CCN and IN updates to the Thompson microphysics scheme

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Outline

Short introduction of the linking of aerosols to droplet and ice formation in the Thompson microphysics scheme in WRF.

Case study of dust – IN activation

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Linking aerosols to CCN and IN in WRF

Crawl:

Constant cloud droplet number that influences precipitation. Ice initiation based on temperature or supersaturation alone

Walk:

Creating ice and droplet number based on simple, but realistic aerosols

Run:

Full integration with WRF-Chem and multiple aerosol species

CCN activation

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Physical based droplet activation must be solved analytical and is not a simple computation.

Parameterization based on measurements

$N_{CCN} = cS^k$ (used in many models)

Parameterizations based on parcel model simulations (used in for example WRFchem)

Look up tables from parcel model simulations (used in for example RAMS and in the new Thompson scheme)

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Droplet activation look-up table

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1) aerosol concentration
2) updraft velocity
3) temperature
4) hygroscopicity (kappa)
5) aerosol mean radius
6) Standard deviation of size distribution
7) Condensation coefficient

Look-up table of activated fraction of aerosols created using parcel model by Feingold and Heymsfield (1992) and changes by T. Eidhammer & S. Kreidenweis

N_a (cm^{-3})	w (m/s)	T (^oC)	k	r (μm)
10	0.01	−30	0.2	0.01
31.6	0.0316	−20	0.4	0.02
100	0.1	−10	0.6	0.04
316	0.316	0	0.8	0.08
1000	1	10		0.16
3160	3.16	20		
10000	10	30		
	31.6			
	100			

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Ice nucleation parameterization / Thompson microphysics scheme

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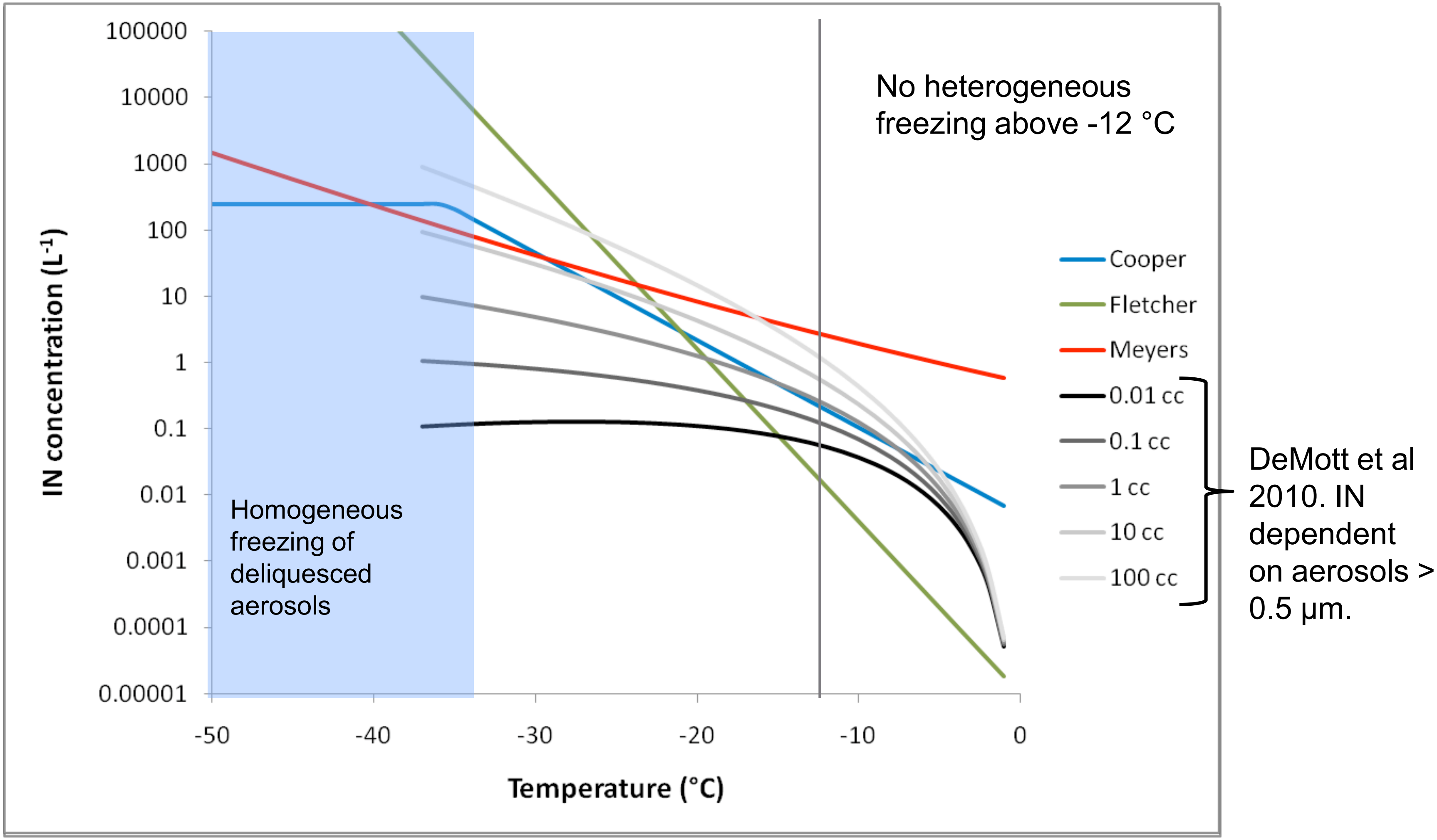

$$N_{IN,T} = a(273.15-T)^{b}(n_{aer,0.5})^{(c(273.16-T)+d)}.$$

a=0.0000594, b=3.33, c=0.0264, d=0.0033

Aerosol input

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- Aerosol number concentration:
  - Dust > 0.5 μm, and sulfate and sea-salt.
- Static file for input and boundary conditions:
  - GOCART monthly average global mean concentration (2000-2007)
  - 1x1.25 degree resolution
- Use a modified *mozbc* software to transport GOCART data to WRF grid. (see P.77 Pfister for information about *mozbc*)

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Dust Module in the Thompson Scheme

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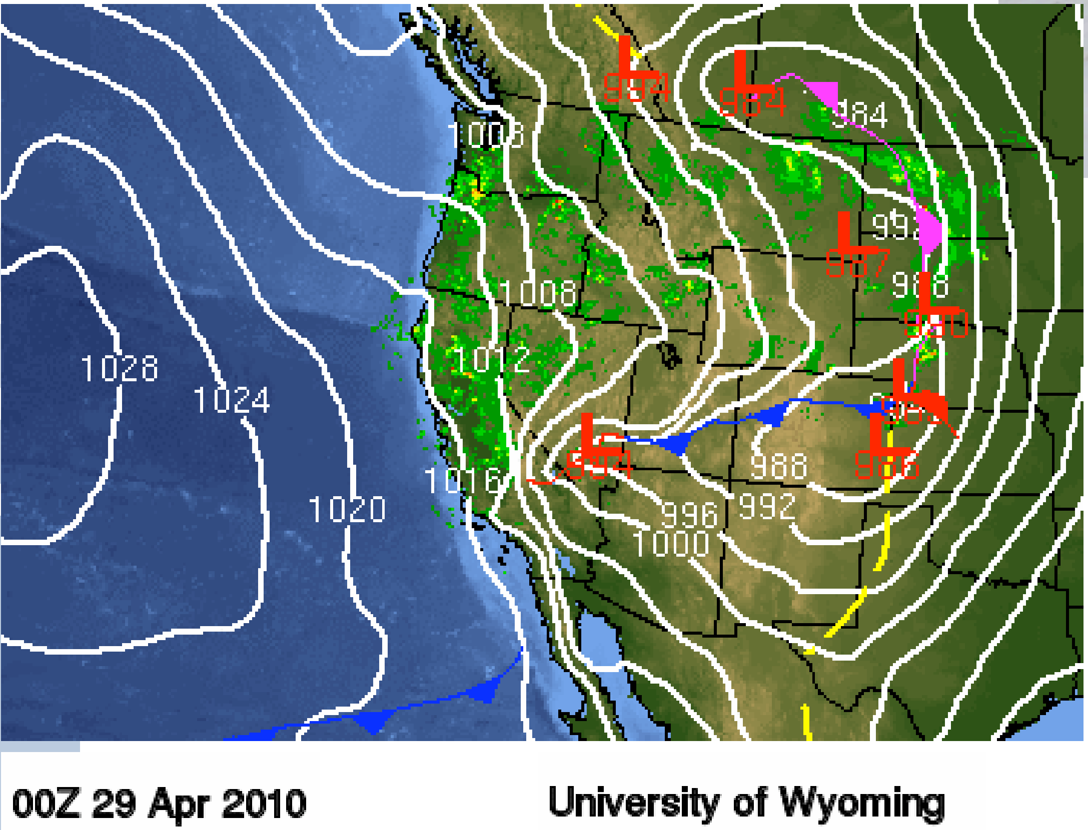
- Assume constant dust distribution shape (D = 0.8 μm and σ = 2 (standard deviation))
- Emission of dust is included. Dependent on land surface, soil moisture and wind speed (need evaluation).
- Wet deposition included (main source of deposition for dust sizes important for ice nucleation).

Test case of dust/IN:

Precipitation in North and Western Colorado with heavy dust scavenging April 28-29, 2010

http://summitvoice.files.wordpress.com/2010/04/dust4.jpg

Summit county, Colorado



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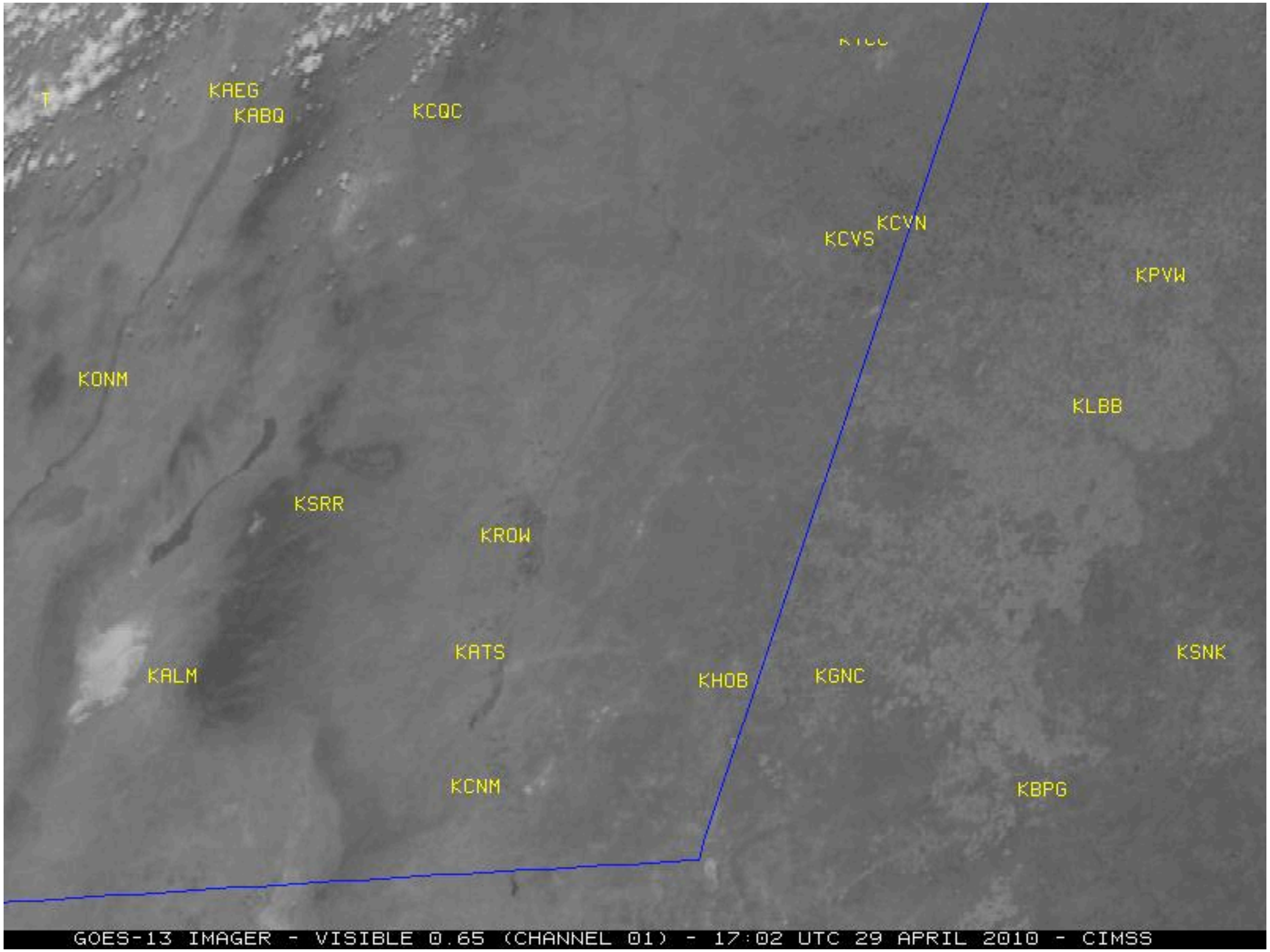

McIDAS images of the GOES-13. Dust plume originate from White Sands, New Mexico

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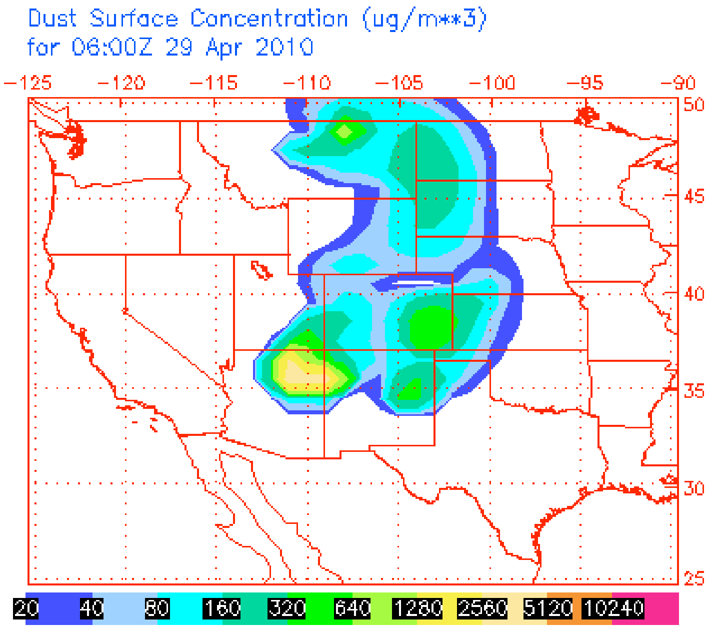
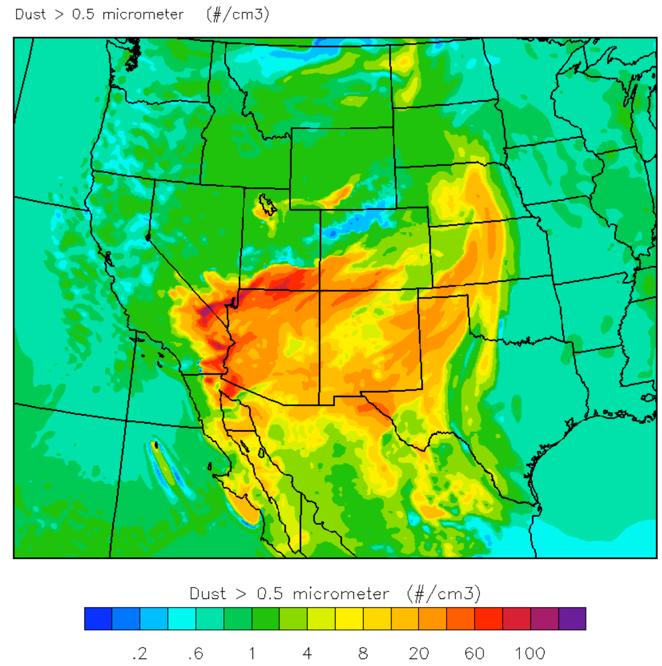
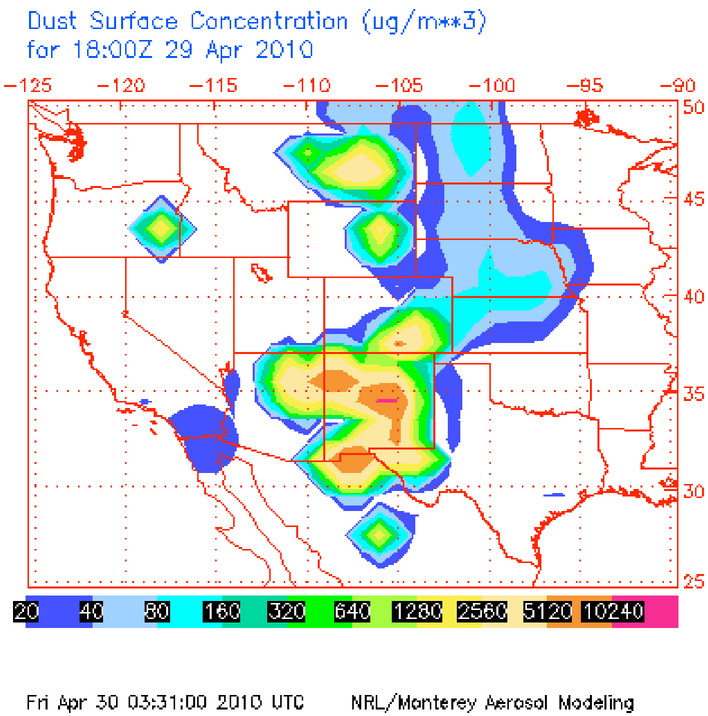
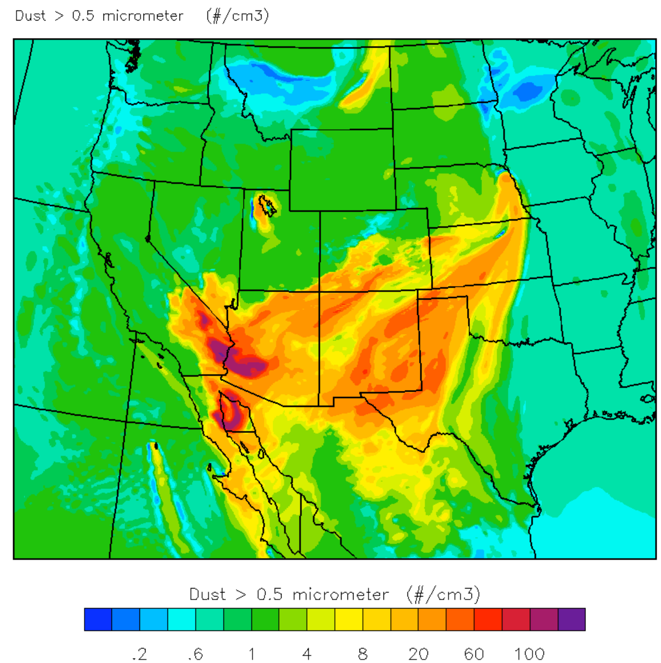
NAAPS (Navy Aerosol Analysis and Prediction System) Global Aerosol Model









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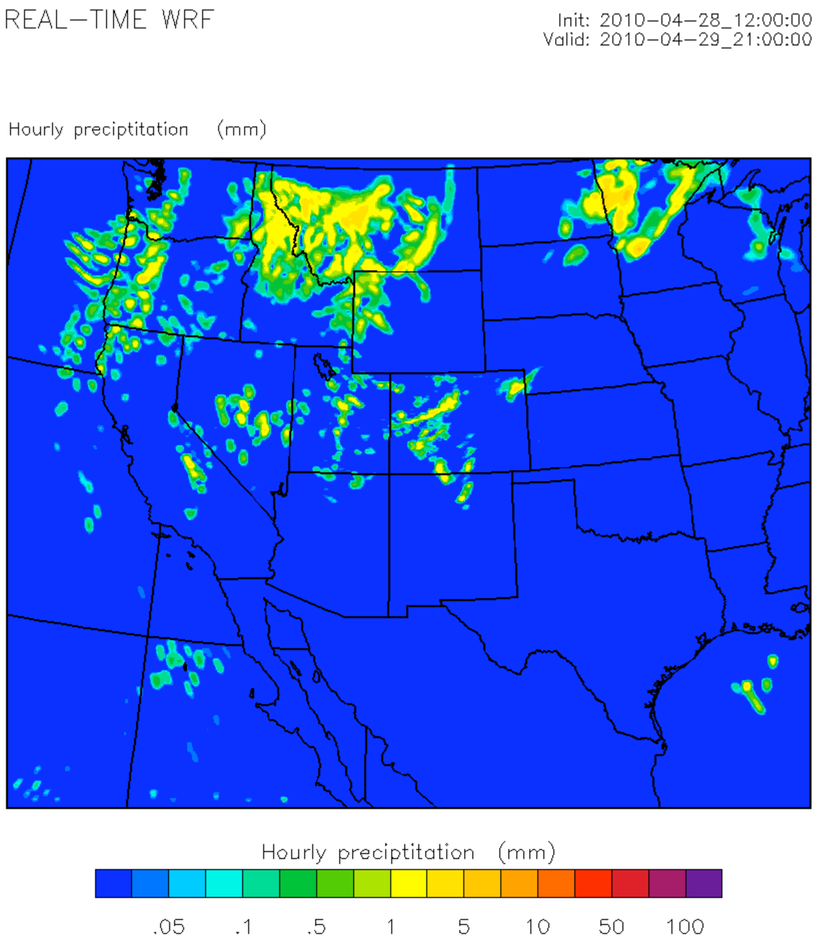
Hourly precipitation



Surface dust concentration

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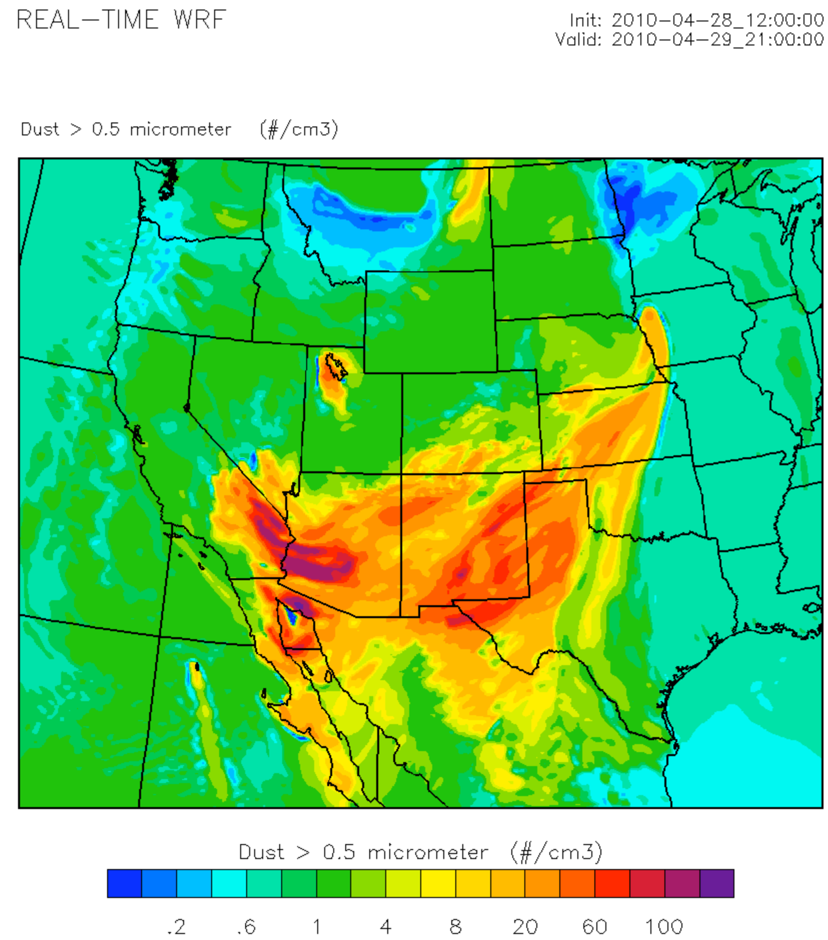


Dust concentration with height.

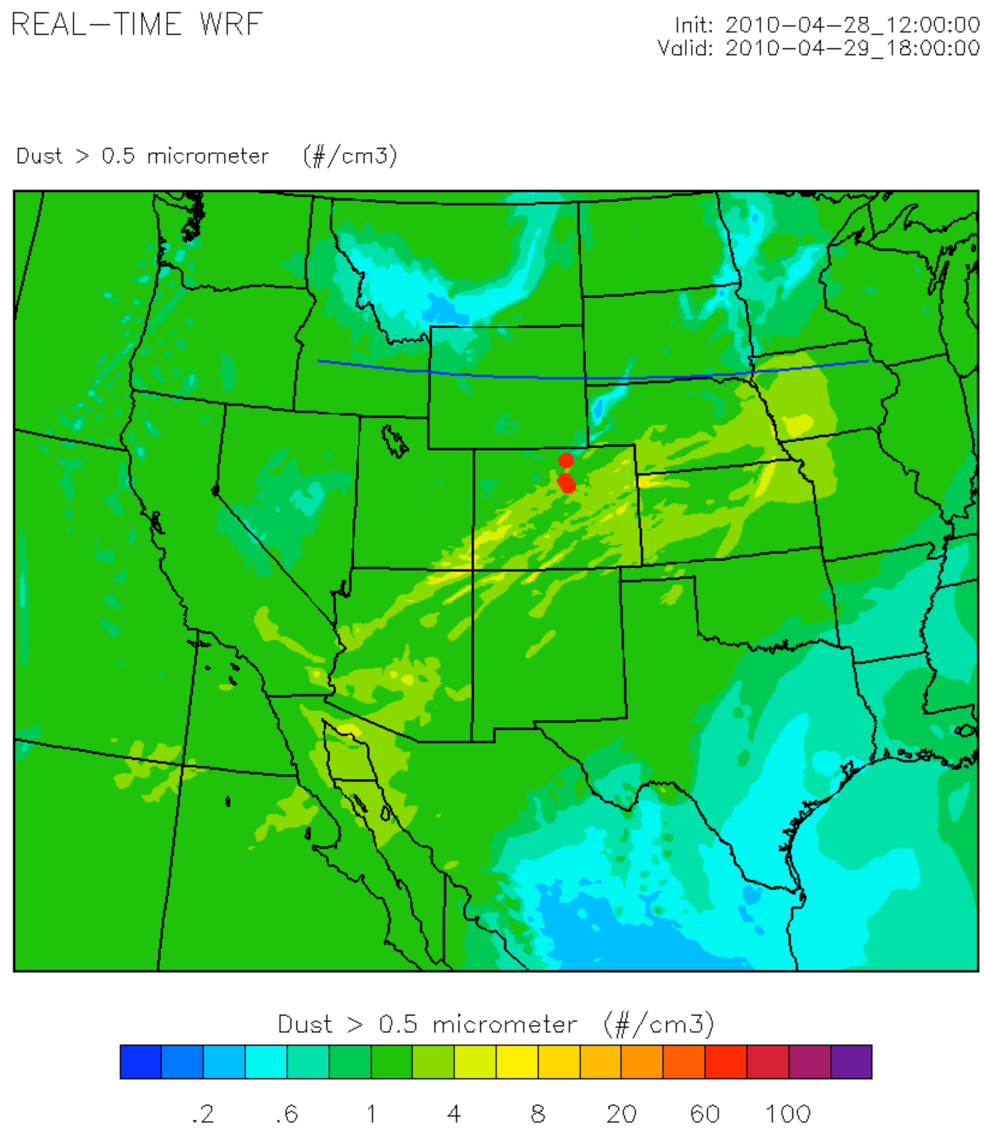
Model level 0

Model level 2

Model level 4

Model level 6

Model level 8



Ice crystal concentration for different schemes and dust concentration

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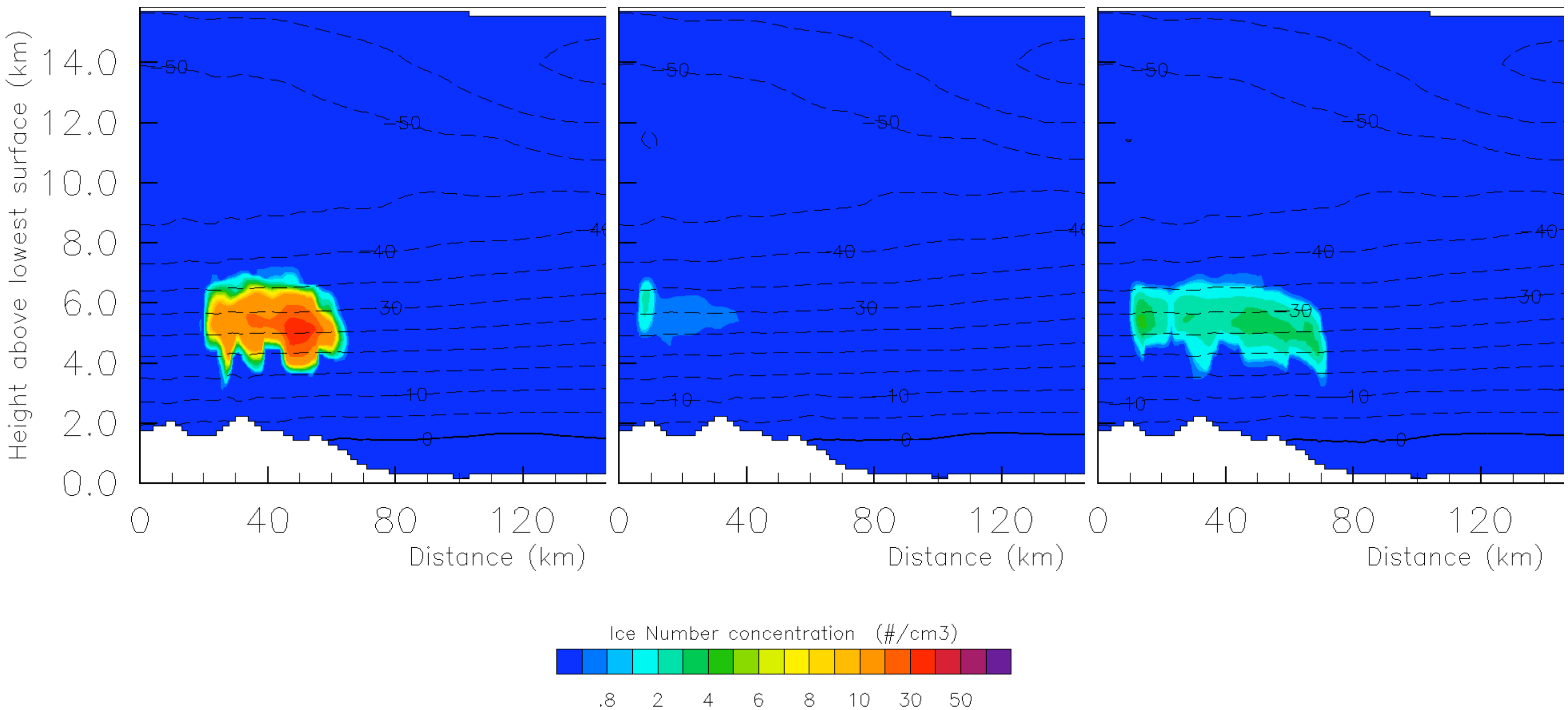
Cooper parameterization

Dust 0.1 cm^{-3}

GOCART (variable dust concentration)



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Snow, graupel and rain mixing ratio

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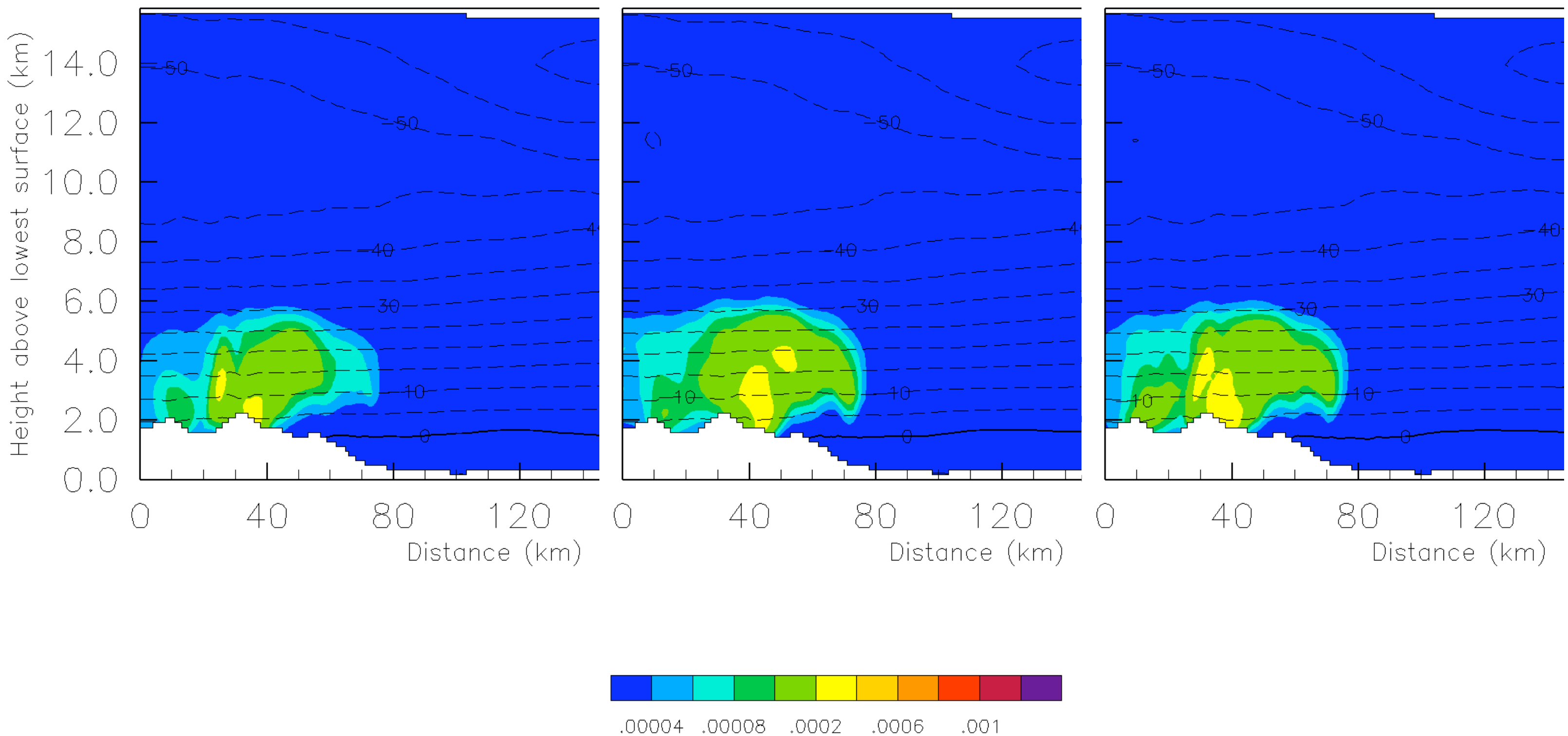
Cooper parameterization

Dust 0.1 cm^{-3}

GOCART (variable dust concentration)



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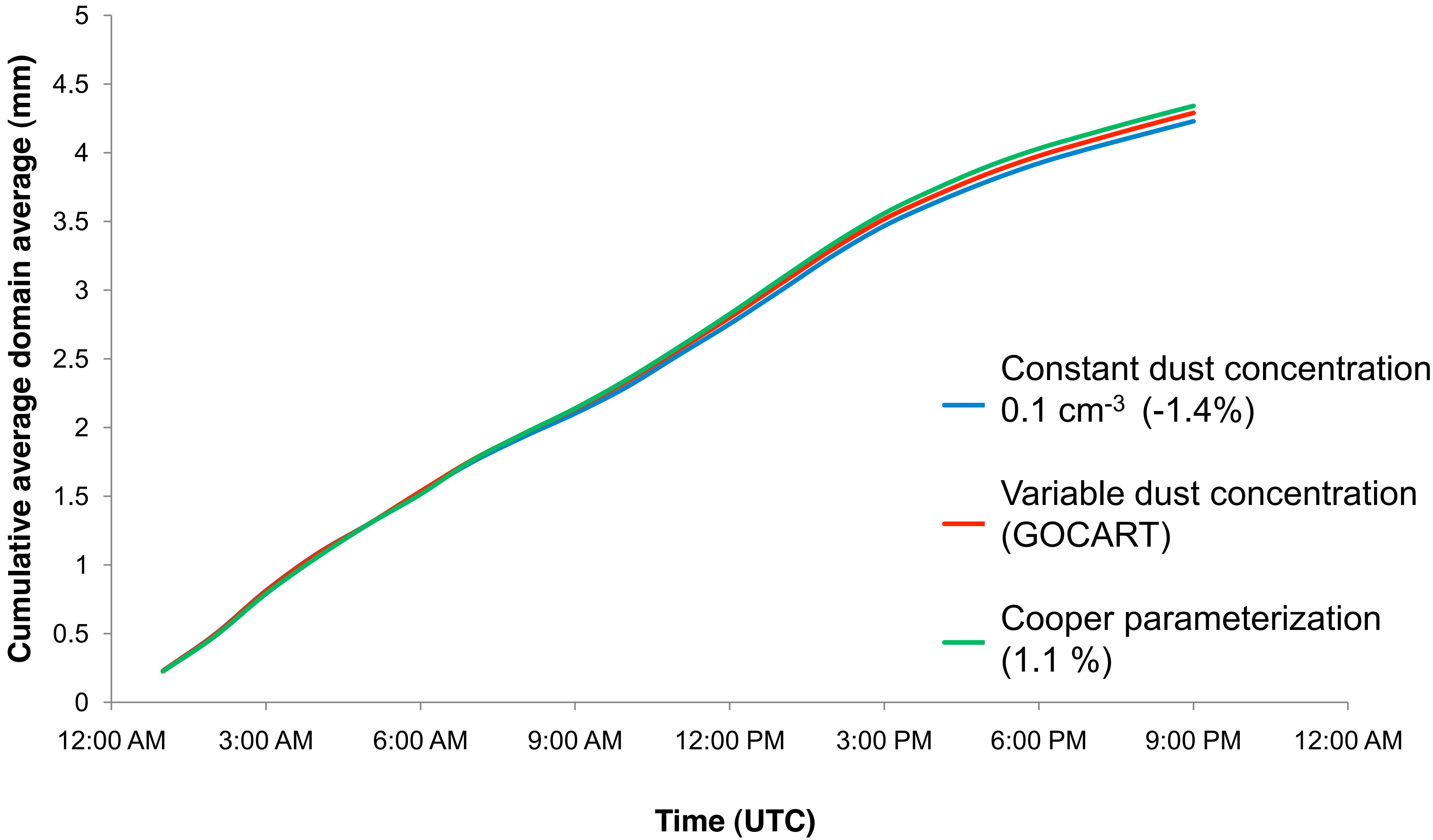
Average 3rd domain precipitation



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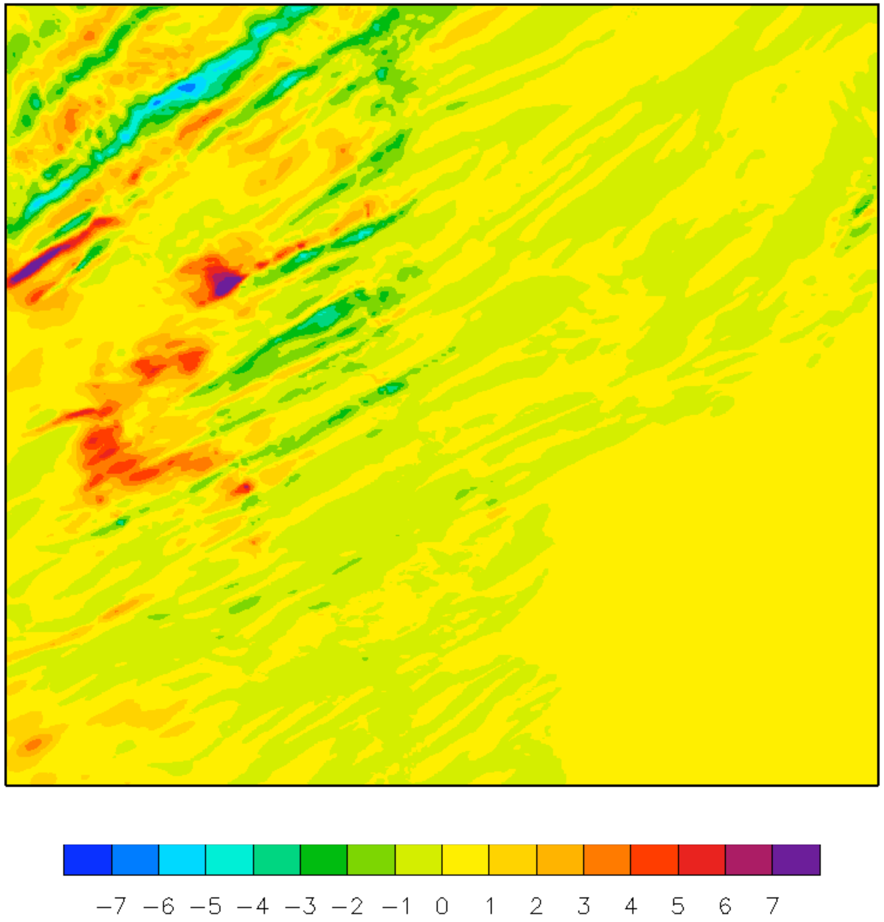
Difference between accumulated domain precipitation,

“high – low” ice crystal concentration
(“Cooper “– “0.1 cm^{-3} dust concentration”)



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Summary

We are working on a new version of the Thompson microphysics scheme that will be dependent on aerosols for droplet activation and ice initiation.

Aerosols initializations from global modeled climatology

Use Look-up Tables with 5 variables for droplet activation (N_{aer}, aerosol radius, chemical composition, temperature and updraft velocity).

Included new Ice nucleation parameterization by DeMott et al (2010).

Initial results for a simulated case with heavy dust loading do not indicate large difference in total domain precipitation, but the location of the precipitation have changed.

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