Recent climate and fire disturbance impacts on boreal and arctic ecosystem productivity estimated using a satellite-based terrestrial carbon flux model

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Abstract

Continued warming and changing fire regimes in the northern (≥ 45 °N) latitudes have consequences for land-atmosphere carbon feedbacks to the climate system. A satellite-based terrestrial carbon flux model integrating NDVI and burned area records, and global reanalysis data was used to quantify vegetation gross primary productivity (GPP) and net ecosystem CO₂ exchange (NEE) across a pan-boreal/Arctic domain, and their sensitivity to climate variability, drought and fire disturbances from 2000 to 2010. Model validation against regional tower eddy-covariance measurements showed favorable results for GPP (n=47, R≥0.7, RMSE<2.5 g C m⁻² d⁻¹), and overall consistency for NEE (n=22, R>0.5) at predominantly undisturbed sites. The model fire disturbance simulations largely tracked NEE recovery indicated by tower CO₂ flux measurements from three boreal fire chronosequence networks. The simulations indicated a generally positive regional productivity response to warming, except for Eurasian boreal forests,
which showed warmer and drier growing seasons, and greater drought sensitivity relative to other northern land areas. The NEE response to regional climate variability and fire disturbance was mitigated by compensating changes in GPP and respiration though net ecosystem carbon losses were generally observed in areas with severe drought or burning. Drought and temperature variations also had larger regional impacts on boreal GPP and NEE than fire disturbance during the study period, though fire disturbances were heterogeneous, with larger impacts on carbon fluxes for some areas and years. These results are being used to inform development of an operational level 4 carbon (L4_C) product for the NASA Soil Moisture Active Passive (SMAP) mission.

**Popular Summary**

Continued warming and changing fire regimes in the northern (≥45°N) latitudes have consequences for land-atmosphere carbon feedbacks to the climate system. The authors used a terrestrial carbon flux model that integrates satellite information with information from a numerical model of Earth system processes to quantify the carbon fluxes from vegetation growth and senescence and from soil respiration. The net carbon flux between the land surface and the atmosphere (that is, the net ecosystem carbon dioxide exchange, or NEE) over northern latitudes and its sensitivity to climate variability, drought and fire disturbances from 2000 to 2010 was investigated. The carbon flux estimates were validated against measurements from tower-based instruments. The validation showed favorable results and overall consistency for NEE at predominantly undisturbed sites. The model fire disturbance simulations also largely tracked the NEE recovery that was indicated by tower carbon dioxide flux measurements.

The simulations indicated that vegetation uptake of carbon generally increases in response to warming, except for Eurasian boreal forests, which showed warmer and drier growing seasons, and greater drought sensitivity relative to other northern land areas. The NEE response to regional climate variability and fire disturbance was mitigated by compensating changes in vegetation uptake and respiration of carbon, although net ecosystem carbon losses were generally observed in areas with severe drought or burning. These results inform the development of an operational terrestrial carbon flux data product in the context of the NASA Soil Moisture Active Passive (SMAP) mission.