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Improving the modeling of the seasonal carbon cycle of the boreal forest with chlorophyll fluorescence measurements

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The boreal ecosystems are characterized a very strong seasonal cycle and they are very sensitive to the climatic variables. The vegetation's deep wintertime dormancy requires a long recovery time during spring before the plants reach their full photosynthetic capacity. During this recovery time the plants are highly susceptible the night frosts. The transition period is different during spring and autumn for the evergreen plants. During spring there is plenty of light, but cold air temperatures inhibit the photosynthesis. The plants therefore experience to high stress levels, as they need to protect their photosynthetic apparatus from intense light. In autumn the air temperature and light level decrease more concurrently. To have a realistic presentation of the carbon cycle in boreal forests it is important to have these characteristics properly modeled, so that also the implications of changing seasonality under climate change can be more reliably predicted.

In this study, we focus on the CO_2 exchange of a Scots pine forest Sodankylä located in Finnish Lapland, 100 km north from the Arctic Circle. Micrometeorological flux measurements provide information about the exchanges of carbon, energy and water between atmosphere and vegetation. To complement these fluxes, we use dark-adapted chlorophyll fluorescence (CF) measurements, which is an optical measurement and tracks the development of the photosynthetic capacity. These two approaches combined together are very useful when we want to improve the modeling of the forest's CO_2 exchange.

We used two models that describe the photosynthesis with the biochemical model of Farquhar et al. The FMI-CANOPY is a canopy level model that is feasible to use in parameter estimation. We used the CF measurements of Fv/Fm, that is a measure of the maximum photosynthetic capacity, to include a seasonal development in the base rate of the maximum carboxylation rate (Vc(max)) in FMI-CANOPY. The simulation results matched the observations better after this modification.

We chose the S index from Mäkelä et al. to describe the development of photosynthesis in evergreen plants throughout the year, and applied this approach to represent the development of the Fv/Fm ratio in the JSBACH model, which is a comprehensive land-surface scheme that can be applied at global, regional and sites scales. With the inclusion of this representation into JSBACH, we were able to assess the influence of the seasonality of photosynthesis on the regional carbon balance estimates. The dark-adapted fluorescence measurement can further be explored as a possible way to parameterize the seasonal development into a CF model that has been implemented into JSBACH.