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The full annual carbon balance of Eurasian boreal forests is highly sensitive to precipitation

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Boreal forest biomes are identified as one of the major sinks for anthropogenic atmospheric CO_2 and are also predicted to be particularly sensitive to climate change. Recent advances in understanding the carbon balance of these biomes stems mainly from eddy-covariance measurements of the net ecosystem exchange (NEE). However, NEE includes only the vertical CO_2 exchange driven by photosynthesis and ecosystem respiration. A full net ecosystem carbon balance (NECB) also requires inclusion of lateral carbon export (LCE) through catchment discharge. Currently LCE is often regarded as negligible for the NECB of boreal forest ecosystems of the northern hemisphere, commonly corresponding to $\sim$5% of annual NEE.

Here we use long term (13 year) data showing that annual LCE and NEE are strongly correlated ($p=0.003$); years with low C sequestration by the forest coincide with years when lateral C loss is high. The fraction of NEE lost annually through LCE varied markedly from <3% to ca. 25%. Deviation in annual precipitation from the 28-year average (1980-2008) explained 90% of the variation observed in the fraction of C lost annually by LCE. The relationship suggests that an increase in annual precipitation of 10-20% in the boreal region would approximately double the fraction of NEE lost annually from the terrestrial system to surface waters.

The correlation between NEE and LCE arises because the annual precipitation is correlated with both NEE ($p<0.004$) and LCE ($p<0.001$). Both these strong correlations contribute to an overall correlation between annual NECB and precipitation. The likely mechanism behind decreased NEE in response to increasing precipitation is a reduction in incoming solar radiation caused by clouds. The dual effect of precipitation implies that both the observed and the predicted increases in annual precipitation at high latitudes may reduce NECB in boreal forest ecosystems. Based on regional scaling of hydrological discharge and observed spatio-temporal variations in forest NEE we conclude that our finding is relevant for large areas of the boreal Eurasian landscape.