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Large-scale droughts responsible for dramatic reductions of terrestrial net carbon uptake over North America in 2011 and 2012

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Recently, severe droughts occurred in North America that have brought strong reductions in the terrestrial carbon sink capacity. However, these perturbations of the terrestrial carbon sink have not been well quantified. Here, we assess the response of terrestrial carbon fluxes to droughts in North America in 2011 and 2012. In both years, strong summer droughts hit North America, but with contrasting, unusually cold (2011) and warm (2012) spring conditions that preceded summer droughts. These meteorological differences offer an opportunity for a comparative analysis of spring-summer carbon cycle dynamics, which we hypothesized might lead to different carbon cycle responses. The analysis is based on a comprehensive ensemble of data-driven and process-oriented carbon cycle models (FLUXCOM, 6 models from the TRENDY project, SiBCASA, and two atmospheric inversions, i.e. CarbonTracker Europe 2016 and CarbonTracker 2016) and emerging Earth observations (GLEAM root-zone soil moisture, GRACE terrestrial total water storage, GOME-2 solar-induced fluorescence and MODIS enhanced vegetation index).

Our study indicates that the strongest reductions of net ecosystem production (NEP) in 2011 (-0.20 $\pm$ 0.17 PgC/yr; -0.24 $\pm$ 0.17 PgC/yr, if excluding two atmospheric inversions) and 2012 (-0.16 $\pm$ 0.23 PgC/yr; -0.17 $\pm$ 0.25 PgC/yr, if excluding two atmospheric inversions) relative to the baseline 2008–2010 are attributable to decreased gross primary production (GPP; -0.17 PgC/yr) and synchronously increased ecosystem respiration (Reco; +0.07 PgC/yr) caused by a summer drought in 2011 and to a larger increase of Reco (+0.48 PgC/yr) than GPP (+0.31 PgC/yr) induced by an extra warmer spring in 2012, respectively. The warming spring compensated largely the negative carbon anomaly but also enhanced the summer drought in 2012. We further identified two ecoregions Crops/Agriculture and the Grass/Shrubs in the temperate area that are the largest contributions to these reductions and also dominate the inter-annual variations of NEP in North America during the study period. Compensation of drought-induced carbon uptake reductions due to warm spring thus occurs only in some specific ecoregions. Overall, our analysis offers a refined view on recent carbon cycle variability and extremes in North America. It corroborates earlier results, for instance related to spring-summer compensatory carbon cycle dynamics, but also highlights differences with respect to ecoregion-specific carbon cycle responses to drought and heat.