Project: **1215**

Project title: **A big unknown in the climate impact of atmospheric aerosol: Mineral soil dust**

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Report period: **2022-11-01 to 2023-10-31**

Work in the report period has focussed on two main aspects: (1) Sensitivity of dust emission to land-surface heterogeneity and model resolution; and (2) Dust chemical aging. Results obtained are summarized in the following:

Sensitivity of dust emission to land-surface heterogeneity and model resolution

We studied the impact of heterogeneity in land surface properties on mineral dust emissions using the ICON-ART model in an idealized Large-Eddy Simulation (LES) framework. We focused on vegetation cover and soil texture, conducting sensitivity runs across three grid resolutions (20m, 40m, and 80m). In the scenario without vegetation and with uniform soil, dust emissions exhibited minimal variation across grid resolutions. The presence of vegetation resulted in emission reductions proportionate to the domain-averaged vegetated fraction, with the most significant effect observed at the lowest resolution due to reduced final friction velocities. The interaction of vegetation and soil type significantly influenced emissions variability, with randomly scattered vegetation patterns demonstrating greater variability at coarser resolutions compared to those in clustered vegetation. We also identified bimodal emission patterns in simulations with two soil clusters, highlighting the impact of soil type on emissions, although it was weaker than the influence of vegetation distribution. These findings underscore the need to consider land surface heterogeneity for accurate dust emission predictions, especially regarding the interaction between multiple land surface parameters. Besides the impact of land-surface heterogeneity, we tested the impact of model resolution (and therefore the resolution of modelled wind speeds) on dust emission, deposition, and column loading. Results confirm that the modelled dust cycle is sensitive to resolution (Fig. 1), an aspect to be further quantified and addressed in the future.

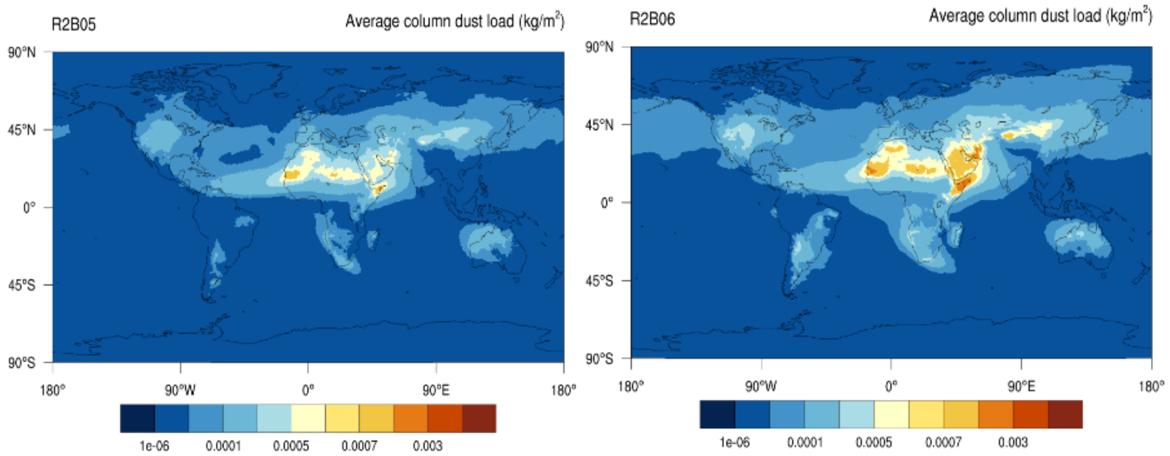

Figure 2. Spatial distributions of average dust column load [kg m^{-2}] during June-July-August 2020 from ICON-ART simulations at grid resolutions R2B05 (~80 km, left) and R2B06 (~40 km, right).

Dust chemical aging

Dust aerosols, emitted as water-insoluble particles, experience chemical aging by accumulating soluble materials like sulfate and nitrate. This process affects the chemical composition and size distribution of the dust particles as well as its interactions with radiation and clouds. In this study, we employed the aerosol dynamics module (AERODYN) in ICON-ART. AERODYN includes soluble, insoluble, and mixed aerosol modes and aerosol dynamic processes such as nucleation, condensation and coagulation. The aerosol size distribution in the model is represented by eight unimodal lognormal distributions (also called modes) with constant width. These modes describe four size groups (Aitken, accumulation, coarse and giant) and two hygroscopic classes in a homogeneous or core-shell mixture (insoluble, soluble, and mixed). We conducted global simulations using ICON-ART at ~80 km grid resolution (R2B05) with a vertical resolution of L60, extending up to 75 km. We applied a simplified gas-phase chemistry mechanism that includes SO2 oxidation by OH to produce H2SO4, and a slow decay rate for HNO3, NH3, and H2SO4. Additionally, we reinitialized these gases at daily interval using CAM-Chem model output.

Our default model configuration resulted in inefficient mixing of soluble and insoluble aerosols, especially in the accumulation mode where the soluble particles were populated in smaller size range than the insoluble ones. To address this, we analyzed the sensitivity of simulated dust to size parameters, namely initial geometric median diameter (GMD), standard deviations (σ) of mode distribution, and threshold diameters (d_{shift}) for transitions from mixed-accumulation to mixed-coarse mode. Our goal was to identify optimal settings for these parameters to create a more accurate overall representation of particle size distribution. This work will be continued in the next allocation period to quantify the impact of chemical aging on dust-radiation interactions.

Changes compared to planned work

Some changes regarding the planned work became necessary. Delays in hiring staff persisted and therefore the planned implementation of additional dust emission schemes and case studies on dust-cloud interactions needed to be further postponed.