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Does atmospheric CO_2 explain increased carbon sink at a boreal coniferous forest flux site?

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The long-term eddy-covariance measurements (1997 – 2017) at a boreal coniferous forest in Hyytiälä, Southern Finland, indicate significant increase of annual ecosystem CO_2 sink. During this period, the annual CO_2 sink has increased by about 6.2 g C / m2 per year. This increase is dominated by enhanced gross-primary productivity (GPP, +10.5 g C / m2 per year), which is only partly compensated for by increased ecosystem respiration (+4.3 g C / m2 per year). Measured atmospheric CO_2 concentration has risen from 360 ppm to 410 pm during the 20 year period, prompting a question as to how much of the increased CO_2 sink is due to CO_2 fertilization and other climatic factors. Theoretical arguments, process-model runs, and experiments are combined to show that the increased CO_2 concentration can lead to increased photosynthesis and reduced transpiration if no photosynthetic downregulation occurs. What was observed during the same period was an increase instead of a decrease in annual evapotranspiration (ET, from $\sim$300 mm/ year to $\sim$380 mm / year).

Our scientific questions are then as follows: How much of the increased GPP is attributed to the CO_2 fertilization and changes in other climatic factors? To which degree can the changes in stand structure, leaf area index or flux footprint explain the observed trends in net ecosystem exchange (i.e. GPP and ET)?

To answer the aforementioned questions, we: 1) quantify the long-term changes of annual and growing season CO_2 balance, GPP and ET, as well as trends in ecosystem light use efficiency and water use efficiency, and 2) determine the effect of increasing atmospheric CO_2 concentration, growing season length and changes in stand structure and species composition using a multi-layer canopy gas-exchange model. The model can propagate changes in ecosystem structure and climatic forcing into ecosystem-atmosphere fluxes and resulting carbon and water budgets, and provides viable explanations for observed trends.