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Interactive comment on “Saharan dust and ice nuclei over Central Europe” by H. Klein et al.

H. Klein et al.

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Response to Reviewer S. Brooks: This paper presents measurements of ice nucleation collected at a ground-based central European mountain site. Measurements were continuously collected before, during, and after a regional dust event. Transport of the dust is modeled using the Eulerian aerosol DREAM model. Comparisons are made between concentrations of ice nuclei (IN) and measured aerosol properties. This work is appropriate for publication in ACP, particularly because few measurements of ice nucleation are available in this local. Also, the duration of measurements is commendable, though the range of operating conditions (temperature and relative humidity) is limited here. However, some of the interpretation of the measurements needs modification prior to modification, since the stated conclusions do not follow directly from the measurements. These are specified below:

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Comment: In the abstraction and elsewhere. One major conclusion, “..dust is always a dominant constituent of ice nucleating aerosol in Central Europe.” does not follow from the previous sentence, “The ice nucleating characteristics of the aerosol with respect to temperature and supersaturation are similar during the dust episode [to characteristics observed throughout] the course of the year. Given that there are many unexplored aerosol types which may be effective IN (and thus nucleate at warm temperatures and low supersaturations), this conclusion is weak.

Reply: We thank S. Brooks for her comments. Her important point above which expresses a general skepticism against our statements that “dust is always a dominant constituent of ice nucleating aerosols in central Europe” is very close to the comments of Reviewer Gabor Vali, to which we have addressed at length in our response. We would thus like to refer here to Point 1 in our reply to G. Vali. As a general consequence of this criticism we have weakened our statement on the overall dominance of mineral dust in the abstract, chapter 3.2, and summary.

Comment: On a related note, it is not clear from the text what range of conditions each sample was exposed to in the FRIDGE ice chamber.

Reply: The following sentence which describes the conditions of analysis was added to the text: “Each sample was analyzed at the following sequence of temperatures (and supersaturations with respect to ice (RHICE)): -8°C (103%, 105%, 107%); -13°C (106%, 110%, 113%) and -18°C (110%, 115%, 119%).”

Comment: What I glean from the methods section (14997) is that each sample was cooled to a single temperature (in the range of -8 to -18 C) and was then observed at a range of subsequently higher supersaturations. If so, mineral dust, biomass and definitely some biogenic aerosols may all produce the same results. Thus, based on these measurements alone, it should not be stated that the contributing IN throughout the year is dust.

Reply: After measurement at a selected temperature and supersaturation the chamber

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is evacuated and ice sublimates. After that water vapour is inflated again at a different (usually higher) vapor pressure. We cannot see any reason that different nucleating materials must react in the same way in FRIDGE. In contrast, we have found that SNOMAX-aerosol sampled onto the wafers behaves in a very different way, as can be seen in the Figure attached to this reply (last page).

Comment: In the same section on page 14998 referred to above, the text states that deposition and condensation freezing IN were observed and counted. Please clarify, can the FRIDGE differentiate between these two heterogeneous mechanisms or is a single IN count reported?

Reply: FRIDGE cannot distinguish between deposition and condensation mode. The ice crystals that we counted can have developed by either of both mechanisms.

Comment: Page 15: Regarding two other major conclusions in the manuscript, which appear to be in conflict with one another, as currently written. It is noted that spikes in IN concentration are correlated with spikes in the PM10 dust, not the total mass of PM10. This is an important result since it provides strong evidence that dust is acting as the IN in those episodes. Please explain how PM10 dust is measured/determined.

Reply: Yes, we observe that the IN are higher correlated to the modelled PM10 than to the measured PM10, and note that this argues for mineral dust as ice nuclei, since PM10dust (now termed PM10model according to referees suggestion) is pure mineral dust, whereas the measured PM10 may contain mineral dust plus other materials that do not nucleate ice. How is PM10 dust measured/determined: PM10dust is pure mineral dust with $dp < 10\mu\text{m}$, modelled by DREAM in bins 1-7 (this is stated explicitly in chapter 2.2). PM10 (measured) is derived from the measurements of aerosol spectra of $dp < 10\mu\text{m}$ by APS, and contains mineral dust plus all other materials. This notation and the assumption made in the calculation (density, shape factor) are explained at the end of the second paragraph of chapter 2.1.

Comment: The second result is that IN number is better correlated with aerosol surface

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area than with aerosol volume. If I understand correctly, here the authors are referring to surface area of the total aerosol, not the dust. The previous conclusion, that IN is related to dust, not total aerosol, is based on mass (which roughly equates to volume). If IN is in reality connected to volume of dust aerosol, not total aerosol, what evidence is there that a better relationship with surface area than with volume is anything more than coincidence? Better justified is needed here, or this conclusion about surface area must be removed.

Reply: We are referring to the sum of particle surfaces of bins 1 -7, i.e. the range of 0.2 – 10 μm dp, which is largely made up by dust. “Bins 1-7” was added and in table 2 “total” replaced by ? We are not sure that we understand what the reviewer means by “coincidence” on that point. Our conclusion from correlation analysis, that IN were largely made up by mineral dust, is based on i) the correlation between independent observational (and modelled) variables (e.g. IN and surface of aerosol larger than 0.2 μm , the lower end of bin 1, not total aerosol) and is backed by a proposed mechanism that involves surface (e.g. discussed by Phillips et al., 2008), and ii) on the result that the correlation of IN is highest with those variables that are most specific for mineral dust, i.e. the surface of pure mineral dust which comes from the model, and the (measured) surface in the 1.2-2 μm size bin that is strongly affected by dust according to the size spectra of Figure 6 (new).

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 14993, 2010.

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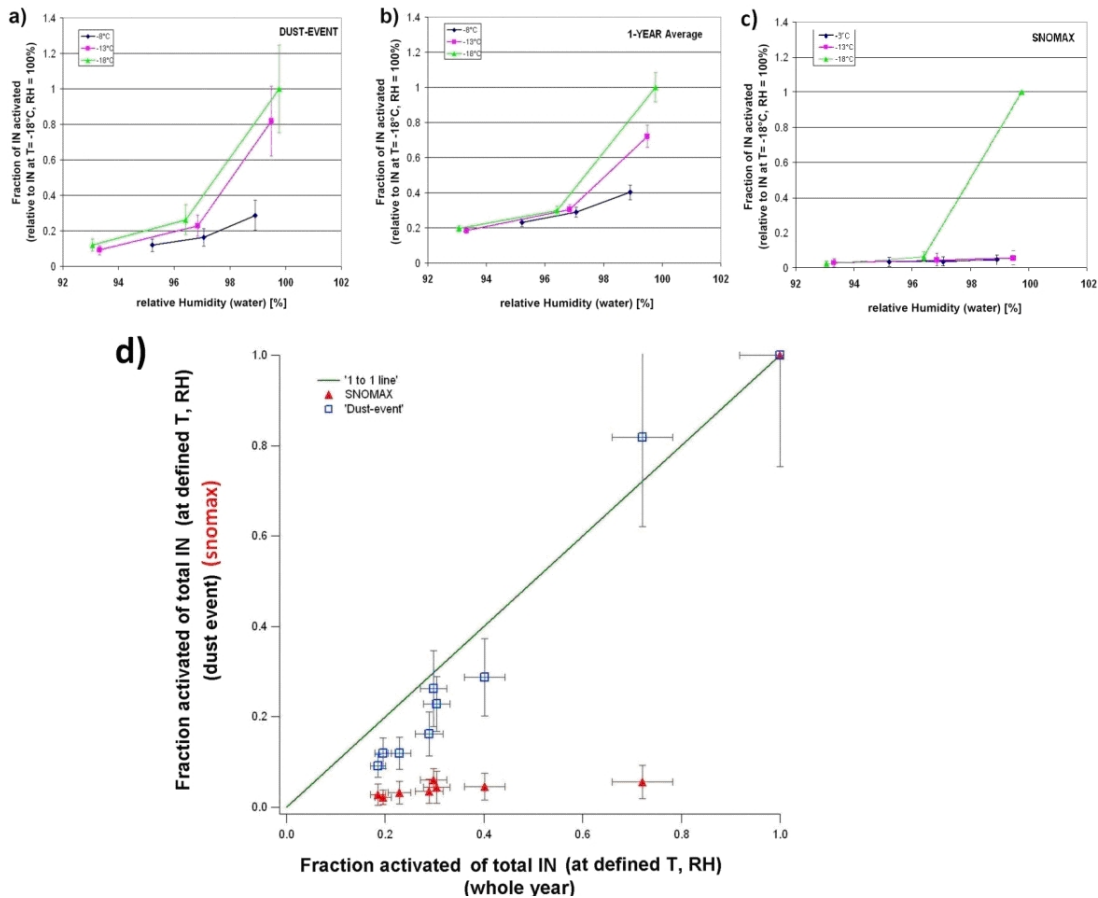


Fig. 1. attached Figure (contains additional analysis-data of SNOMAX-aerosol)