Dust IN concentrations and the impact on clouds in COSMO

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1) Introduction

- One of the main sources of uncertainty in climate simulations is the role aerosols have in influencing the physical properties of clouds. Mineral dust, mostly emitted from deserts, have been identified as the main contributor to atmospheric ice nucleation.

- A significant Saharan dust outbreak in May 2008 transported large amounts of dust to central Europe. Heterogeneous freezing on these dust particles produces ice crystals which have an important influence on precipitation and radiative properties.

- During May 2008, background atmospheric dust concentrations over Europe were about an order of magnitude larger than normal. Maximum concentrations were 10^7 m^{-3} (Figure 1: left), and for June 2008 had maximum concentrations of 10^6 m^{-3}.

- The Consortium for Small-scale Modeling (COSMO) MUlti-Scale Chemistry Aerosol Transport (MUSCAT) modeling system was used to simulate the emission and transport of Saharan dust, in 5 size bins, to Europe.

2) Dust and Ice Nuclei Distributions

- A parameterisation for immersion freezing (Niemand et al. 2012) (Figure 1: middle) in the temperature range 261 - 237 K, and deposition freezing (Steinke et al. 2013) (Figure 1: right) in the temperature range 253 - 220 K, were applied to the modeled Saharan dust concentrations to estimate the ice nuclei (IN) concentrations. Both parameterisations are based on laboratory measurements of freezing on a variety of dust types in the AIDA cloud chamber.

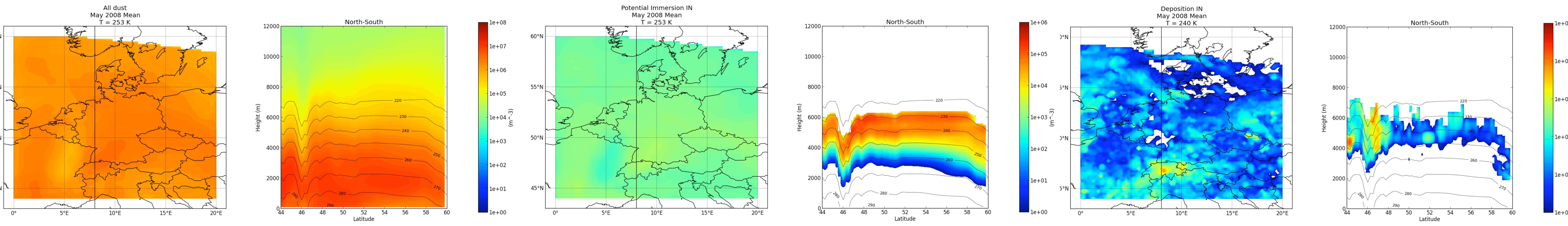

FIGURE 1. LEFT: Mean simulated total dust concentration for May 2008; MIDDLE: Mean potential Immersion ice nuclei concentration for May 2008; RIGHT: Mean deposition ice nuclei concentration for May 2008.

3) Dust and Ice Nuclei Evaluation

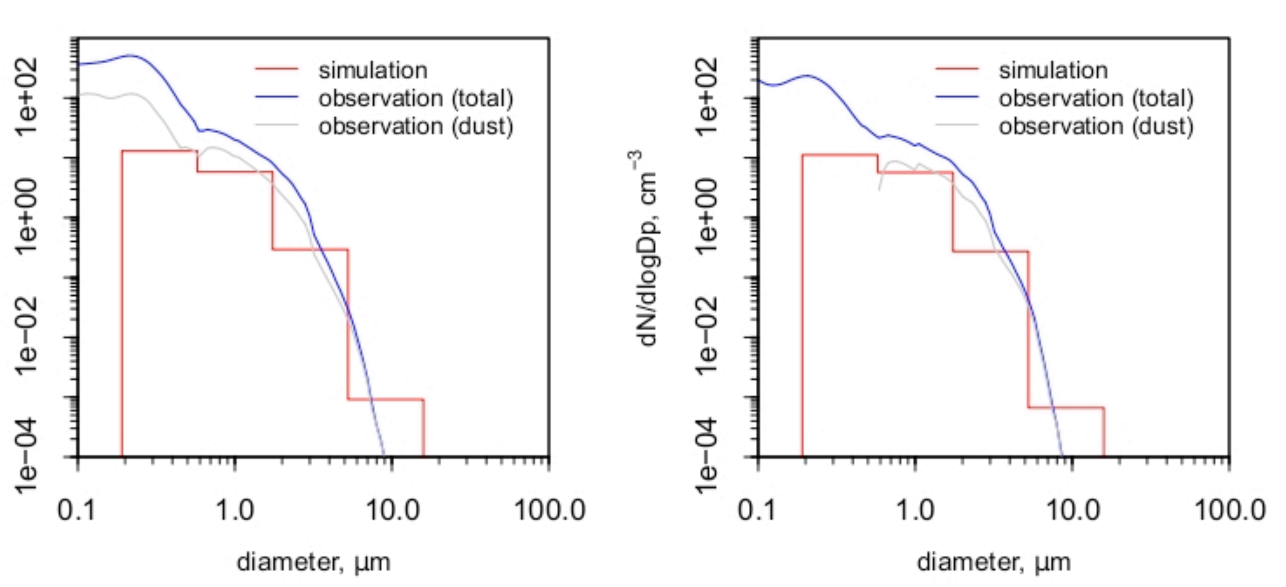

FIGURE 2. Simulated dust number concentration compared to surface measurements of aerosol number concentrations at Cape Verde Islands.

- Dust number concentrations were evaluated with surface measurements from Cape Verde Islands for two days in May 2008, shown in Figure 2. The blue curve shows total aerosol, and the grey curve shows dust aerosol concentrations.

- The mean estimated potential immersion IN, that is the maximum possible immersion IN given a completely saturated atmosphere, for May 2008 were evaluated against available observations (Figure 3). This shows the number of immersion IN as a function of temperature. The colour scale shows the normalised bin density (counts/bin volume).

- The observational data, originally published by Möhler et al. (2007), were collected with a Continuous Flow Diffusion Chamber (CFDC) from both dust dominated field experiments and cloud chamber experiments. The dashed line is a best fit from DeMott et al. (2010.)

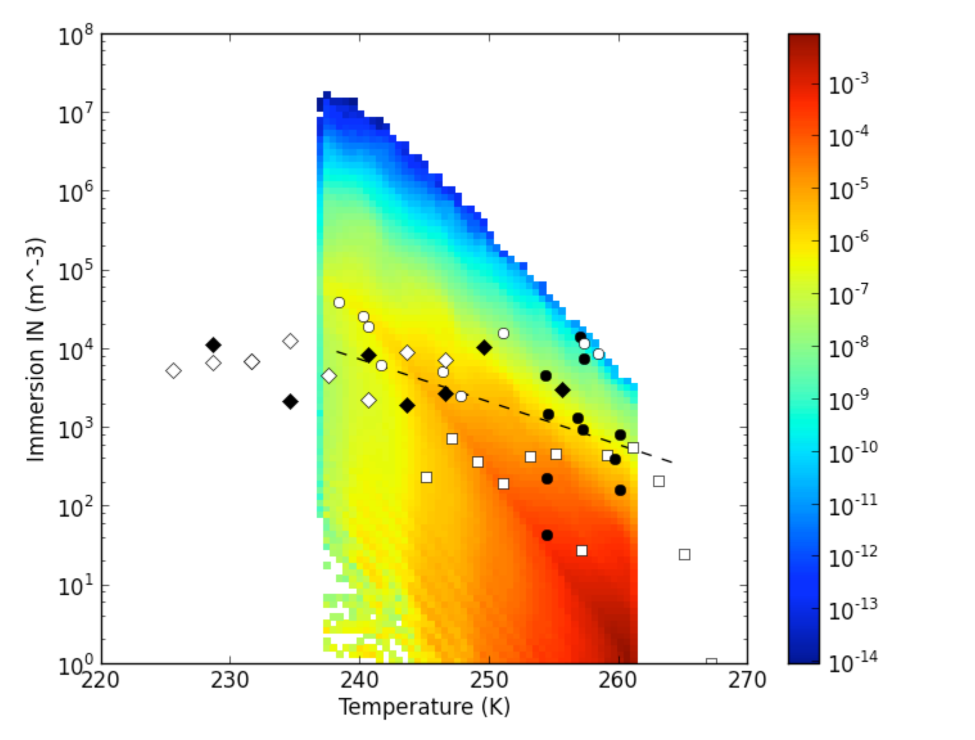

FIGURE 3. Potential Immersion freezing IN compared to field and laboratory measurements of aerosols (Möhler et al, 2007).

4) COSMO Simulations

- The COSMO model was run for a test case on 19.5.2013 with a horizontal resolution of 2.8 km. A simulation with the mean May 2008 immersion and deposition IN (KIT-IN) was compared to the IN activation scheme by Meyers et al. (1992). Figure 4 shows simulated cloud ice water content (LEFT), total precipitation (MIDDLE), and cloud water content (RIGHT) 23 hours after model initialisation.

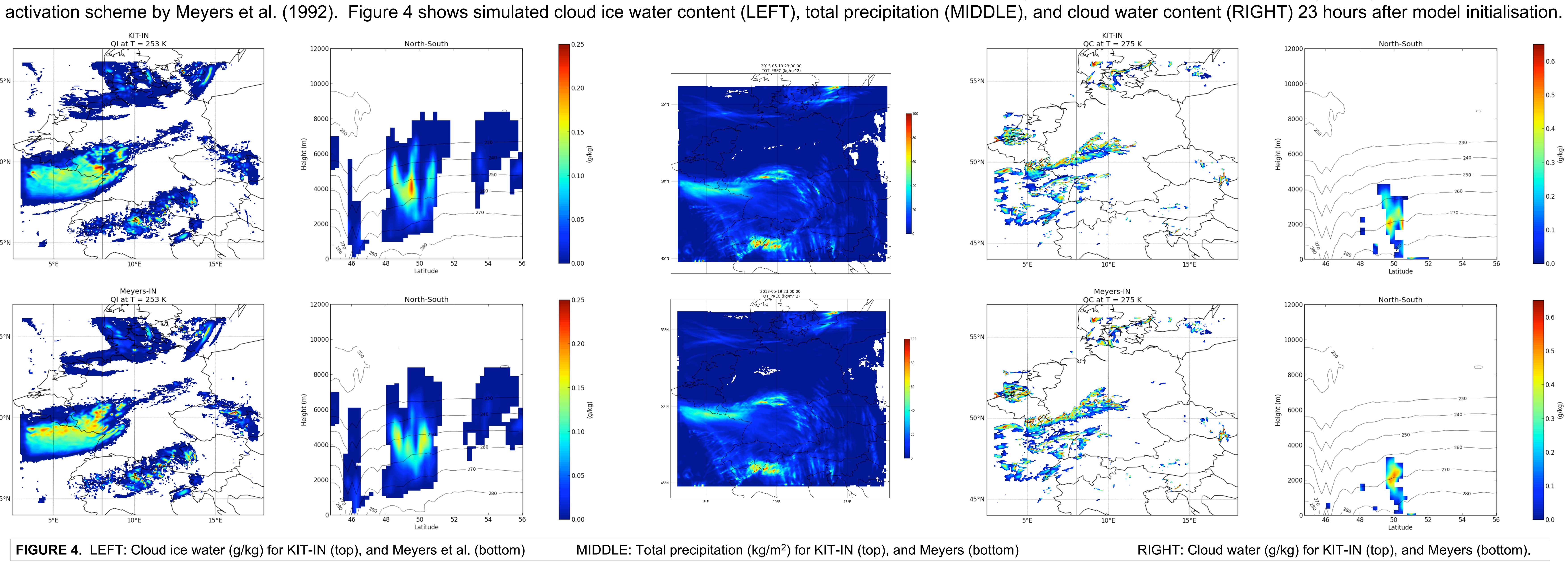

FIGURE 4. LEFT: Cloud ice water (g/kg) for KIT-IN (top), and Meyers et al. (bottom) MIDDLE: Total precipitation (kg/m²) for KIT-IN (top), and Meyers (bottom) RIGHT: Cloud water (g/kg) for KIT-IN (top), and Meyers (bottom).

5) Conclusions and Outlook

- Modeled Saharan dust concentrations over Europe for May 2008 were about an order of magnitude larger than normal. This results in ice nuclei (IN) from immersion and deposition freezing over Europe of up to 10^6 m^{-3}, significantly higher than average. The modeled dust concentrations compare well to surface observations from Cape Verde Islands. A statistical evaluation of potential immersion freezing IN shows good agreement with available observations from field and laboratory measurements.

- Providing the COSMO model with a realistic spatially variable IN distribution results in changes in the spatial distribution and quantity of cloud ice water content. The KIT-IN simulation has a higher concentration of ice particles, but lower specific cloud ice content than the Meyers simulation. These differences propagate to other variables, such as cloud liquid water. The KIT-IN simulation has a higher cloud droplet number, and specific cloud liquid water content than the Meyers simulation. The simulated total precipitation is not strongly affected by the KIT-IN fields.

- This work will be extended to include IN depletion and multiple aerosol types. The simulations will be applied to the HD(CP)² high resolution simulations with the ICON-LES model.

References

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