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Dynamical vegetation-atmosphere modelling of the boreal zone

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Vegetation interacts with climate on seasonal to inter-annual time scales through albedo, roughness, evapotranspiration, CO_2 sequestration and by influencing snow accumulation and ablation. The Scandinavian mountains and high latitudes is a hot spot for land-atmosphere feedback, as the future's increased winter minimum temperature supports a boreal tree line advance, lowering the surface albedo. The northern ecosystem is dominated by mires, boreal forests and alpine heaths, in addition to agricultural land. Model studies have shown that vegetation-climate feedbacks are strong enough to lead to regime shifts in vegetation and local climate in boreal regions. Biogeophysical factors, such as albedo, the Bowen ratio, and surface roughness, are all involved in these feedbacks, and they are also altered by land use change such as reforestation.

For calculations of the dynamical coupling between the atmosphere and the vegetation we have used the Earth System Model NorESM, which includes several advanced features in its land surface model (CLM4.5), such as the inclusion of the radiative forcing due to black carbon and dust deposit onto snow, improved representation of fire, permafrost and its hydrological impact, a new snow cover fraction parameterization reflecting the hysteresis in fractional snow cover for a given snow depth between accumulation and melt phases, as well as dynamic vegetation coupled with carbon-nitrogen cycles. These new features improve the representation of surface albedo feedback in Arctic. We have performed experiments with coupled as well fixed ocean for the current as a quadrupled atmospheric CO_2 situation. This model configuration is used to study changes in vegetation in a high end radiative forcing case. It is contrasted with an experiment where vegetation dynamics is neglected. Changes in the features of the vegetation along with surface fluxes, albedo and atmospheric temperatures are analysed, with main emphasis on the boreal zone. In particular we have addressed the cold bias which is typical for climate models in parts of the Arctic and which we have found to be strengthened as a result of the dynamic vegetation coupling.