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Global variability of cloud condensation nuclei concentrations

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Atmospheric aerosols can influence cloud optical and dynamical processes by acting as cloud condensation nuclei (CCN). Globally, these indirect aerosol effects are significant to the radiative budget as well as a source of high uncertainty in anthropogenic radiative forcing. While historically many global climate models have fixed CCN concentrations to a certain level, most state-of-the-art models calculate aerosol-cloud interactions with sophisticated methodologies based on interactively simulated aerosol size distributions. However, due to scarcity of atmospheric observations simulated global CCN concentrations remain poorly constrained. Here we assess global CCN variability with a climate model, and attribute potential trends during 2000-2010 to changes in emissions and meteorological fields. Here we have used ECHAM5.5-HAM2 with model M7 microphysical aerosol model. The model has been upgraded with a secondary organic aerosol (SOA) scheme including ELVOCs. Dust and sea salt emissions are calculated online, based on wind speed and hydrology. Each experiment is 11 years, analysed after a 6-month spin-up period. The MODIS CCN product (Terra platform) is used to evaluate model performance throughout 2000-2010. While optical remote observation of CCN column includes several deficiencies, the products serves as a proxy for changes during the simulation period. In our analysis we utilize the observed and simulated vertical column integrated CCN concentration, and limit our analysis only over marine regions. Simulated annual CCN column densities reach $2{\cdot}10^8$ cm^{-2} near strong source regions in central Africa, Arabian Sea, Bay of Bengal and China sea. The spatial concentration gradient in CCN(0.2%) is steep, and column densities drop to <50% a few hundred kilometers away from the coasts. While the spatial distribution of CCN at 0.2% supersaturation is closer to that of MODIS proxy, as opposed to 1.0% supersaturation, the overall column integrated CCN are too low. Still, we can compare the relative response of CCN to emission and meteorological variability. Most evident pattern of high temporal correlation is found over North Atlantic ocean, extending throughout Europe and up to Gulf of Mexico. All of these regions show a generally decreasing trend throughout the decade in control simulations and MODIS CCN, and the simulations including the emission trends clearly improve the simulations with climatological emissions. In regions where the observed intra-annual cycle correlates well with sea-spray emissions, the long-term annual correlation usually remains poor. This could indicate that the model is unable to capture the natural variability in marine aerosol emissions.