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Easy Aerosol - Robust and non-robust circulation responses to aerosol radiative forcing in comprehensive atmosphere models

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A number of recent studies illustrated the potential of aerosols to change the large-scale atmospheric circulation and precipitation patterns. It remains unclear, however, to what extent the proposed aerosol-induced changes reflect robust model behavior or are affected by uncertainties in the models' treatment of parametrized physical processes, such as those related to clouds. "Easy Aerosol", a model-intercomparison project organized within the Grand Challenge on Clouds, Circulation and Climate Sensitivity of the World Climate Research Programme, addresses this question by subjecting a suite of comprehensive atmosphere general circulation models with prescribed sea-surface temperatures (SSTs) to the same set of idealized "easy" aerosol perturbations. This contribution discusses the aerosol perturbations as well as their impact on the model's precipitation and surface winds. The aerosol perturbations are designed based on a global aerosol climatology and mimic the gravest mode of the anthropogenic aerosol. Specifically, the meridional and zonal distributions of total aerosol optical depth are approximated by a superposition of Gaussian plumes; the vertical distribution is taken as constant within the lowest 1250m of the atmosphere followed by an exponential decay with height above. The aerosol both scatters and absorbs shortwave radiation, but in order to focus on direct radiative effects aerosol-cloud interactions are omitted. Each model contributes seven simulations. A clean control case with no aerosol-radiative effects at all is compared to six perturbed simulations with differing aerosol loading, zonal aerosol distributions, and SSTs. To estimate the role of natural variability, one of the models, MPI-ESM, contributes a 5-member ensemble for each simulation. If the observed SSTs from years 1979-2005 are prescribed, the aerosol leads to a local depression of precipitation at the Northern Hemisphere center of the aerosol and a northward shift of the intertropical convergence zone (ITCZ). This is consistent with the aerosol's shortwave heating of the atmosphere and the fact that SSTs are fixed. Moreover, the Northern hemisphere mid-latitude jet shows an annual-mean zonal-mean poleward shift. Due to large natural variability, however, these signals only emerge clearly in ensemble runs or if the aerosol optical depth is increased by a factor of five compared to the observed magnitude of the present-day anthropogenic aerosol. When SSTs are adapted to include the cooling effect of the aerosol, the ITCZ and the Northern hemisphere jet shift southward in the annual- and zonal-mean. The models exhibit very similar precipitation and zonal wind changes in response to the SST change, showing that SSTs are a key factor for the circulation response. Yet, model differences in the surface and top-of-atmosphere energy balances due to evaporation and cloud-radiative effects imply that the models would show much more different responses if they were coupled to an interactive ocean.