A new Spectral-Bin Microphysical scheme in WRF (and in SAM*) – the MCE3-0520 test case

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- SAM – System for Atmospheric Modeling :

http://rossby.msrc.sunysb.edu/~marat/SAM.html

Main idea: the SBM scheme can be used with FULL or FAST versions :

- **in FULL all size distribution included and interact (see below)**
- **in FAST the user can switch between dense (Hail) to less-dense (Graupel) ice particles**

FULL - 43 bins 11 Particle Size Distributions	FAST - 33 bins 4-7 Particle Size Distributions
Aerosols	Aerosols
Water drops	Water drops
Ice-crystals (plates, columns,dendrites)	- - - (small snow bins mimic IC)
Snow	Snow
Rimed fraction in snow (T<0)	[optional]
Liquid fraction in snow (T>0)	[optional]
Graupel	Graupel (or Hail)
Liquid fraction in graupel	[optional]
Hail	Hail (or Graupel)
Liquid fraction in hail	[optional]
Bin-wise Polarimetric operator	Bin-wise Polarimetric operator

Details / Remarks

- Each size distribution is defined on mass grid containing 33/43 bins (0.6cm/6cm hail)
- Nucleation at cloud base (analytical calculation of supersaturation maximum)
- Calculation of snow density
- Time dependent melting
- Spontaneous breakup of raindrops and snow
- Collisional breakup of ice (to be included)
- Ice-ice sticking efficiency (to be included)
- Polarimetric fields the same as NEXRAD (Ze,Zh,Zdr,Kdp,Rhohv …)

What ice hydrometeor is dominating in case of deep convection?

CASE STUDY: Mesoscale convective system (squall line) observed during the Midlatitude Continental Convective Clouds Experiment (MC3E-0520) that took place in Central Oklahoma during 19-20 May 2011

We compare 3 versions of FAST SBM (FSBM): H43, H33 and G33 :

Fast SBM H43

H43 Size distributions for
- Aerosols
- Water drops
- Snow
- **Hail (43 bins)**

Bin-wise Polarimetric operator

Fast SBM H33

H33 Size distributions for
- Aerosols
- Water drops
- Snow
- **Hail (33 bins)**

Bin-wise Polarimetric operator

Fast SBM G43

G3 Size distributions for
- Aerosols
- Water drops
- Snow
- **Graupel (33 bins)**

Bin-wise Polarimetric operator

Snow and graupel or snow and hail?

- Simulation Design

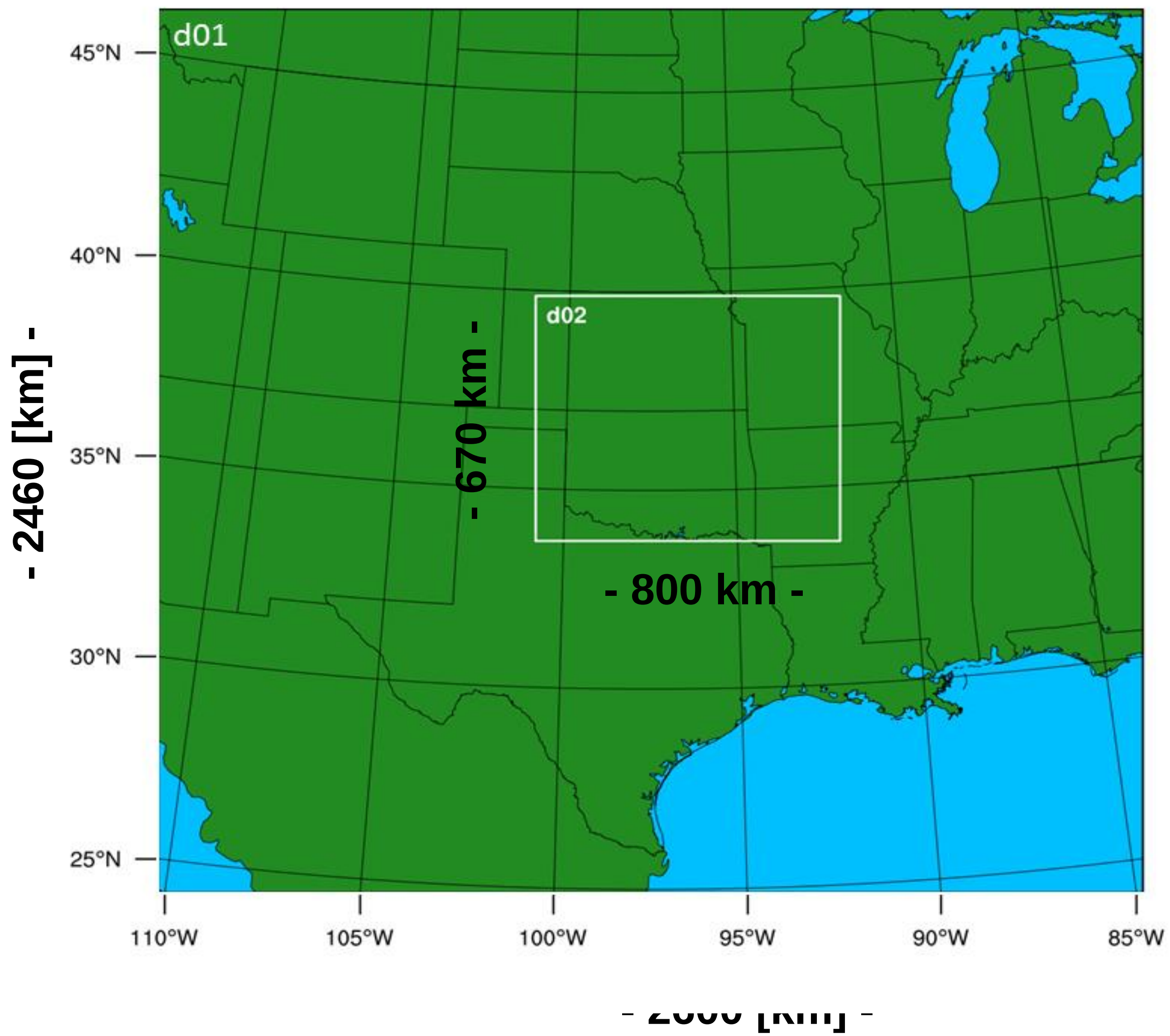
Outer domain :

- 4km resolution
- 648 x 614 x 51 grid points
- SBM is used

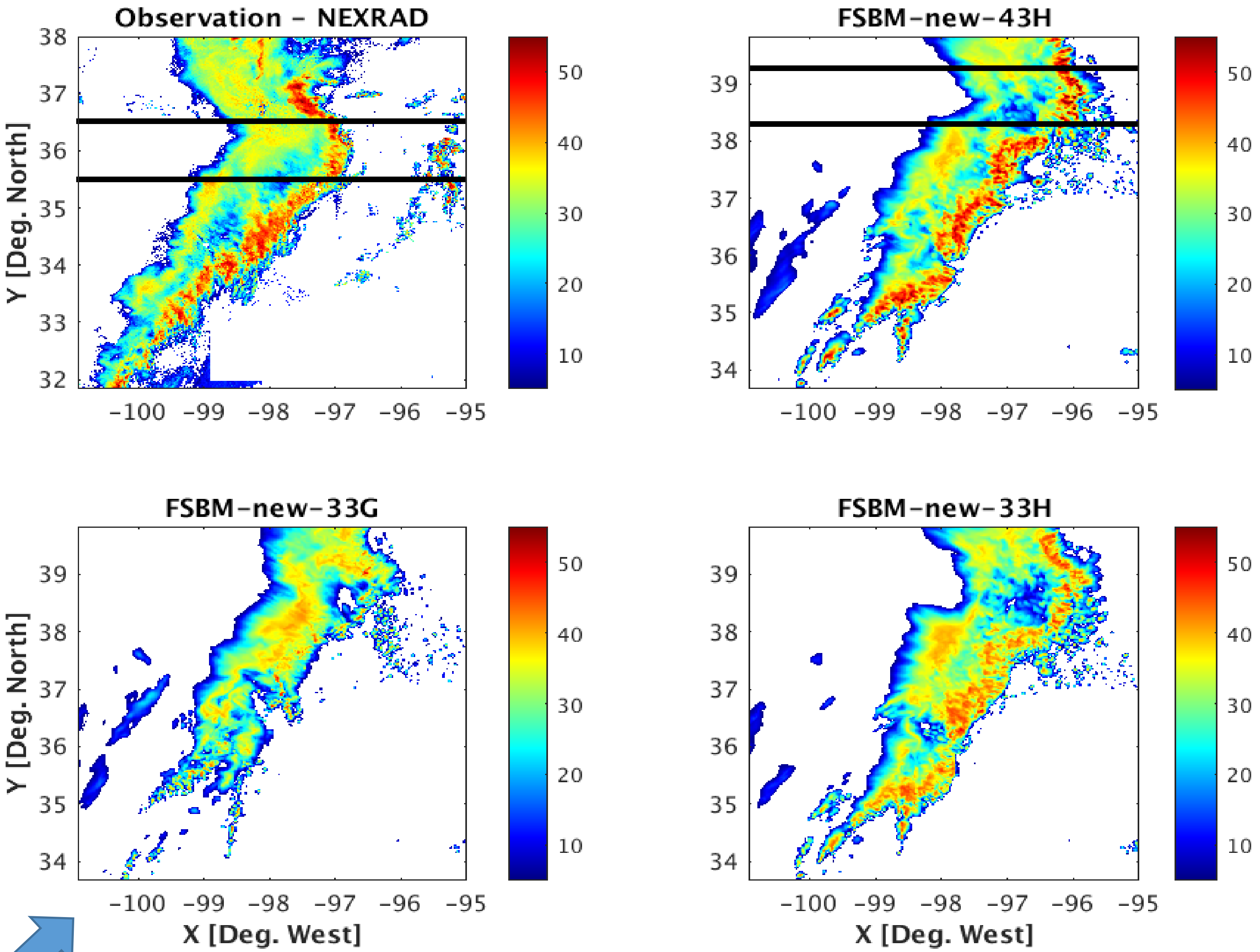
Inner domain :

- 1.3km resolution
- 614 x 511 x 51 grid points
- SBM is used

Computational time:
12h of physical processes = ~ 36h-48h computational time using 720 cores



▪ Radar Reflectivity at 2.5 [km] - NEXRAD 11:00 / WRF-sbm 10:00 [UTC]



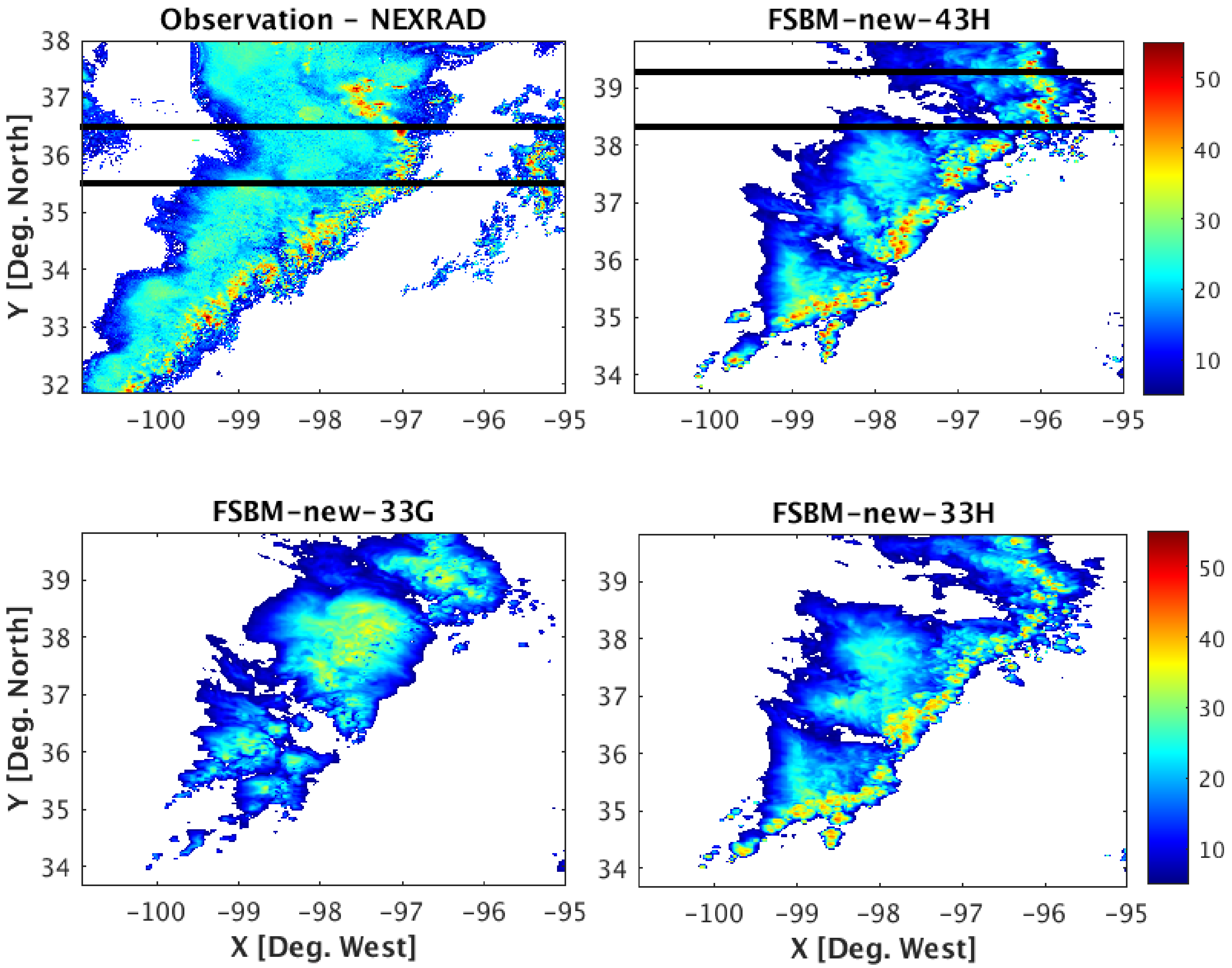
H43 produces the structure of the squall line realistically

Aerosol Conc. = 1800 [cm-3]

H33 produces the structure of the squall line realistically (but convection in the front is weaker as compared to H43)

G33 produces unrealistic structure : no convective zone

- **Radar Reflectivity at z= 8 [km] - NEXRAD 11:00 / WRF-sbm 10:00 [UTC]**

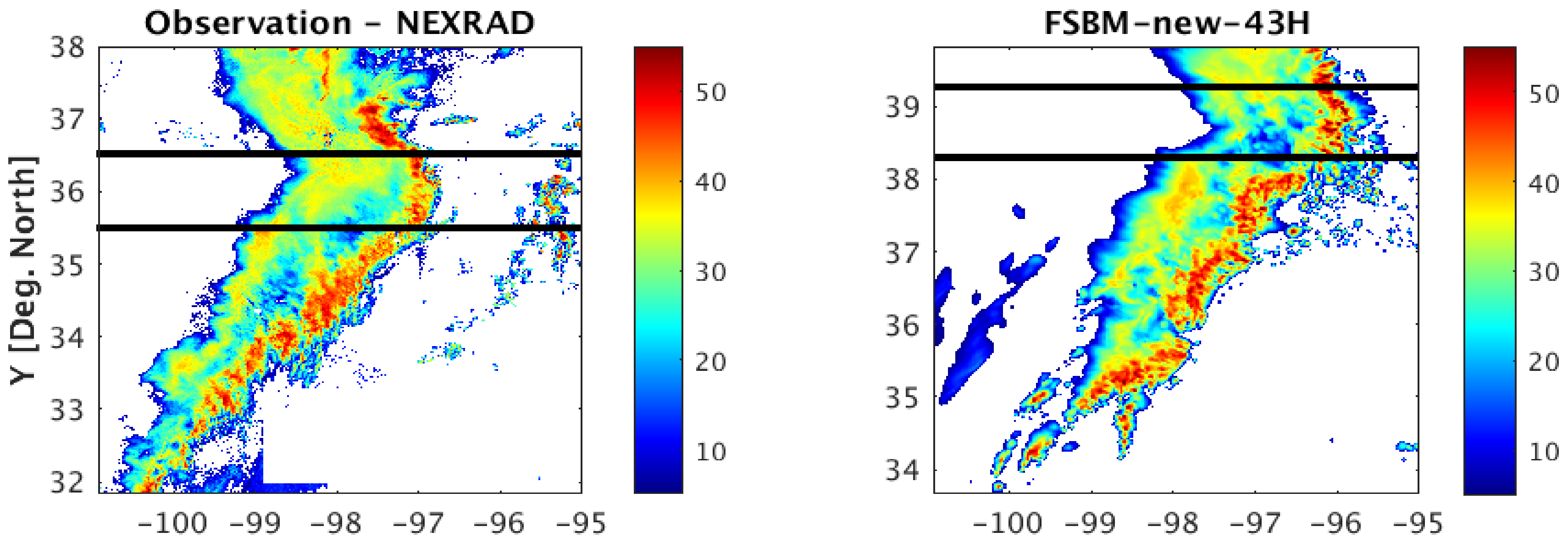


H43 represents the convective area at 8 km

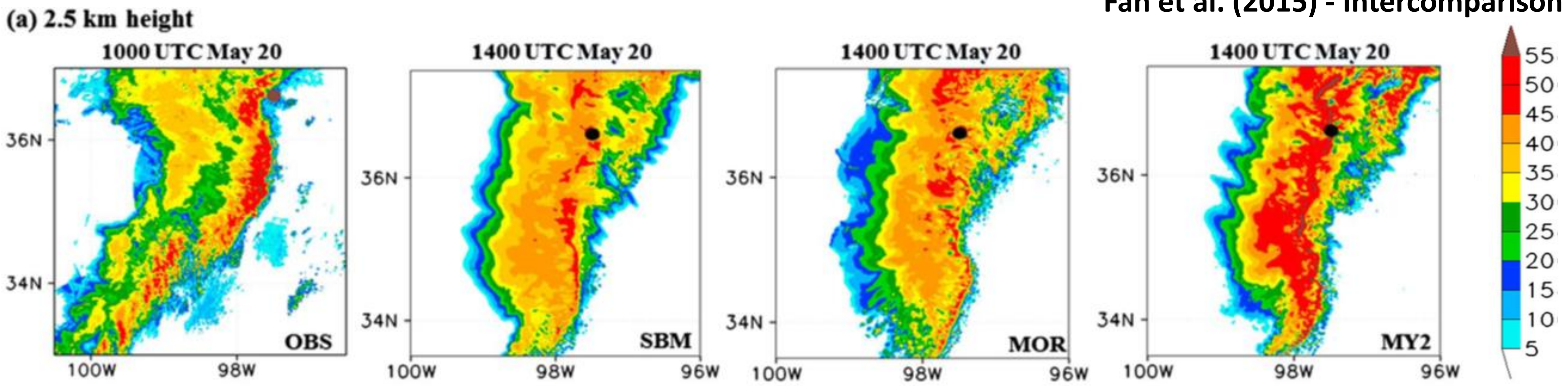
Reflectivity in the stratiform area is underestimated

G33 represents unrealistic structure : no convective zone

- **Comparison with the current FSBM (FSBM-old)**

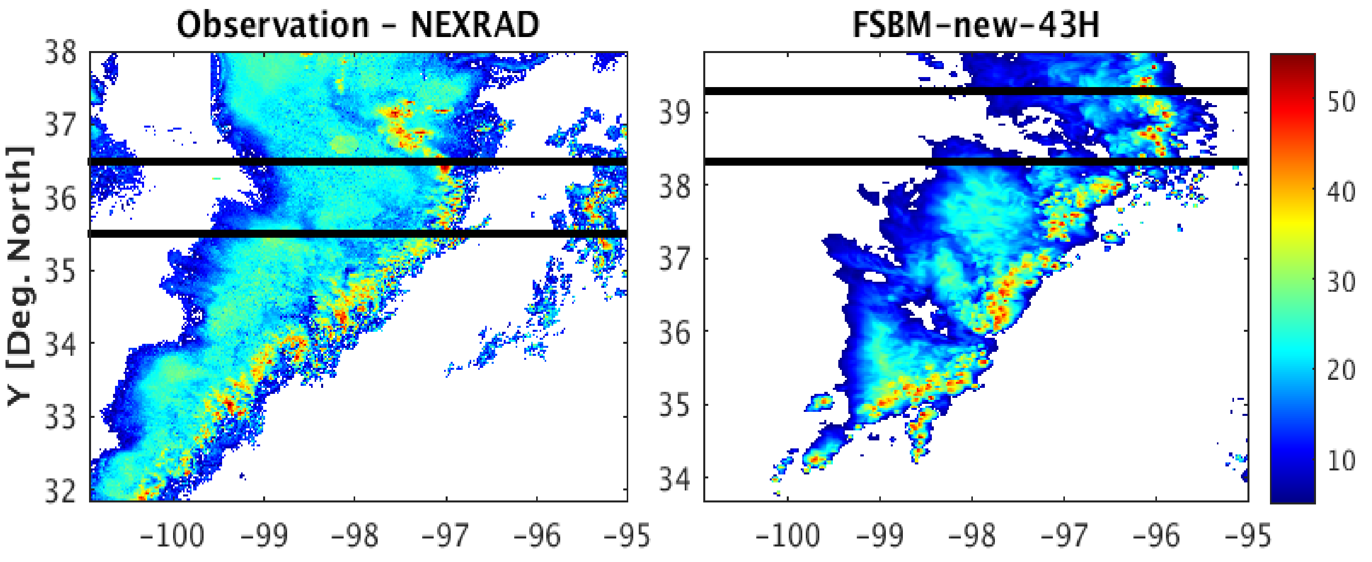


Fan et al. (2015) - Intercomparison study



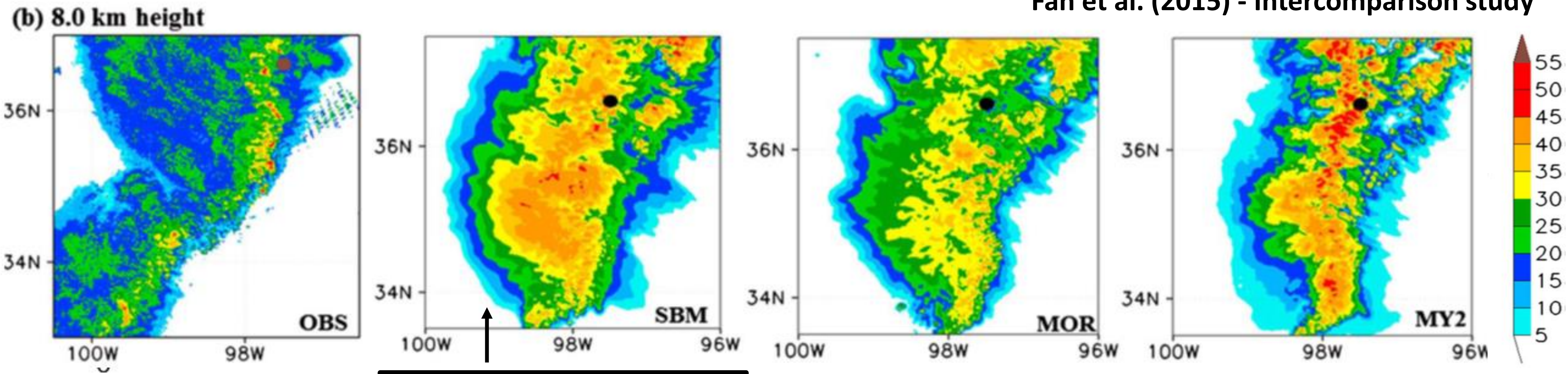
FSBM-OLD does not simulate convective front well

- **Comparison with the current FSBM (FSBM-old)**

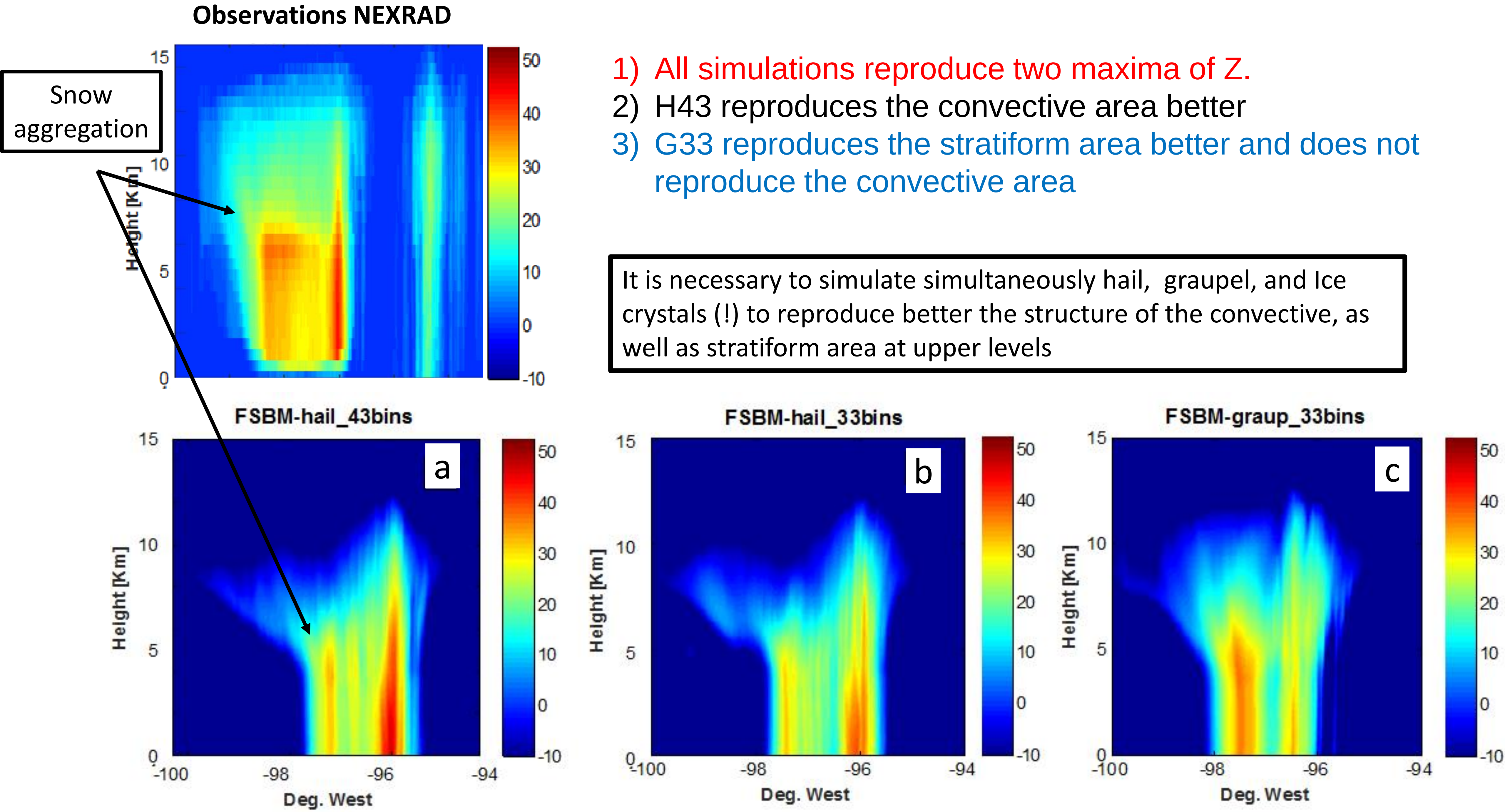


FSBM-new represents convective front

Fan et al. (2015) - Intercomparison study



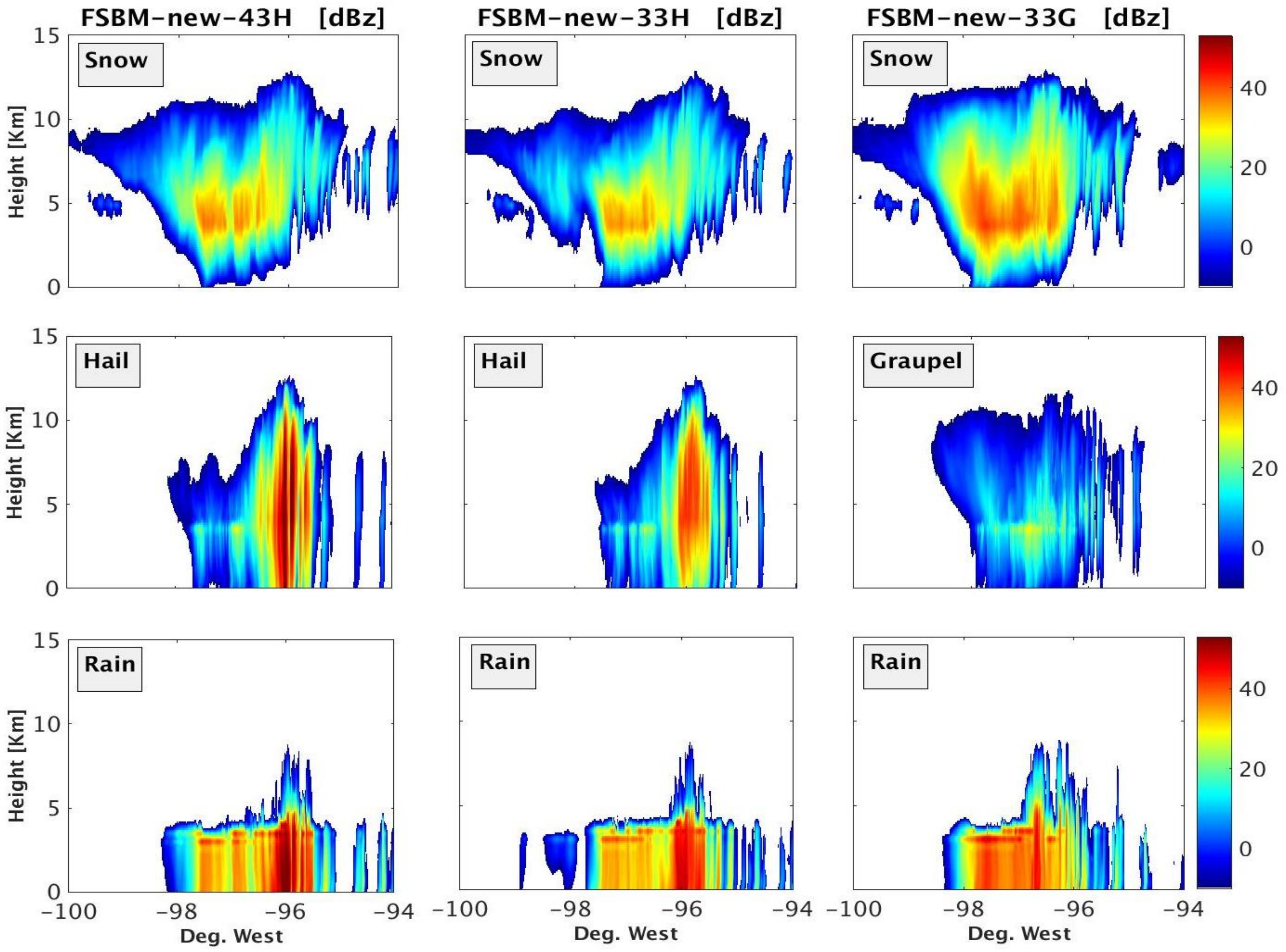
FSBM-OLD does not simulate convective front



1) All simulations reproduce two maxima of Z.
2) H43 reproduces the convective area better
3) G33 reproduces the stratiform area better and does not reproduce the convective area

It is necessary to simulate simultaneously hail, graupel, and Ice crystals (!) to reproduce better the structure of the convective, as well as stratiform area at upper levels

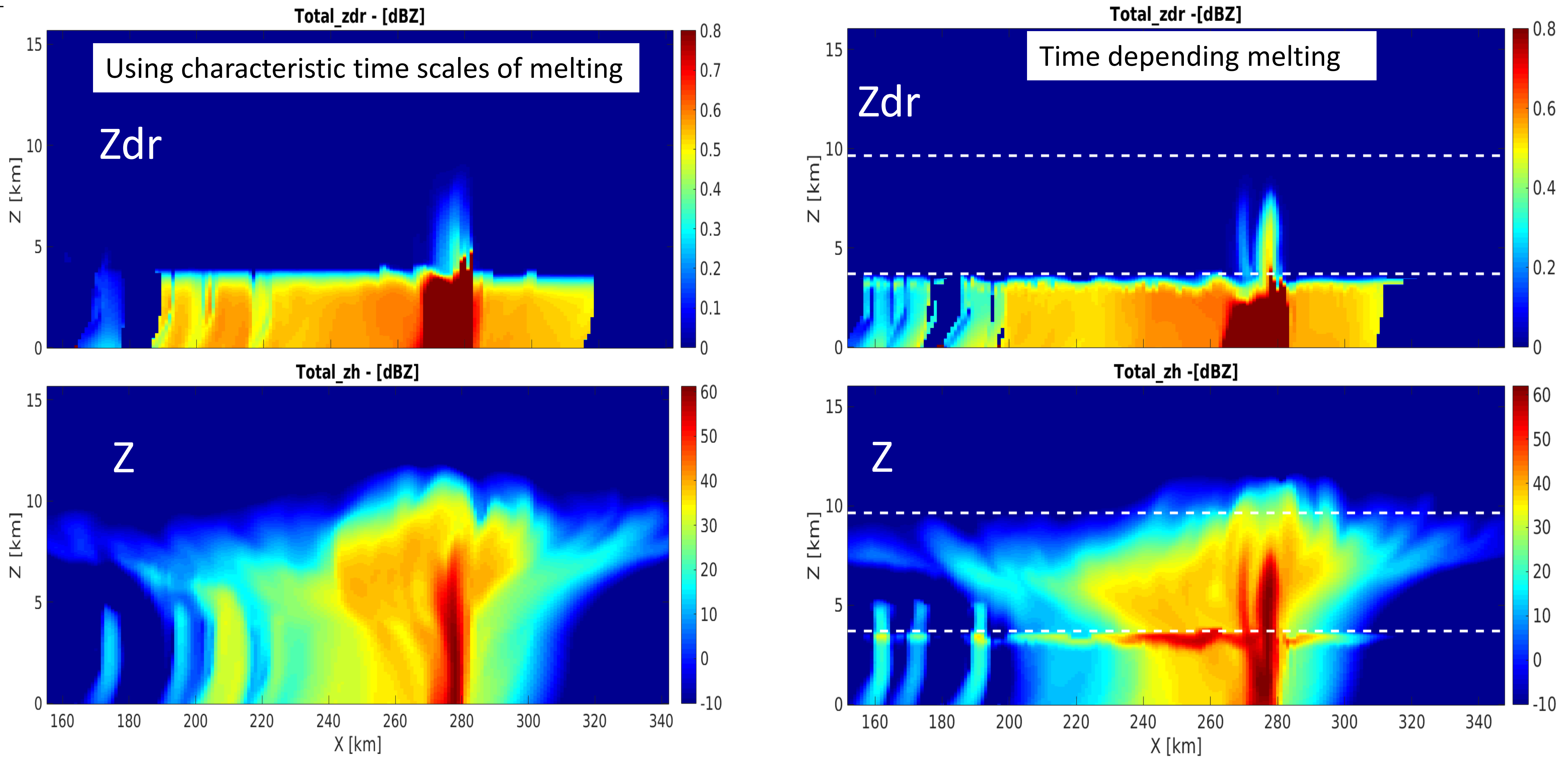
- **Max (North-South) Radar reflectivities for Snow, Hail/Graupel and Rain**



- **Hail is max in H43: large hail is required to form convective front**
- **Rain forms by melting in convective zone**
- **G33-graupel does not lead to formation of convective front No riming: warm rain takes place in the convective zone**
- **G33-graupel and snow melting creates max reflectivity in stratiform zone**

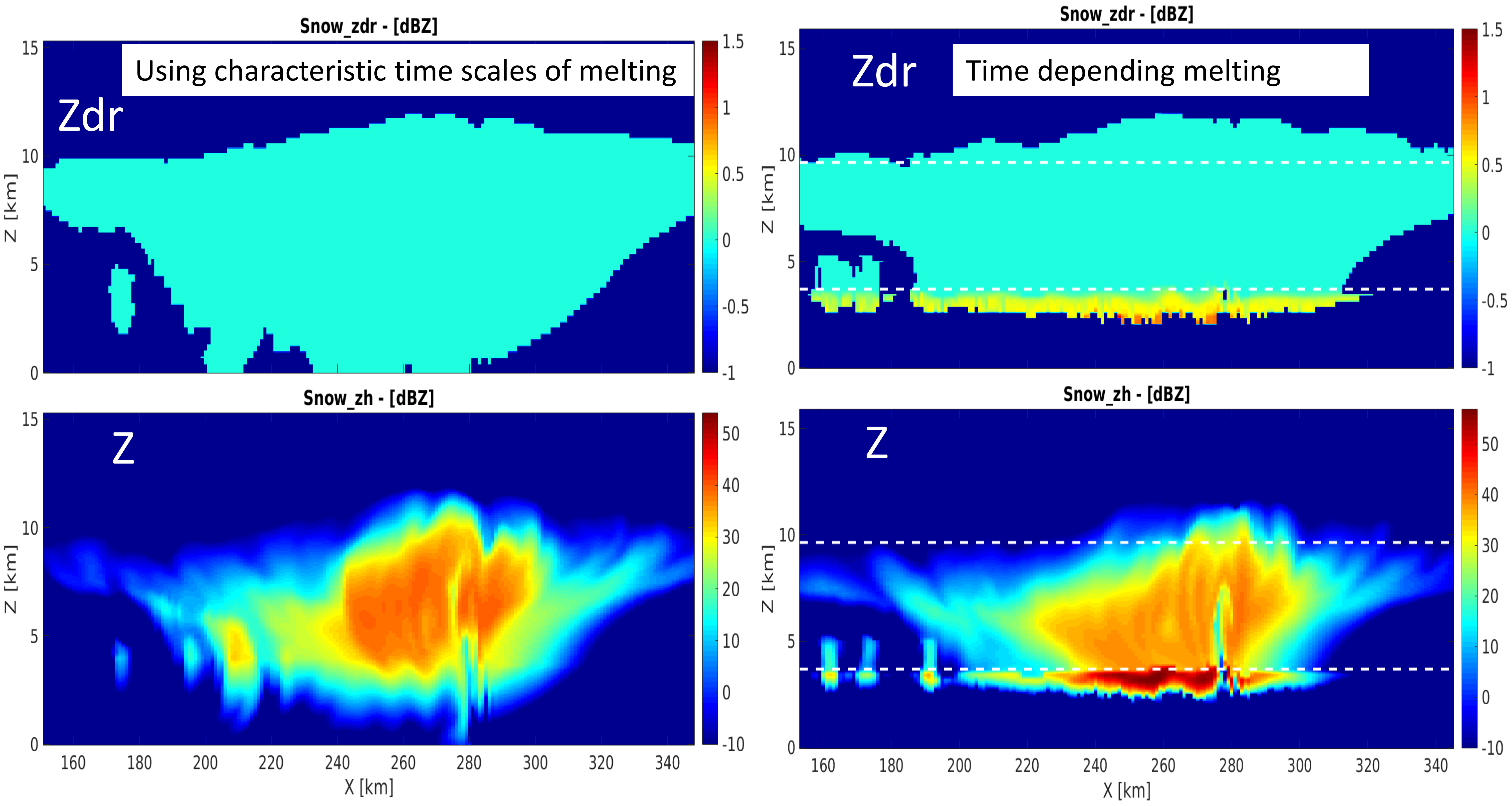
Version FSBM_new H43 with time dependent melting (calculation of LWF in melting particles)

Total Ze / Total Zdr

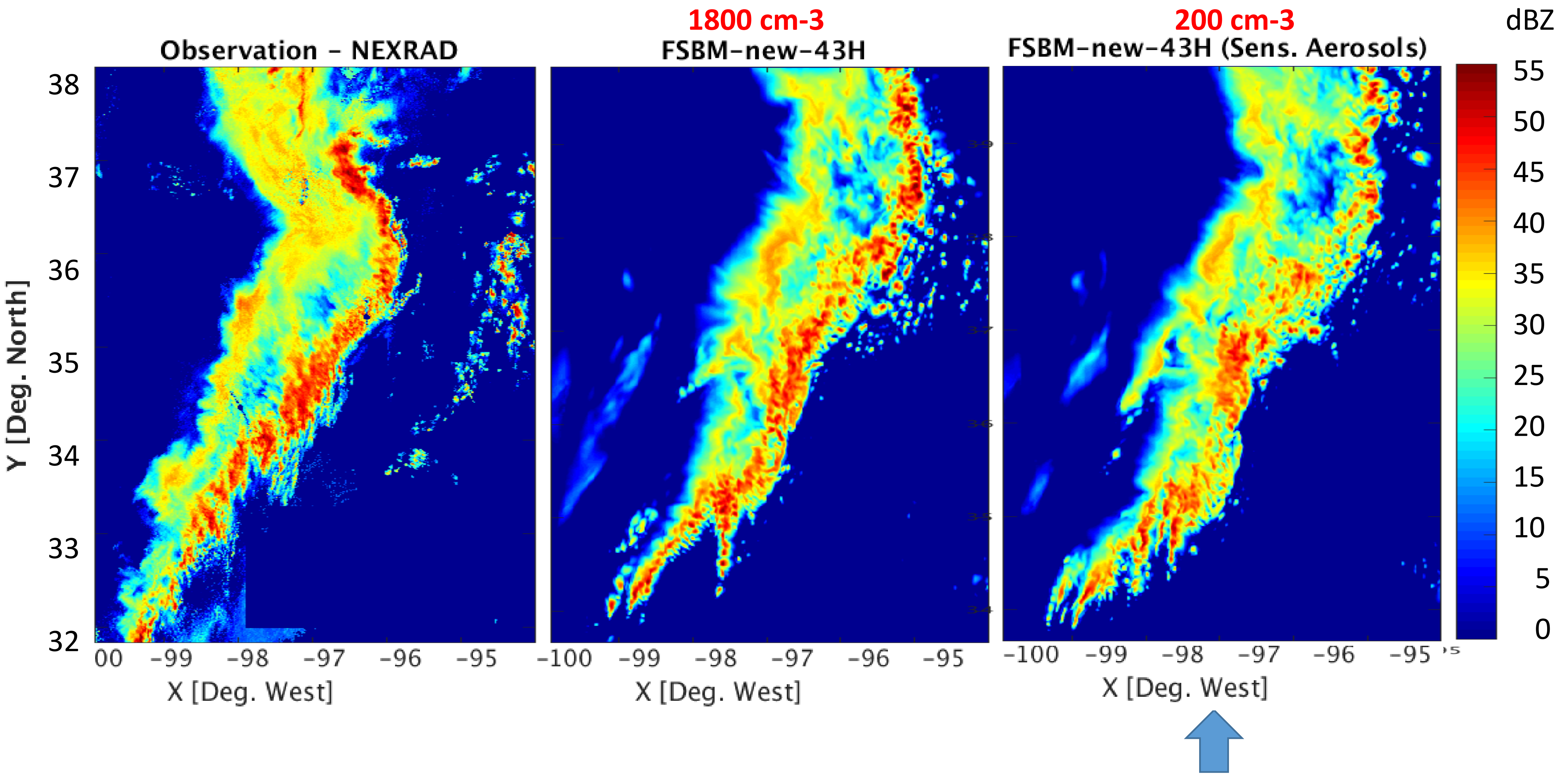


Snow Melting

Version FSBM_new with time dependent melting (calculation of LWF in melting particles)



SENSITIVITY EXPERIMENTS. Sensitivity to aerosols 1800 cm-3 vs 200 cm-3



At low CCN concentration hail is small

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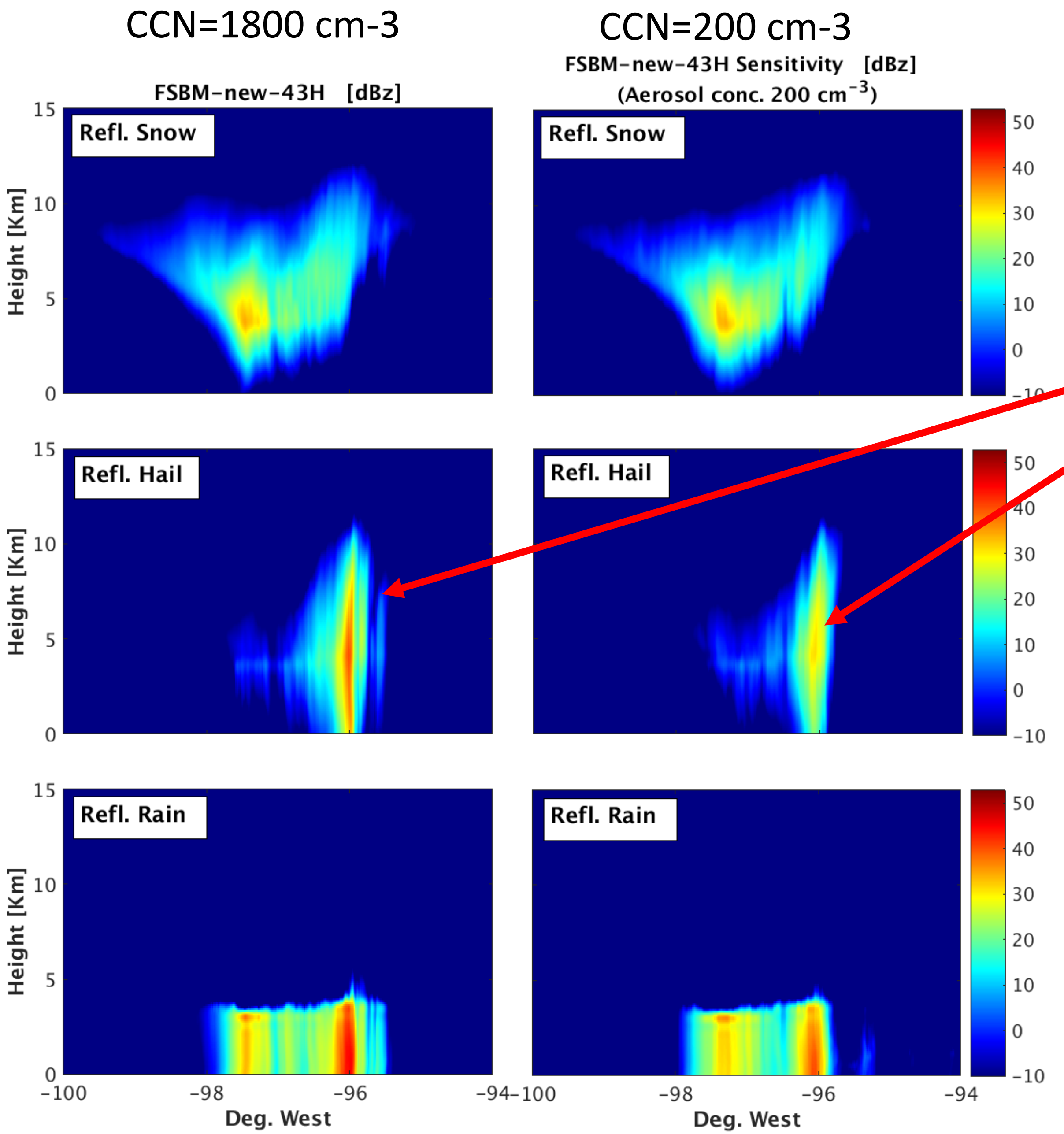

At low CCN concentration hail is small

CONCLUSIONS

- NEW WRF/SBM is developed in several options: **Full** (11 size distributions) and **Fast** (4 to 7 size distributions)
- NEW Fast SBM_new indicates **much better** agreement with observations than FSBM-OLD

What is the minimum number of hydrometeor types needed to simulate squall lines and to have sensitivity to aerosols?

- It is possible to simulate mesoscale convective systems with deep convection using aerosols, water, **snow and hail.**
- To simulate realistically W, and radar reflectivity in convective zone, it is necessary to use enough bins to simulate **large hail** (a few cm in diameter).
- To simulate BL microphysics, melting layer, it is necessary to use time dependent melting (i.e. to add 2 size distributions **for liquid water in snow and hail**)
- To simulate better stratiform area **graupel** is also needed.
- FSBM with time dependent melting, we will get the possibility not only to simulate microphysical processes more accurately, but to get more information (e.g., **polarimetric signatures**)

THANK YOU!