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The global middle-atmosphere aerosol model MAECHAM5-SAM2: comparison with satellite and in-situ observations

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Abstract. In this paper we investigate results from a three-dimensional middle-atmosphere aerosol-climate model which has been developed to study the evolution of stratospheric aerosols. Here we focus on the stratospheric background period and evaluate several key quantities of the global distribution of stratospheric aerosols and their precursors with observations and other model studies. It is shown that the model fairly well reproduces in situ observations of the aerosol size and number concentrations in the upper troposphere and lower stratosphere (UT/LS). Compared to measurements from the limb-sounding SAGE II satellite instrument, modelled integrated aerosol quantities are more biased the lower the moment of the aerosol population is. Both findings are consistent with earlier work analysing the quality of SAGE II retrieved e.g. aerosol surface area densities in the volcanically unperturbed stratosphere (SPARC/ASAP, 2006; Thomason et al., 2008; Wurl et al., 2010).

The model suggests that new particles are formed over large areas of the LS, albeit nucleation rates in the upper troposphere are at least one order of magnitude larger than those in the stratosphere. Hence, we suggest that both, tropospheric sulphate aerosols and particles formed in situ in the LS are maintaining the stability of the stratospheric aerosol layer in the absence of direct stratospheric emissions from volcanoes. Particle size distributions are clearly bimodal, except in the upper branches of the stratospheric aerosol layer where aerosols evaporate. Modelled concentrations of condensation nuclei (CN) are smaller than measured in regions of the aerosol layer where aerosol mixing ratios are largest. This points to an overestimated particle growth by coagulation.

Transport regimes of tropical stratospheric aerosol have been identified from modelled aerosol mixing ratios and correspond to those deduced from satellite extinction measurements. We found that convective updraft in the Asian Monsoon region significantly contributes to both stratospheric aerosol load and size. The timing of formation and descend of layers of fine mode particles in the winter and spring polar stratosphere (CN layer) are well reproduced by the model. Where temperatures in the stratosphere increase with altitude, nucleation is unlikely to occur. Nevertheless, in these regions we find a significant concentration of fine mode aerosols. The place of origin of these particles is in the polar stratosphere. They are mixed into the mid-latitudes by planetary waves. There enhanced condensation rates of sulphuric acid vapour counteract evaporation and extend aerosol lifetime in the upper branches of the stratospheric aerosol layer.

Measured aerosol precursors concentrations, SO_2 and sulphuric acid vapour, are fairly well reproduced by the model throughout the stratosphere.

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