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Investigating land-atmosphere coupling and convective triggering associated with the moistening of the northern North American Great Plains

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Parts of the North American northern Great Plains have undergone a 6 W m^{-2} decrease in summertime radiative forcing. At the same time agricultural practices have shifted from keeping fields fallow during the summer ("summer fallow") towards no-till cropping systems that increase summertime evapotranspiration and decrease soil carbon loss. MERRA (Modern-Era Retrospective analysis for Research and Applications) for the area near Fort Peck, Montana, (a FLUXNET site established in 2000) shows a decrease of summertime (June-August) sensible heat fluxes ranging from -3.6 to -8.5 W m^{-2} decade^{-1}, which is associated with an increase of latent heat fluxes of similar magnitude (5.2–9.1 W m^{-2} decade^{-1}). While net radiation changed little, increasing downward longwave radiation (2.2–4.6 W m^{-2} decade^{-1}) due to greater cloud cover, was mostly compensated by reduced solar irradiance. The result was a strong decrease of summer Bowen ratios from 1.5–2 in 1980 to approximately 1–1.25 in 2015. At the same time, atmospheric soundings have shown significant increases in both convective available convective energy (CAPE) and convective inhibition (CIN) for the same time span. Overall, these findings are consistent with the effects on increased summertime evapotranspiration due to reduction in summer fallow that should lead to smaller Bowen ratios and a larger build-up of moist static energy as expressed in higher values of CAPE. In order to further investigate the impact of the surface energy balance and flux partitioning on convective development and local land-atmosphere coupling in the North American prairies, a 1-dimensional mixed-layer model is used to compare the evolution of mixed-layer heights to the lifted condensation level, a necessary but not sufficient condition for the occurrence of convective precipitation. Using summertime eddy covariance data from Fort Peck and atmospheric soundings from the nearby Glasgow airport, we establish that the mixed-layer model adequately captures mixed-layer heights and timing of locally triggered convection at the site. The model is then used to quantify the sensitivity of mixing-layer height, CAPE and convective triggering potential, in response to changes in surface flux partitioning between latent and sensible heat due to changes in soil moisture and agricultural management. Results are used to establish the exact nature or land-atmosphere coupling associated with moistening of the atmospheric boundary-layer and increases in convective triggering and will contribute to disentangling local and regional effects on trends in observed precipitation in the northern Great Plains.