14B.1 Evaluating cloud microphysics schemes in nested NMMB forecasts

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North American Mesoscale (NAM) model

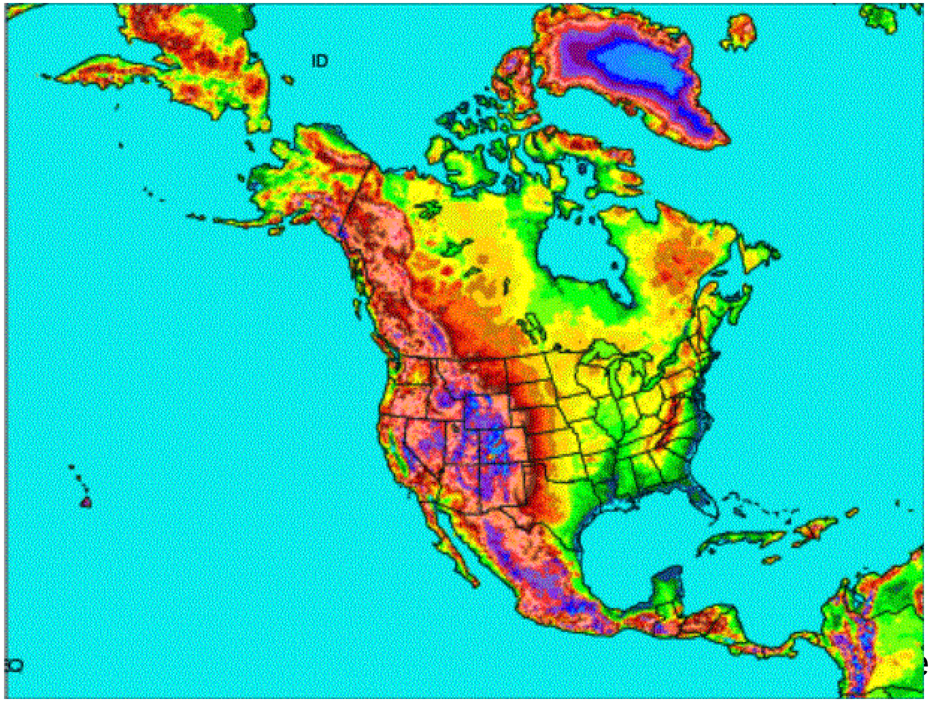
Current Ops

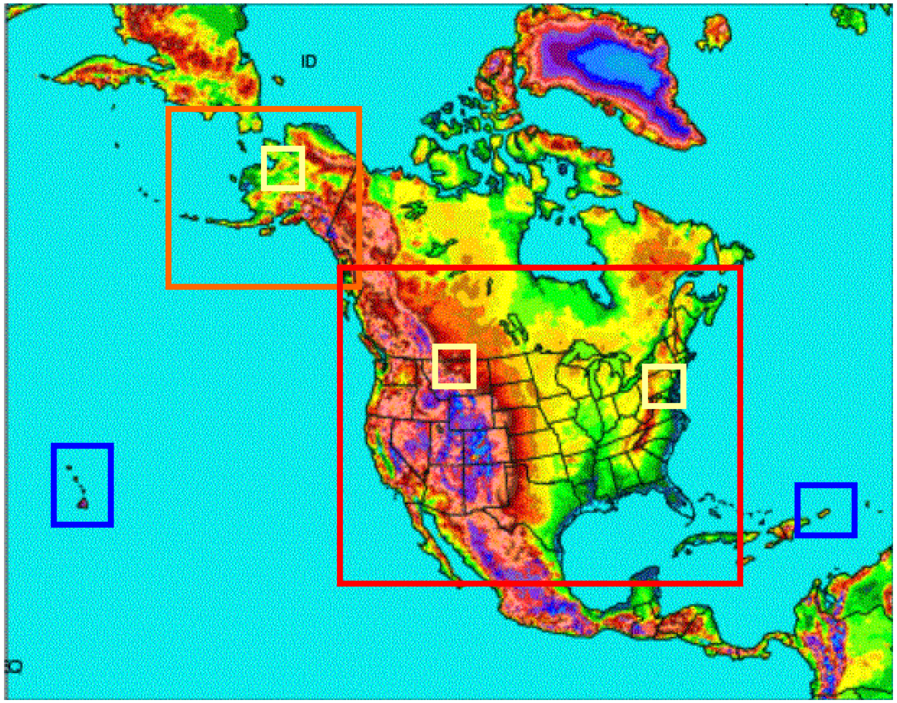
- WRF-NMM (Egrid)
- 4/Day, each to 84 hours
- 12 km, 60L up to 2 hPa
- 60 layers with 2 mb top
- 12 h NDAS assimilation,
  4 3-h fcsts + GSI analysis

2011 Upgrade

- NEMS based NMMB (B-grid)
- Multiple Nest Runs
  - **4 km CONUS nest to 60h**
  - **6 km Alaska nest to 60h**
  - 3 km HI & PR nests to 60h
  - ~1.33 km Fire WX to 36h

(More in 15A.1, Rogers et al.)





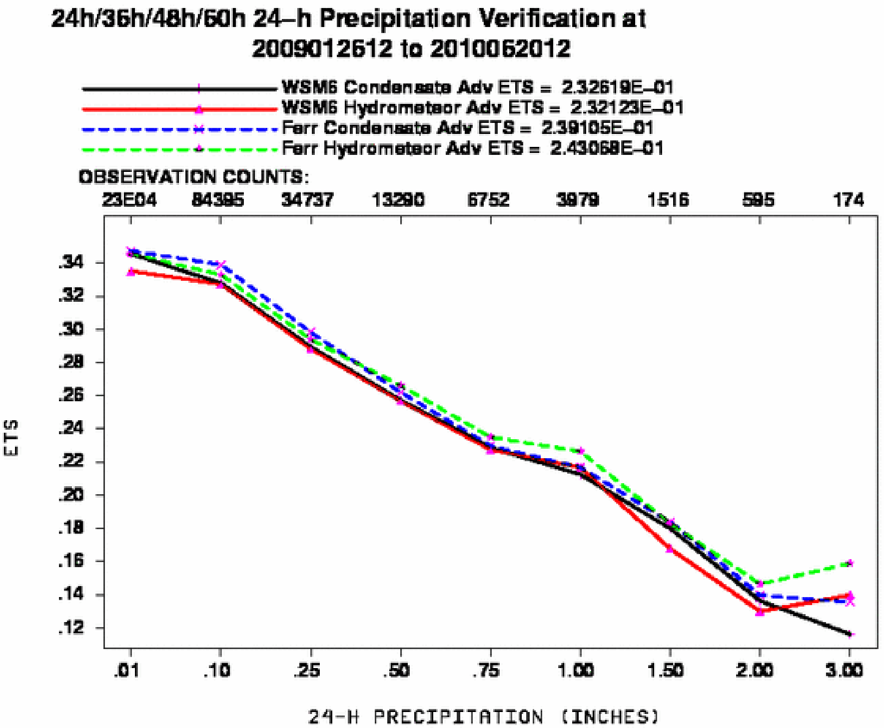
NMMB Microphysics Development

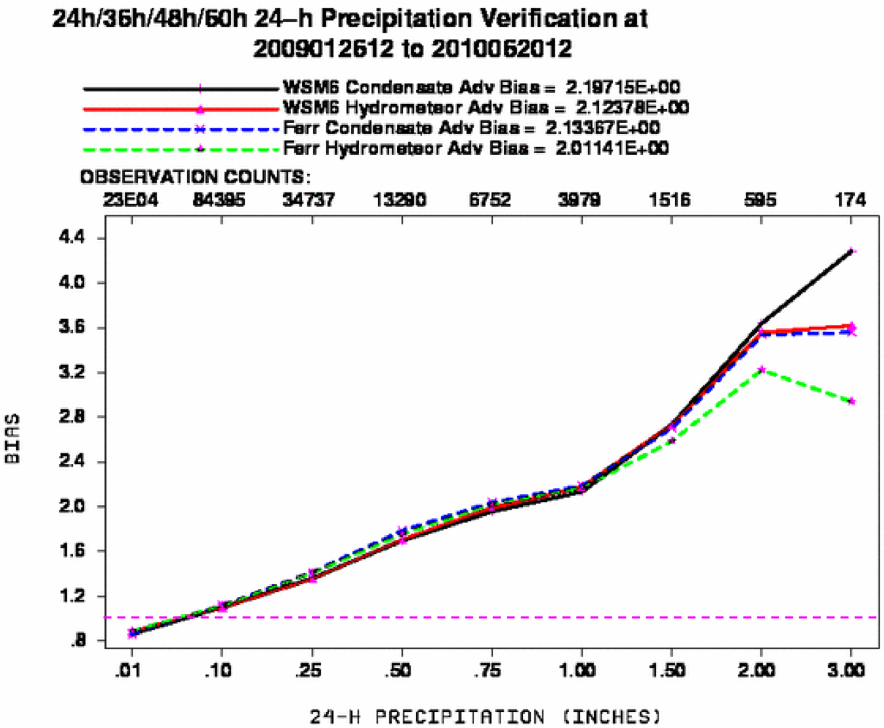
- Added WSM6 microphysics
  - Used in WRF NSSL runs (Kain et al.)
  - Tested in 12-km/CONUS 4-km NMMB runs
  - Similar skill, uses 25-30% more CPU time
- Condensate advection flag
  - Advect individual hydrometeors (true) or total condensate (false)
  - Works for *wsm6* & *fer* microphysics
  - Similar skill seen with either advection option

(see poster 468 by Wang *et al*.)

24-h QPF Verification

4-km CONUS Nest Runs (24h – 60h)





WSM6 Condensate Adv ETS = 2.32619E–01
WSM6 Hydrometeor Adv ETS = 2.32123E–01
Ferr Condensate Adv ETS = 2.39105E–01
Ferr Hydrometeor Adv ETS = 2.43068E–01

WSM6 Condensate Adv Bias = 2.19715E+00
WSM6 Hydrometeor Adv Bias = 2.12378E+00
Ferr Condensate Adv Bias = 2.13367E+00
Ferr Hydrometeor Adv Bias = 2.01141E+00

Revised Ferrier Microphysics (1 of 2)

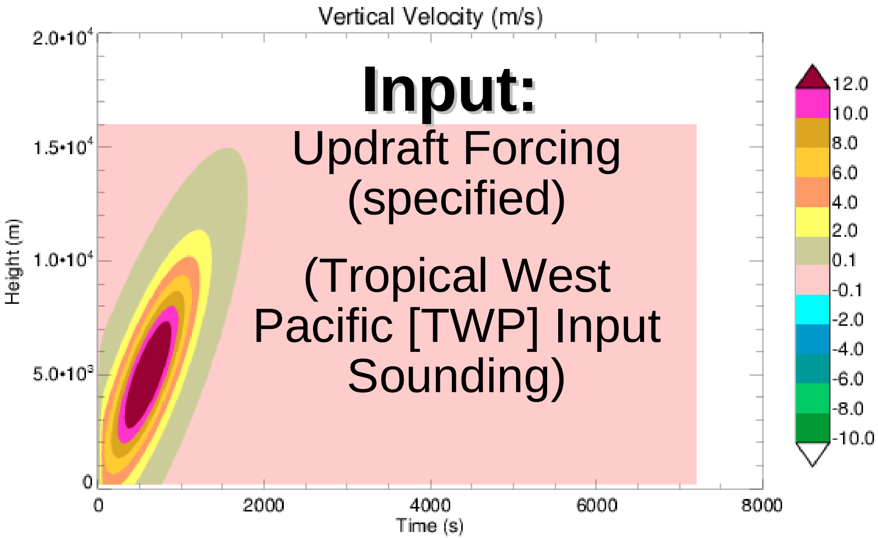
- Expanded rain look up tables
  - Largest *mean* drop sizes (λ^{-1}) increased from 0.45 mm to 1 mm
- Cloud ice sedimentation
- New cloud water to rain autoconversion (Liu & Daum et al.)
  - No autoconversion threshold
  - Functional dependence of cloud water mixing ratio is quite different from Kessler formulation
  - Increased droplet # conc from 100 to 200 cm^{-3}

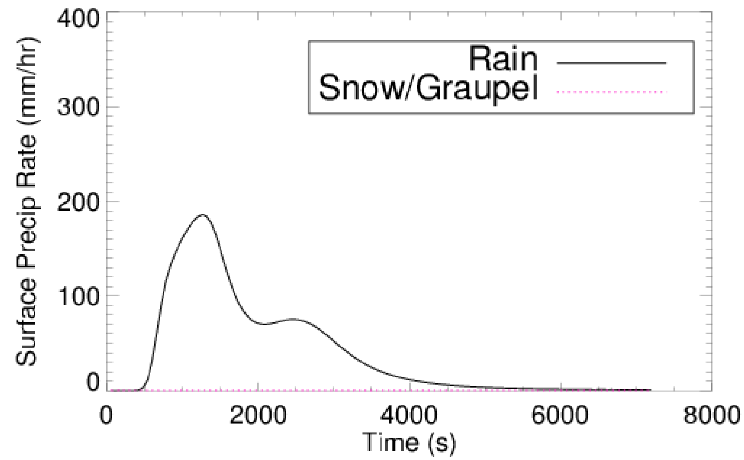
Revised Ferrier Microphysics (2 of 2)

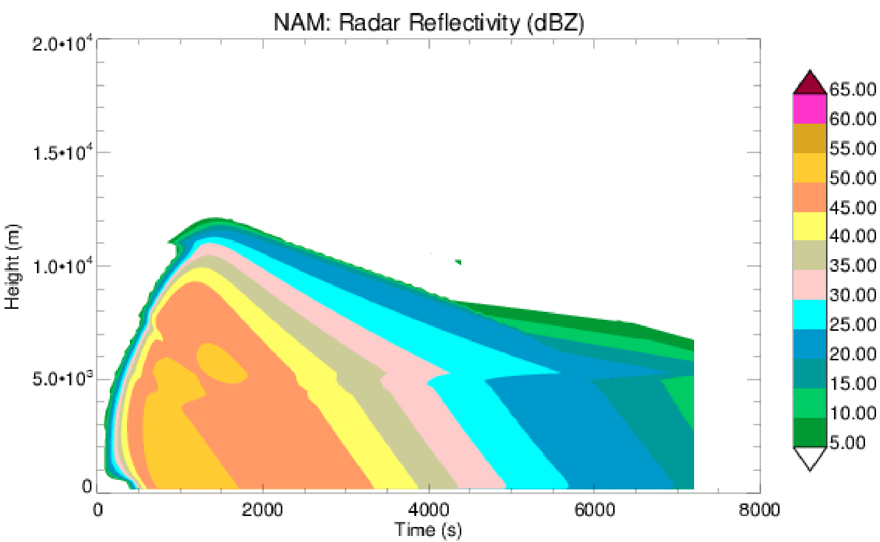
- T_ice_init=0 – no “artificial” delay in the temperature at which ice initiation starts
- FLARGE2=0.07 (from Nakagawa’s runs)
- VEL_INC~VRIMEF**2 - faster rimed ice fall speeds (VRIMEF>1 when riming occurs)
- Minor changes to speed up code
- Early tests in single-column (KiD) runs (thanks to Ben Shipway@UKMO)

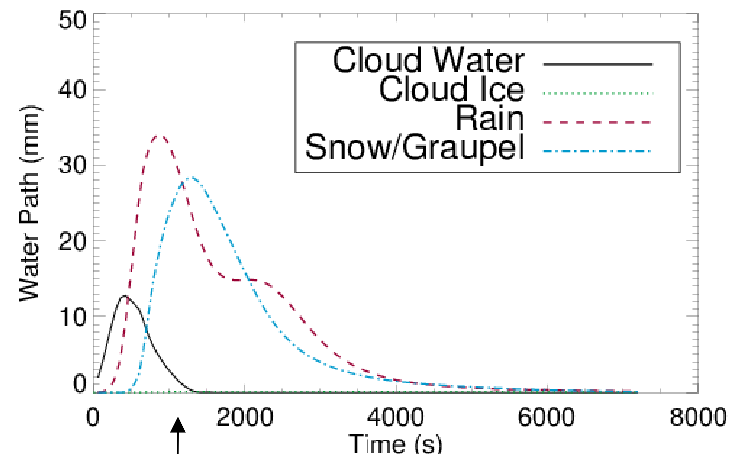
1D Column Tests (1 of 3)

Sample 1D input/output





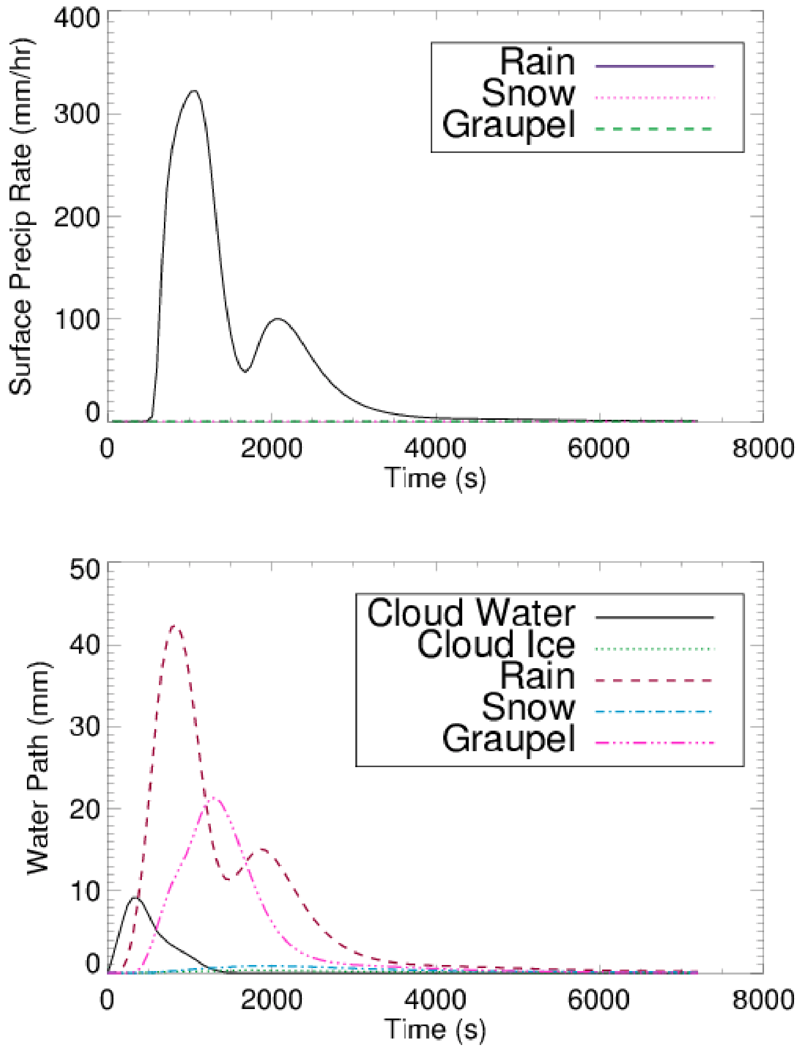




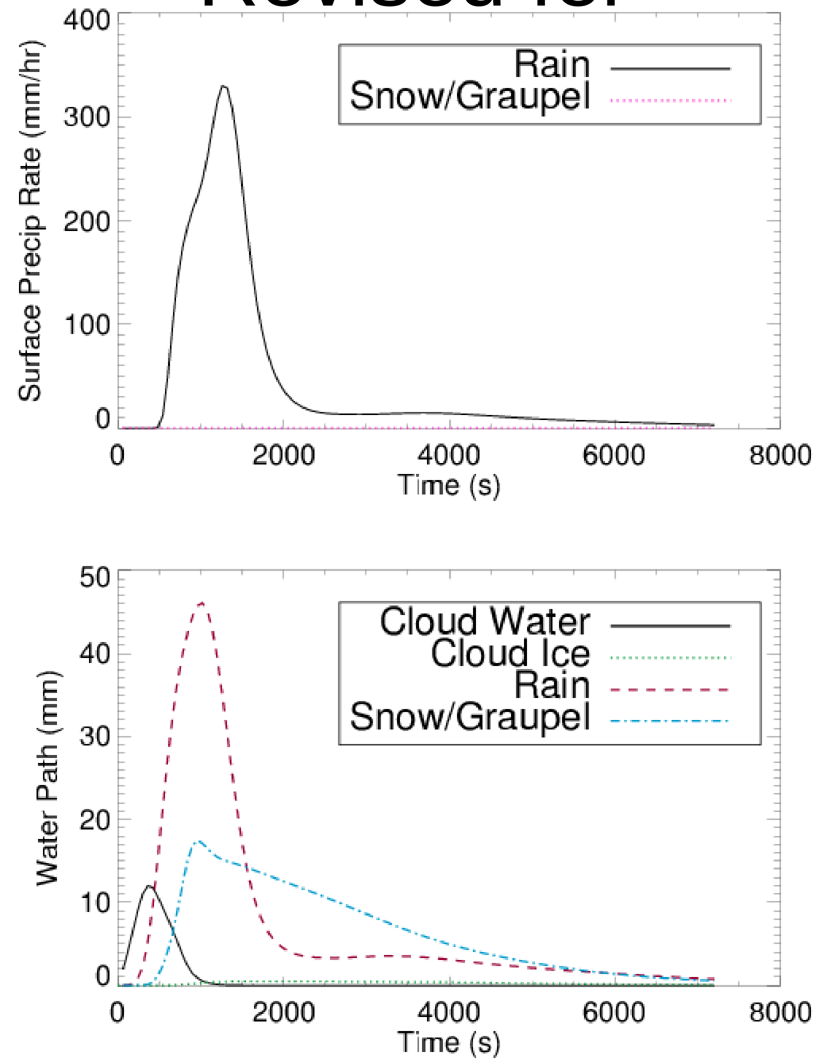
et al. ← **Output (fer)**

1D Column Tests (2 of 3)

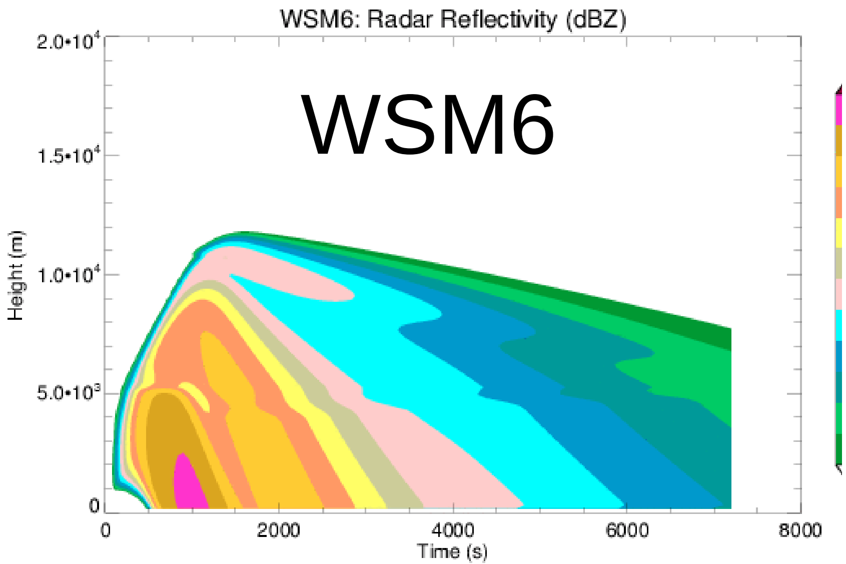
WSM6

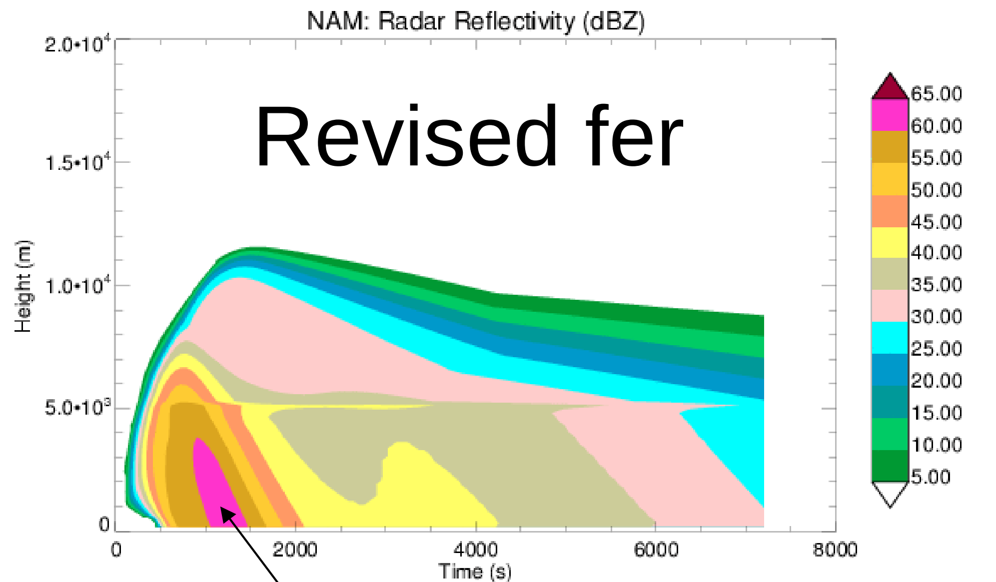


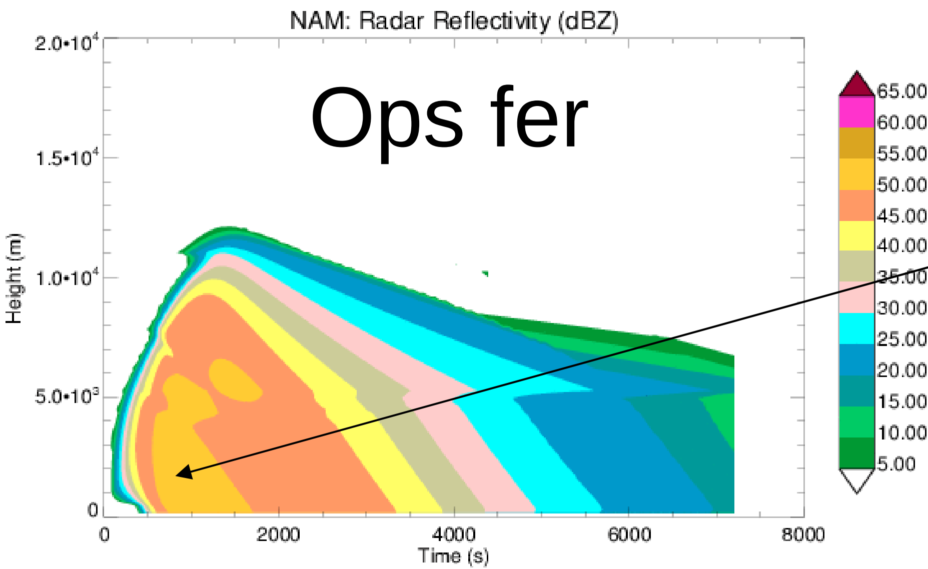
Revised fer



1D Column Tests (3 of 3)

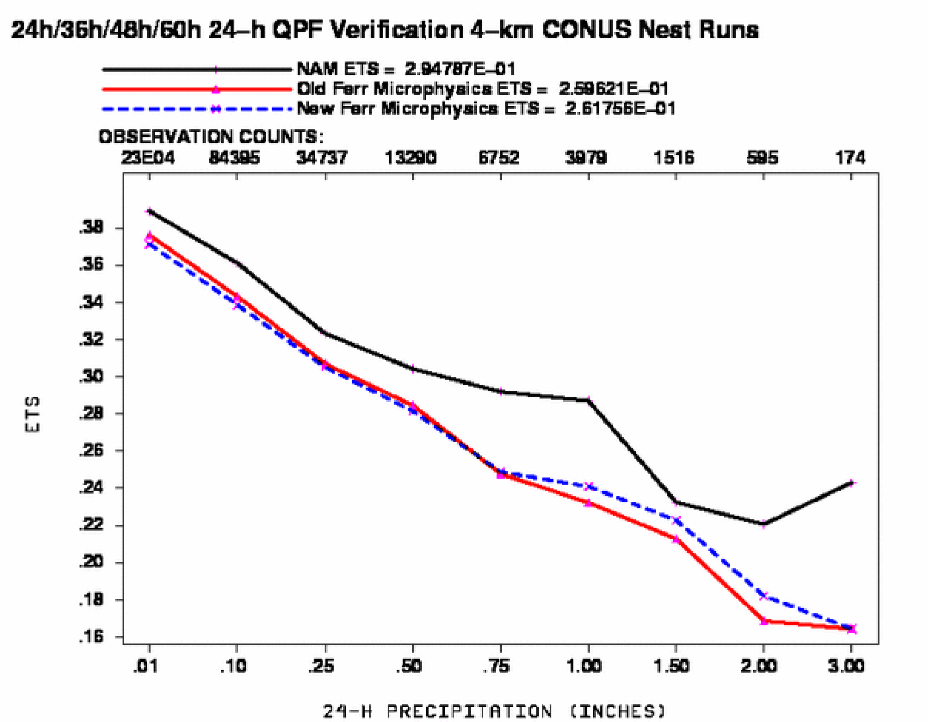


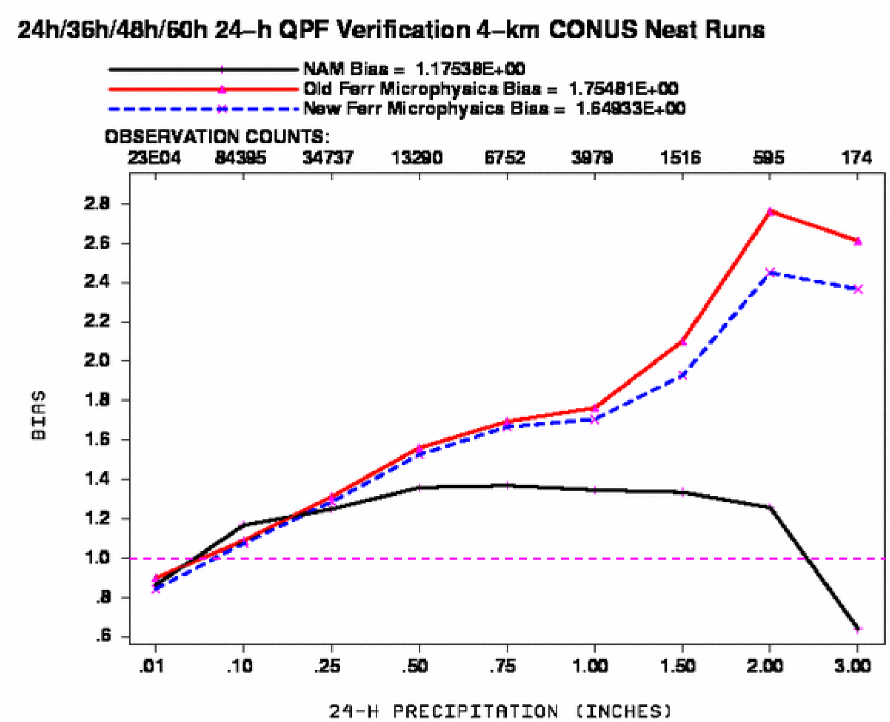




Much higher dBZ & peak rain rates in revised vs. ops fer

24-h QPF Verification





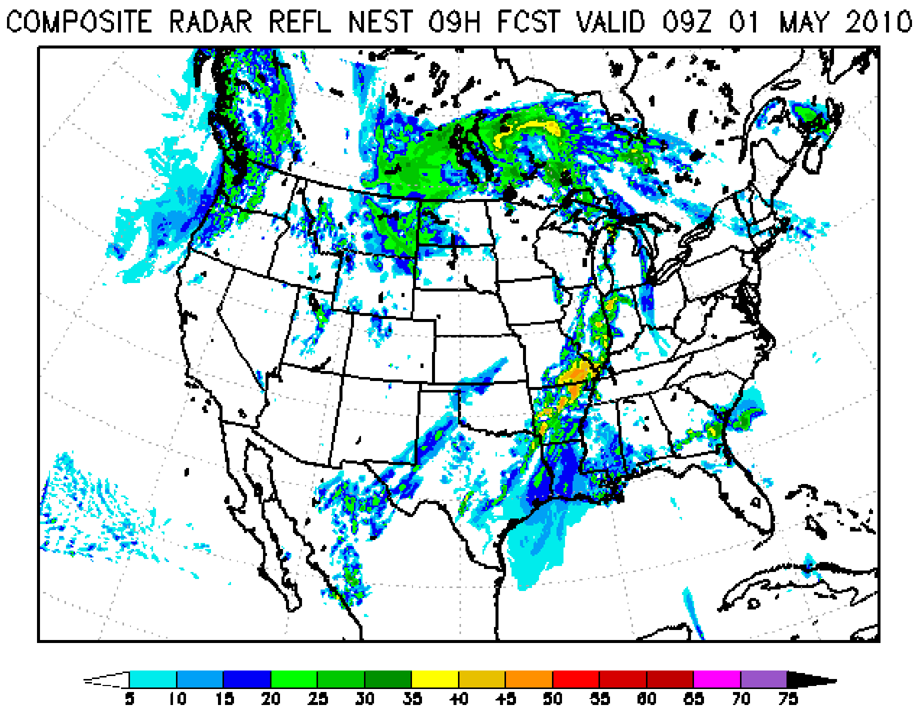
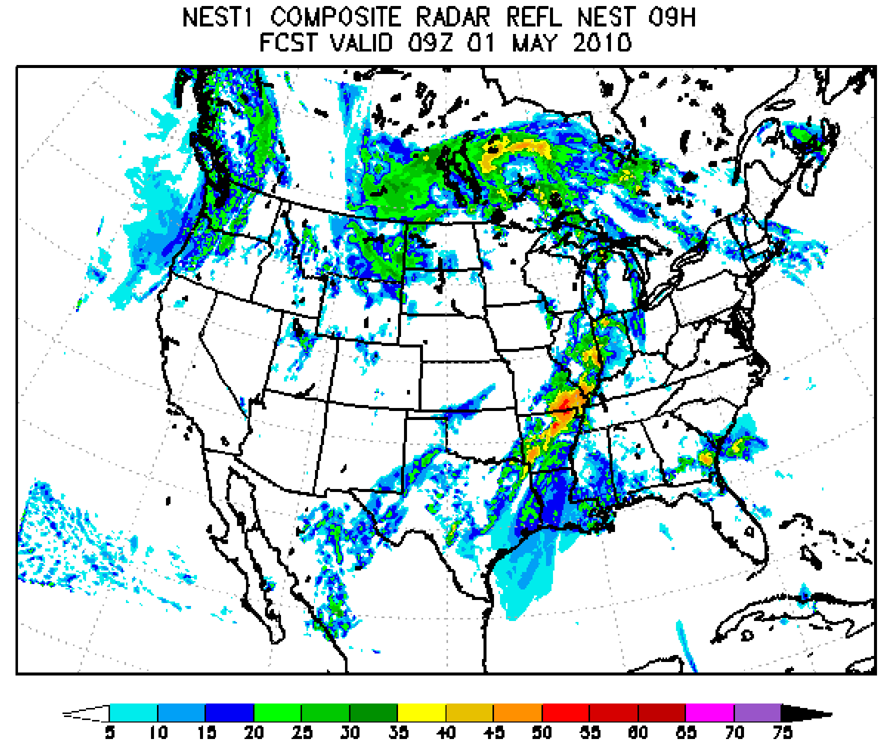
NAM ETS = 2.94787E–01
Old Ferr Microphysics ETS = 2.59621E–01
New Ferr Microphysics ETS = 2.61756E–01

} Nests {

NAM Bias = 1.17538E+00
Old Ferr Microphysics Bias = 1.75481E+00
New Ferr Microphysics Bias = 1.64933E+00

- **Small impact on QPF & skill scores**

Impact of microphysics change

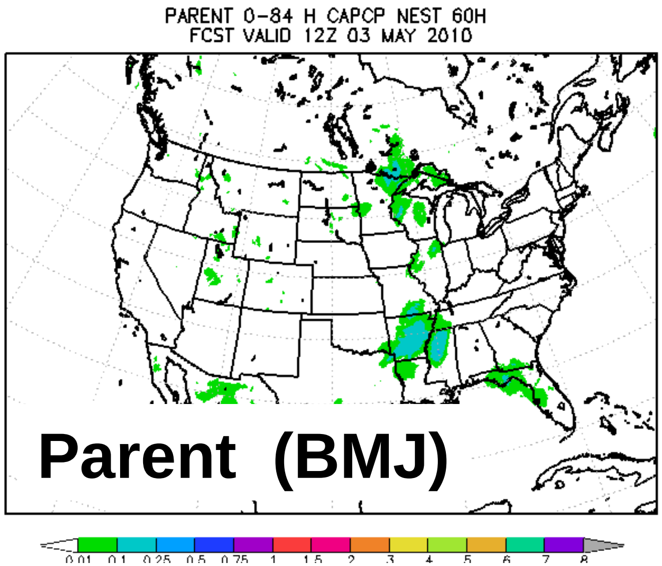
Ops fer	Revised fer
	

- **Higher composite dBZ in revised version (right)**

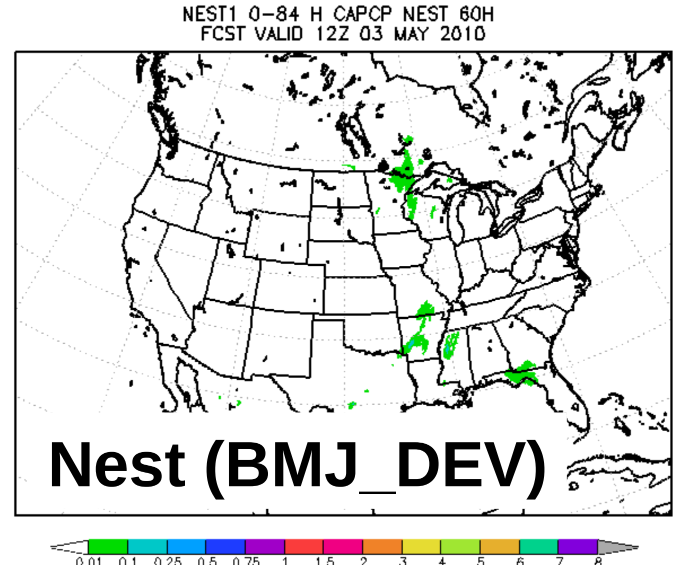
Modified Convection in Nests

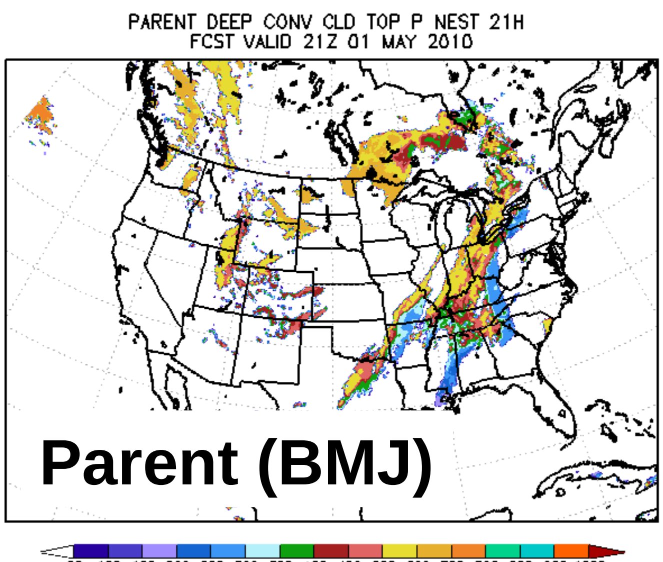
- BMJ_DEV tests in 4-km CONUS runs
  - Moister profiles
  - Less triggering of deep convection
  - Reduced convective QPF
  - Better QPF bias than running w/o convection
  - Improved surface & upper-level scores (not shown)
  - Small impact on CAPE forecasts

Reduced BMJ_DEV triggering in 4-km nest

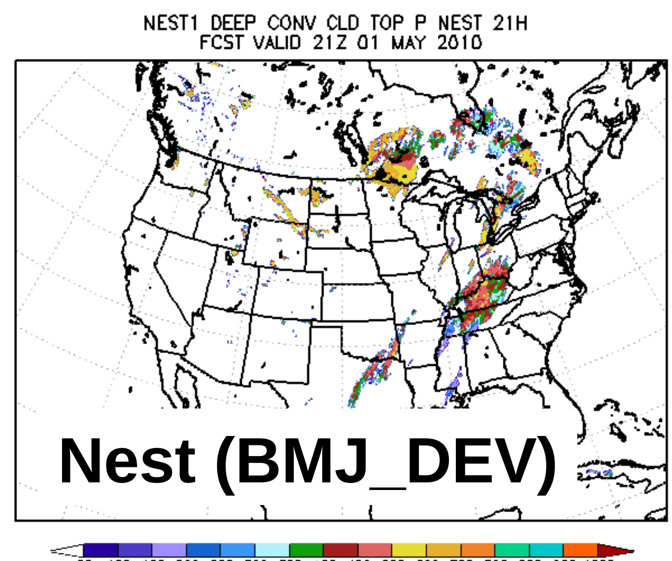


0-60 h Cu QPF

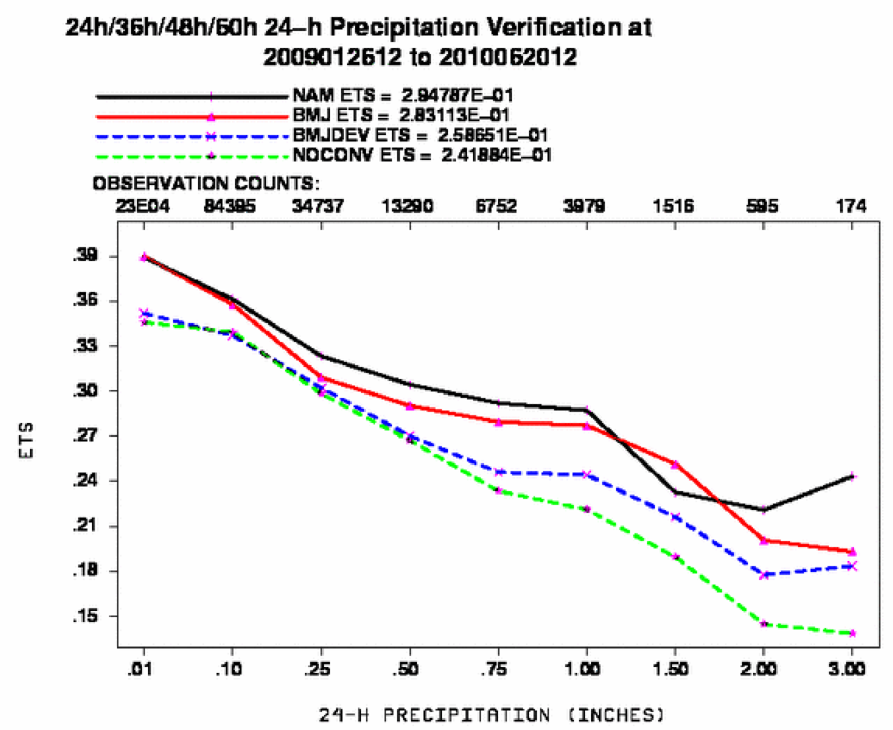


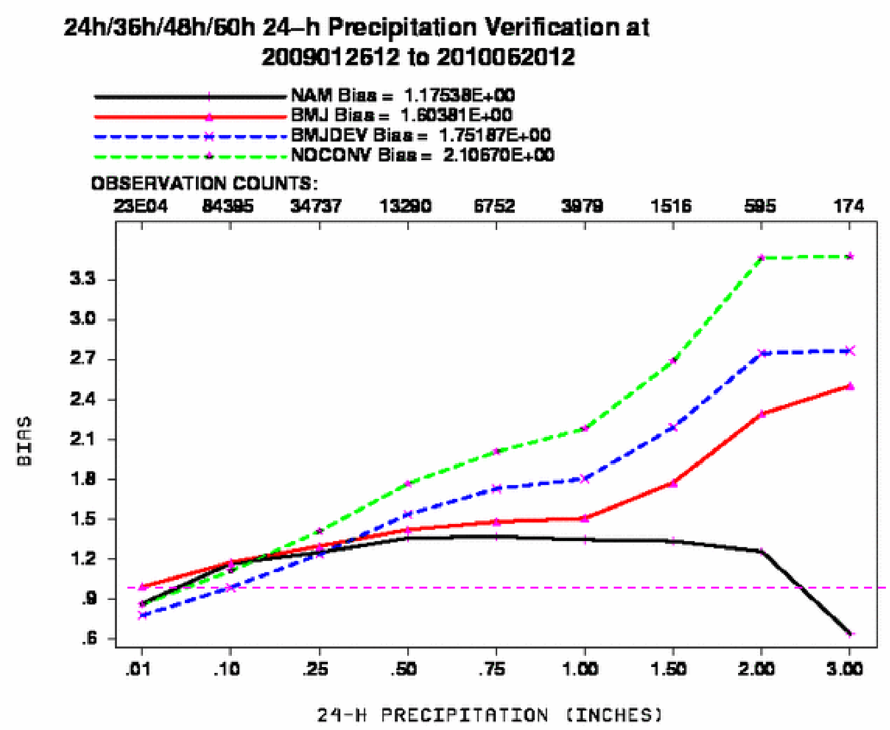


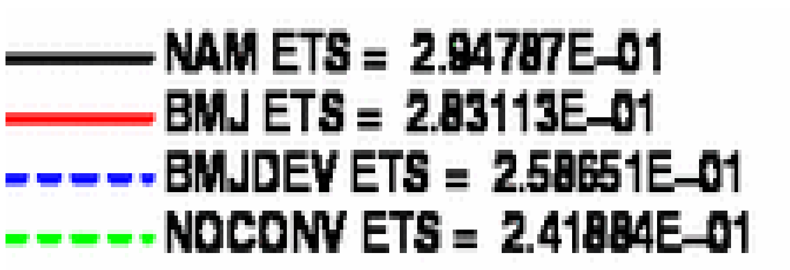
Deep Cu Cloud Top Pressure (hPa)

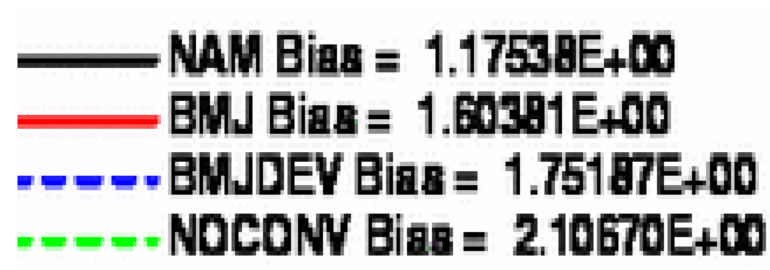


QPF Verification in NMMB Nests

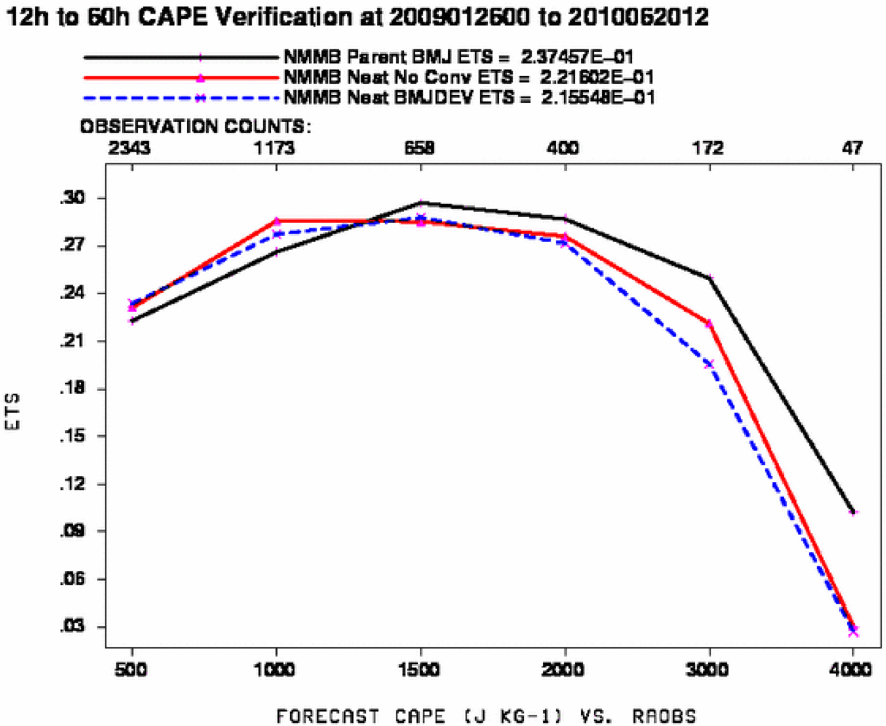


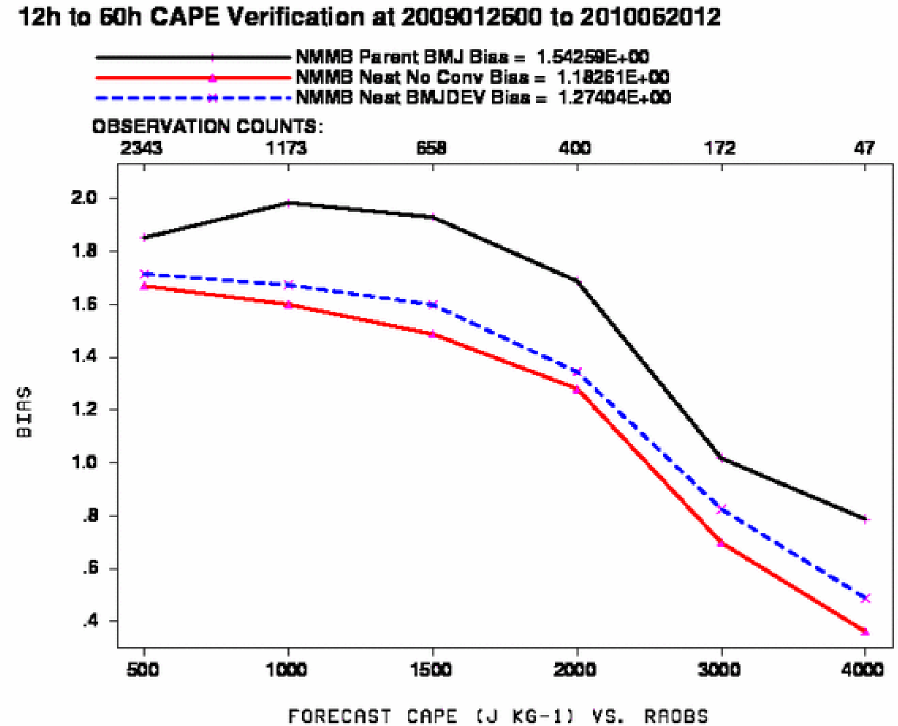






CAPE Verification in NMMB Nests

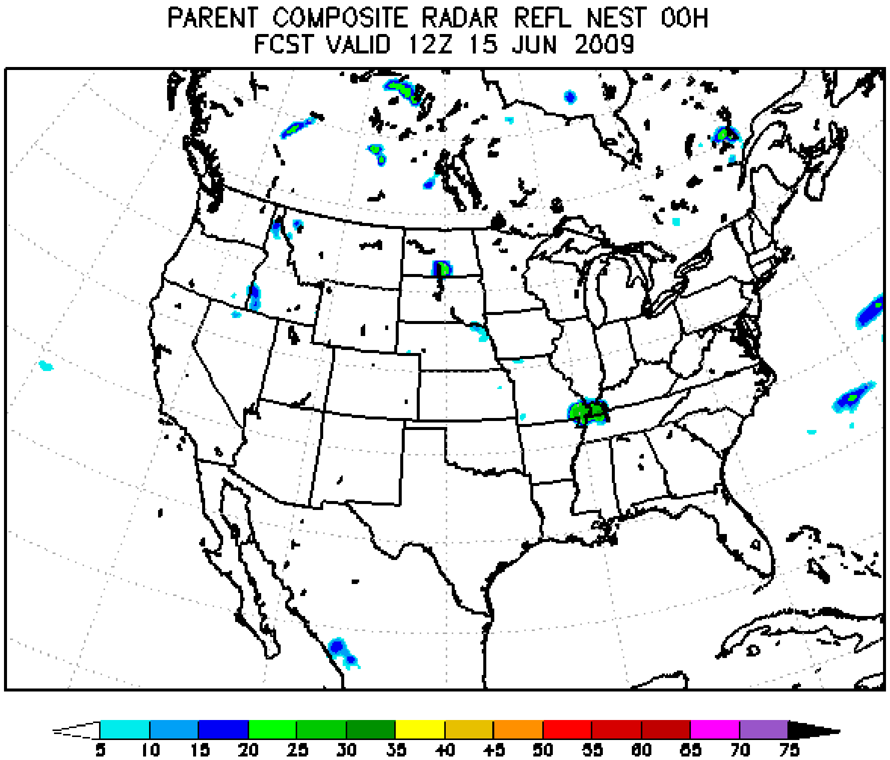


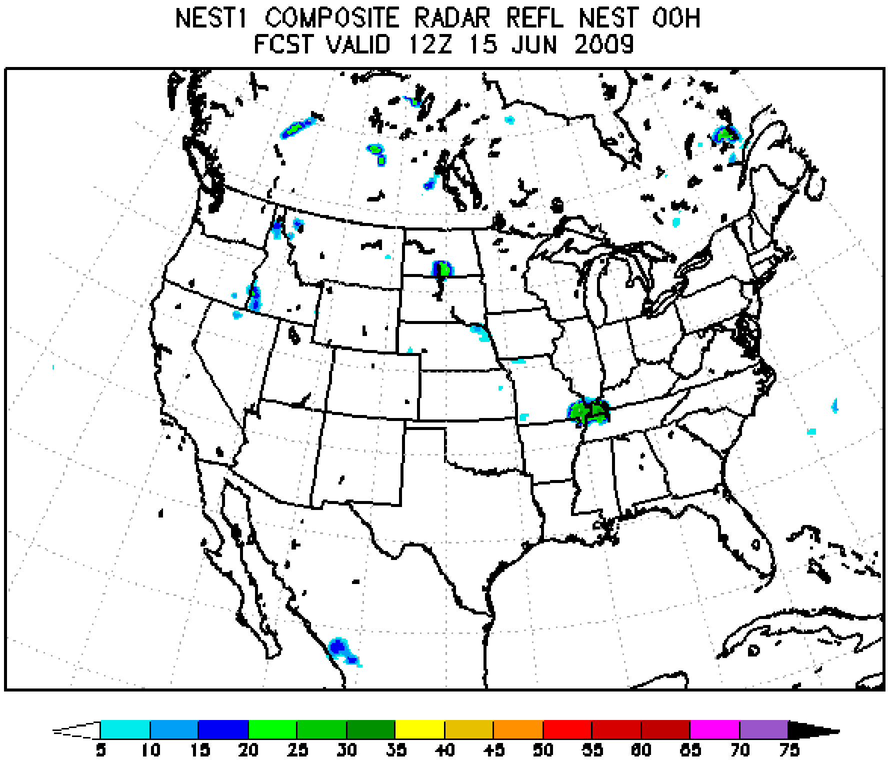


NMMB Parent BMJ ETS = 2.37457E–01
NMMB Nest No Conv ETS = 2.21602E–01
NMMB Nest BMJDEV ETS = 2.15548E–01

NMMB Parent BMJ Bias = 1.54259E+00
NMMB Nest No Conv Bias = 1.18261E+00
NMMB Nest BMJDEV Bias = 1.27404E+00

NMMB Forecast Reflectivities





<u>12-km Parent</u>

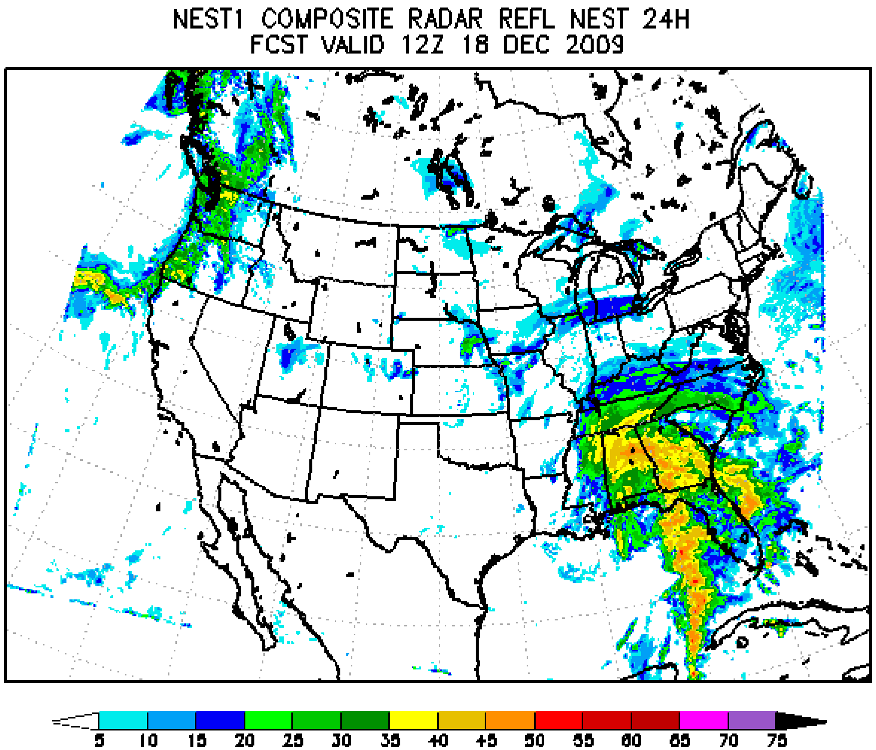
- Size is ½ of NAM domain
- Same BMJ Cu as in NAM
- Modified fer microphysics

<u>4-km CONUS Nest</u>

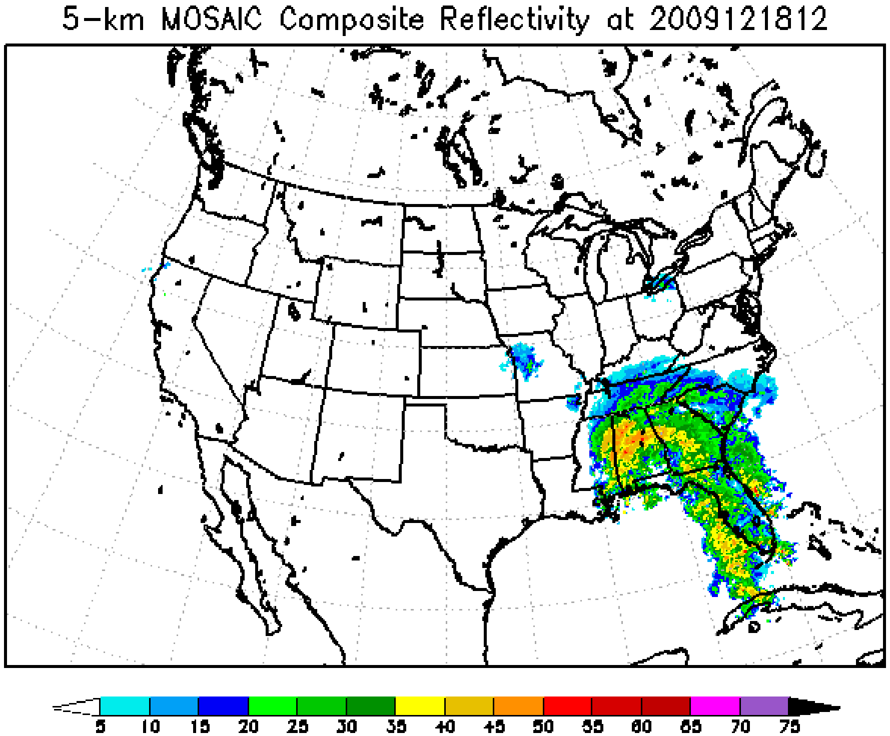
- BMJ_DEV convection (reduced triggering)
- Modified fer microphysics

Reflectivity Verification (1 of 2)

4-km NMMB Nest

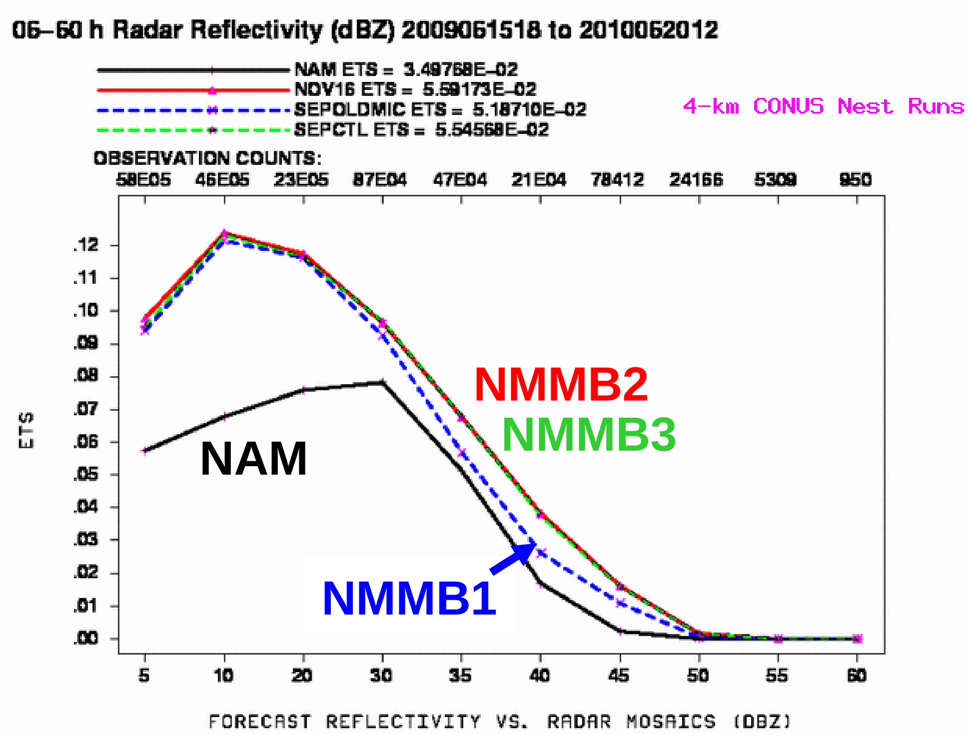


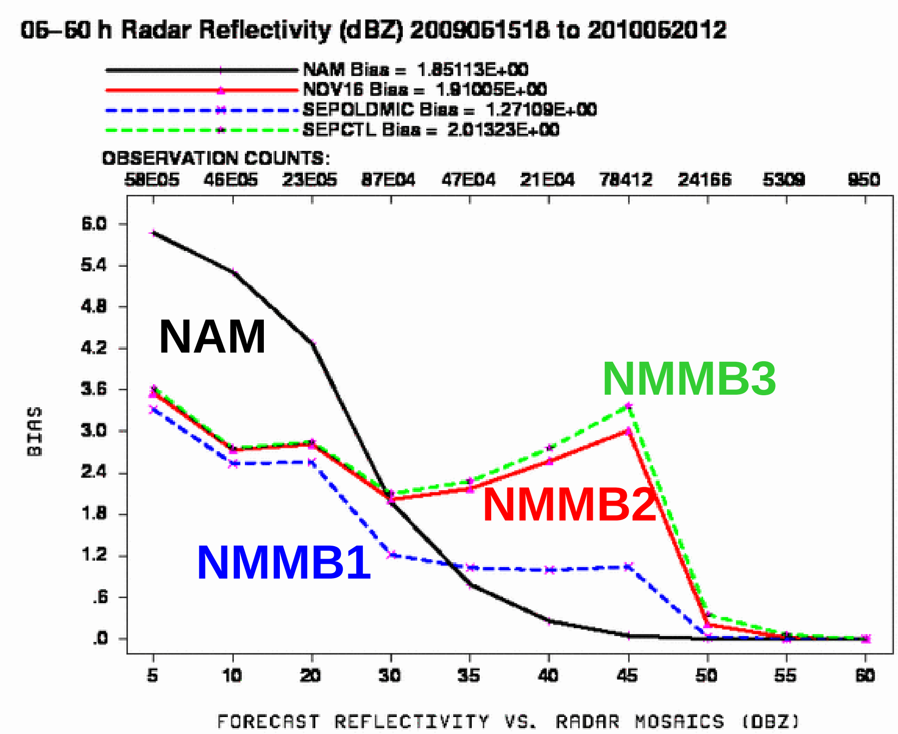
5-km Mosaic product



(see poster 94 by Colón *et al.*)

Reflectivity Verification (2 of 2)



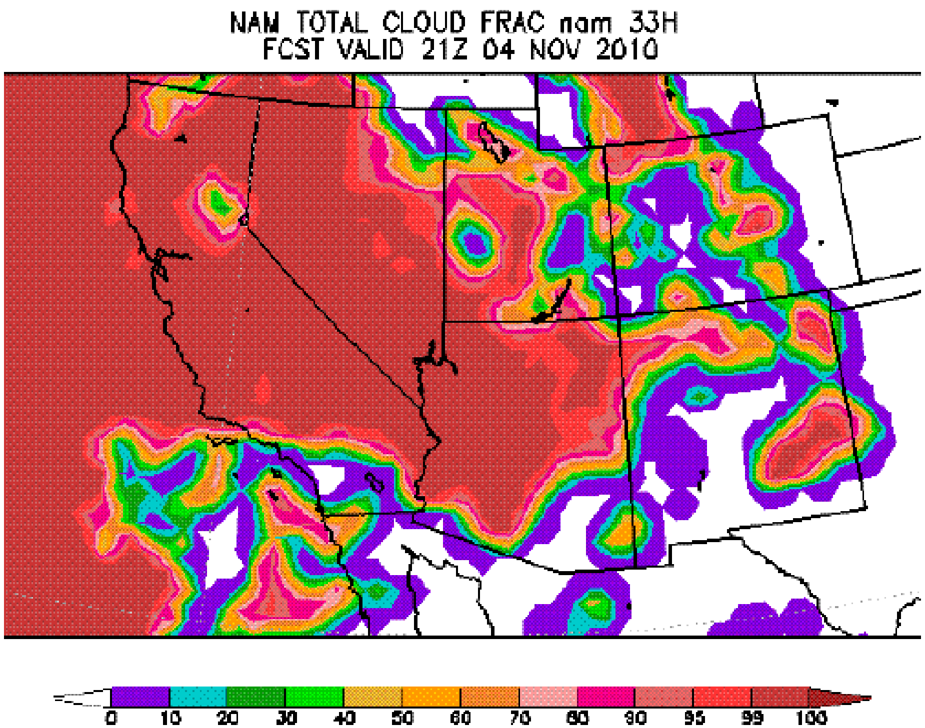


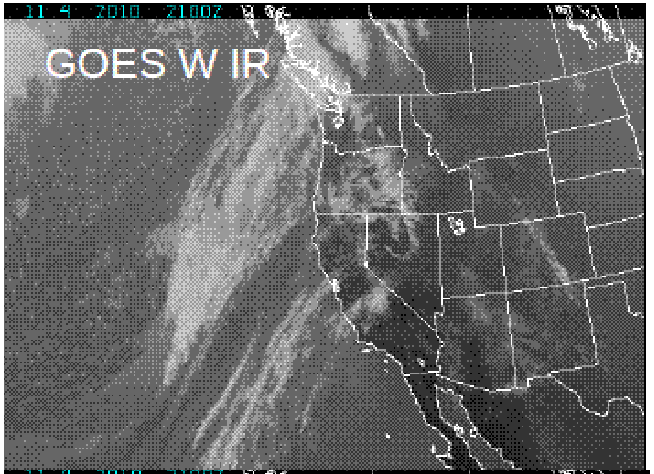
NMMB1 - "old" microphysics / NMMB2 & NMMB3 – "new" microphysics

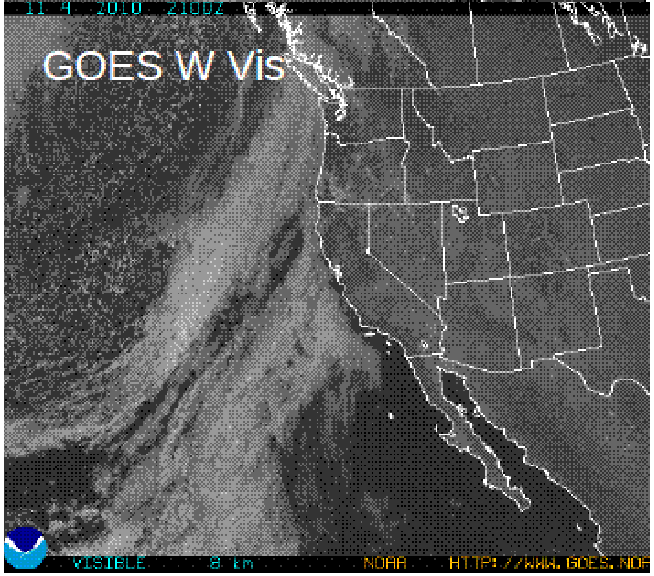
- **Better threat scores in "new" version, but also higher biases at ≤ 40 dBZ (Colón *et al.* poster)**

Cloud Fraction Changes (1 of 5)

Large overprediction of cloud cover in the NAM

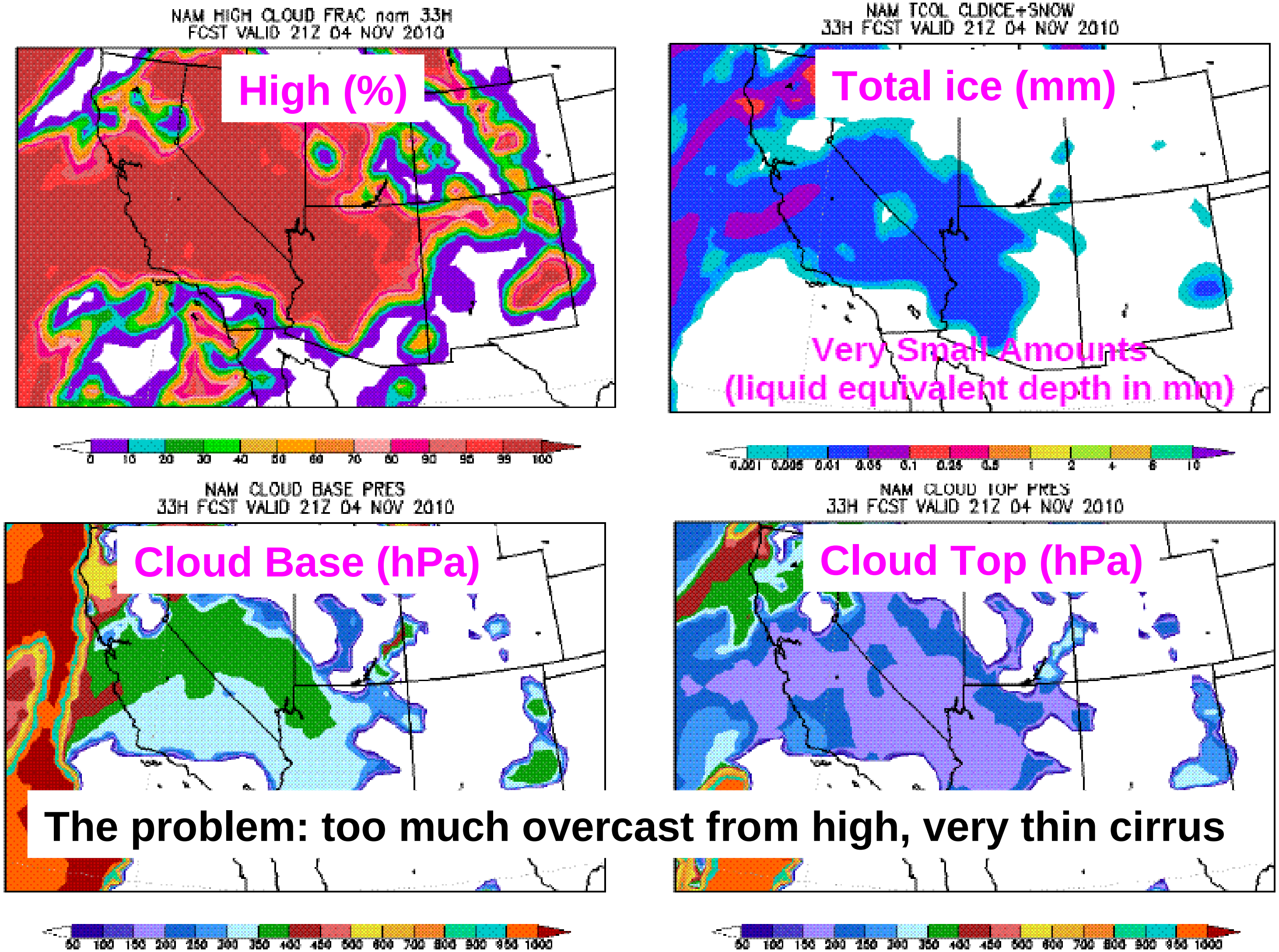






In response to comments from weather.com

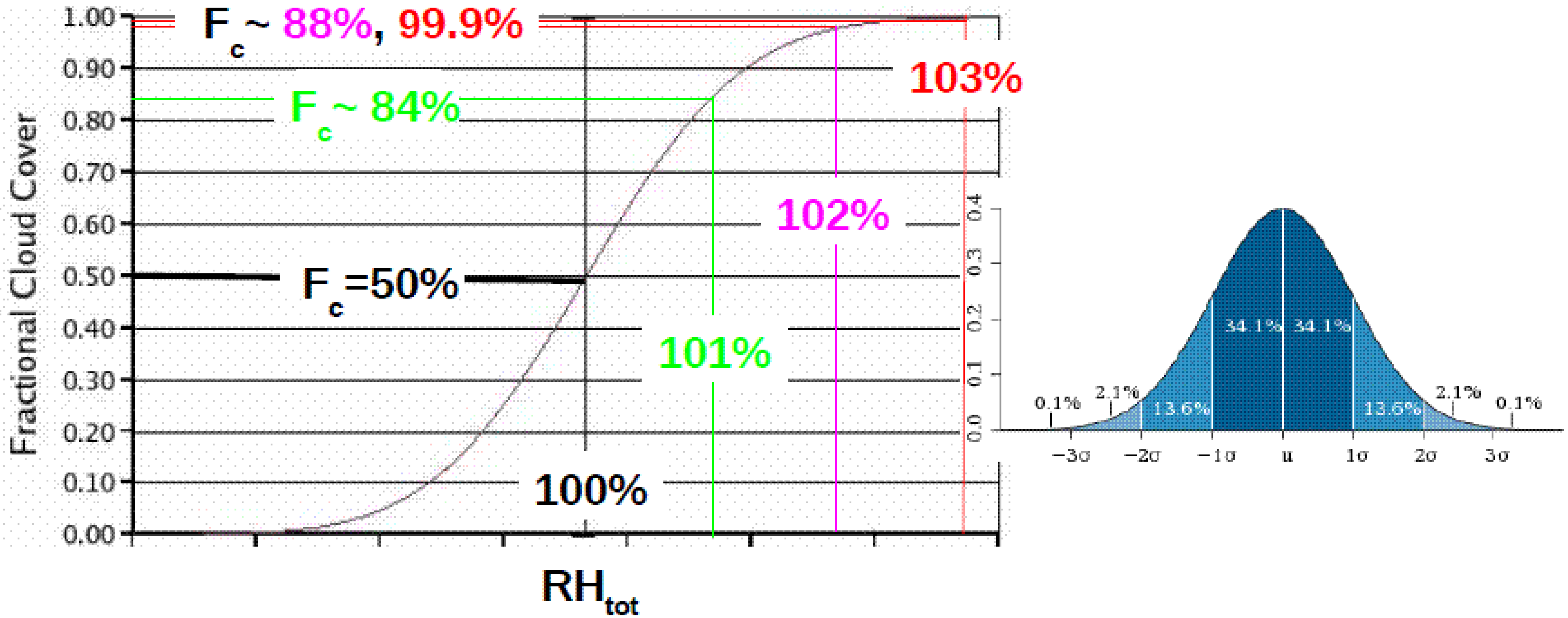
Cloud Fraction Changes (2 of 5)



The problem: too much overcast from high, very thin cirrus

Cloud Fraction Changes (3 of 5)

- Total relative humidity, $RH_{tot}=(Q_v+Q_{cld})/Q_{sat}$
- Cloud fraction (F_c) a function of RH_{tot}, assumed to be Gaussian with σ =1%



Cloud Fraction Changes (4 of 5)

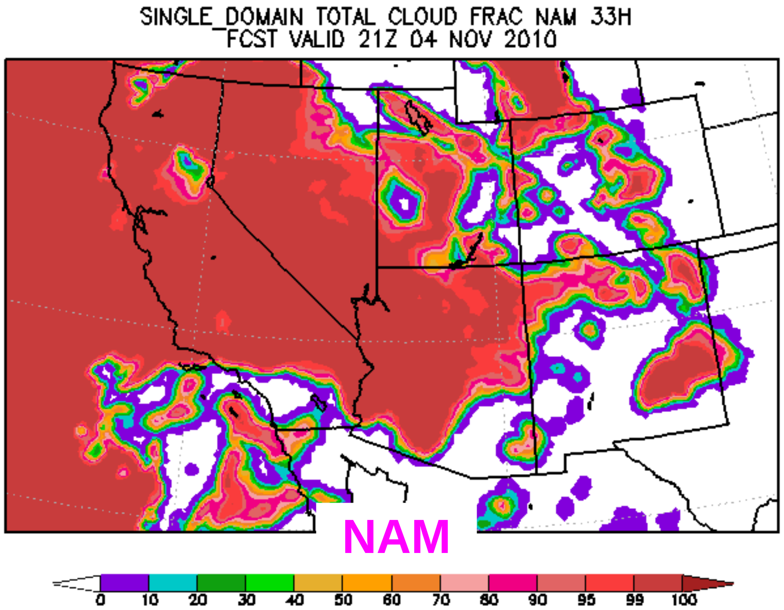
- Cloud water condensation
  - Many CCN, droplet # O(10^2 – 10^3 cm^{-3})
  - Water supersaturations rarely exceed 1%
- Vapor deposition onto ice
  - Far fewer IN, crystal # O(1 – 10^3 L^{-1})
  - Much higher SS_{ice} at water saturation

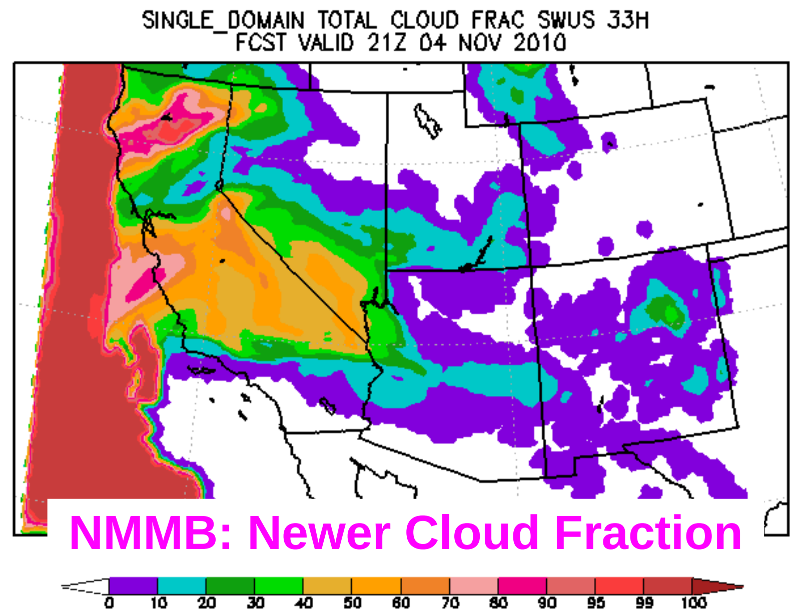
    ~10% (-10ºC), ~21.5% (-20ºC), ~34% (-30ºC), ~48% (-40ºC)
- Ice saturation used for Q_{sat} in F_c at T<0ºC
- RH_{tot}»100% & $F_c \rightarrow 1$ even when $Q_{cld} \rightarrow 0$

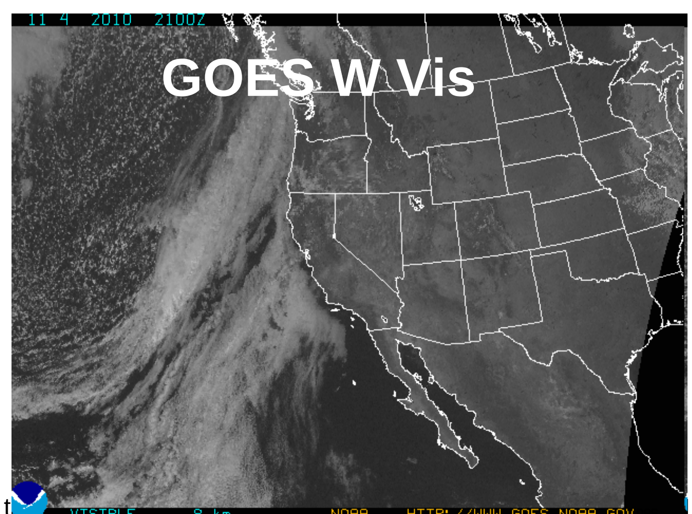
Cloud Fraction Changes (5 of 5)

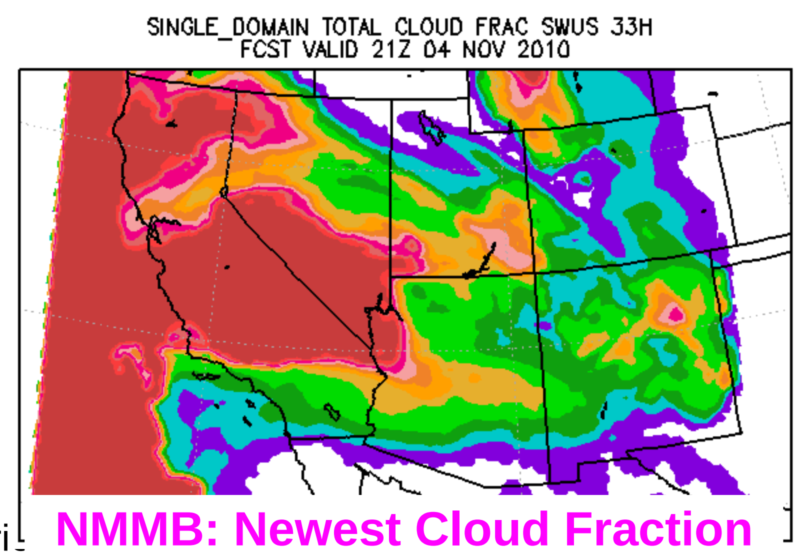
- Simple, temporary "fix" (newest test in green)
  - F_c=min[1, SQRT(10^4*Q_{cld})]; (10^5 in latest test)
    - F_c=0, Q_{cld}<0.001 g kg^{-1}, (10^{-4} g kg^{-1})
    - F_c=0.01, Q_{cld}=0.001 g kg^{-1}, (10^{-4} g kg^{-1})
    - F_c=0.32, Q_{cld}=0.01 g kg^{-1}, (10^{-3} g kg^{-1})
    - F_c=1, Q_{cld}>=0.1 g kg^{-1}, (10^{-2} g kg^{-1})
  - F_c treated more as cloud "porosity"
- Cloud amounts =1 in radiation if F_c>0, maintains currently tuned SW, LW behavior

Total Cloud Fractions (%)

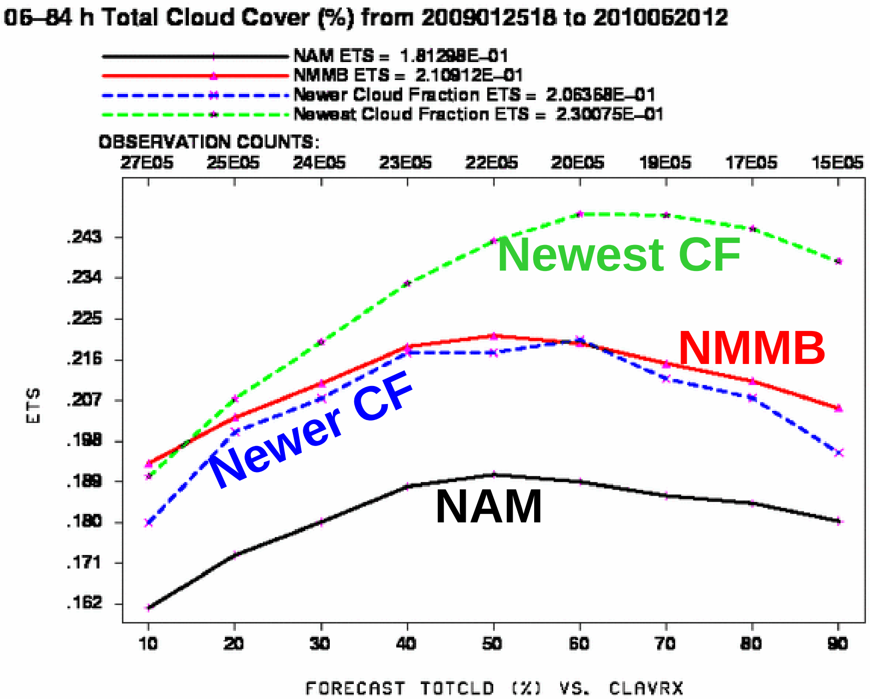


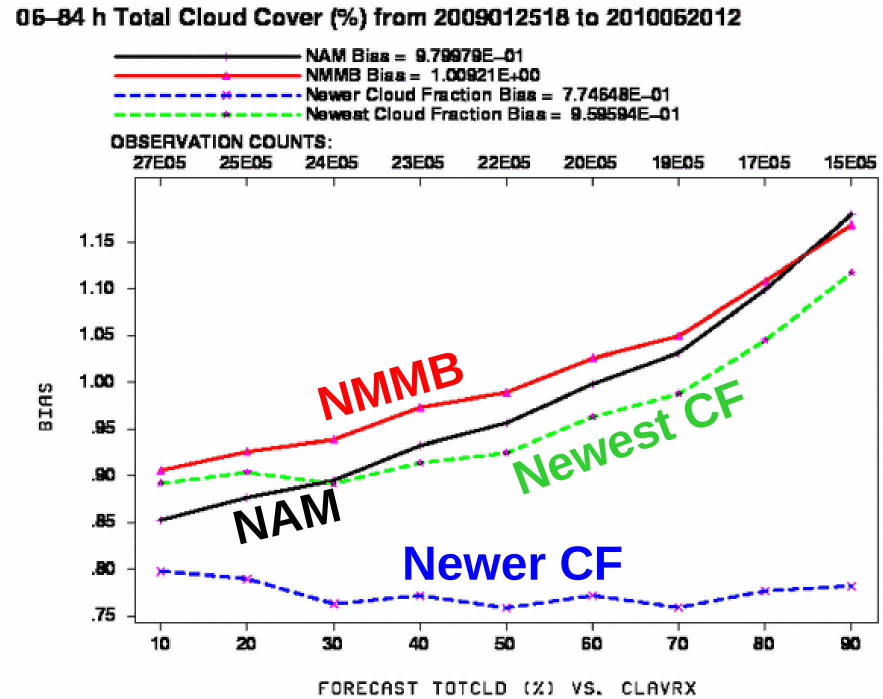






Cloud Verification (CLAVRx)





NAM, NMMB runs use the "old" cloud fractions
Newer CF – NMMB run using newer cloud fractions
Newest CF – NMMB run using the newest/latest cloud fractions

Better threats & biases using newest cloud fractions

(See Colón *et al.* poster)

Conclusions

- Microphysics changes
  - Higher peak dBZ, RR (1D column runs)
  - Small impact on QPF
  - Improved >50 dBZ, but worse (higher) biases ≤40 dBZ
- Convection changes in nest
  - Reduced triggering
  - Slight better QPF, little impact on CAPE
- Cloud fraction changes
  - Reduced high (overcast) bias for high, thin cirrus
  - Improved threats & bias using newest formulation