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Upscaling terrestrial CO_2 fluxes across high-latitude regions with statistical modeling

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Climate warming is changing the high-latitude carbon dioxide (CO_2) balance, but predicting future changes is difficult as the spatial and temporal variation of the contemporary CO_2 balance is not fully understood. Previous Arctic syntheses have focused on changes in CO_2 balance in time, but the spatial distribution of CO_2 sources and sinks has received less attention. This synthesis aims to upscale CO_2 fluxes at 1-kilometer resolution in order to identify hot spots of CO_2 fluxes at high resolution and to estimate the balance of the entire pan-Arctic area. We gathered published Eddy covariance and chamber studies with annual and summer CO_2 flux budgets (net ecosystem exchange, gross primary production, ecosystem respiration) from high-latitude tundra and boreal biomes (number of sites=139). We used an ensemble of multiple statistical models and predicted summer and annual budgets for 1990-2015 with a set of climatic, vegetation, topographic and soil predictors with a reasonable good cross-validated predictive power. However, the uncertainty varied across modeling methods with machine learning methods outperforming linear regression methods. The high-latitude region was a CO_2 sink of -846 +- 79 Tg/C/yr with the tundra biome being a small sink (-55 +- 92 Tg/C/yr) and the boreal biome a strong CO_2 sink (-791 +- 73 Tg/C/yr). Northern Alaska, northern mainland Canada and northwestern Siberia were the largest CO_2 sources. Additionally, we show large spatial heterogeneity of CO_2 fluxes even within a few kilometers. These new data-driven upscaled estimates of the CO_2 balance show that the sink of the high-latitude region is approximately 27 % of the global terrestrial CO_2 sink, thus highlighting the region's importance for the global carbon cycle.