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CarbonTracker-Lagrange: A model-data assimilation system for North American carbon flux estimates

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Understanding the regional carbon fluxes is of great importance for climate-related studies. To derive these carbon fluxes, atmospheric inverse modeling methods are often used. Different from global inverse modeling, regional studies need to deal with lateral boundary conditions (BCs) at the outer atmospheric domain studied. Also, regional inverse modeling systems typically use a higher spatial resolution and can be more computation-intensive.

In this study, we implement a regional inverse modeling system for atmospheric CO_2 based on the CarbonTracker framework. We combine it with a high-resolution Lagrangian transport model, the Stochastic Time-Inverted Lagrangian Transport model driven by the Weather Forecast and Research meteorological fields (WRF-STILT). The new system uses independent information from aircraft CO_2 profiles to optimize lateral BCs, while simultaneously optimizing biosphere fluxes with near-surface CO_2 observations from tall towers. This Lagrangian transport model with precalculated footprints is computational more efficient than using an Eulerian model. We take SiBCASA biosphere model results as prior NEE from the terrestrial biosphere. Three different lateral BCs, derived from CarbonTracker North America mole fraction fields, CarbonTracker Europe mole fraction fields and an empirical BC from NOAA aircraft profiles, are employed to investigate the influence of BCs. To estimate the uncertainties of the optimized fluxes from the system and to determine the impacts of system setup on biosphere flux covariances, BC uncertainties and model-data mismatches, we tested various prior biosphere fluxes and BCs. To estimate the transport uncertainties, we also tested an alternative Lagrangian transport model Hybrid Single Particle Lagrangian Integrated Trajectory Model driven by the North American Mesoscale Forecast System meteorological fields (HYSPLIT-NAM12). Based on the above tests, we achieved an ensemble of inverse estimates from our system, and then compared this result with similar recent inversion results.

Our results suggest that: (1) The CarbonTracker-Lagrange system involving BC optimization makes mole fraction simulations more consistent with observations over all available sites, especially better fitting the aircraft sites; (2) This system is mostly insensitive to the choice of prior lateral BC products; (3) Our new Lagrangian inverse system (without continuous in-situ data) places the North American Carbon sink for the year 2010 at -0.43 to -0.69 PgC/yr, comparable to the TM5 based estimates of CarbonTracker North America (-0.41 PgC/yr) and CarbonTracker Europe (-0.62 PgC/yr). We conclude that CarbonTracker-Lagrange is a viable, credible, and efficient new tool to understand regional carbon fluxes from an atmospheric perspective.