How the Emitted Size Distribution and Mixing State of Feldspar Affect Ice Nucleating Particles in a Global Model

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1. Motivation

- Most global modeling studies of dust acting as INPs assume uniform dust composition, whereas relatively few have taken dust mineralogy into consideration (Hoose et al., 2008; Atkinson et al., 2013; Vergara-Temprado et al., 2017). INPs have been calculated in latter studies, based on the assumption that the mineral fractions measured in wet-sieved soil samples directly determine the mineral fractions of the emitted dust aerosols.
- In contrast, some recent modeling efforts of mineral speciation of dust (Perlwitz et al., 2015a,b; Scanza et al., 2015), based on brittle fragmentation theory (re-aggregation of soils and partial fragmentation at emission, Kok, 2011), robustly improve the simulation of the size distribution of the observed mineral fractions.
- The goal of the current study is to evaluate the uncertainty in calculated INP due to different assumptions on the emitted size distribution of dust minerals, especially K-feldspar, and on the mixing state of feldspar with other minerals.

2. Experiments

- SMF AeroCom Size: AeroCom size distribution; NASA GISS ModelE sources; soil mineral fraction directly determine dust aerosol mineral fractions.
- SMF AeroCom Emis: AeroCom size distribution; AeroCom sources; soil mineral fraction directly determine dust aerosol mineral fractions.
- AMF Baseline: size distribution derived from brittle fragmentation theory, combined with empirical data for large particle sizes; NASA GISS ModelE sources; dust aerosol mineral fractions based on soil re-aggregation.

2. Experiments cont.

- AMF Mod. Feldspar: Same as AMF Baseline, but with feldspar size distribution like quartz size distribution to account for measurement uncertainty.

For all experiments, INP are calculated using two formulations of an active size parameterization, one for external mixing and the other one for internal mixing of K-feldspar with other minerals (Atkinson et al., 2013).

3. Results

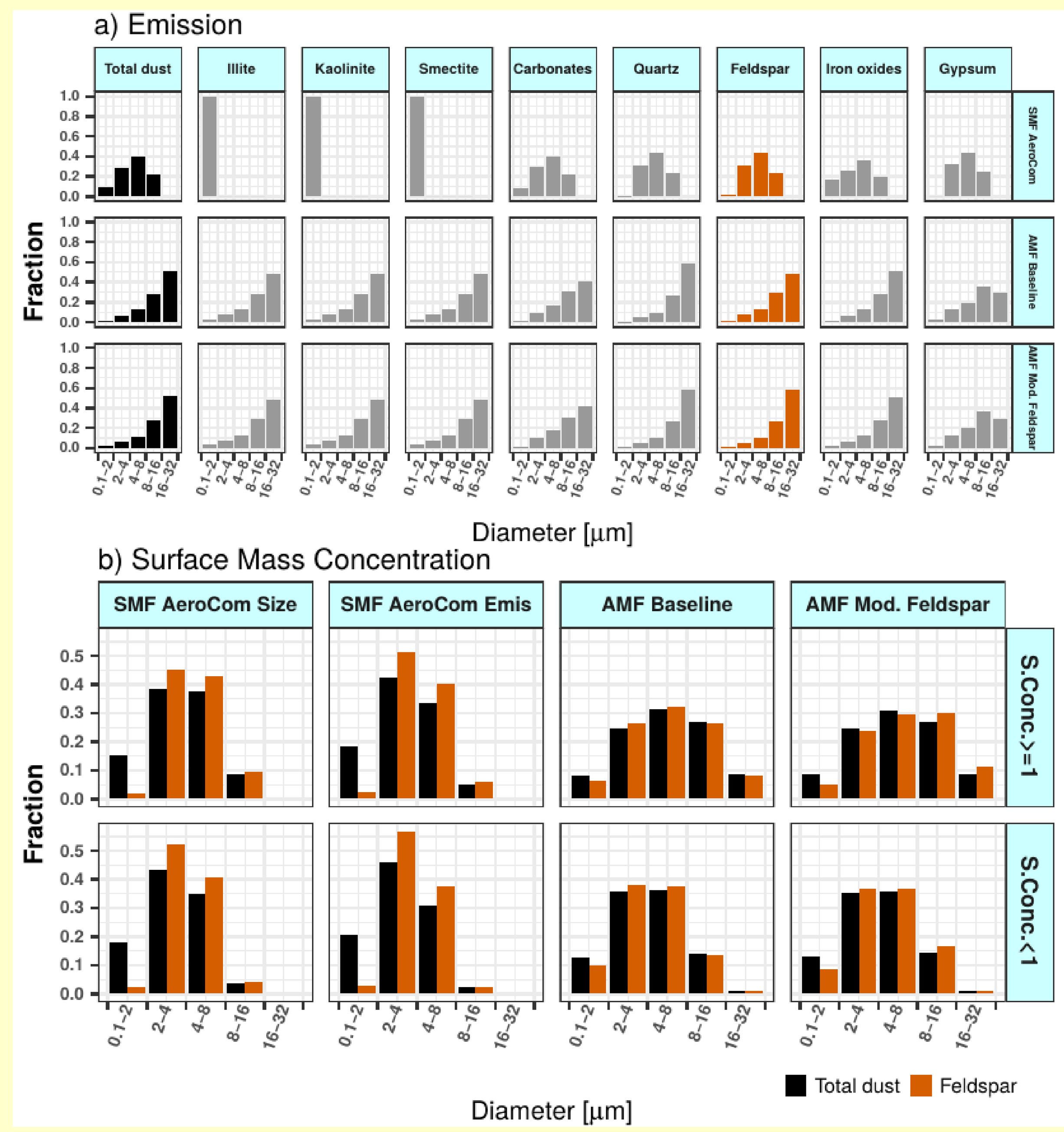

Figure 1. a) Globally averaged normalized mass fractions of total dust and each mineral at emission and b) surface mass concentrations as a function of particle diameter.

- Emitted mineral mass fractions differ significantly between AMF and SMF (Fig. 1a). No phyllosilicate mass is present for particles > 2 µm in SMF cases. Most of the phyllosilicate mass is in size range > 2 µm in AMF cases. In latter, largest fraction of most minerals is emitted in size range 16-32 µm.

- Even though the total dust mass is smaller in the AMF experiments due to a larger depletion from gravitational deposition, a larger relative feldspar fraction is found for large particles sizes in remote regions in the AMF experiments, compared to the SMF experiments (Fig. 1b). This effect is enhanced in the AMF Mod. Feldspar experiment.

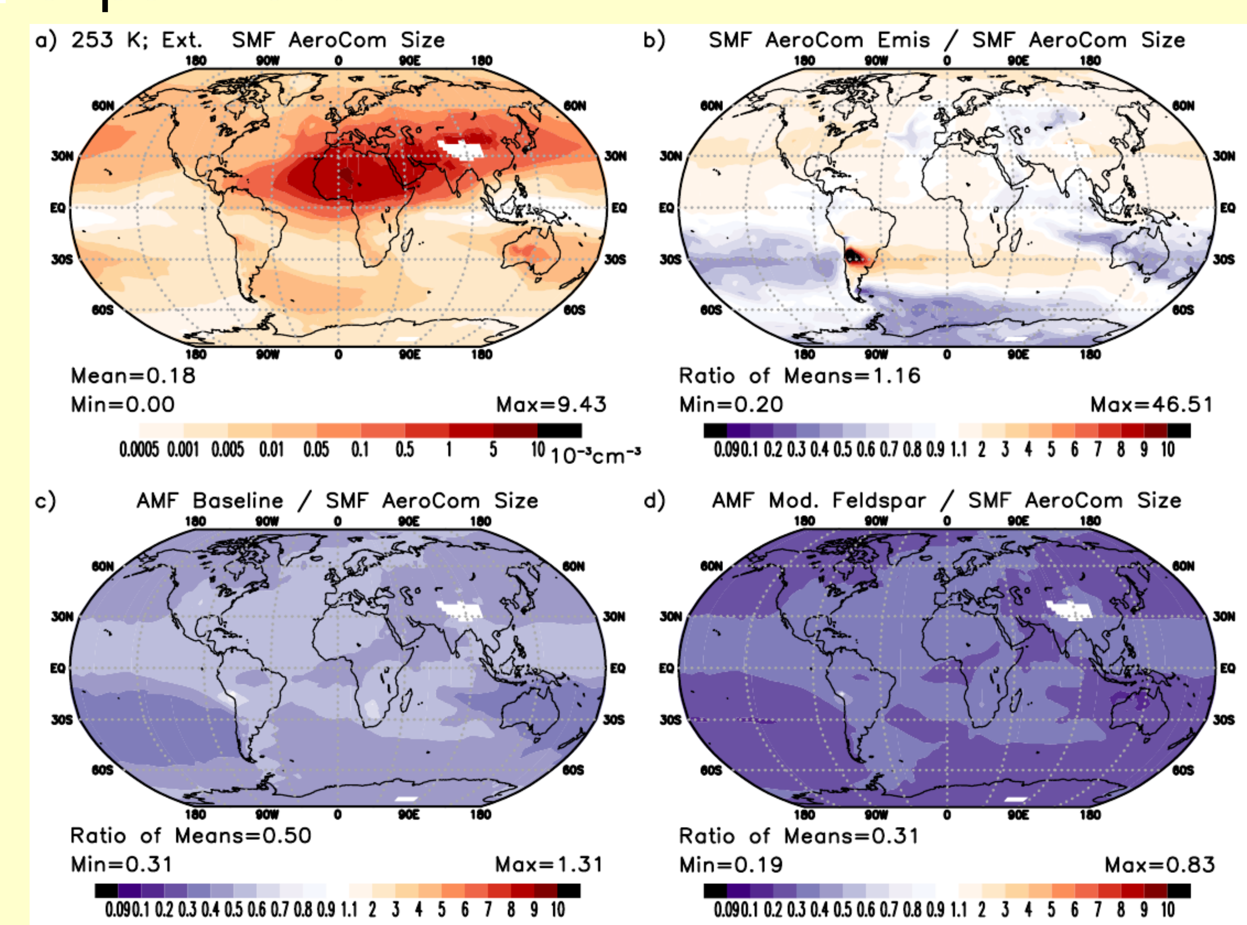

Figure 2. INP concentration in SMF AeroCom Size and ratios between INP concentrations in the other experiments to SMF AeroCom Size.

- Different source distributions between AeroCom and ModelE (comparing the SMF experiments, Fig. 2, upper left and upper right) can lead to larger regional differences, for instance exceeding 50% over some Southern Ocean regions. This indicates some sensitivity of the regional INP number to assumptions on the dust sources between different models.
- Accounting for the various aspects that modify the size distribution of emitted dust, compared to the simpler approach, reduces the globally averaged INP concentration by a factor of two to three, comparable to the previously stated uncertainty (Vergara-Temprado et al., 2017).

3. Results cont.

- However, the effect of the size distribution assumptions for emitted dust varies geographically along with the source regions of dust, depending on the mineral composition of the parent soil. It can amount to an uncertainty of up to a factor of five in individual regions (Fig. 2, lower panels).

Figure 3. INP concentration as a function of particle diameter for different activation temperatures and internal vs. external mixing.

- The largest INP contribution comes from the diameter range of 2 to 4 µm (Fig. 3). Even though the total INP number is reduced in the AMF cases, a relatively larger INP number fraction relative to the total INP number is found for sizes greater than 4 µm.
- Results vary only a little with the activation temperature and mixing state of feldspar, except at the coldest temperature, where behavior may be specific to the INP parameterization used.

4. Conclusions

- We hypothesize that the main results will hold for other parameterizations as well.
- The results suggest that INP measurements are needed up to at least 10 µm diameter.