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A data assimilation framework for constraining upscaled cropland carbon flux seasonality with MODIS

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Agroecosystem models are strongly dependent on information on land management patterns for regional applications. Land management practices play a major role in determining global yield variability, and add an anthropogenic signal to the observed seasonality of atmospheric CO_2 concentrations. However, there is still little knowledge on spatial and temporal variability of important farmland activities such as crop sowing dates, cultivar selection, and fertilisation application, and thus these remain rather crudely approximated within carbon (C) cycle studies.

In this study, we present a data assimilation framework allowing for spatiotemporally resolved simulation of cropland C fluxes under observational constraints on sowing dates and canopy greenness. MODIS 250 m vegetation index data were assimilated both variationally (for sowing date estimation) and sequentially (for improved model state estimation, using the EnKF) into a crop C mass balance model (SPAc). In doing so, we are able to accurately quantify the multiannual (2000–2006) regional C flux seasonality of maize-soybean crop rotations surrounding the Bondville (IL, US) Ameriflux EC site, averaged over 104 pixel locations within the wider area (32 km $\times$ 25 km).

We find that MODIS-derived sowing dates allow for highly accurate simulations of growing season C cycling at locations for which ground-truth sowing dates are not available. Resulting simulations provide an envelope on upscaled cropland phenology, with significant deviations from plot-scale observations at Bondville: study area average growing season length is $\sim$20 days longer than observed, primarily because of an earlier estimated start of season. Relative spatial variability of net ecosystem exchange (NEE) of C ranges from $\sim$7% to $\sim$10%, but variability in net biome productivity is considerably larger ($\sim$24% to $\sim$32%). Differences between Bondville and upscaled NEE are especially large in years with non-optimal weather conditions for sowing. This shows that regional patterns of land management are important drivers of agricultural C cycling and major sources of uncertainty if not properly accounted for. Our framework enables modellers to accurately simulate current (i.e. last 10 years) C cycling of major agricultural regions with sufficient individual field patch sizes. DA methodology applied in this study can help to isolate an anthropogenic signal from natural variability in atmospheric CO_2 concentration time series.