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Estimating the compensation strength of coniferous forests for climate change

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Since several years it is been realised that our climate conditions are changing. Scenarios to approximate future conditions as realistic as possible have been constructed and projections for different areas on Earths have been made. However, several complex processes such as aerosols and feedback cycles are not fully understood. One of those feedback cycles is the interactions between different vegetation types and the atmosphere. Each vegetation type has its climate optimum conditions. Changing those a new distribution of plants and trees has to follow or the ecosystem has to adapt. This is usually a lengthy process but critical for coniferous forests such as in boreal regions. Especially the question how much of the changing climate conditions can be compensated by the forest on a shorter time scale. Spracklen et al. (2008) explained that the forest takes up carbon dioxide and increases its leaf area index, thus biomass at future conditions. This will decrease its surface albedo. Compared to a surface without forest the albedo effect was estimated to be +2.3 W m^{-2} for current cnditions. On the contrary the forest emits notable amounts of volatile organic compounds (VOCs) under stress conditions that significantly take part in atmospheric new particle formation. These new particles grow and result nowadays in a doubling of the cloud condensation number (CCN) over Scandinavia leading to a energy reduction by about -2.9 W m^{-2}, thus a net cooling of -0.6 W m^{-2} (-0.3 °C) was estimated. This study focusses on the increase of the cooling (compensating) effect at future conditions with elevated temperature conditions. Therefore, we defined four nucleation parameters including the effect of ozone and water vapour on new particle formation as well as the global radiation as a proxy for OH related compounds. In doing so we found a good agreement with field observations for the nucleation parameter which included all effects. Hence, we apply this parameter for expected future conditions. Interestingly if the mean climate is warming by two degrees, the increase in ozone mixing ratio is about as strong as the water vapour mixing ratio at the same relative humidity. Thus both effects cancel each other. Solar radiation is not to be expected to change significantly. Only the terpene emission as precursor for atmospheric particle mass and maybe nucleation remains unbalanced. The emission is known to increase for the most important VOC of coniferous forest by 9% for each temperature increase by one degree. This results in ca. 20% for a mean temperature increase assumed for global change. However, the value is expected to be remarkably larger for boreal regions. If we apply 20% increase in new formed particle number and take into account the reduction during the growth process until the particles reach 50 nm in diameter (ca. +16%), where they can act as CCN, we can approximate the effect of an increase on the indirect (and direct) aerosol radiation effect. Doing so, an additional reduction of 1 W m^{-2} was calculated. With a simple rule of proportion one can calculate an additional cooling of 0.5 °C. This is actually about a quarter of the actual change at a doubling of carbon dioxide. Thus the forest seems to be able to compensate only about 25% of the expected temperature changes and might reach a critical value within this century in notable areas.