Project: **1215**

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

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Report period: **2023-11-01 to 2024-10-31**

Work in the report period has focussed on two main aspects: (1) Impact of mineral dust chemical aging on the dust direct radiative effect, (2) Constraining global dust emissions, and (3) Test Suite for ICON(-ART) simulations. Results obtained are summarized in the following:

Impact of mineral dust chemical aging on the dust direct radiative effect:

During transport, the physical and chemical properties of dust particles can be altered through interactions with atmospheric gases, including water vapor, and other aerosols. These aging processes impact both, dust-radiation and dust-cloud interactions and thereby dust climate effects. Mineral dust aging can be simulated with ICON-ART using AERODYN (Muser et al., 2020), but it is currently not yet considered in dust-radiative effect calculations. After progress has been achieved in the last allocation period on optimizing aerosol size-parameter settings to represented mixing of soluble and insoluble aerosols, the objectives for this allocation period were to finalize the aerosol size-parameter configuration, quantify the degree of chemical dust aging and to implement a multiple-call to ICON-ART's radiation routines to be able to quantify the direct radiative effect (DRE) of dust aerosol for the surface and top of the atmosphere as well as for dust as a whole and by size mode.

Figure 1 shows as an example the annual average DRE obtained for 2012 at the top of the atmosphere for dust in all sizes (left column) and for the coarsest of the three size modes (right column) for longwave (top row) and shortwave (bottom row) radiation. Whereas the longwave DRE is positive for both, all dust sizes and the coarsest mode, the shortwave DRE is positive for all dust sizes and partly positive and negative for the coarsest dust mode, depending on the properties of the underlying surface.

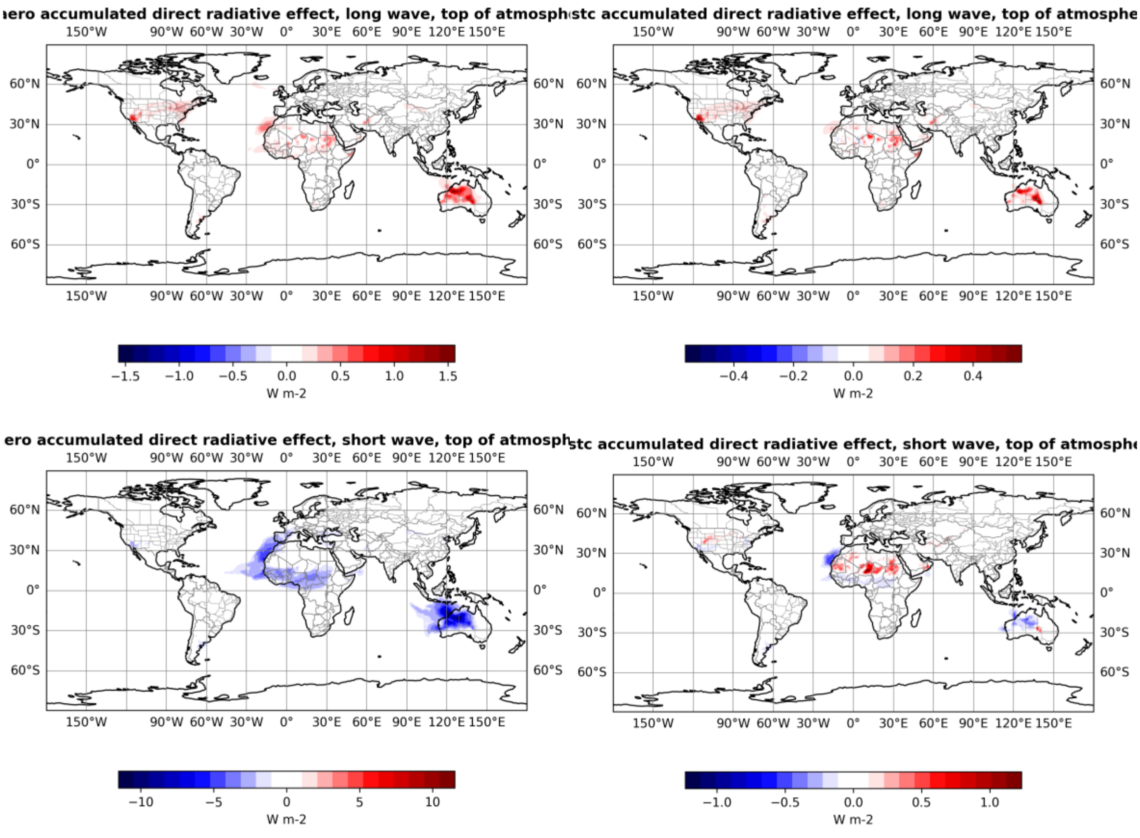

Fig 1.: Dust direct radiative effect (DRE) at the top of the atmosphere for all dust aerosol (left) and the coarsest mode (right) and longwave (top) and shortwave (radiation).

Constraining global dust emissions:

Dust emission is a threshold process that depends non-linearly on wind forces and is also highly sensitive to land-surface properties. It was therefore expected that dust emissions benefit from a more detailed representation of the land surface and better resolved winds at high resolution, provided that the dust emission parameterizations are physics-based and without strong empirical constraints which are often used to compensate for the lack of detailed land-surface descriptions at coarse resolution. For this purpose, we have implemented two state-of-the-art physics-based dust emission parameterizations in ICON-HAM-lite, to test their performance both at coarse and at high resolution, and to constrain dust emissions globally. The reason for choosing ICON-HAM-lite is its reduced-complexity design enable storm-resolving simulations at global scale.

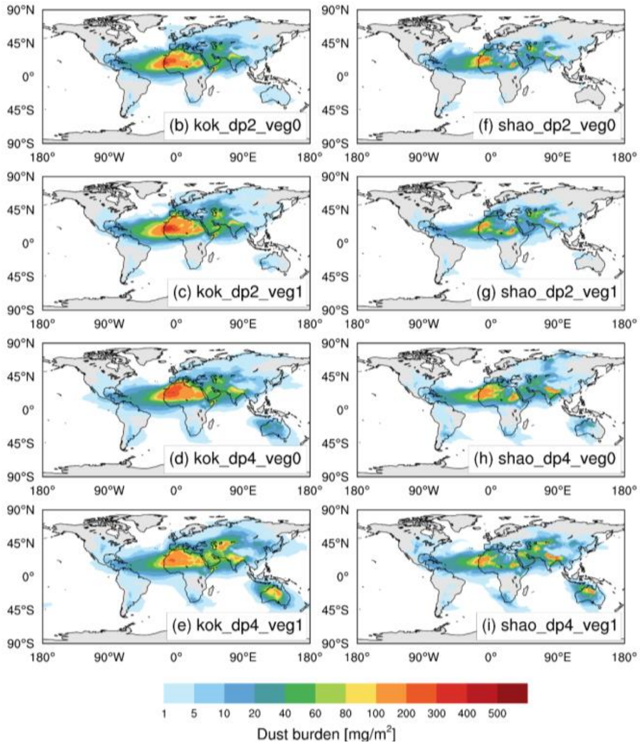

Fig. 2: Average dust burden obtained for June, July, and August 2020 with different combinations of parameterizations related with dust emission.

Figure 2 exemplarily shows the average dust burden obtained with four different combinations of parameterizations related with mineral dust emission at a resolution of R2B5 for summer (June, July, August) 2020. The results demonstrate the sensitivity of simulated dust fields to dust emission parameterizations. Further tests and a detailed evaluation against observations are planned to identify the optimal combination of parameters. An additional simulation at a resolution of R2B9 confirmed that storm-resolving resolutions are highly beneficial for dust modelling particularly regarding models winds, e.g. in areas of pronounced topography, and for relatively small, but very intense dust phenomena, such as haboob dust storms, i.e. dust storms generated by the cold pool outflow of moist convection.

Test suite:

For tests and benchmarking, the set of ART standard cases, published along with the publication of ICON-ART, (https://www.icon-art.kit.edu/) is taken as baseline to cover most of the functionality of the ART submodule. It is extended by the same number of additional test cases, specifically targeting individual components of the ART module and tuned for small resource requirements. Thus, a set of test is established covering most of the functionality and providing specifically lightweight tests for core functionality. Further, the number has proven a good compromise between test coverage and time investment for development and maintenance of the test cases. The test were successfully applied for model testing during the development of the radiation multicall scheme for ICON-ART, proving their capability for continuous testing and benchmarking during model development. These test were optimized regarding runtime environment settings for the default grid (R2B5 in most cases), thus providing benchmark cases. Application to other grid resolutions and optimization to these is planned for the remainder of the year.