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Climate response to soil dust aerosol and its sensitivity to mineralogical composition in Northern Africa

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Soil dust aerosol produced by wind erosion of arid and semi-arid surfaces is generally treated as a homogeneous species, although observations evidence significant variability in its composition depending on the source region. Among other climate-relevant features, mineralogy influences optical properties, which remain one of the key uncertainties in the characterization of the direct effect of dust upon climate.

We assess the radiative forcing and fast climate response (temperature and precipitation), for a constrained range dust mineralogy variations over North Africa. We adapt the NMMB-MONARCH model, which allows long-wave and short-wave aerosol-radiation interaction, to run 20-yearlong atmosphere-only regional climate simulations over Northern Africa, Middle East and Europe.

We run three different scenarios with varying dust absorption in the shortwave and the longwave based on estimated soil mineralogical composition variations in Northern Africa. Refractive indexes for eight minerals are mixed using the multi-component Maxwell-Garnett method to derive effective indices of dust internal mixtures. The variability of the resulting effective refractive indices is within the observed uncertainties reported from field campaigns and laboratory experiments. The intensive optical properties required by the model are then calculated considering the 50th, 10th and 90th percentiles of the imaginary index, which define the median, scattering and absorbing cases, respectively.

The single scattering albedo largely affects the TOA forcing, changing the sign from positive over bright surfaces for the absorbing scenario, to negative for the scattering dust definition. The precipitation response during the Monsoon season in the Sahel is tightly linked to the TOA forcing, increasing/decreasing for absorbing/scattering dust definitions. Daily minimum, mean and maximum temperatures also respond differently among scenarios, due to changes in surface and TOA forcing, precipitation and soil humidity.

Our approach is validated through the evaluation of the modelled optical properties. NMMB-MONARCH′s single scattering albedo lies within AERONET observed values for all three scenarios in the Mediterranean and the Middle East, whilst in the Sahel and North Africa the median and scattering scenarios fall closer to the observations.