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Investigations of BVOC-SOA-cloud-climate feedbacks via interactive biogenic emissions using NorESM

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Climate feedbacks represent a large source of uncertainty in future climate projections. One such feedback involves a change in emissions of biogenic volatile organic compounds (BVOCs) under global warming and a subsequent change in cloud radiative effects. Parts of the atmospheric BVOCs will oxidize in the atmosphere, which may reduce their volatility enough to form secondary organic aerosols (SOA). A changed SOA load will affect cloud radiative properties through aerosol-cloud interactions (ACI) and therefore act to reduce or enhance the temperature change resulting from greenhouse gases alone. In order to study this effect, a development version of the Norwegian Earth System Model (NorESM) has been extended to include explicit atmospheric particle nucleation and a treatment of SOA based on work by Risto Makkonen and collaborators. Biogenic sources of monoterpene and isoprene are interactively calculated by the Model of Emissions of Gases and Aerosols from Nature (MEGAN), version 2.1, incorporated into the Community Land Model, version 4.5. Monoterpene and isoprene are oxidized by O_3, OH and NO_3 to form SOA with a yield of 15 % and 5 % respectively. It is assumed that 50 % of the product from monoterpene ozonolysis is of low enough volatility to nucleate new particles. The remaining oxidized BVOCs condensate onto preexisting particles. The model improvements include three new tracers to account for both SOA and the BVOCs. This allows for transport of both SOA and precursor gases, making it possible for SOA to form above the surface layer of the model. The new SOA treatment also changes the size distribution of most model aerosols due to condensation.
Preliminary results from 6-year simulations with prescribed sea surface temperatures show that the present day emissions of both isoprene (435.9 Tg/yr) and monoterpenes (121.4 Tg/yr) are within the range found in other studies. The resulting SOA production is on the order of 77 Tg/yr, also within the range found by others, but on the high side. The global annual atmospheric burden of SOA is on the order of 1.0 Tg. A fraction of 4.5% of the produced SOA is nucleated into particles, while the remainder forms condensate. In the current set-up, emissions of both monoterpene and isoprene are slightly higher pre-industrially than in present day, which seems to be due to large land use changes. In regions of small land use changes, the change in 2 m air temperature dominates, with high air temperatures corresponding to high BVOC emissions. An estimate will be made of the change in cloud radiative properties from pre-industrial times to present caused by the change in BVOC emissions and resulting change in SOA burden.