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Modelling nitric acid uptake by mineral dust using parameterizations of different complexity

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Mineral dust is amongst the largest contributors to the global aerosol mass load and dominates climate effects over large areas of the Earth. Dust undergoes heterogeneous chemical reactions during transport that increase its hygroscopicity, while altering its optical properties, and the associated radiative forcing. The rates of heterogeneous chemical reactions on the dust surface that form coatings of sulfate, nitrate, chloride, or organics depend strongly on the dust mineralogical composition. For example, the uptake of sulfur dioxide by calcite exceeds by at least an order of magnitude uptake by quartz, feldspar and hematite. Dust composition also affects the partitioning of semi-volatile inorganic compounds, altering their burden and radiative forcing.

In this work, we perform an analysis of the treatment of nitric acid heterogeneous chemistry on mineral dust in atmospheric models. We have implemented aerosol nitrate formation on coarse particles in the Multiscale Online Nonhydrostatic AtmospheRe CHemistry model (MONARCH) and we have performed sensitivity experiments with parametrizations of varying complexity. First-order uptake reactions with/without dependence on relative humidity are compared against approaches based on thermodynamic equilibrium assumptions, that range from just considering the effect of dust mineralogy upon aerosol pH to including the formation of subproducts from the gas-mineral interaction. The sensitivity to the mineral dust treatment (i.e., minerological composition) in each approach is discussed. The different implementations are evaluated against observations and compared with literature results.

Our preliminary findings highlight the important role that mineralogy plays in mineral dust chemistry, and the relevance that thermodynamic assumptions have when simulating the complex evolution of mineral dust in the atmosphere. This work aims to set a benchmark for future sensitivity studies to factors affecting dust heterogeneous chemistry, such as the explicit representation of regional variations in the mineralogical composition of dust.