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Interannual Variability in Net Ecosystem Exchange in United States Great Plains Grasslands

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The grasslands in the United States Great Plains occupy about 1.5 million km2 and span considerable moisture and temperature gradients. The grasslands are characterized by different photosynthetic pathways, from C3 dominance in the north to C4 dominance in the south. The contributions of grasslands to local and regional carbon budgets remain uncertain due to the lack of carbon flux data for these extensive and diverse grassland ecosystems and local variances in climate variability, land use changes, and varying land management practices. There are limited studies on the seasonal, spatial, and interannual variabilities in carbon exchange as well as responses to climatic change across the Great Plains. Our objective was to quantify how the grassland ecosystems will respond to climate under a variety of environmental conditions.

Net ecosystem exchange (NEE) was measured at 15 flux towers distributed throughout the Great Plains. These sites represent the wide spatial, ecological, and climatological ranges of grasslands found in this region. We developed a remote sensing-based piecewise regression (PWR) model to estimate grassland carbon fluxes from 2000 to 2008 using flux-tower data and remotely sensed data (250-m resolution) input at 7-day intervals. The model integrated MODIS-derived vegetation indices, weather data, and phenological parameters with the observed NEE data. The correlation coefficient (r) for the independent tests between tower-measured NEE and PWR-estimated NEE were 0.61 to 0.98 for the individual tower sites withheld and 0.81 to 0.92 for the individual years withheld. We mapped 7-day interval NEE at 250-m resolution for the years 2000 to 2008 and evaluated the interannual variability of NEE and its response to climatic variation. NEE varied in space and time across the 9 years (from 0.3 in 2002 to 47.7 g C • m–2 • yr–1 in 2005) with an average annual NEE of 24 $\pm$ 14 g C • m$-$2 • yr$-$1 and a cumulative flux of 214 g C • m$-$2. On average, the entire Great Plains grassland region was a carbon sink during the 9 years. However, three ecoregions were sources for carbon because of frequent droughts during 2000–2009 with a cumulative flux of -10 g C • m$-$2 for the Northwestern Great Plains, -438 g C • m$-$2 for the Western High Plains, and -696 g C • m$-$2 for the Southwestern Tablelands. NEE exhibited large spatial variation in the drier west (carbon sources) and in the wetter east (carbon sinks). In addition, large temporal variations in annual NEE were observed over the Great Plains during the 9 year period, especially in the western and southern portion of the region. These results suggest that Great Plains grassland ecosystems are potentially large carbon sinks but may turn to carbon sources during drought periods or upon conversion to agriculture.