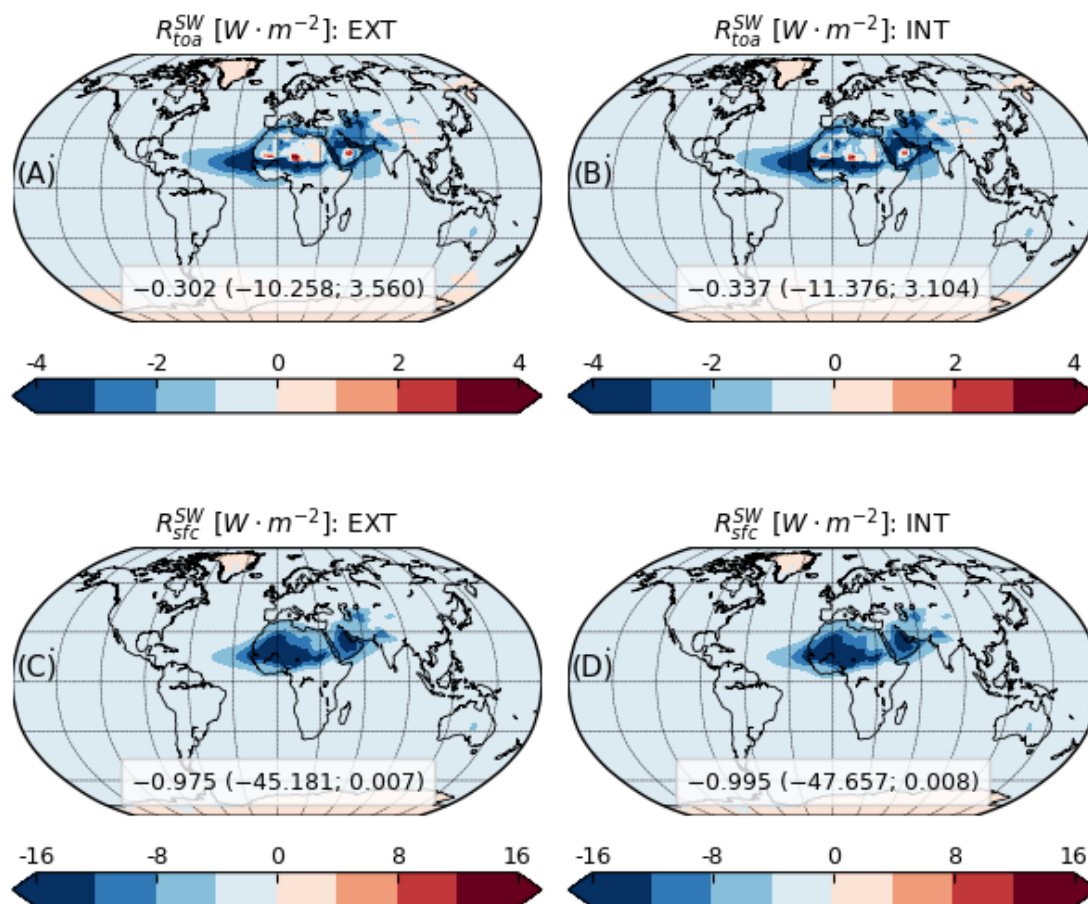**Figure S1.** Annual mean direct radiative effect at the top of atmosphere (R_{toa}^{SW}) and at surface (R_{sfc}^{SW}), from the mineral experiments with external (EXT; A and C, respectively) and internal (INT; B and D, respectively) mixing configuration. The direct radiative effect is relative to the entire shortwave spectrum ($0.30 - 4\,\mu m$). The extremes of the color bars are set to include 1st and 99th percentiles of the mapped variables. Global average along with minimum and maximum (within parentheses) are also reported.
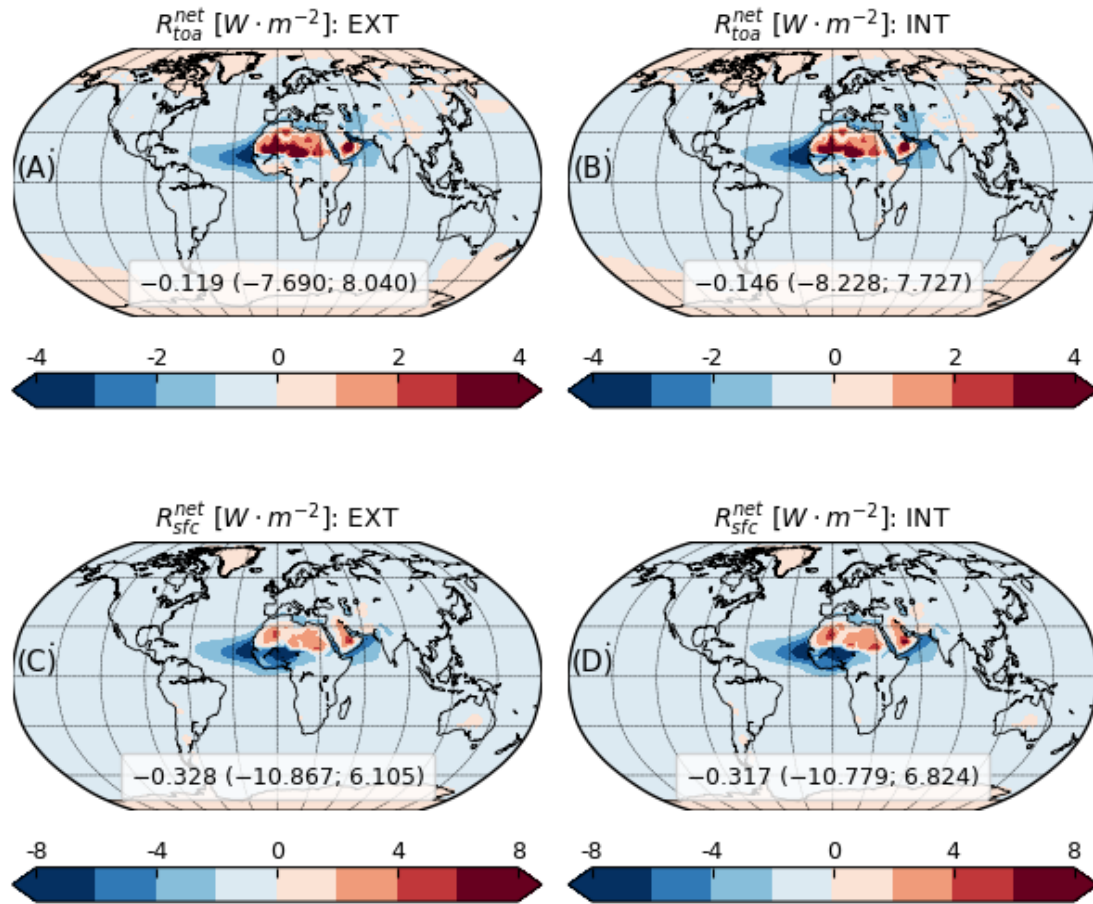
Figure S2. Same as Figure S1 but showing the net direct radiative effect (R_{toa}^{net} and R_{sfc}^{net}, at the top of atmosphere and surface, respectively), calculated as the sum of shortwave and longwave contributions.
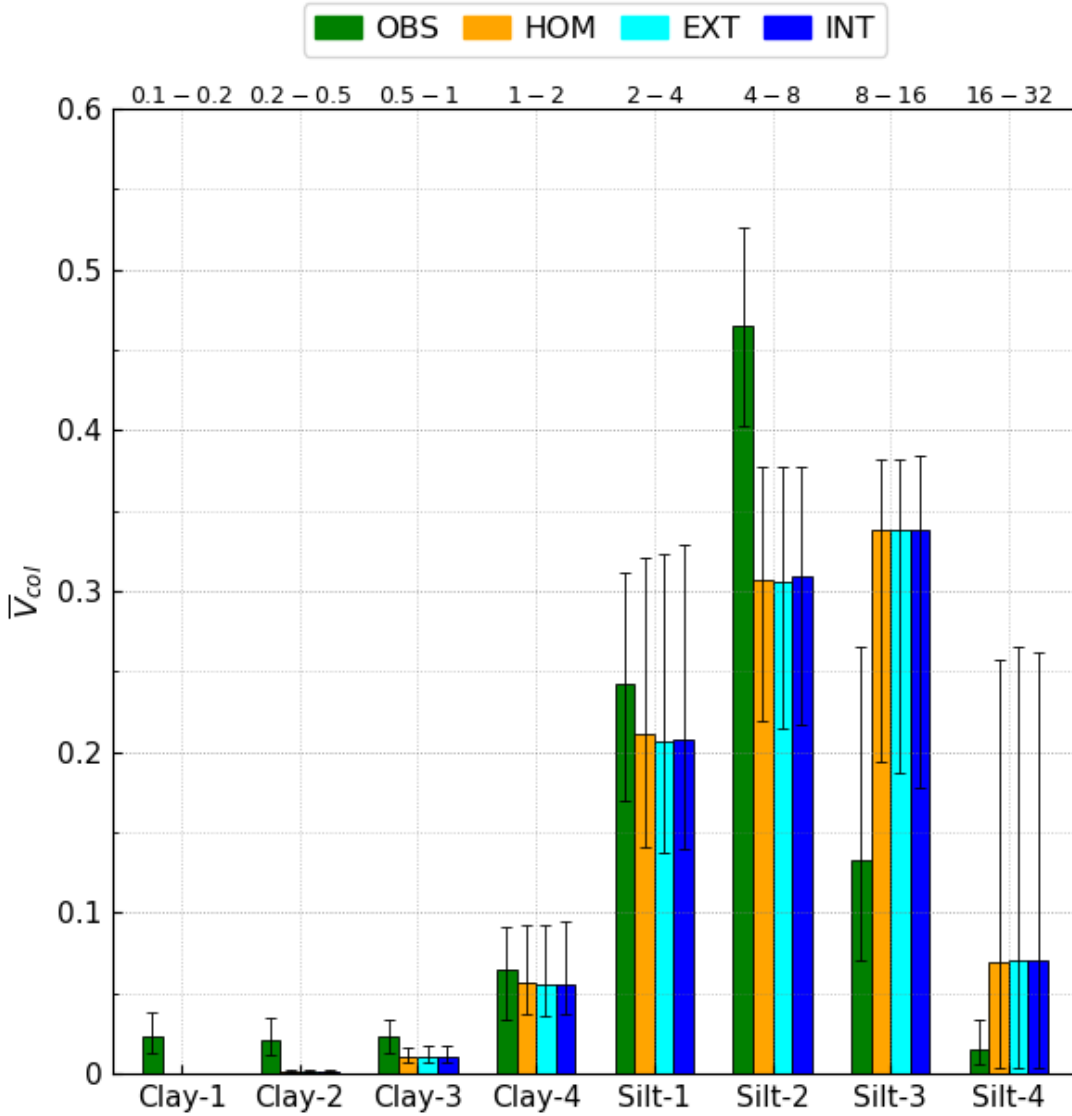
Figure S3. Normalized size distribution of monthly column volume ($\overline{V}_{col}$) of model dust from the control run with homogeneous composition (HOM) and the mineral experiments with external (EXT) and internal (INT) mixing configuration, compared to AERONET monthly retrievals (OBS) at the selected stations and months, that are projected onto the model size bins. The ranges reported on the upper x-axis indicate the diameters (expressed in μm) covered in each size bin (Table B2). The solid bars represent medians, along with 1st and 99th percentiles (error bars), of the monthly means within each region and season.