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How the Assumed Size Distribution of Dust Minerals Affects the Predicted Ice Forming Nuclei

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Motivation for the study

- New dust module in Earth System Model E2 with prognostic mineral species (Perlwitz et al., ACP 2015a,b).
- Challenges to be addressed to achieve that.
- One big challenge came with following question:
How do measured soil mineral fractions translate to the mineral fractions of the dust aerosols?
- Why is this a challenge? **To a large degree because of wet sieving!**
- Combining brittle fragmentation theory (Kok, PNAS 2011) with empirical mineral size distribution (Kandler et al., Tellus B 2009) to derive the mineral fractions of the emitted dust aerosol.

Soil Texture and Mineral Fractions Determined Using Techniques Leading to Nearly Full Destruction of Aggregates

Figure 5-5. Laboratory sieves for mechanical analysis of grain size distribution. Shown (right to left) are sieve Nos. 3/8-in. (9.5-mm), No. 10 (2.0-mm), No. 40 (250- μ m) and No. 200 (750- μ m) and example soil particle sizes including (right to left): medium gravel, fine gravel, medium-coarse sand, silt, and dry clay (kaolin).

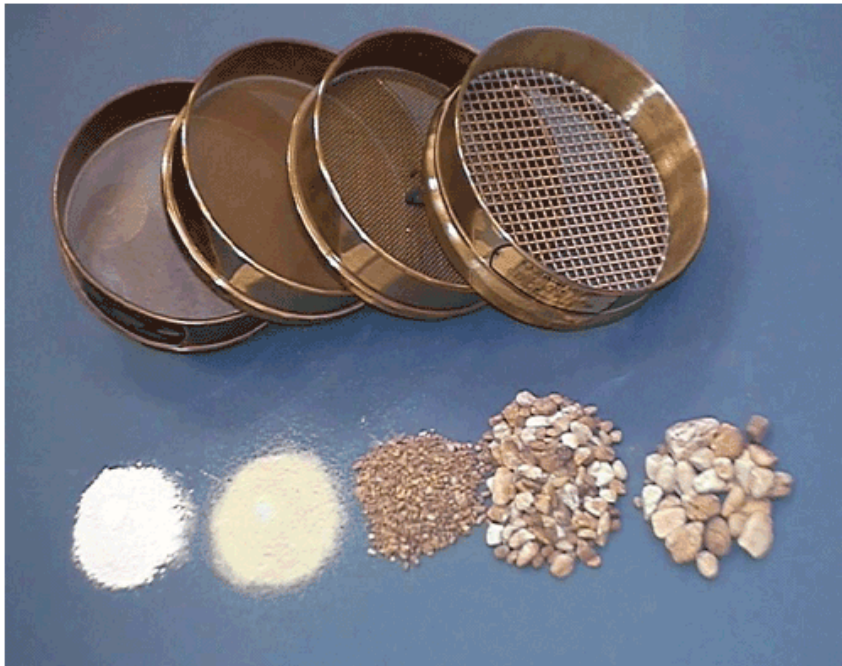


Figure 5-6. Soil hydrometer apparatus (<http://www.ce.siu.edu/>).



Source: <http://www.fhwa.dot.gov/engineering/geotech/pubs/05037/05a.cfm>



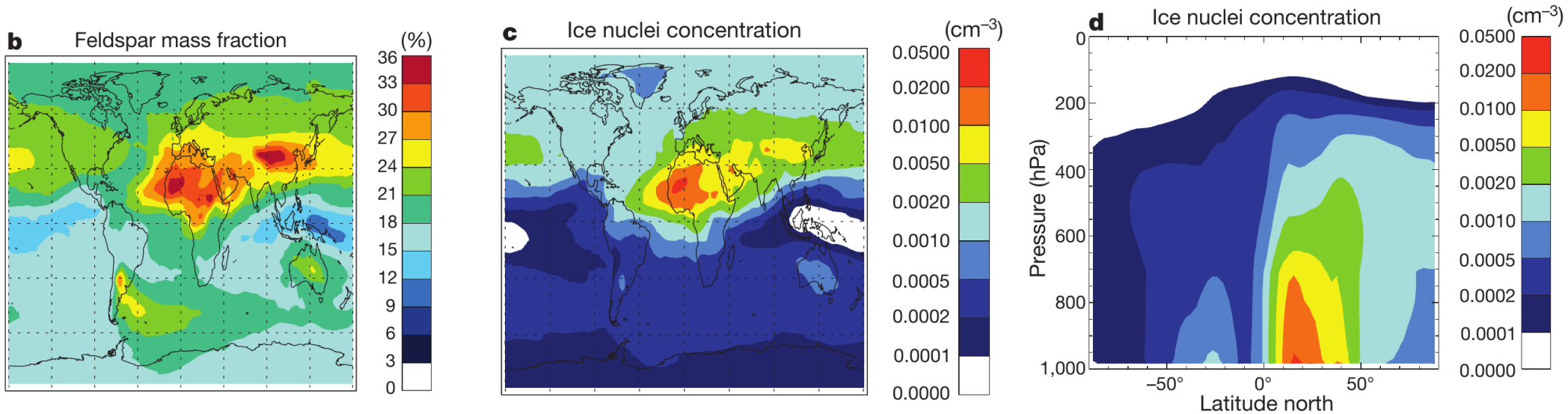
Wet Sieved Soil Texture Fractions \neq Size Distribution of Eroded Soils

Wet Sieved Soil Texture Fractions \neq Suspended Dust Size Distribution

Wet Sieved Clay/Silt Mineral Fractions \neq Mineral Fractions of Suspended Dust

More motivation

- Very few attempts to calculate ice forming nuclei (IFN) abundance from mineral species simulated with a global model.
- Kaolinite and illite/montmorillonite: Hoose et al., ERL (2008).
- **Feldspar: Atkinson et al., Nature (2013)**
- Approach: Using directly the mineral fractions in soils for the mineral fractions of dust aerosols

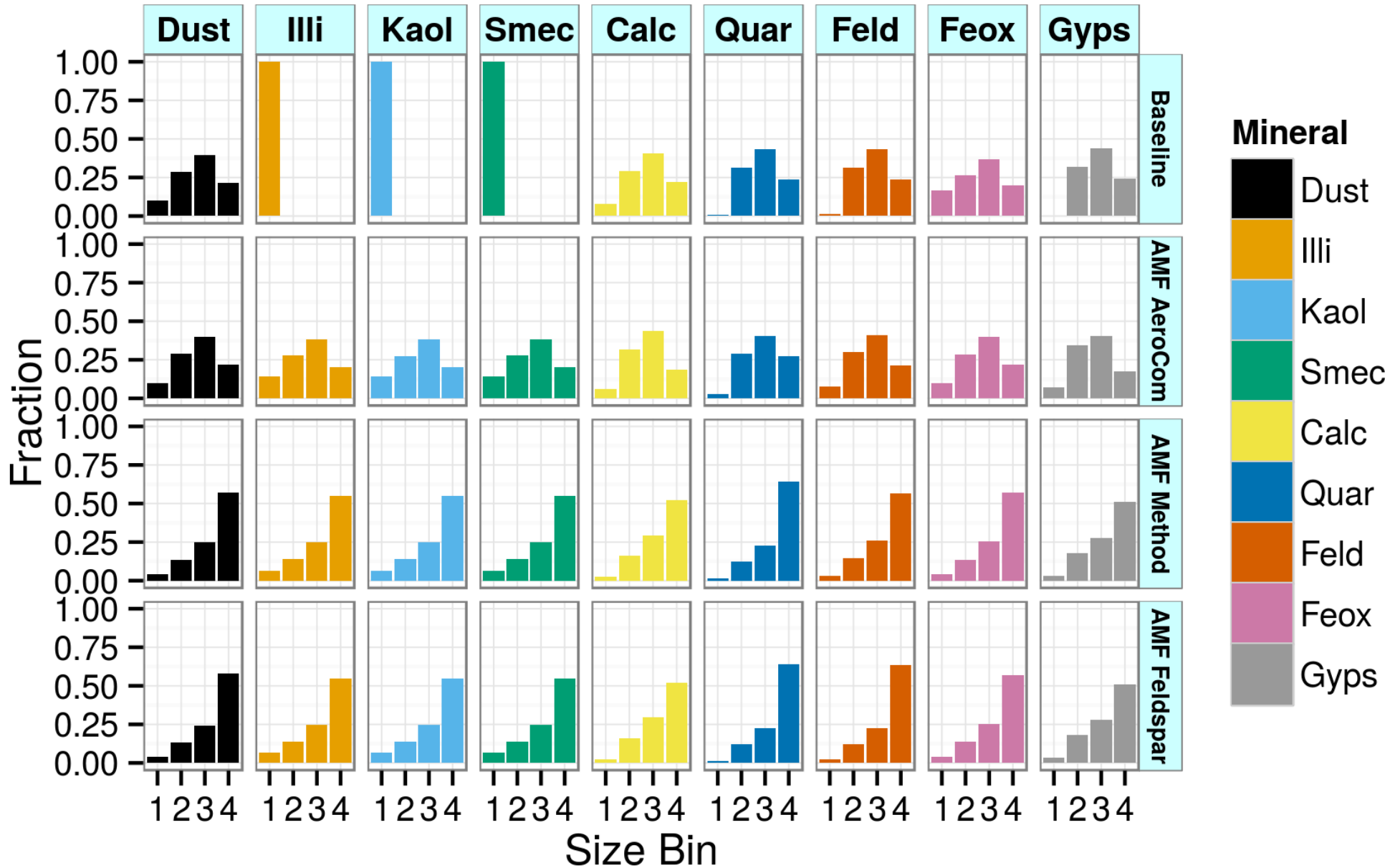


What about IFN numbers by feldspar if we use our improved dust mineral model instead?

Four experiments:

1. Baseline experiment: Same set up as by Atkinson et al. (active sites parameterization with nucleation densities at fixed temperatures), mineral fractions in soil projected onto AeroCom dust emission.
2. Aerosol mineral fraction (AMF) method: used for minerals in dust module as described in Perlwitz et al. (2015a,b).
3. AMF AeroCom: Mineral fractions from AMF method, projected onto AeroCom dust emissions.
4. AMF Feldspar: Sensitivity to a feldspar distribution that is steeper toward larger particle sizes.

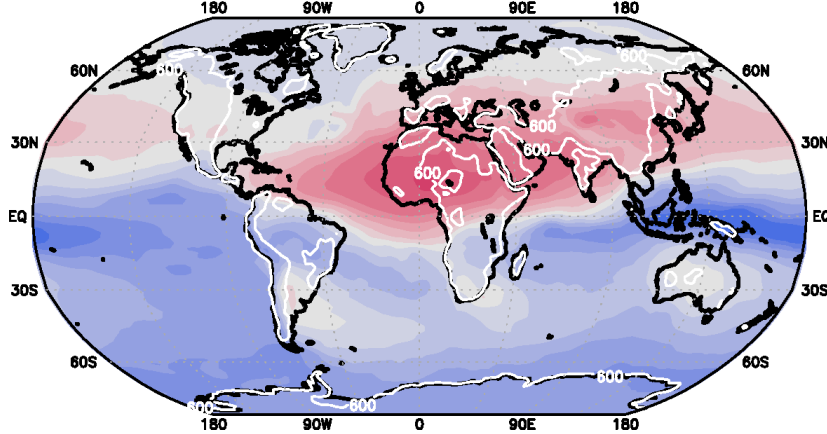
Normalized Emitted Mass Size Distributions



Can we reproduce the previous study?

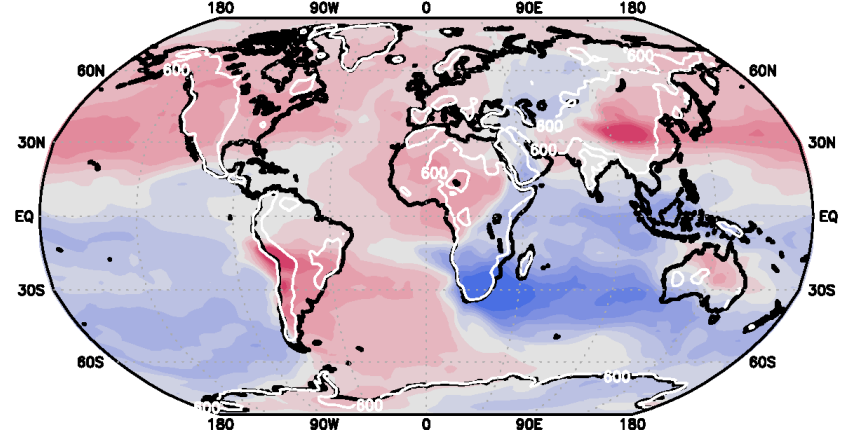
Active Sites Parameterization Sigma Level 11 (About 600 hPa)

a) Dust Number Concentration <math>< 16 \mu\text{m}</math>



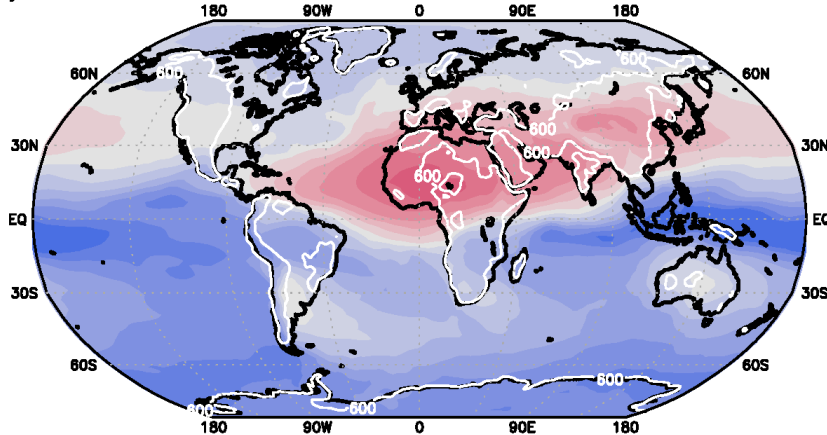
Mean= $2.97 \pm 0.06(2\sigma)$
Min=0.00
Max=112.52
0.005 0.01 0.02 0.05 0.1 0.2 0.5 1 2 5 10 20 50 100 cm^{-3}

b) Feldspar Mass Fraction <math>< 16 \mu\text{m}</math>



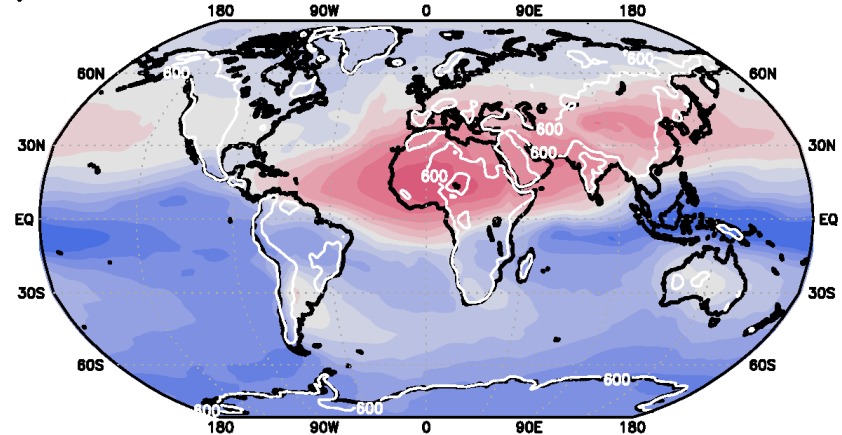
Mean= $21.22 \pm 0.0060(2\sigma)$
Min=11.04
Max=31.80
13 14 15 16 17 18 19 20 21 22 23 24 25 26 %

c) IFN Concentration—External Mixture 253 K



Mean= $0.04 \pm 0.0008(2\sigma)$
Min=0.00
Max=1.49
0.0001 0.0002 0.0005 0.001 0.002 0.005 0.01 0.02 0.05 0.1 0.2 0.5 1 10^{-2}cm^{-3}

d) IFN Concentration—Internal Mixture 253 K

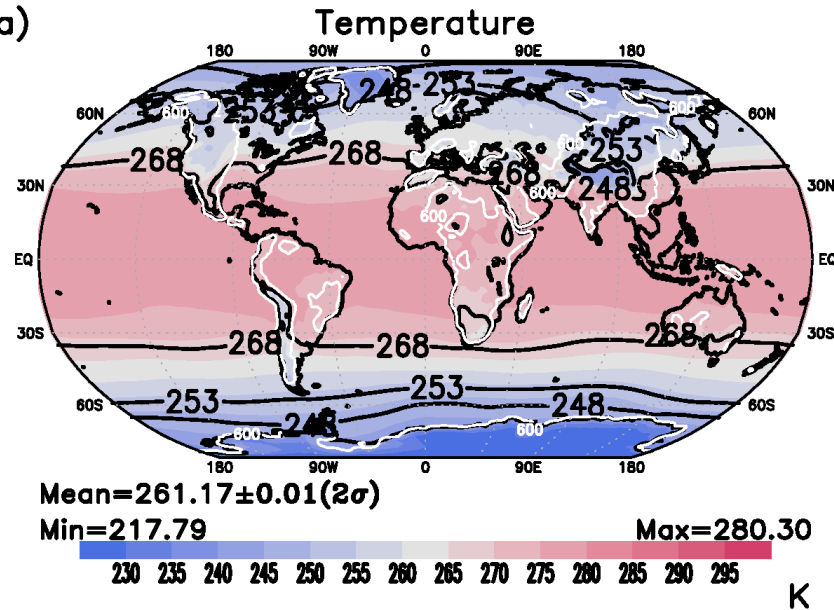


Mean= $0.04 \pm 0.0010(2\sigma)$
Min=0.00
Max=1.79
0.0001 0.0002 0.0005 0.001 0.002 0.005 0.01 0.02 0.05 0.1 0.2 0.5 1 10^{-2}cm^{-3}

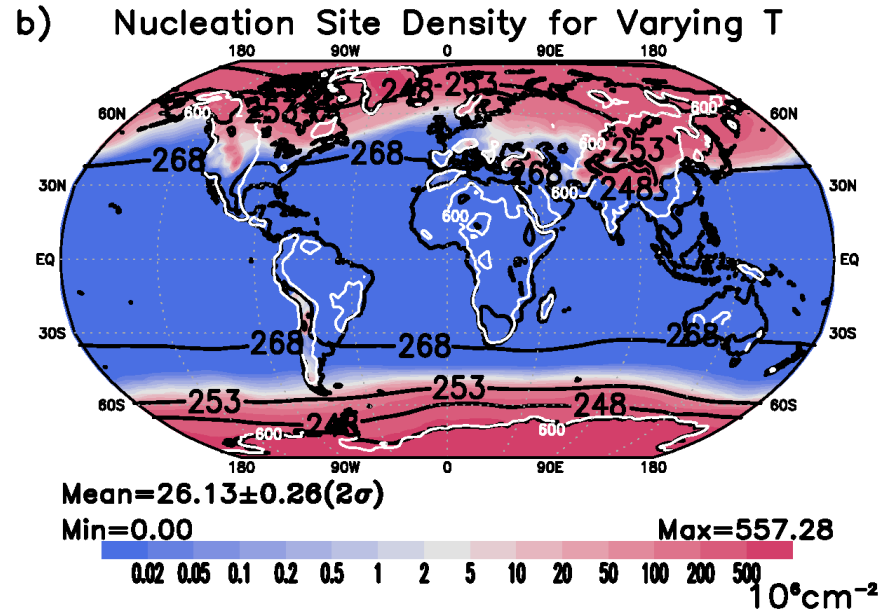
Fixed 253 K vs. more realistic temperature

Active Sites Parameterization Fixed 253 K vs. Varying T (Level 11)

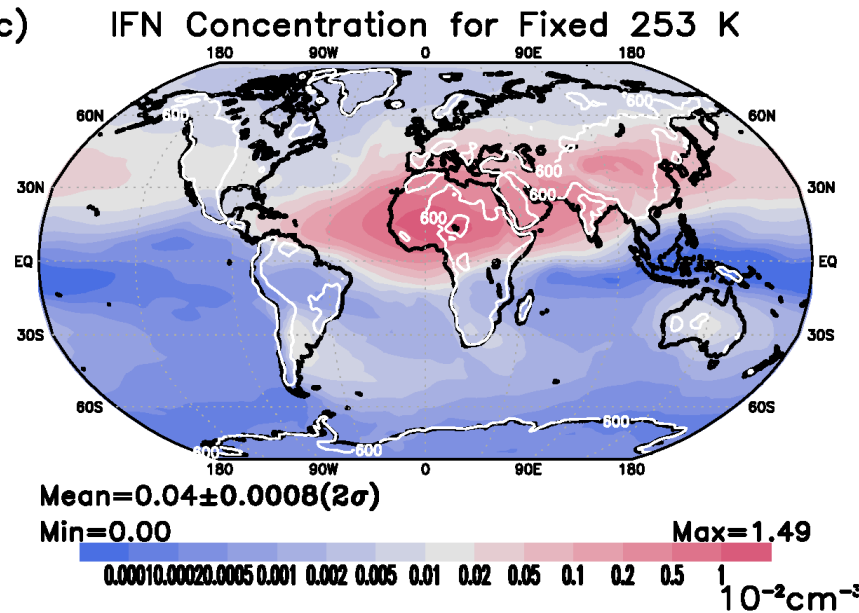
a)



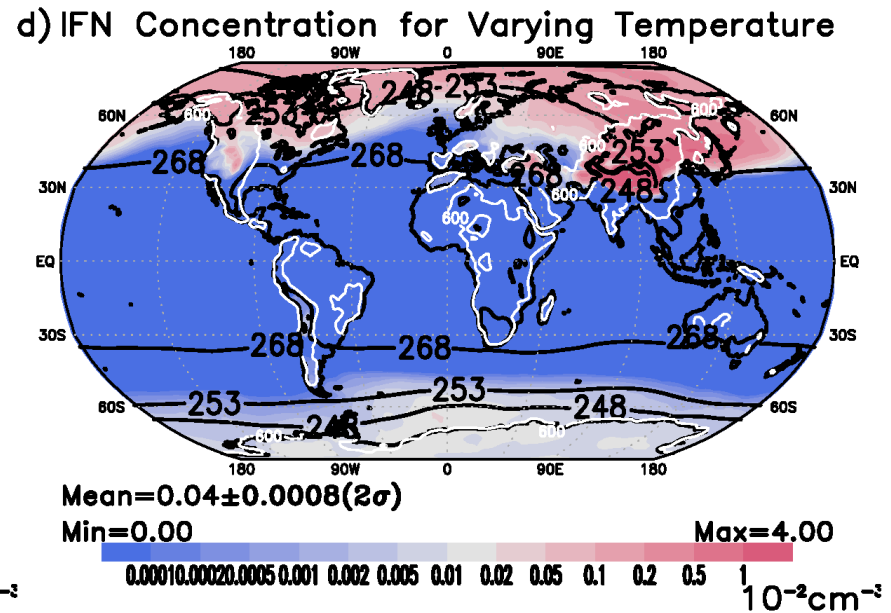
b)



c)

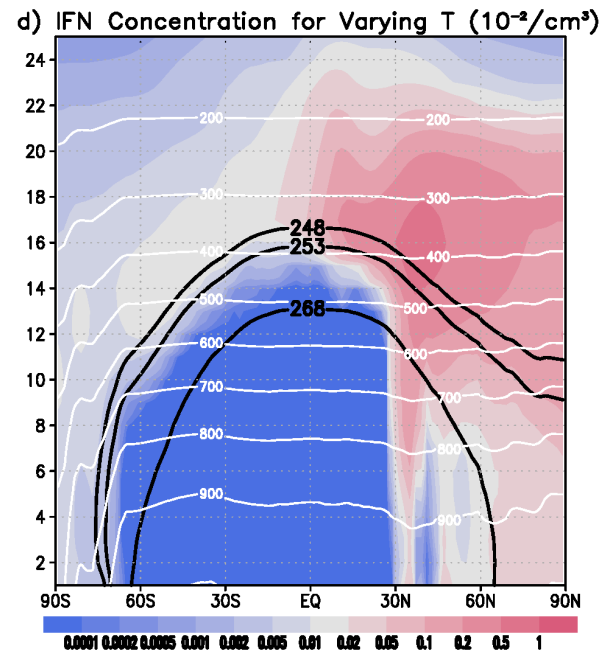
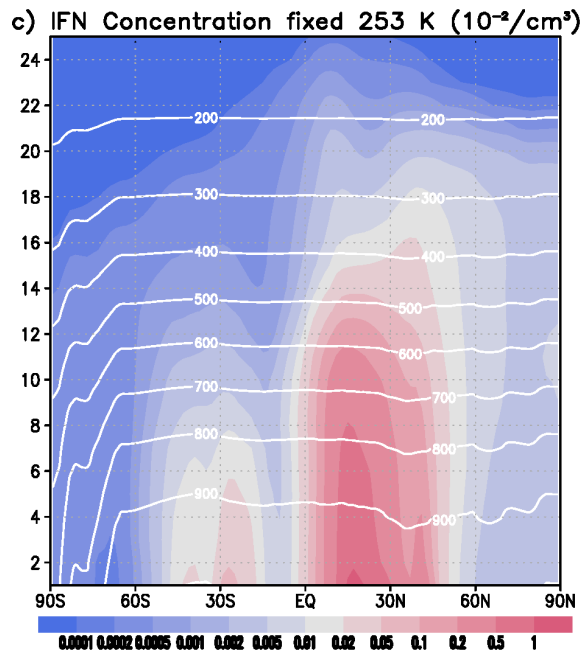
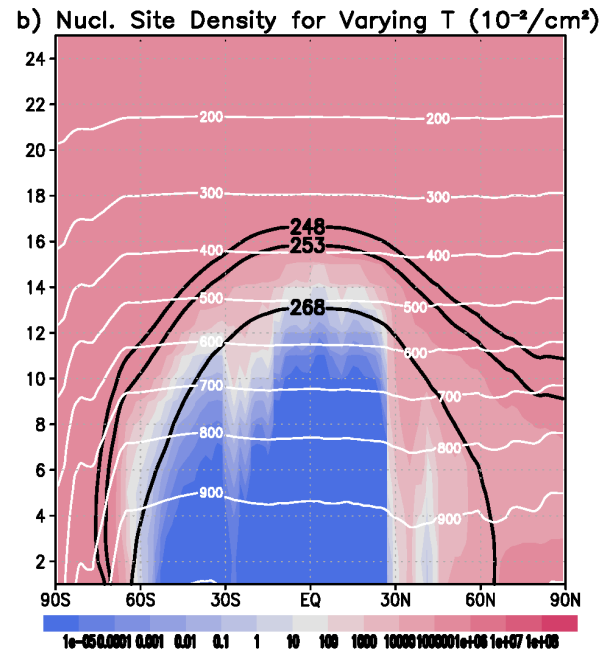
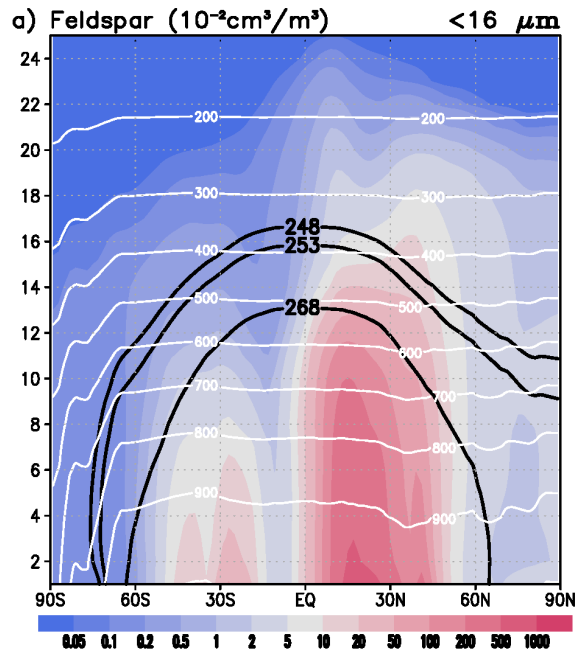


d)



Fixed 253 K vs. more realistic temperature

Active Sites Parameterization Fixed 253 K vs. Varying Temperature

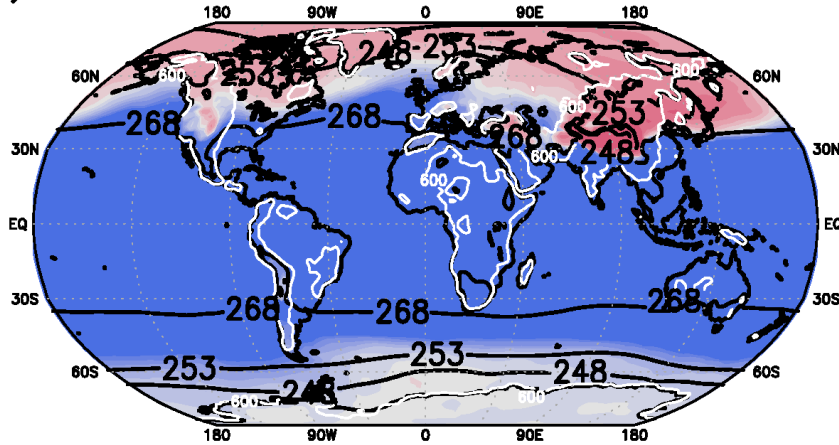


Sensitivity to size distribution

Sensitivity Exp. External Mixture IFN. Var. T. Diff/Std.Dev. (Level 11)

a)

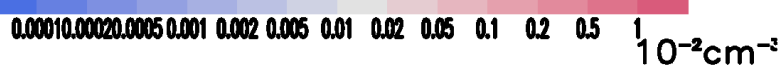
Baseline



Mean=0.04±0.0008(2σ)

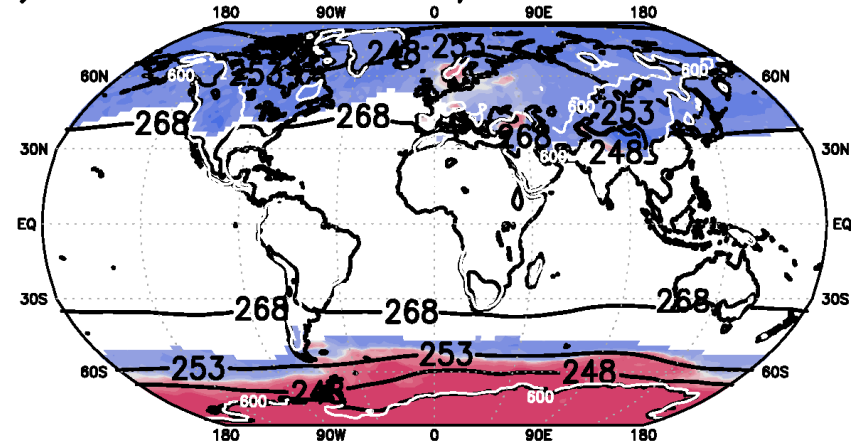
Min=0.00

Max=4.00



b)

AMF Method / Baseline



Diff of Means/σ = -57.74

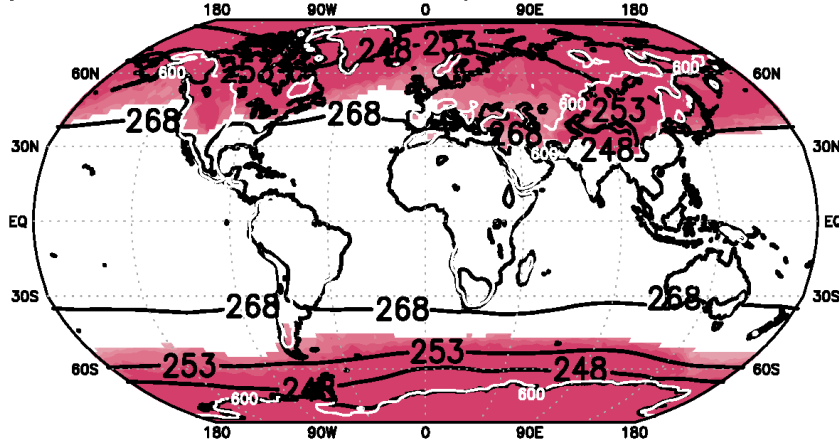
Min=-338.58

Max=772.92



c)

AMF AeroCom / Baseline



Diff of Means/σ = 270.44

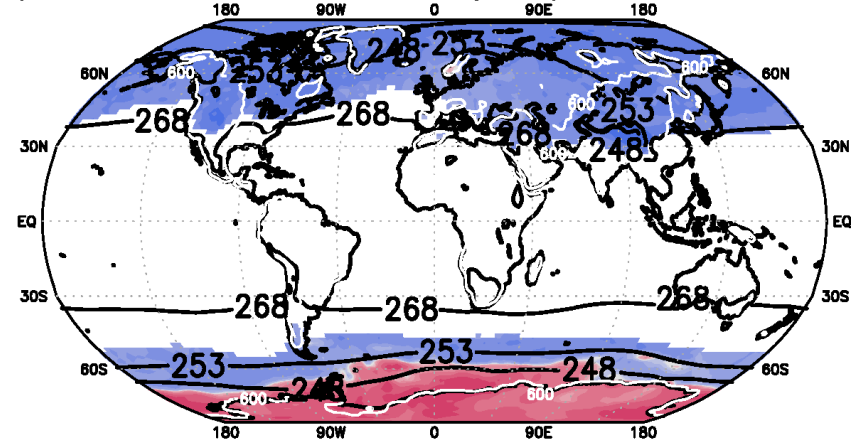
Min=2.53

Max=1249.43



d)

AMF Modified Feldspar / Baseline



Diff of Means/σ = -81.00

Min=-424.90

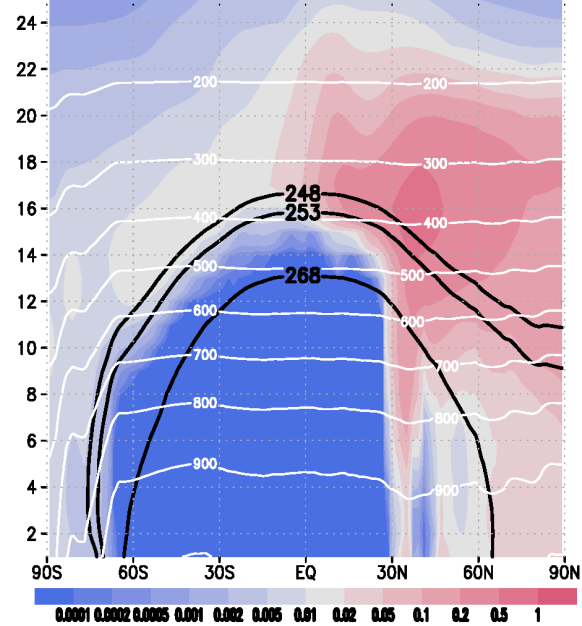
Max=311.67



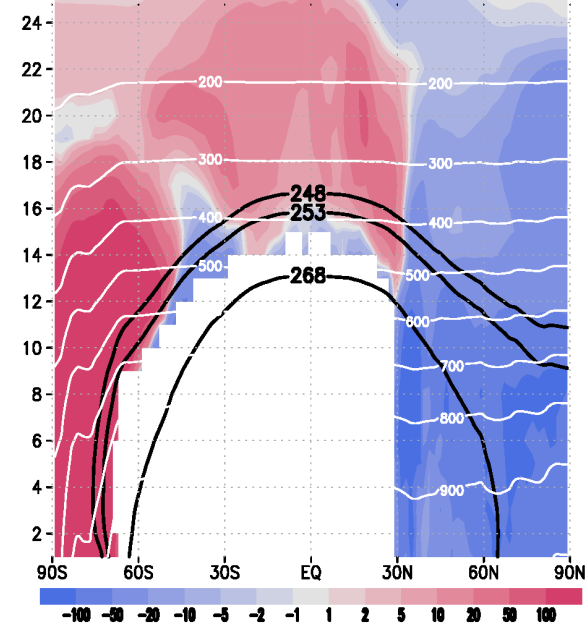
Sensitivity to size distribution

Sensitivity Exp. External Mixture IFN. Var. T. Diff/Std.Dev.

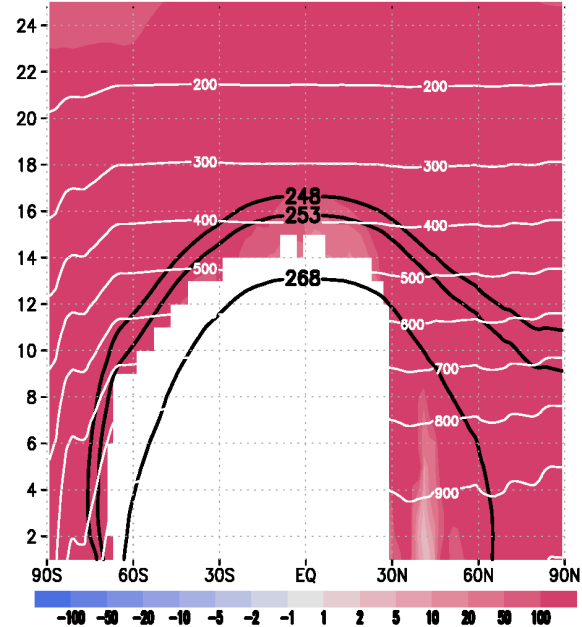
a) IFN Conc. for Var. T ($10^{-3}/\text{cm}^3$) Baseline



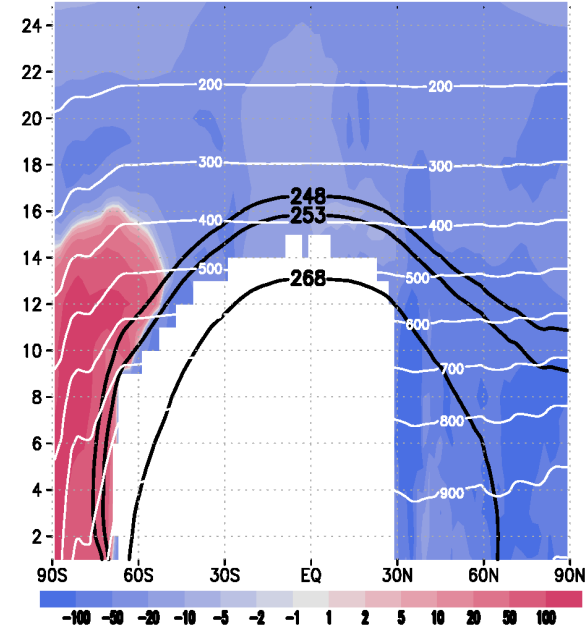
b) AMF Method / Baseline



c) AMF AeroCom / Baseline



d) AMF Modified Feldspar / Baseline



Conclusions

- We can principally reproduce the IFN of the Atkinson et al. study.
- A physically more realistic temperature assumption, compared to a highly idealized one, leads to drastically different results, though. **This is important for drawing correct conclusions about IFN in the atmosphere!**
- Results are sensitive to the size distribution of feldspar.
- Feldspar distributed toward larger sizes decreases IFN. **This is an additional source of uncertainty!**
- Sensitivity to the assumption about feldspar in clay sizes.
- Preliminary results, more thorough studying needed.
- The testing of other parameterizations is also planned.