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Reducing uncertainty in model estimates of high-latitude net ecosystem exchange by incorporating remote sensing observations of snow cover area

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Recent high-latitude studies have indicated that the seasonal timing of initial snow accumulation and final snow melt each year substantially influence net ecosystem exchange (NEE). Previous terrestrial biogeochemical models have either not simulated the influence of snow season processes on NEE, or have used process-based estimates of snow depth or subnivean temperature to estimate snow season NEE. As predictions indicate that the northern carbon balance is likely to be altered by cumulative and interconnected changes in Arctic air temperature, precipitation, and snowpack dynamics, uncertainty in estimates of NEE may be reduced by incorporating independent remote sensing observations of fractional snow cover into terrestrial biogeochemical models.

The objective of this study was to examine whether uncertainty in Vegetation Photosynthesis and Respiration Model (VPRM) estimates of North American NEE north of 55°N could be reduced by using remote sensing observations to explicitly represent the influence of fractional snow cover on NEE. VPRM is a biospheric carbon flux model that generates high resolution estimates of NEE from remote sensing observations of air temperature, shortwave radiation and the normalized difference vegetation index (NDVI). In the standard VPRM ($VPRM_0$) formulation, photosynthesis is limited during the cold season by low air temperatures, diminished shortwave radiation and low NDVI values, and respiration is assumed to be constant below a threshold air temperature. Conversely, in the new $VRPM_{snow}$ formulation, moderate resolution imaging spectroradiometer (MODIS) observations of fractional snow cover are used to simulate the effects snow has on suppressing photosynthetic uptake by vegetation and decoupling soil and air temperatures. Therefore, when MODIS observations indicate that snow is present at a location, the rate of photosynthetic uptake by vegetation is diminished as a function of the fractional snow cover area, and when a region is deemed to be snow-covered, the rate of soil respiration is estimated as a linear function of soil temperature.

Uncertainty in $VPRM_0$ and $VPRM_{snow}$ estimates of daily average NEE was assessed by calculating model mean absolute error (MAE) and root mean squared error (RMSE) according to raw observations of NEE collected at high-latitude sites using the eddy covariance technique. When comparing estimates of daily average NEE over the portion of the year when snow was present, $VPRM_{snow}$ showed diminished error values (mean RMSE=0.9μmol/m^2/s and mean MAE=0.2μmol/m^2/s) across all paired calibration and validation sites relative to $VPRM_0$ (mean RMSE=1.2μmol/m^2/s and mean MAE=0.5μmol/m^2/s). Further analysis consisted of assessing systematic and random errors in $VPRM_0$ and $VPRM_{snow}$ estimates of NEE according to eddy covariance observations from Alaskan AmeriFlux sites. Systematic errors were then attributed to model parameters and remote sensing inputs. Results indicated excellent agreement between local observations of snow onset/melt relative to Landsat and MODIS observations of fractional snow cover, and showed that assimilating MODIS observations of fractional snow cover reduced uncertainty in model estimates of high-latitude NEE.