Aerosol and CCN Distributions over Europe

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1) Introduction

• Aerosols indirectly affect the climate through the modification of clouds, therefore an accurate representation of the spatial and temporal variability of aerosols is needed in models.

• The Consortium for Small-scale Modeling (COSMO) MUlti-Scale Chemistry Aerosol Transport (MUSCAT) modeling system was used to simulate the emission and transport of anthropogenic and natural aerosols to Europe.

• Table 1 shows the aerosol species and properties simulated with the COSMO - MUSCAT modeling system. Also shown, is whether the aerosol species acts as a cloud condensation nuclei (CCN) or an ice nuclei (IN).

• Particle number concentrations were calculated from the particulate masses using the assumed particle properties from Table 1, and assuming external mixing.

Species (externally mixed)	Radius (μ m)	Density (g/cm^3)	Standard deviation	Hygroscopicity	CCN/IN
Ammonium	0.18	1.8	1.6	0.32	CCN
Sulfate	0.18	1.8	1.6	0.33	CCN
Nitrate	0.18	1.7	1.6	0.27	CCN
Elem. Carbon	0.03	1.8	1.8	-	IN
Sea Salt 1	0.1	2.2	1.8	1.16	CCN
Sea Salt 2	1	2.2	1.7	1.16	CCN

TABLE 1. Aerosol particle properties simulated with COSMO - MUSCAT

2) Aerosol Distributions

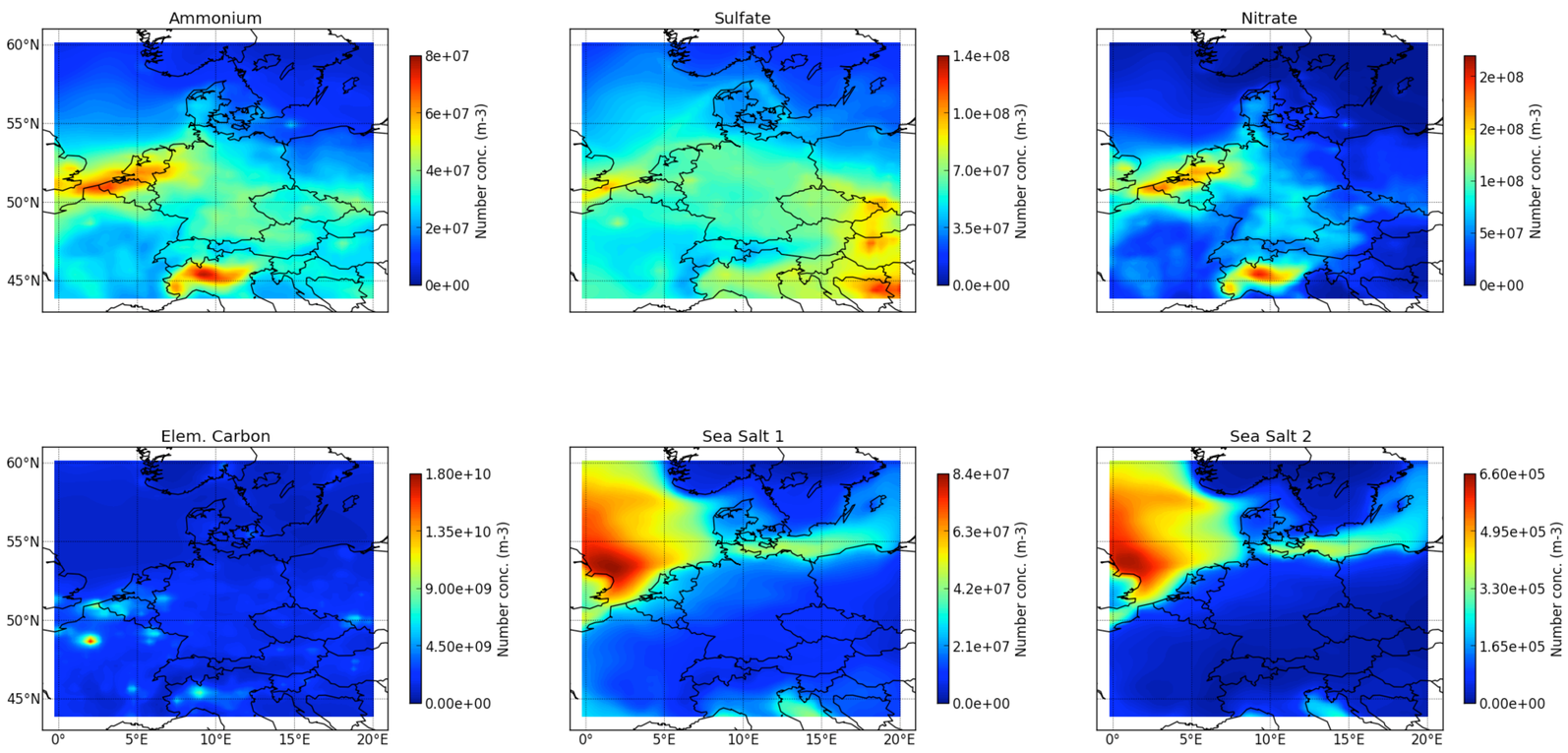

FIGURE 1. Mean near surface aerosol number concentrations for May 2008 for all aerosol species in Table 1.

• The total aerosol concentrations (organic carbon, sulfate, nitrate, ammonium) simulated with COSMO-MUSCAT were evaluated against observations from Melpitz, Germany on 28.05.2008.

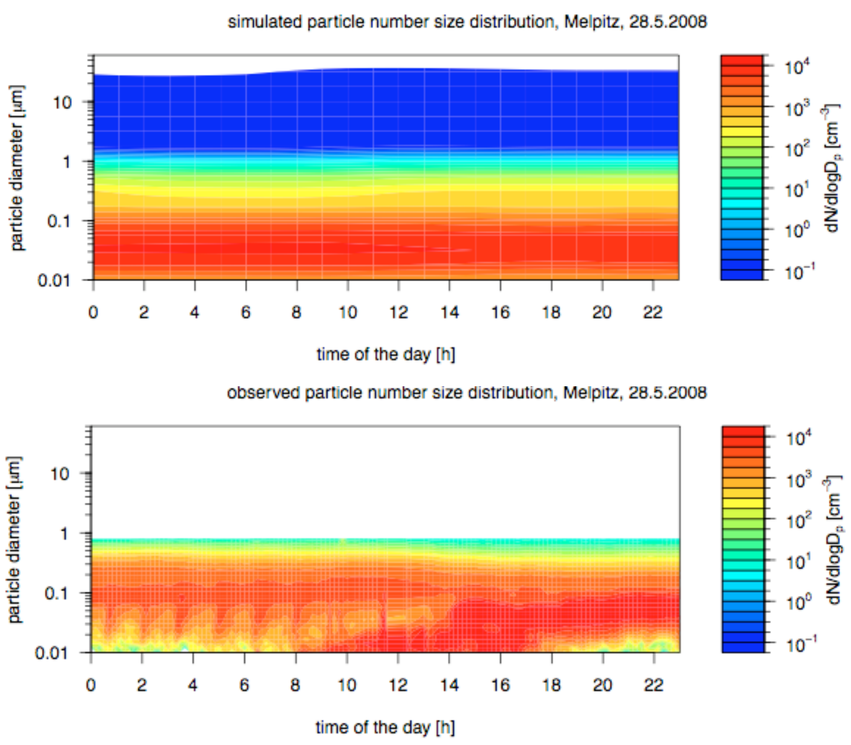

FIGURE 2. TOP: Simulated total aerosol concentrations; BOTTOM: Observed total aerosol concentrations from Melpitz, Germany.

3) Cloud Condensation Nuclei and Ice Nuclei Distributions

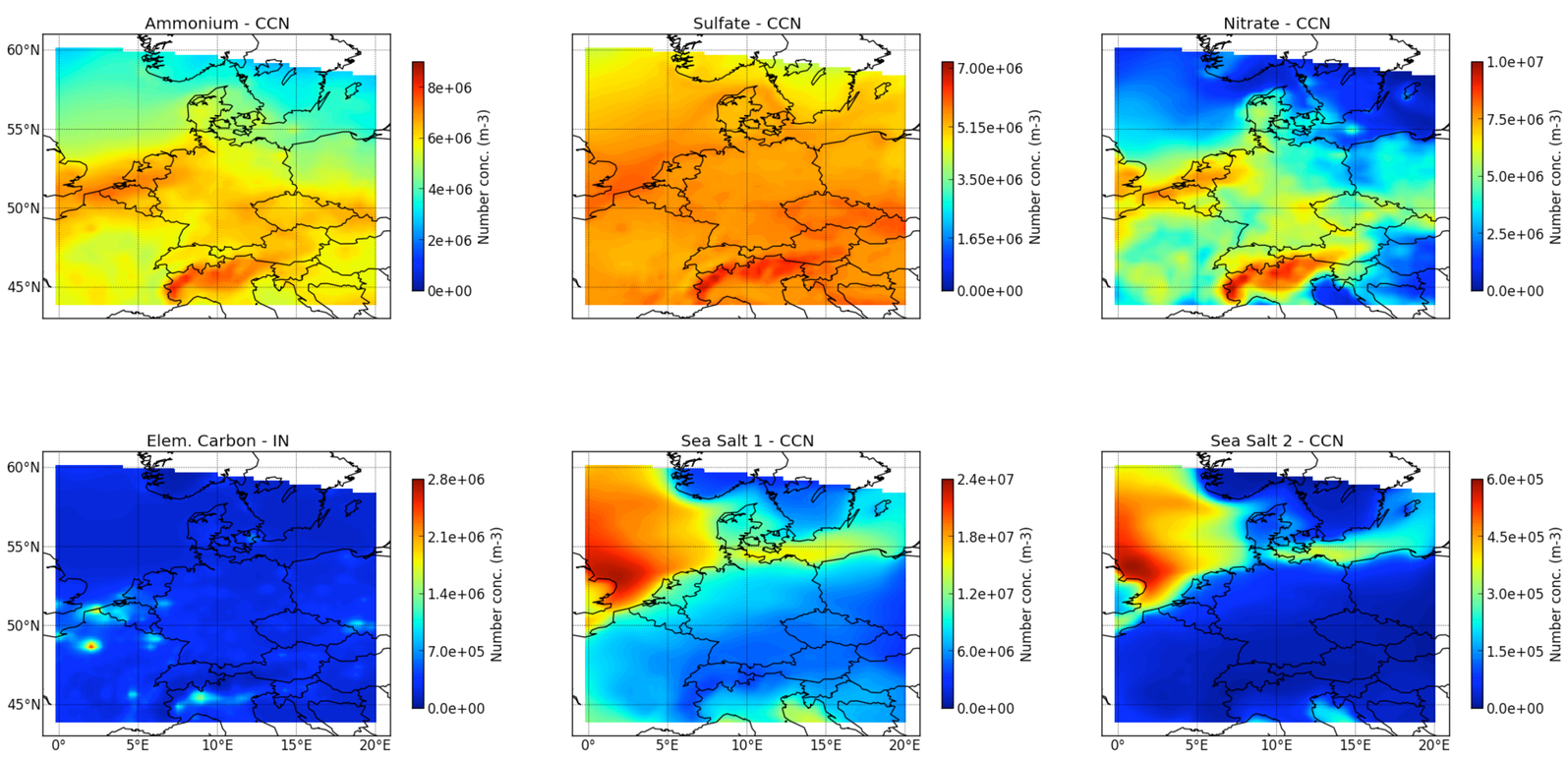

FIGURE 3. Mean near surface CCN and IN number concentrations for May 2008 for all aerosol species in Figure 1.

• The Abdul-Razzak et al. (1998) parameterisation was used to estimate the mean number of activated aerosol particles to form CCN for ammonium, sulfate, nitrate and sea salt aerosols, for May 2008.

• The parameterisation was applied with the mean horizontal temperature field for May 2008, a constant pressure of 800 hPa, and a constant vertical velocity of 1 m/s.

• A parameterisation for deposition freezing on soot particles (Ullrich et al., 2014) was applied to estimate the deposition ice nuclei concentrations from the elemental carbon aerosol fields for May 2008.

• For deposition IN, the RH_{ice} was assumed to be a constant value of 115%, with the mean horizontal temperature field for May 2008. The parameterisation is valid within a temperature range of 195 - 235 K. Here, the surface aerosol concentrations are used, thus the IN estimate represents the potential deposition IN.

• The number concentration of CCN and IN particles near the surface are shown in Figure 3.

4) Conclusions and Outlook

• The COSMO-MUSCAT model suggests mean total aerosol concentrations for all species in Table 1 during May 2008 were roughly 10^{10} m^{-3}. The dominant aerosol types are elemental carbon, followed by sulfate, ammonium, nitrate, and sea salt particles having the lowest concentrations. The simulated aerosol concentrations compare well to observations from Melpitz, Germany.

• On average, about 8% of sulfate aerosols are activated to form CCN, and only a small fraction of elemental carbon aerosols are activated to form IN under the selected prescribed conditions. Activated fraction of aerosols to form CCN is enhanced over high terrain regions, due to colder air temperatures. A difference of about 10 K increases activation by about 13%. The activated fraction of elemental carbon to form IN increases dramatically in colder regions. A difference of about 10 K increases activation by approximately a factor of 4.

• The method will be refined by considering an internal mixture of aerosols, and also extended to include organic carbon. The estimates of CCN and IN will be used in the COSMO model to investigate how a realistic spatially and temporally varying CCN and IN description impacts cloud properties in a meso-scale and an LES scale model. For preliminary results with dust aerosols in a meso-scale model, see poster: ‘Dust IN concentrations and the impact on clouds in COSMO’ (Hande et al.).

References

• Abdul-Razzak, Hayder, Steven J. Ghan, and Carlos Rivera-Carpio. "A parameterization of aerosol activation: 1. Single aerosol type." Journal of Geophysical Research: Atmospheres (1984–2012) 103.D6 (1998): 6123-6131.
• Ullrich et al., Developing a new parameterization framework for the heterogeneous ice nucleation of atmospheric aerosol particles, Geophysical Research Abstracts Vol. 16, EGU2014-10182, 2014, EGU General Assembly 2014.