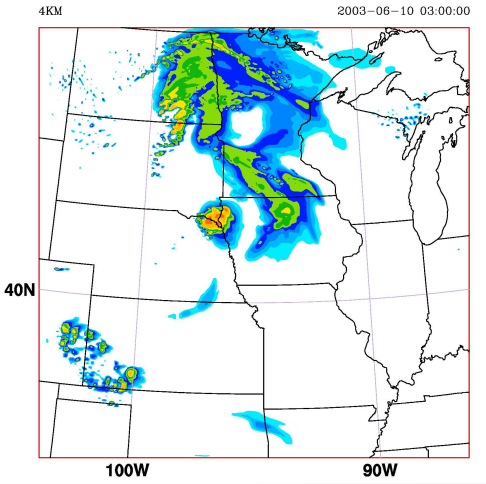
b) LIN scheme



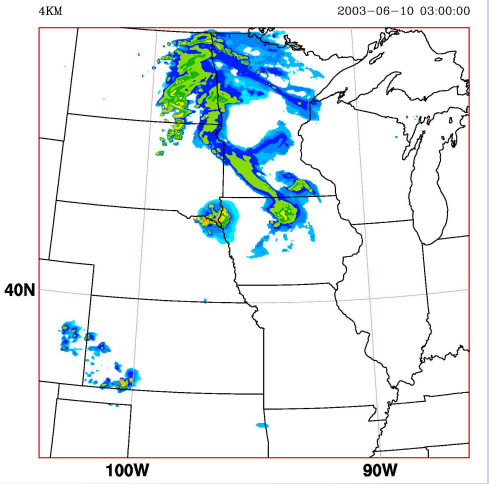
c) WSM-6 scheme



d) Reisner scheme

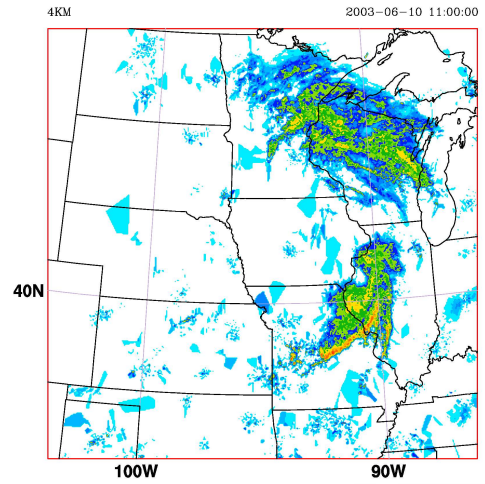


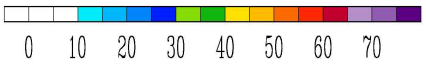
e) SB2004 scheme



JUNE 10 - 00 UTC + 11 h, microphysics schemes

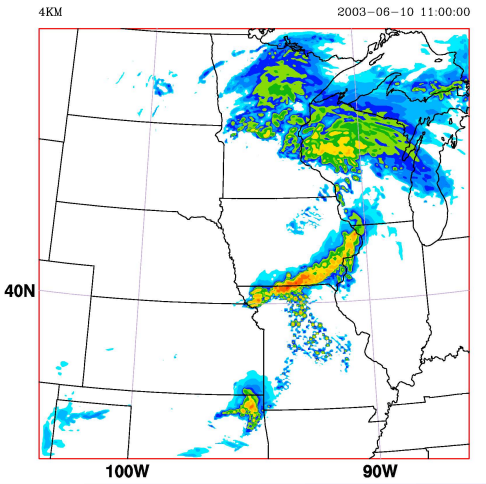
a) NEXRAD Composite



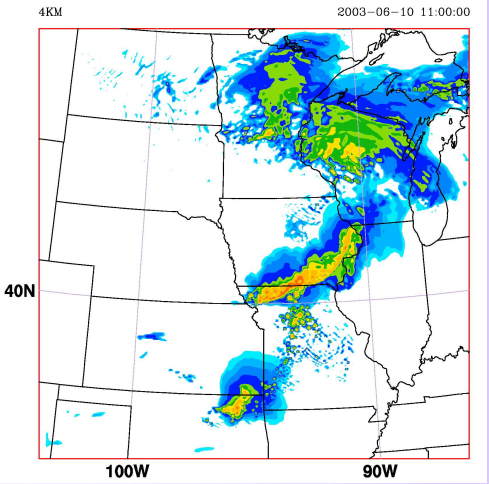


Column max. reflectivity (dBZ)

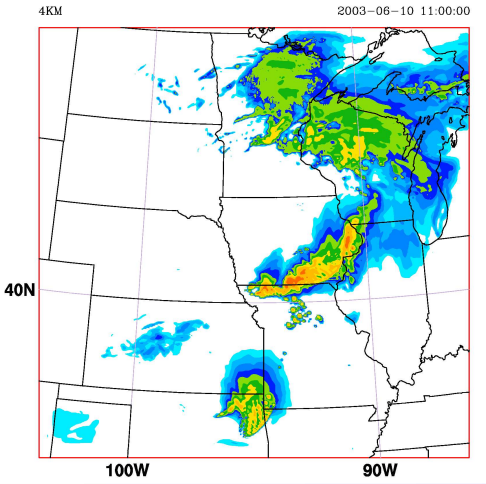
b) LIN scheme



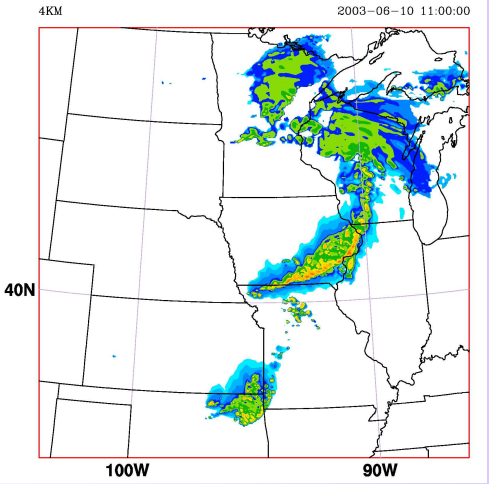
c) WSM-6 scheme



d) Reisner scheme

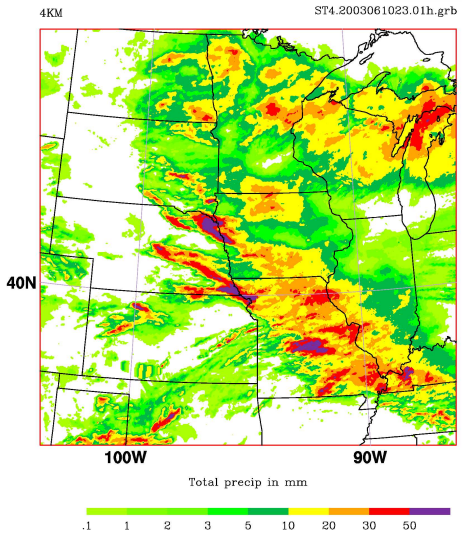


e) SB2004 scheme



JUNE 10 - 00 UTC + 23 h, Accumulated precip

a) Stage IV multi-sensor



b) Stage II radar-only

c) Lin

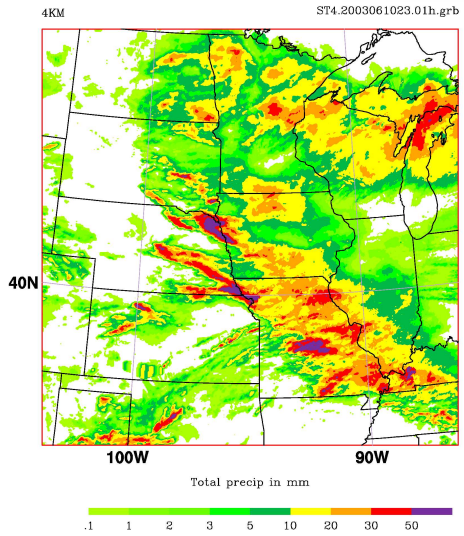
d) WSM-6

e) Reisner

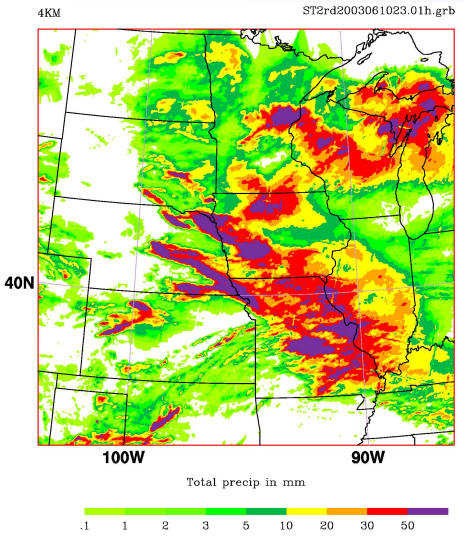
f) SB2004

JUNE 10 - 00 UTC + 23 h, Accumulated precip

a) Stage IV multi-sensor



b) Stage II radar-only



c) Lin

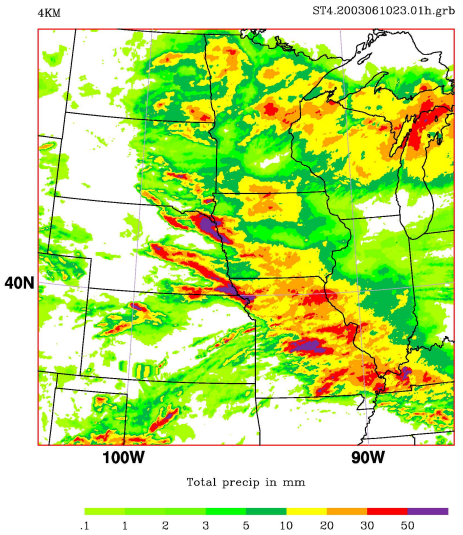
d) WSM-6

e) Reisner

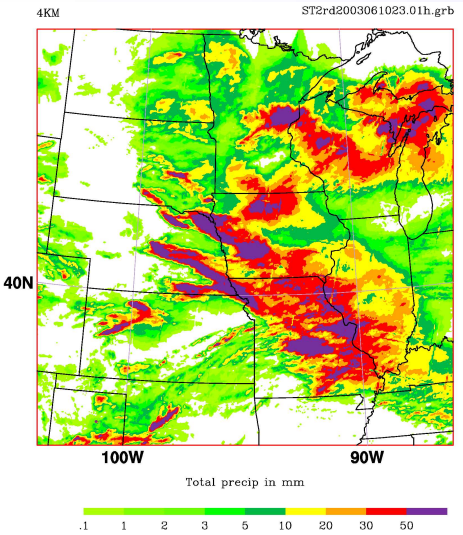
f) SB2004

JUNE 10 - 00 UTC + 23 h, Accumulated precip

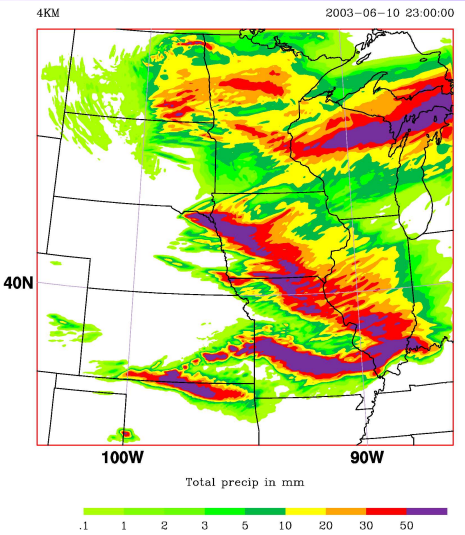
a) Stage IV multi-sensor



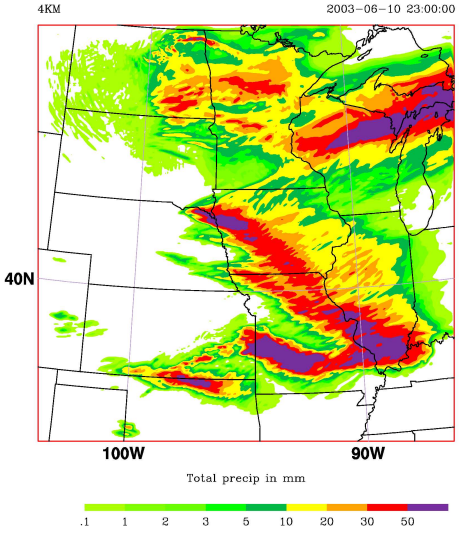
b) Stage II radar-only



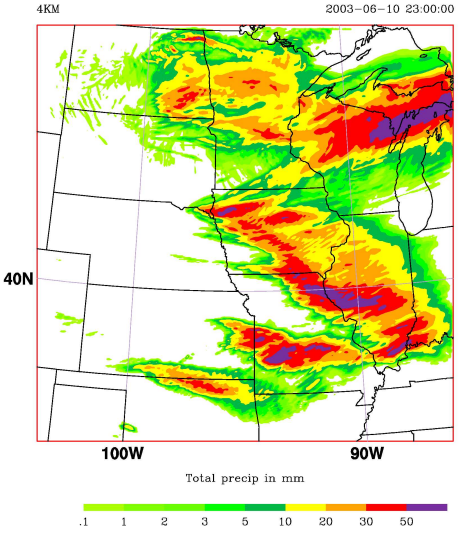
c) Lin



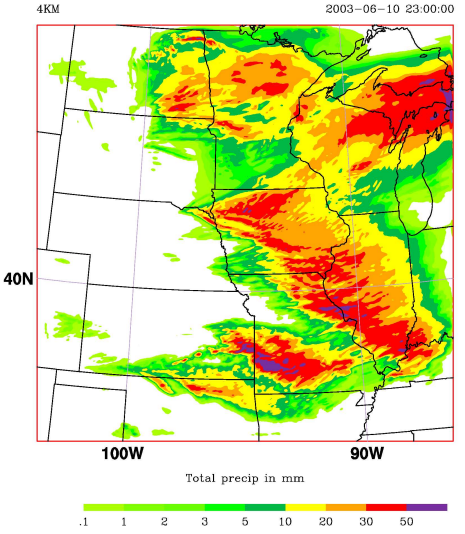
d) WSM-6



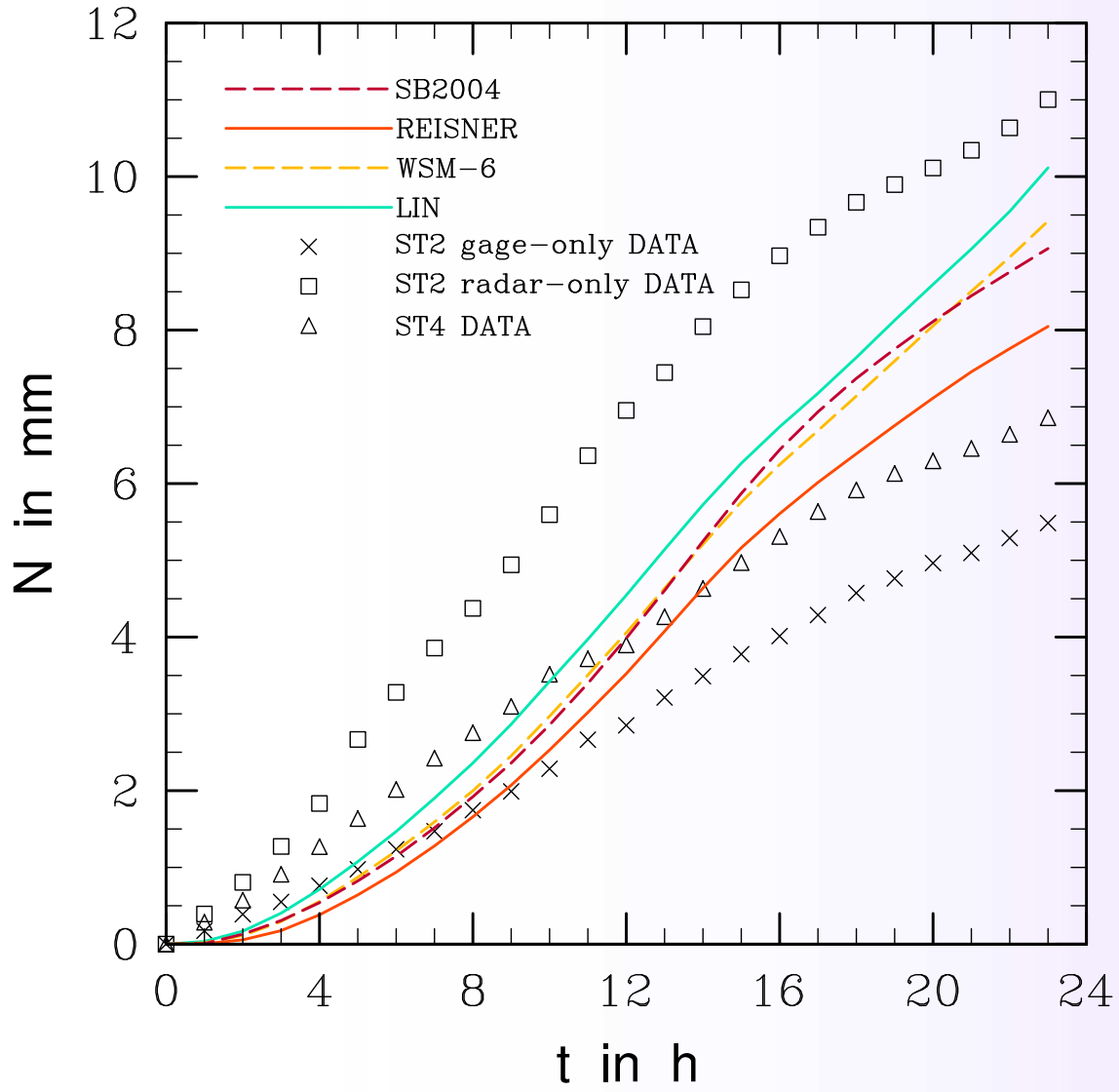
e) Reisner



f) SB2004



JUNE 10 - 00 UTC + 23 h, Total acc. precip

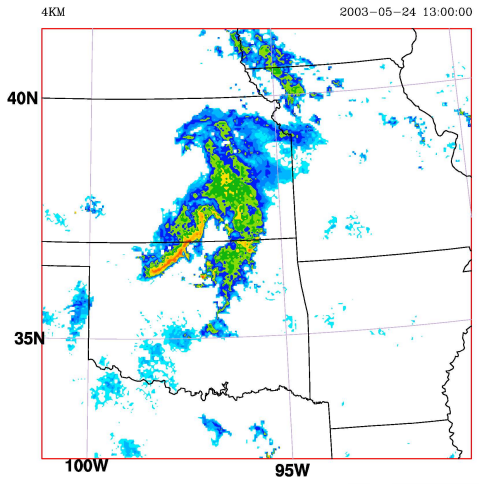


Test case 2:

MAY 24 - Another bow echo

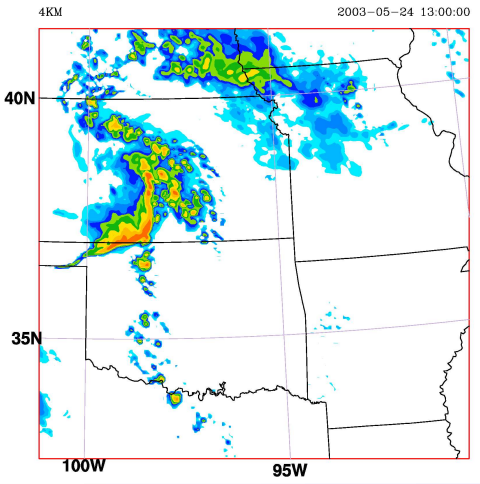
MAY 24 - 00 UTC + 13 h, microphysics schemes

a) NEXRAD Composite

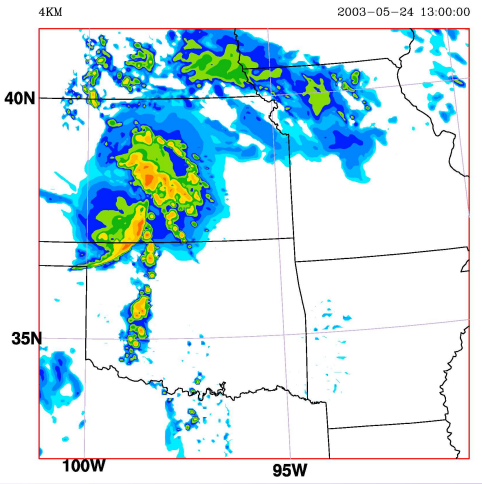


Column max. reflectivity (dBZ)

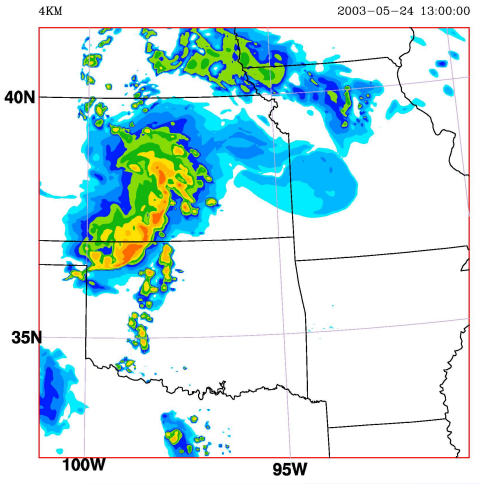
b) LIN scheme



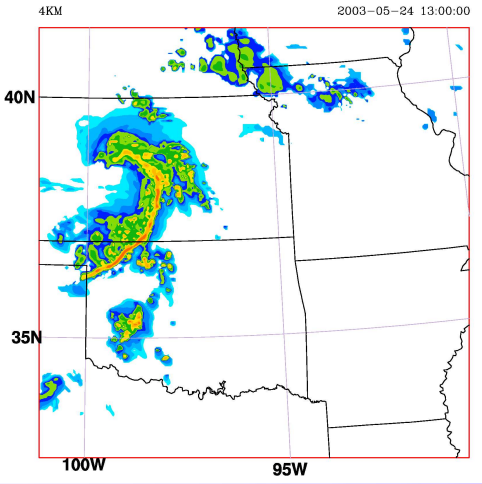
c) WSM-6 scheme



d) Reisner scheme

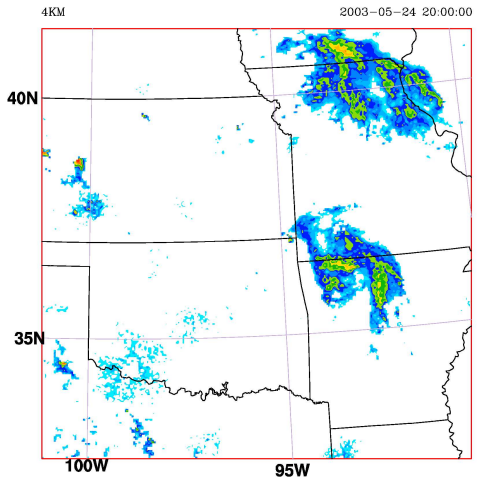


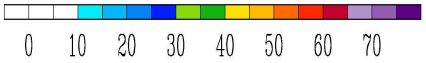
e) SB2004 scheme



MAY 24 - 00 UTC + 20 h, microphysics schemes

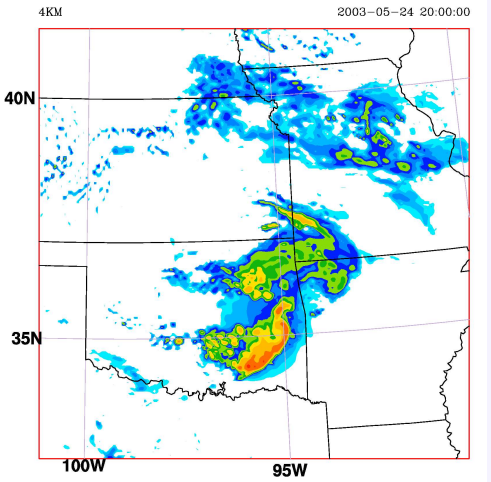
a) NEXRAD Composite



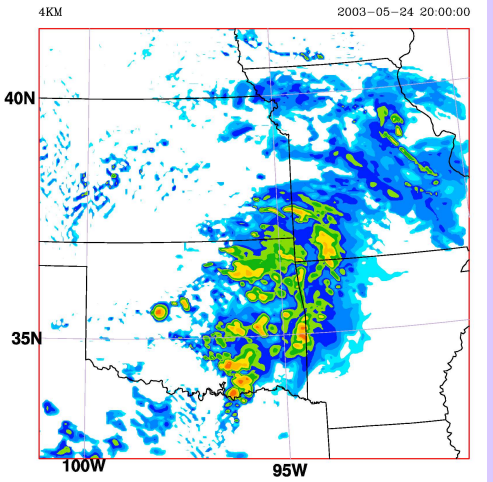


Column max. reflectivity (dBZ)

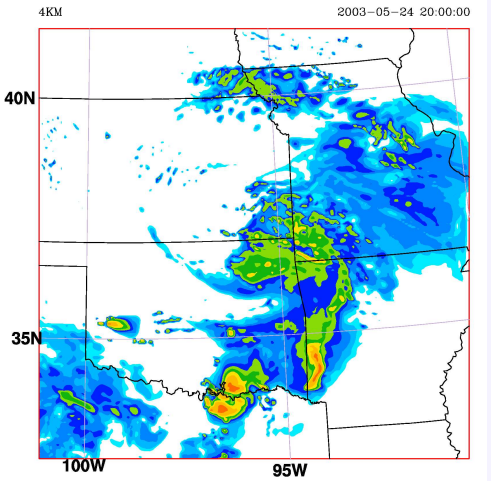
b) LIN scheme



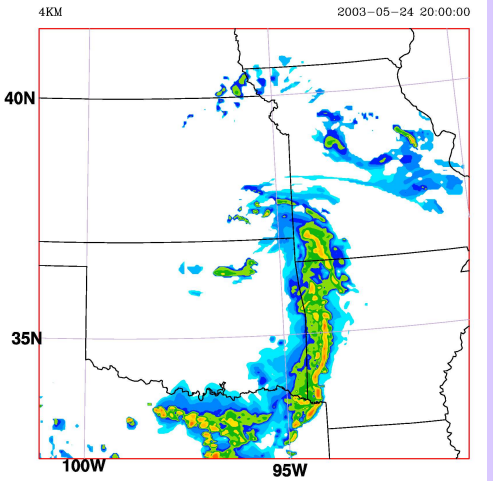
c) WSM-6 scheme



d) Reisner scheme

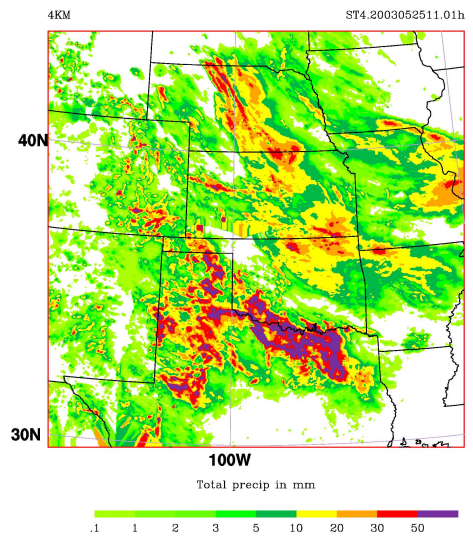


e) SB2004 scheme

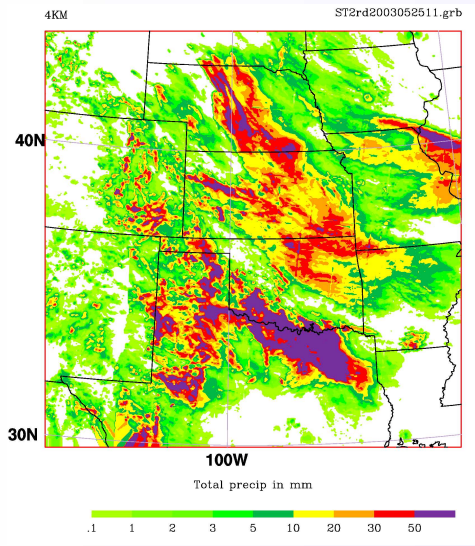


MAY 24 - 00 UTC + 35 h, Accumulated precip

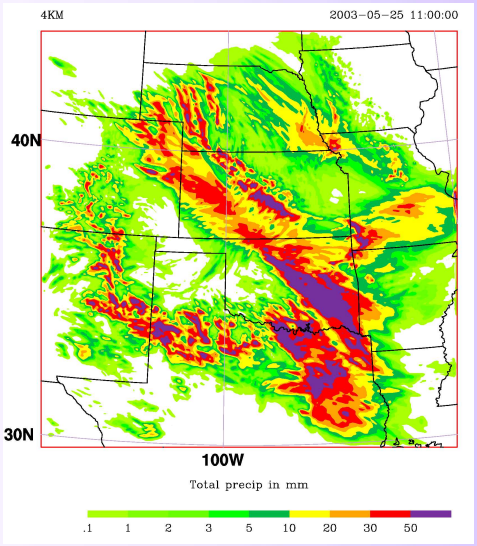
a) Stage IV multi-sensor



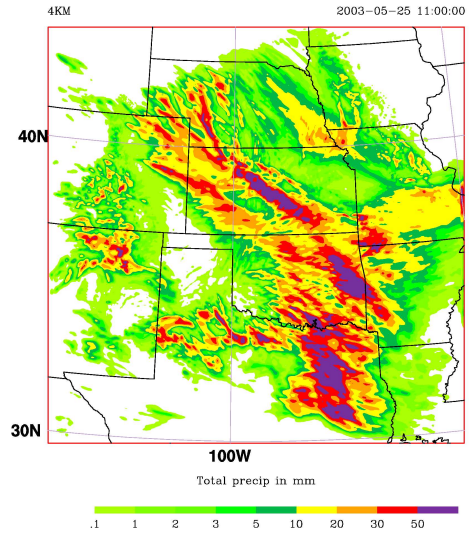
b) Stage II radar-only



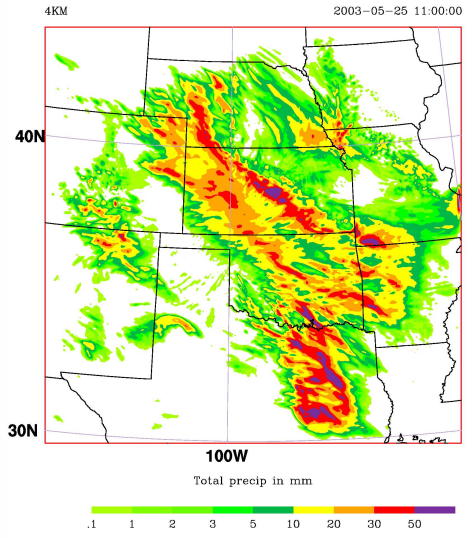
c) Lin



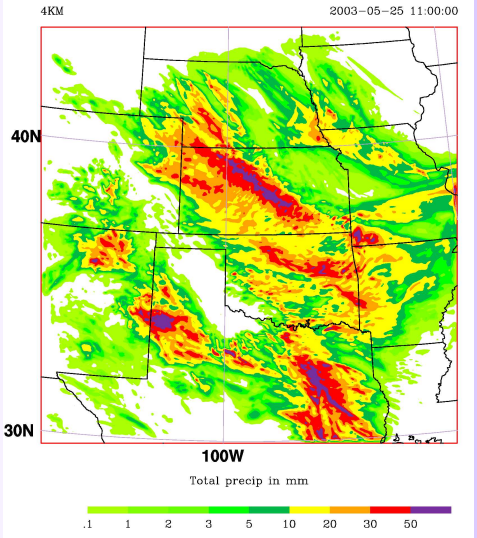
d) WSM-6



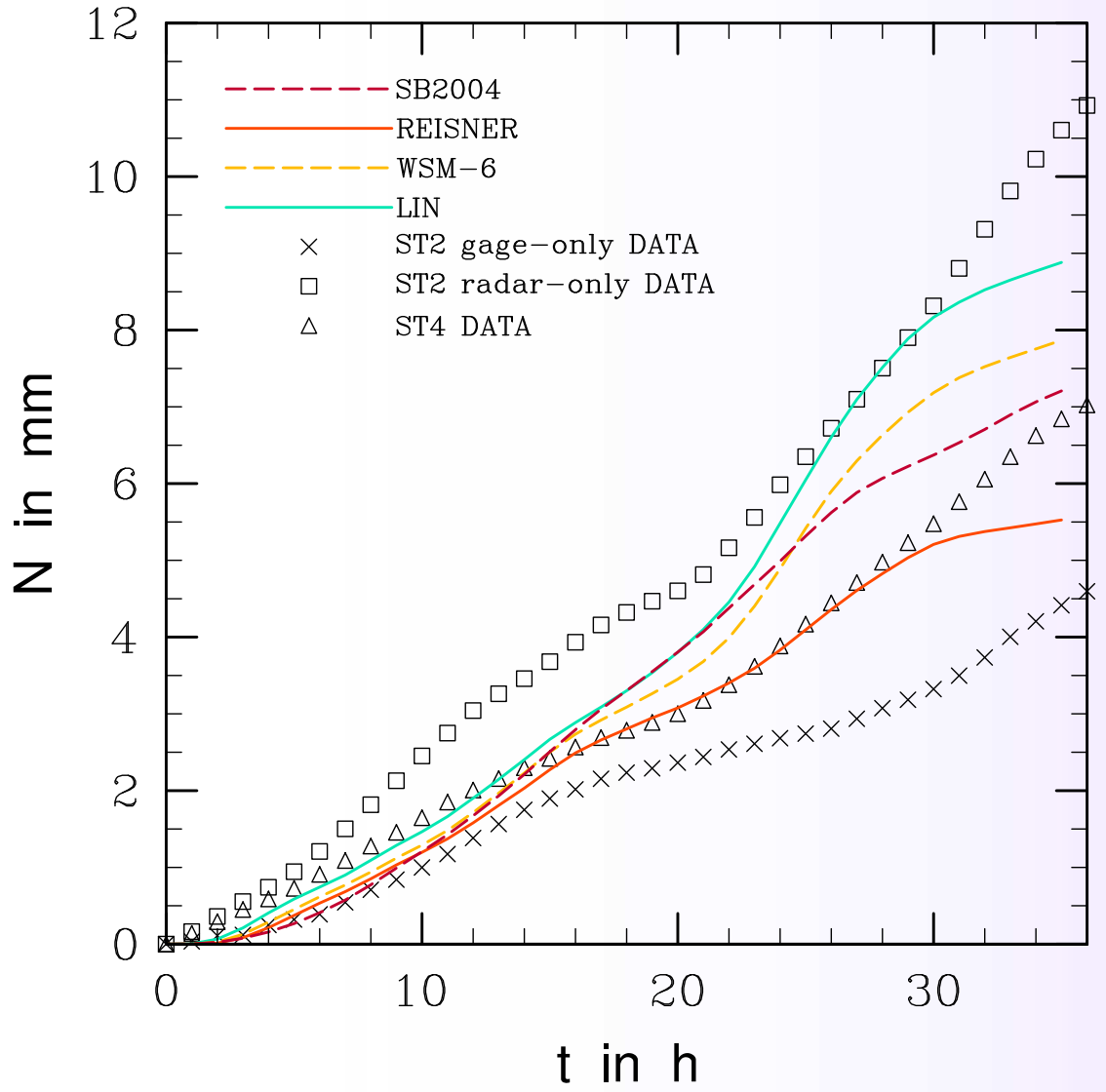
e) Reisner



f) SB2004



MAY24 - 00 UTC + 35 h, Total acc. precip

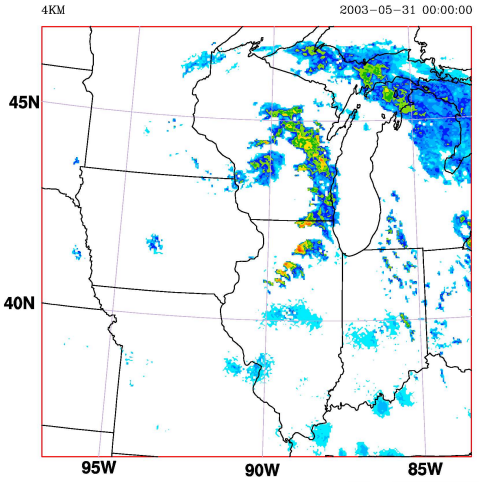


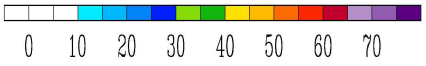
Test case 4:

MAY 30 - Line of cells

MAY 30 - 00 UTC + 24 h, microphysics schemes

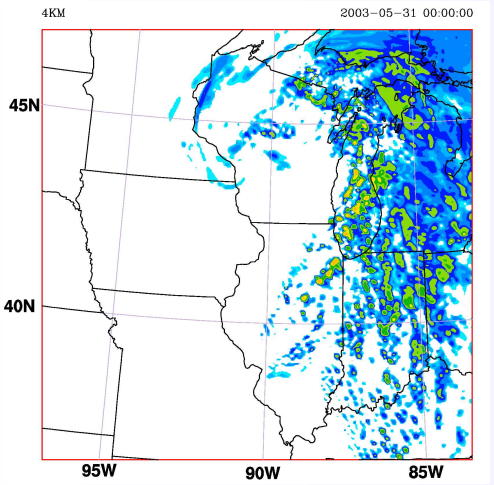
a) NEXRAD Composite



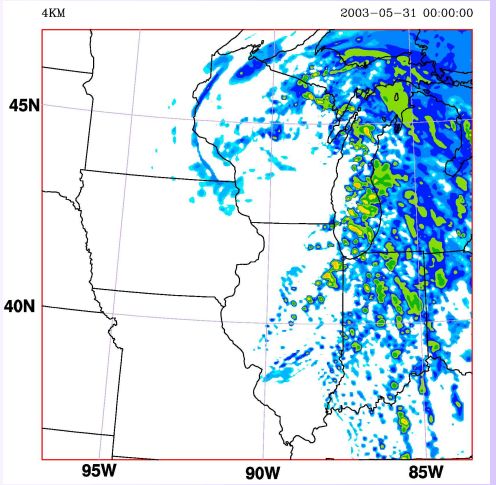


Column max. reflectivity (dBZ)

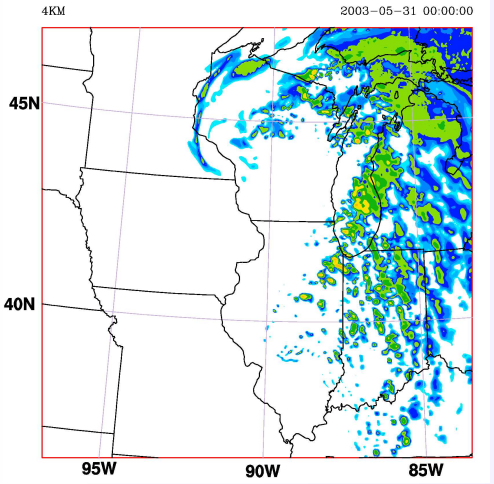
b) LIN scheme



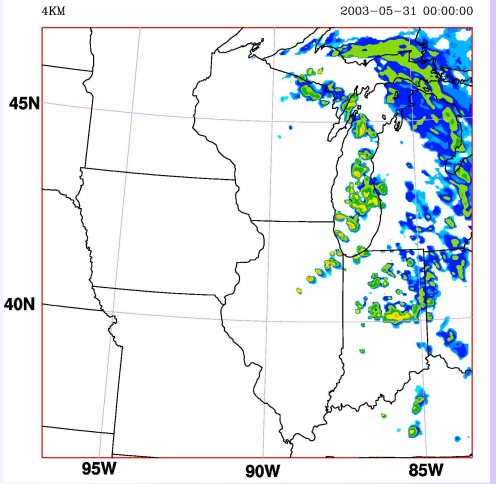
c) WSM-6 scheme



d) Reisner scheme



e) SB2004 scheme



Conclusions:

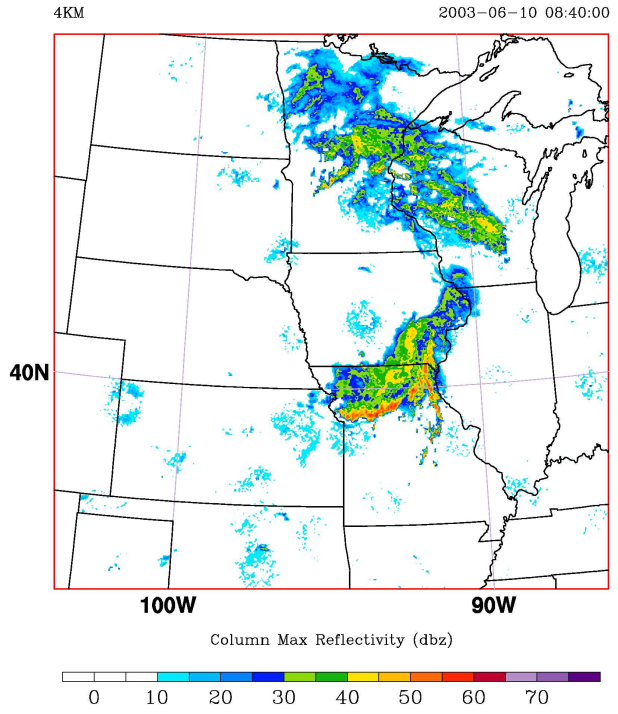
- Little differences within the first 12 h, e.g. propagation speed of convective systems is almost identical. Solutions become different after 20-24 h.
- All one-moment schemes show broad convective regions with high refl., two-moment scheme gives more realistic cloud structure.
- Surface precip is most intense for Lin scheme, Reisner and SB2004 maybe more realistic (WSM-6 somewhere inbetween).
- Significant differences in stratiform regions and in the extent of upper level clouds i.e. storm anvil. These features are also sensitive to the assumption within each scheme. In general, mixing ratios of snow, ice, cloud water can show large differences.

Future work:

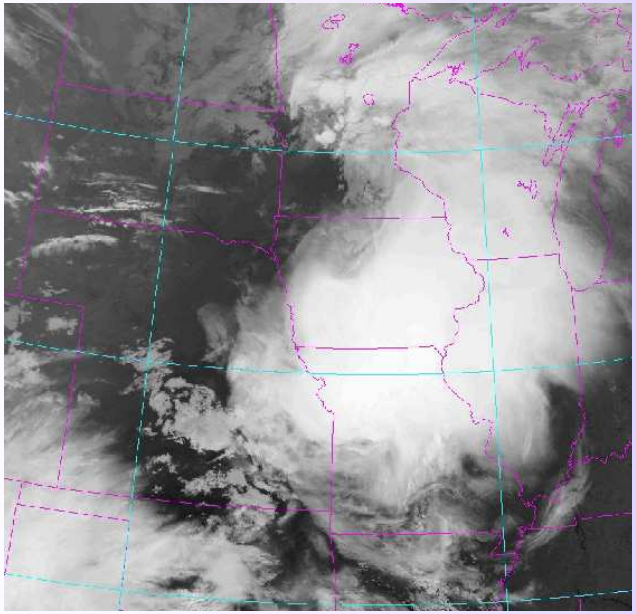
- Cold pools and surface observations.
- Quantitative comparison of model and satellite
- In-situ observations of upper level clouds
- 2km simulations

JUNE 10 - 8:40 UTC - NEXRAD vs NOAA-16 satellite

a) NEXRAD Composite 8:40 UTC



b) NOAA-16 thermal-IR 8:37 UTC

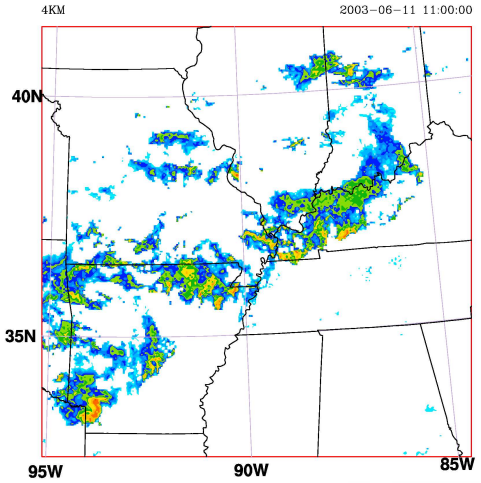


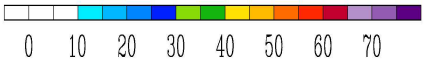
Test case 3:

JUNE 11 - Large MCV

JUNE 11 - 00 UTC + 11 h, microphysics schemes

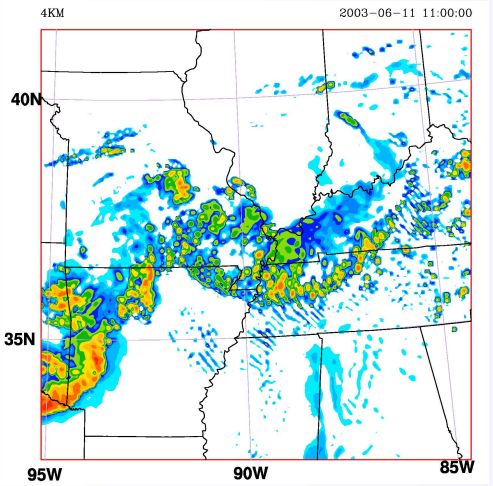
a) NEXRAD Composite



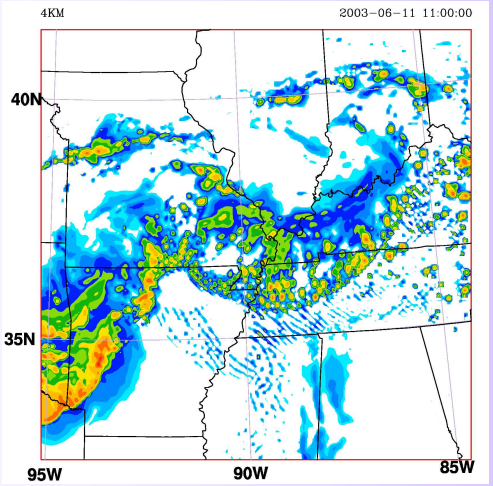


Column max. reflectivity (dBZ)

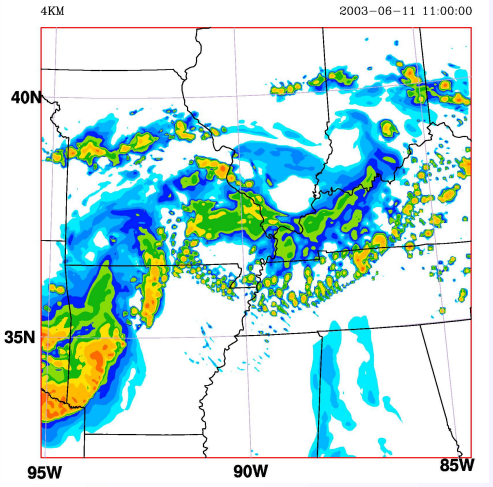
b) LIN scheme



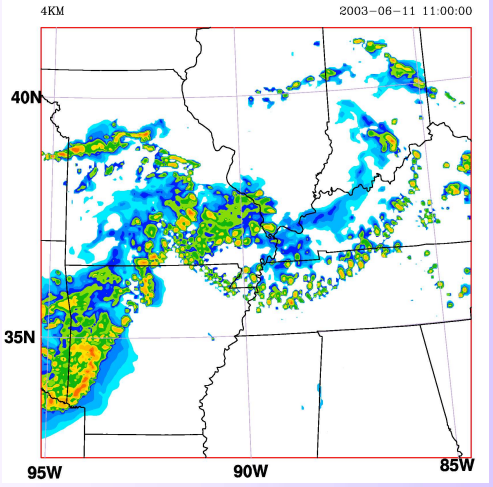
c) WSM-6 scheme



d) Reisner scheme

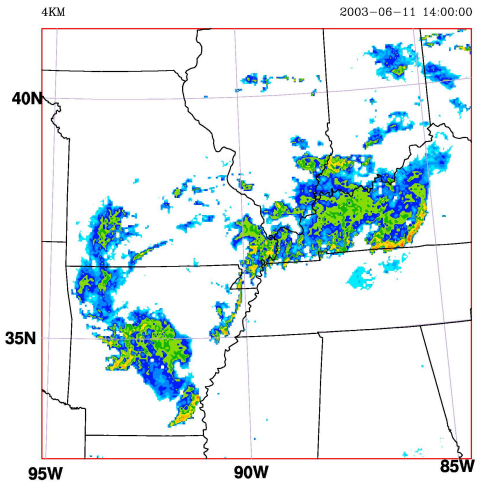


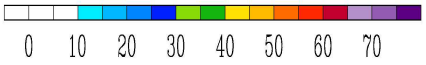
e) SB2004 scheme



JUNE 11 - 00 UTC + 14 h, microphysics schemes

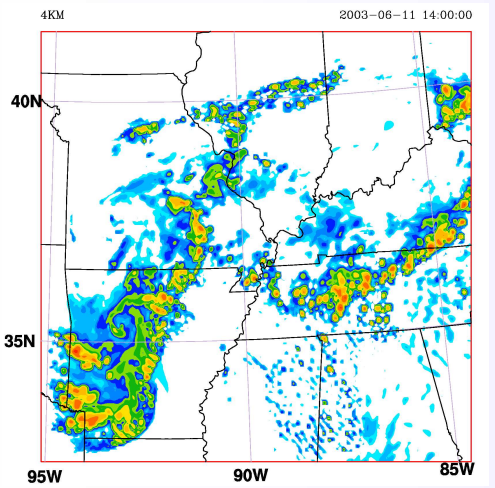
a) NEXRAD Composite



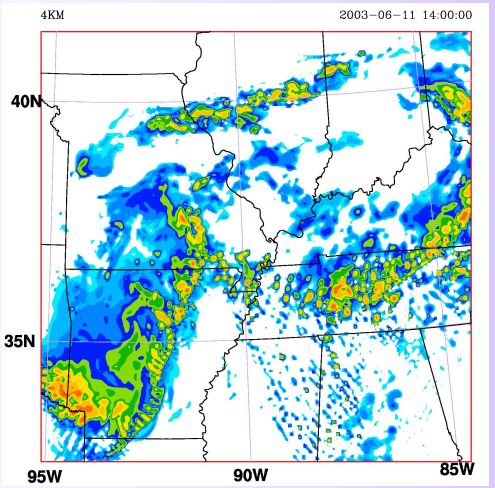


Column max. reflectivity (dBZ)

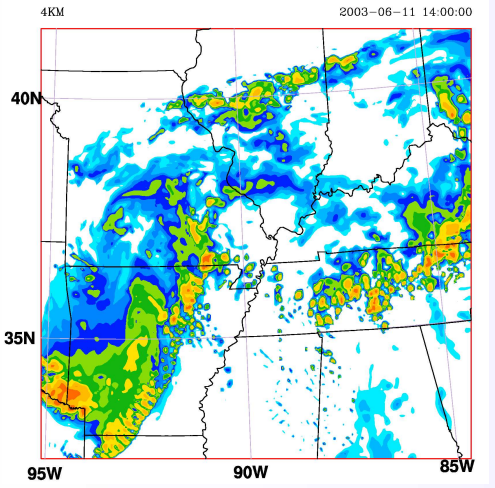
b) LIN scheme



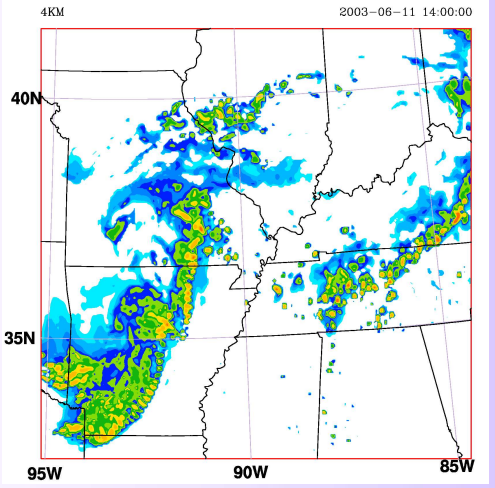
c) WSM-6 scheme



d) Reisner scheme

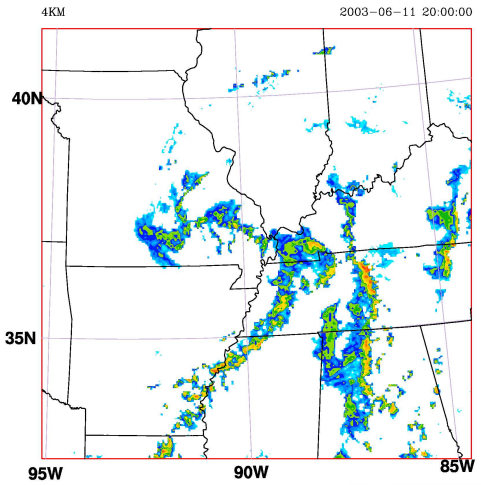


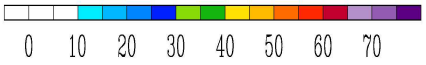
e) SB2004 scheme



JUNE 11 - 00 UTC + 20 h, microphysics schemes

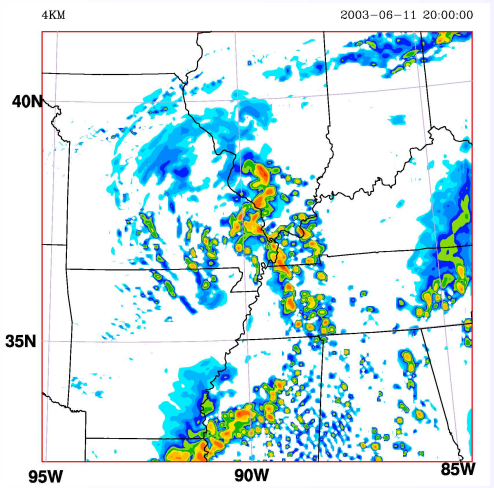
a) NEXRAD Composite



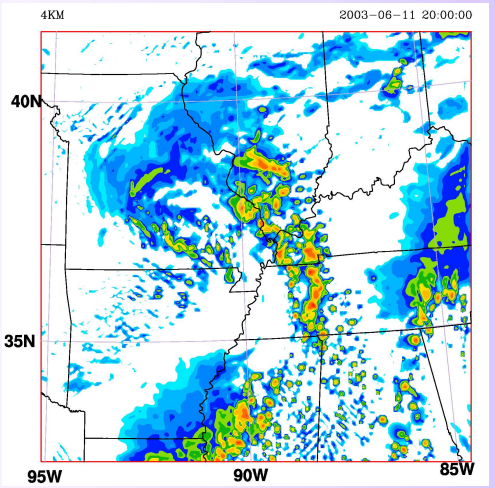


Column max. reflectivity (dBZ)

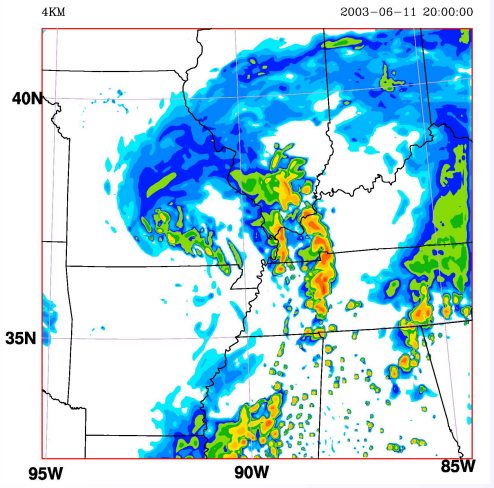
b) LIN scheme



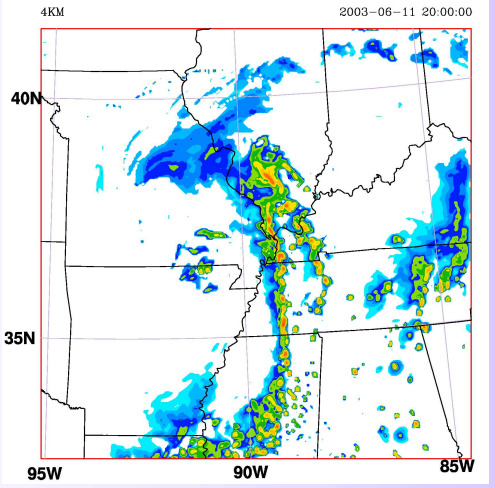
c) WSM-6 scheme



d) Reisner scheme

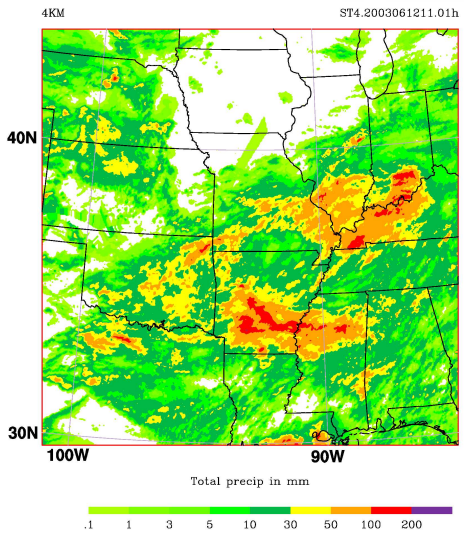


e) SB2004 scheme

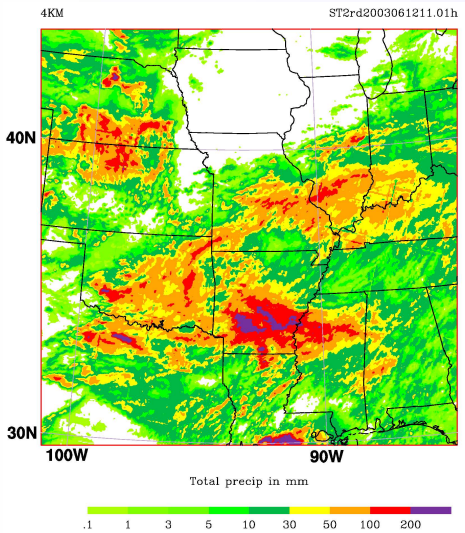


JUNE 11 - 00 UTC + 35 h, Accumulated precip

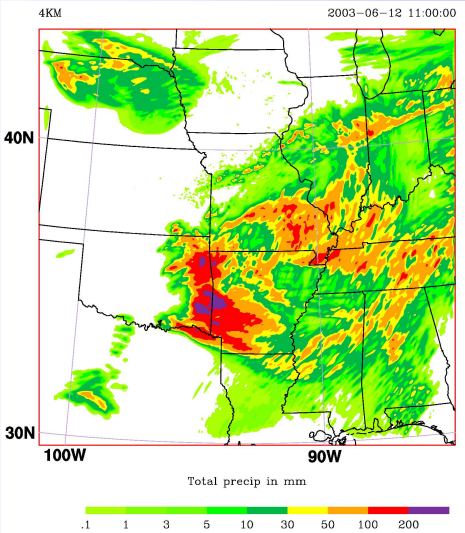
a) Stage IV multi-sensor



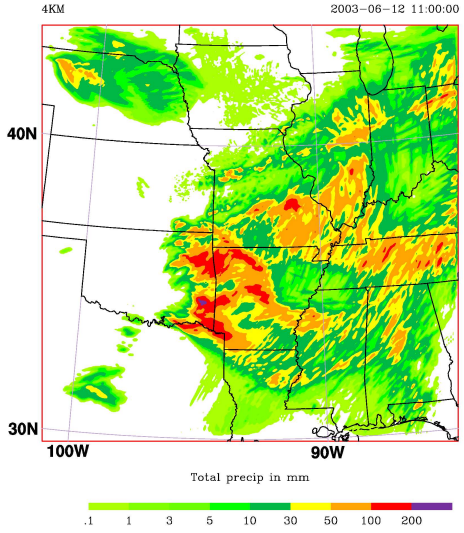
b) Stage II radar-only



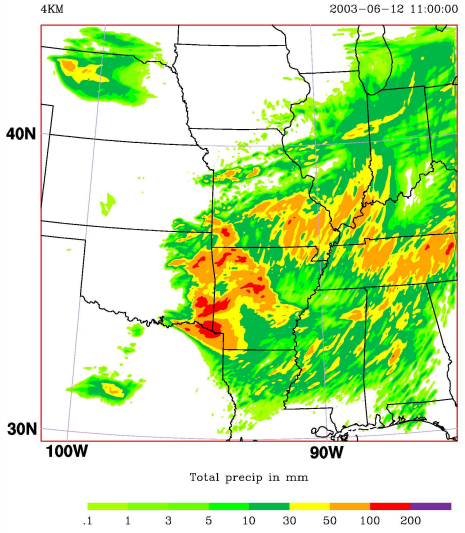
c) Lin



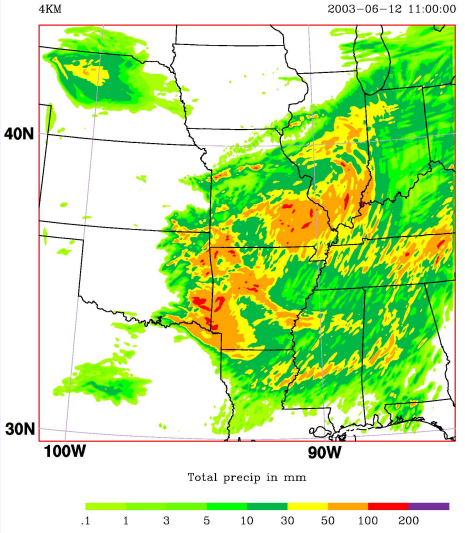
d) WSM-6



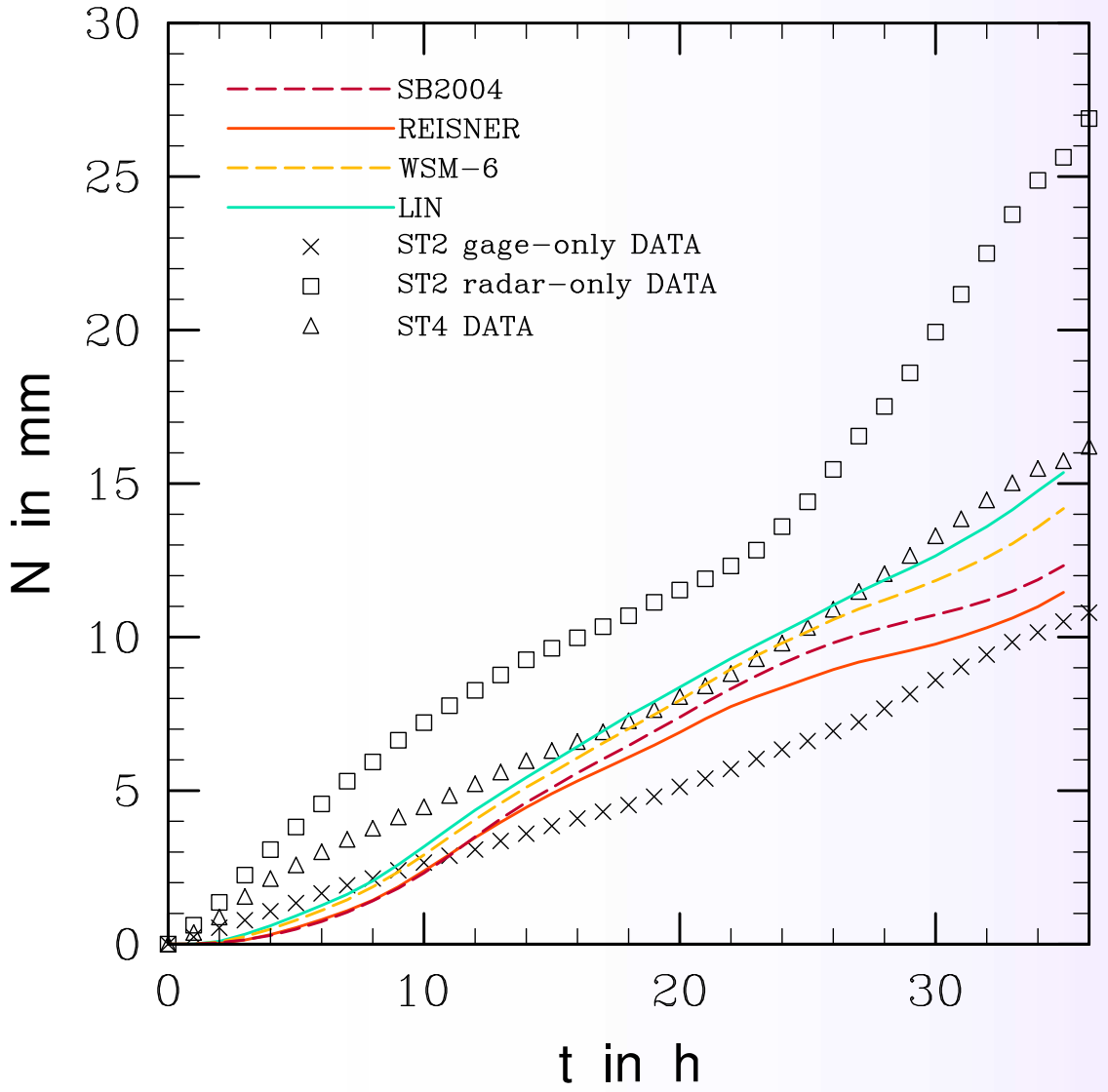
e) Reisner



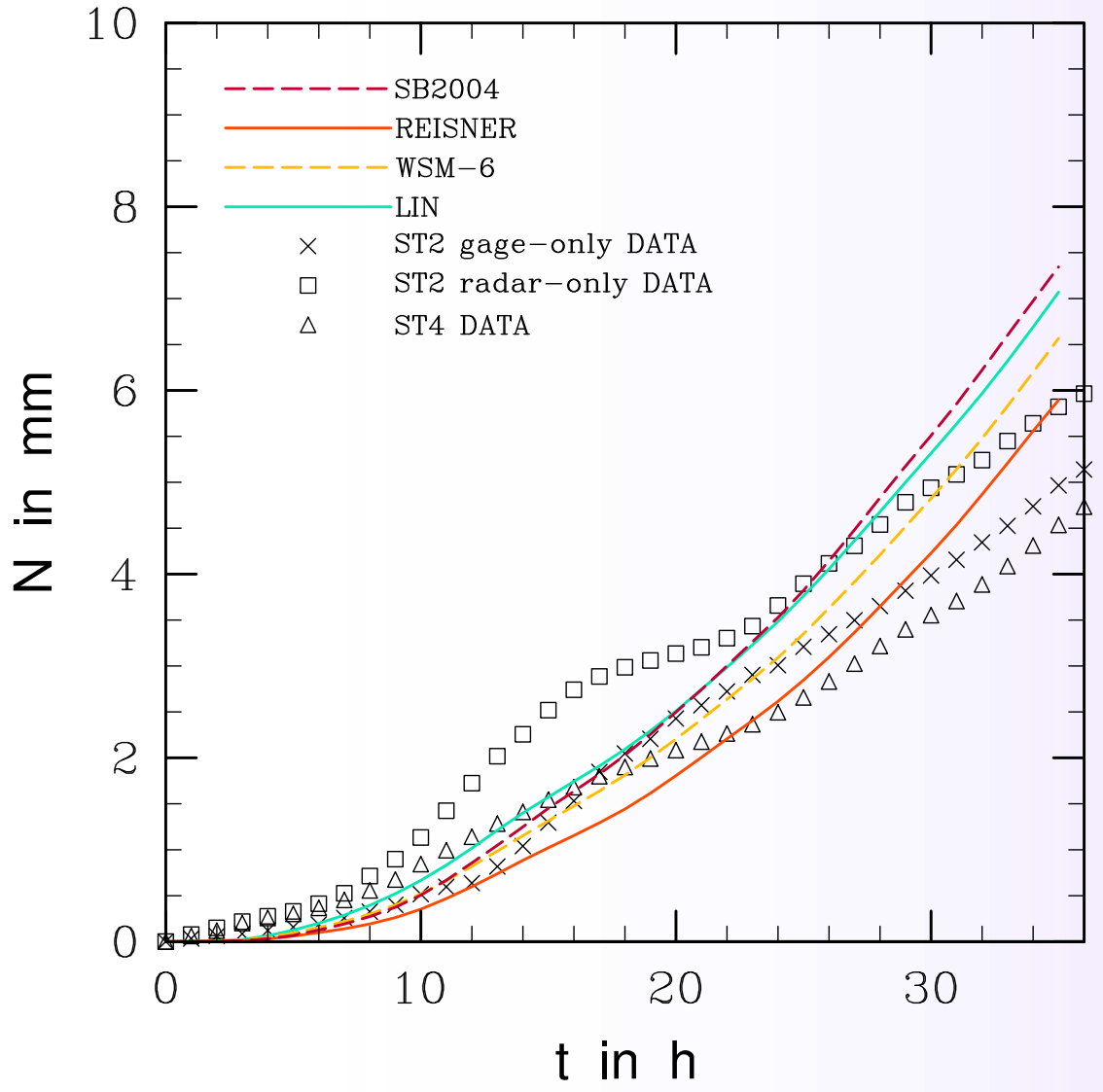
f) SB2004



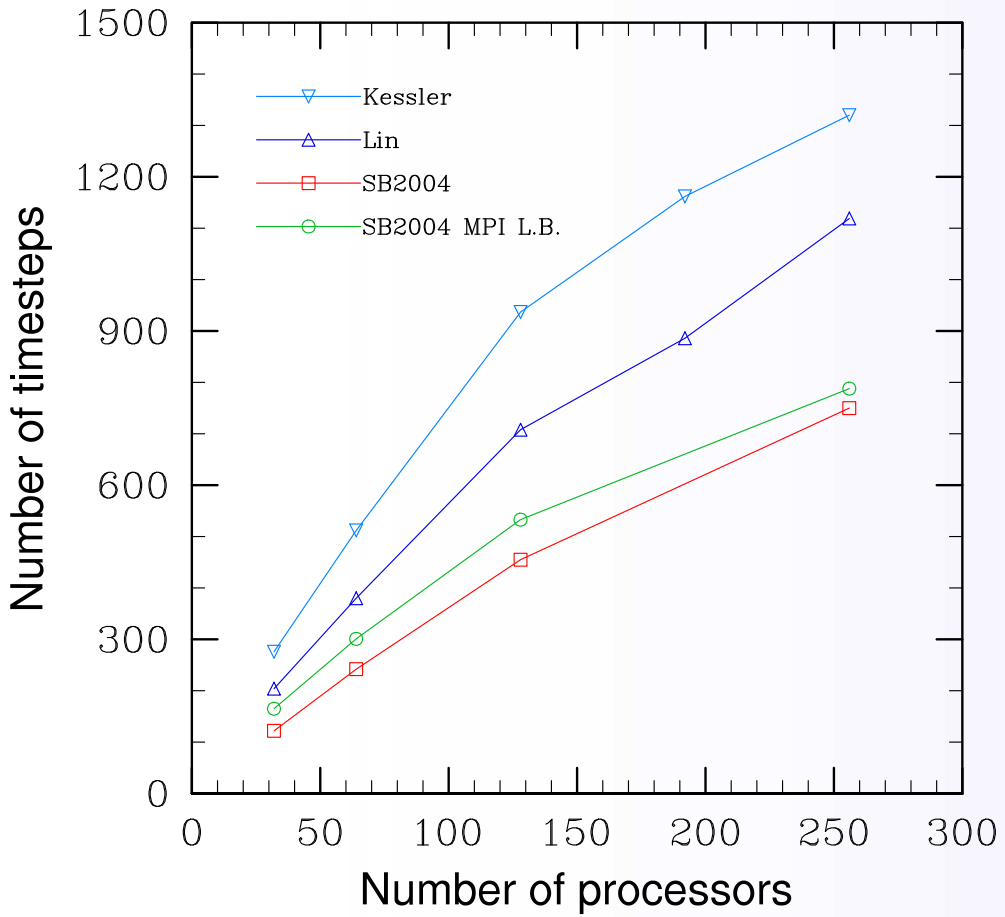
JUNE 11 - 00 UTC + 35 h, Total acc. precip



MAY 30 - 00 UTC + 35 h, Total acc. precip



Need for speed



JUNE 10 case, restart after 6 h simulation

30 min CPU time on blackforest, MPI, no OpenMP