

How much soil dust aerosol is man-made?

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EXTENDED ABSTRACT

A. Introduction

Large parts of the Earth’s land surface have undergone significant modification by humans due to, for example, urbanization and agriculture. Anthropogenic changes in land use due to cultivation and grazing can enhance the emission of soil mineral dust, the most abundant aerosol in mass originating from land sources, and thereby affect weather and climate.

The contribution of anthropogenic sources to the global soil dust load has been under debate over more than two decades with estimates ranging from 10 – 50% [e.g. 1,2,3,4]. Main reasons for this large uncertainty are (1) deficits in the representation of small-scale anthropogenic dust sources (cropland and pasture); (2) a lack of data available to constrain the global dust load; (3) deficits in the model representation of parameters affecting dust emission as well as of the dust emission process itself. Using a high-resolution ($0.1^\circ \times 0.1^\circ$) satellite estimate of atmospheric column dust load for dust source identification and land use maps for source attribution, a recent estimate suggests that 25% of global dust emissions originate from anthropogenic sources [5,6].

B. Objectives and Methods

Here we hypothesize that a combination of the recent advances on source identification and attribution with state-of-the-art integrated numerical modeling and a diverse set of global dust observations will help to better address the following core questions:

- What are the relative contributions of natural and anthropogenic sources to global dust emissions depending on land use classification?
- How large is the uncertainty of natural and anthropogenic dust emissions?
- What are the key processes affecting this uncertainty?

We use NMMB-MONARCH, the Multiscale Online Nonhydrostatic Atmosphere Chemistry model [7,8], to conduct multiple global model simulations. We thoroughly evaluate and constrain the model results based on measurements of dust concentration, deposition, and optical depth to obtain a model best estimate and to quantify the global natural and anthropogenic emission and deposition along with their uncertainty. We discuss the challenges of constraining the anthropogenic fraction of dust and identify model deficits that we are going to address in the future.

C. Modeling framework

NMMB-MONARCH has the capability to simulate the atmosphere including atmospheric constituents such as aerosols or trace gases. Parallelization of NMMB-MONARCH follows a subdomain basis approach, i.e. the model domain into horizontal tiles. Since the global latitude-longitude grid deforms toward the pole region, the nodes

closer to the poles perform additional filtering using Fast Fourier Transform (FFT) to maintain stable integration using a time step of reasonable size. MONARCH is a coupled model constructed over the Earth System Modelling Framework (ESMF) coupling library. This implies that in between the execution of each module (dynamics, physics, chemistry, aerosol), the model executes a coupling step to exchange information. The numerical methods employed within the model are: the Adams-Bashford scheme for horizontal advection, the Crank-Nicholson scheme for vertical advection tendencies, the forward-backward scheme for horizontally propagating fast waves, and an implicit scheme for vertically propagating sound waves. The I/O of the system uses dedicated writing nodes, resulting in a partitioning between computational and I/O nodes.

To run the model, we use the workflow manager *autosubmit* [9] together with the MONARCH-specific extension *auto-monarch* (BSC-ES CES, with acknowledgment), which facilitates easy management of the model runs as well as pre- and post-processing on high-performance computing platforms, such as MareNostrum 4.

D. Preliminary results

Numerical experiments examining the role of vegetation cover, land-use (cropland, pasture, and rangeland), and dust emission parameterization were conducted to investigate the anthropogenic emission fraction and to quantify its uncertainty. Our preliminary results suggest that the global anthropogenic emission fraction is about 10%, i.e. smaller than previously thought when using similar land-use criteria (cropland and pasture) to define anthropogenic sources, but an updated data set. When including rangeland as anthropogenic dust source, the anthropogenic contribution to the global dust cycle increases to about 40% and show a much stronger seasonal and spatial variability (not shown).

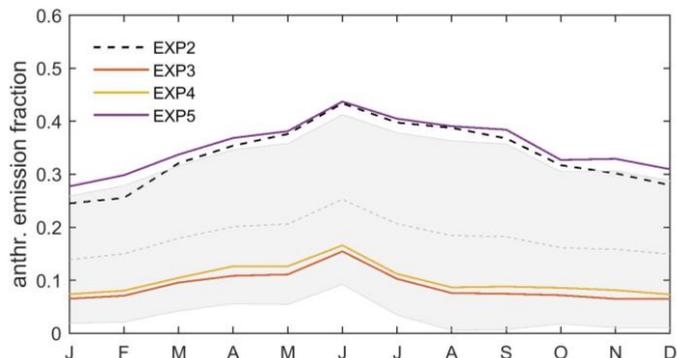


Fig. 1 Global anthropogenic soil dust emission fraction per month in 2012 based on different numerical experiments (colored solid lines) compared to a reference scenario (black dashed line) obtained using NMMB-MONARCH.

E. Summary and Conclusions

Our results demonstrate that anthropogenic sources contribute to the global dust loading and that soil mineral dust cannot be considered only as a pure natural aerosol. Using

different dust emission parameterizations, land-use scenarios, and land-surface representations, we quantify the uncertainty related to the fraction of anthropogenic emissions. We will further refine our estimate of natural and anthropogenic dust emissions in the future, by (a) conducting higher-resolution global model runs, (b) implement a representation of moist-convective dust storms, and (c) expand the use of observational constraints to calibrate and evaluate modeled dust loadings.

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Author biography



Dr. Martina Klose received her diploma (2010) and doctoral degree (2014) in Meteorology at the University of Cologne, Germany. She obtained a two-year postdoctoral fellowship by the German Research Foundation to conduct research in the USA. In 2017, she joined BSC as a Beatriu-de-Pinós Postdoctoral Research Fellow. She was awarded a Marie-Skłodowska-Curie Individual Fellowship, which started in 2018. Her research interests include aeolian processes, their frequency, and impacts on Earth and other planets. Her research focus is to understand the physics of dust emission and to advance its parameterization in models. Her work resulted in 18 publications in peer-reviewed international journals (7 as lead author; 4 reprinted as book chapters), the participation as presenter at 21 and (co-)convener at 5 international conferences/workshops, the organization of 1 international workshop, several invited visits at renowned research institutions around the world, and an invited presentation at the American-Geophysical-Union Fall Meeting. Since 01/2018, she is Associate Editor of the international journal *Aeolian Research*.