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How much can atmospheric data tell us about the North American land sink?

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Global terrestrial vegetation plays a critical role in climate projections which highly depends on its response to rising CO_2 concentrations (e.g. fertilization effect), land use change, and climate change. The global terrestrial sink has kept pace with fossil fuel emissions showing an amazing resiliency to offset continuous growth in anthropogenic CO_2 emissions. As part of the northern mid-latitudes, North American ecosystems are assumed to play a major role globally while emissions from fossil fuel consumption and land use change reach unprecedented levels. Both bottom-up and top-down approaches have been used to constrain terrestrial carbon budgets, but uncertainties remain too large to characterize the drivers of the North American carbon sink. The mechanisms driving the long-term trend in carbon uptake remain highly uncertain, limiting our ability to implement successful national-scale climate mitigation policies.

Here we have used a newly-developed ensemble-based mesoscale modeling system to objectively quantify the uncertainties from fluxes, transport, fossil fuel, and boundary conditions on simulated atmospheric CO_2 concentrations. We demonstrate that large uncertainties in seasonal CO_2 fluxes from terrestrial vegetation models can be evaluated, relative to uncertainty in atmospheric transport, using atmospheric data over North America. Despite errors arising from the boundary conditions, transport models, and fossil fuel emissions, atmospheric data sheds light on the severe under-sampling of biogenic flux uncertainties at various time scales. Our results demonstrate the potential from regional atmospheric modeling systems to improve the phenology and climate response of the terrestrial biosphere to climate anomalies and in turn provide more accurate estimates of carbon sinks at national to continental scales. The incorporation of atmospheric measurements in regional atmospheric systems has the potential to provide an independent assessment of annual changes in nationally reported carbon stocks.