EGU General Assembly 2023

EGU23-12424, updated on 05 Oct 2023
https://doi.org/10.5194/egusphere-egu23-12424
EGU General Assembly 2023

Constraining land surface CO_2 fluxes by ecosystem and atmospheric observations using atmospheric transport

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The growth rate of atmospheric CO_2 mole fractions can be measured with high accuracy, but there are still large uncertainties in our ability to separate anthropogenic and natural sources and sinks. One major source of uncertainty is the net flux of carbon from the biosphere to the atmosphere, or Net Ecosystem Exchange (NEE). There are two major approaches to quantifying NEE; top-down approaches that typically use atmospheric inversions, and bottom-up estimates using process-based or data-driven terrestrial biosphere models, upscaled to the regional or global scale. Both approaches have known limitations. A system that harmonizes these approaches, providing a high-quality estimate of the spatial distribution of NEE, and an accurate integral of NEE at regional and global scales, would improve our ability to model the full carbon budget. With other component fluxes, a harmonized product could help improve our monitoring of regional and national greenhouse gas budgets, and thus verify the trajectory towards CO_2 emission goals.

This study builds upon our previous work that connected the bottom-up eddy-covariance model to top-down estimates of regional NEE from atmospheric inversions using fixed regional linear operators. That work demonstrated that top-down estimates of atmospheric CO_2 provide an important additional constraint to a data-driven bottom up model. The use of top-down constraints improved the regional and global upscaling of NEE, leveraging the strengths of the two different approaches. However, the previous work had a simplified computational link between the top-down and bottom-up fluxes of NEE, and did not access the very large volume of atmospheric observations of atmospheric CO_2. Here, we replace the regional atmospheric inversion estimates of NEE with direct observations of the atmospheric mole fractions of CO_2. The fixed regional linear operators are replaced by estimating the near-field sources of an observation using an atmospheric transport model. For training, the bottom-up model is run for the source locations. We apply this technique to observations from to tropical, extra-tropical and boreal tall-tower sites over different meteorological conditions where we infer NEE from the observed atmospheric mole fraction, corrected for CO_2 background and non-biogenic CO_2 fluxes. This inference is combined in the objective function with tower-level inferences, and directly used to update the bottom-up model. The model can 'see' more varied inputs in the dynamic footprints, and the size of our pool of training data is increased. The new process improves our ability to accurately infer the regional and global distribution of NEE by directly learning across spatial scales, using diverse observations

of CO_2.