Quantifying US Fossil Fuel CO_2 Emissions Using Precise Measurements of ^{14}C in Atmospheric CO_2

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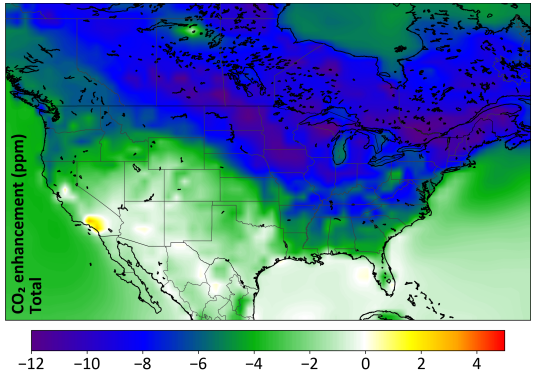
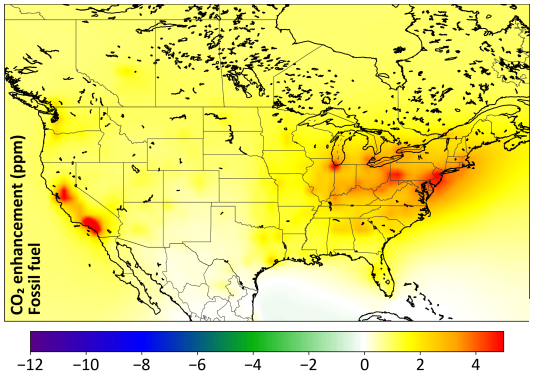
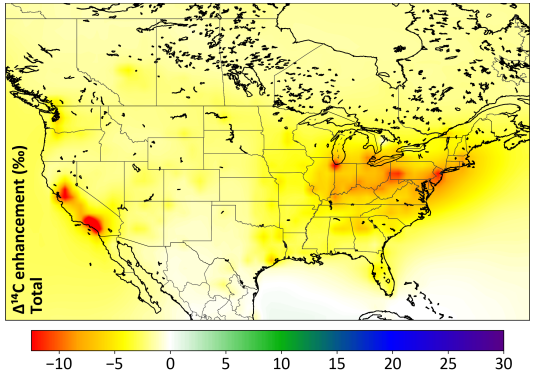
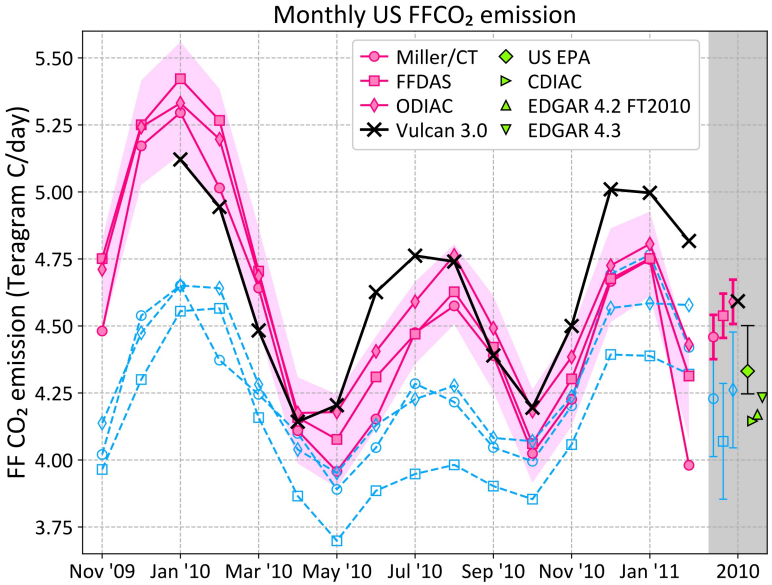




The current $\Delta^{14}CO_2$ measurement coverage in the US (~900 obs/year) allows us to estimate national monthly fossil CO_2 emissions to within ~5%, and national annual totals to within ~2%

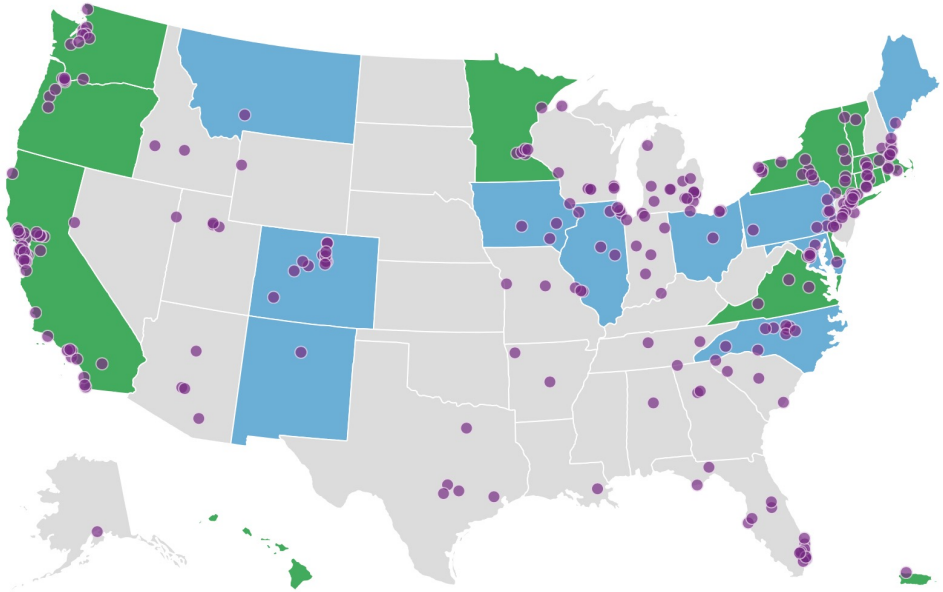


Continental boundary layer gradients of $\Delta^{14}CO_2$ are primarily determined by recent fossil CO_2 emissions, while gradients of CO_2 include biospheric signals



https://www.pnas.org/content/117/24/13300

Why Track Fossil CO_2 Emissions?



ALASKA, HAWAII, AND PUERTO RICO ARE NOT REPRESENTED TO SCALE.

Coalitions like the US Climate Alliance (left) and the Regional Greenhouse Gas Initiative (RGGI) remain committed to GHG reductions of the Paris Accord (or more). Independent regional emission estimation methods are needed to support these efforts.

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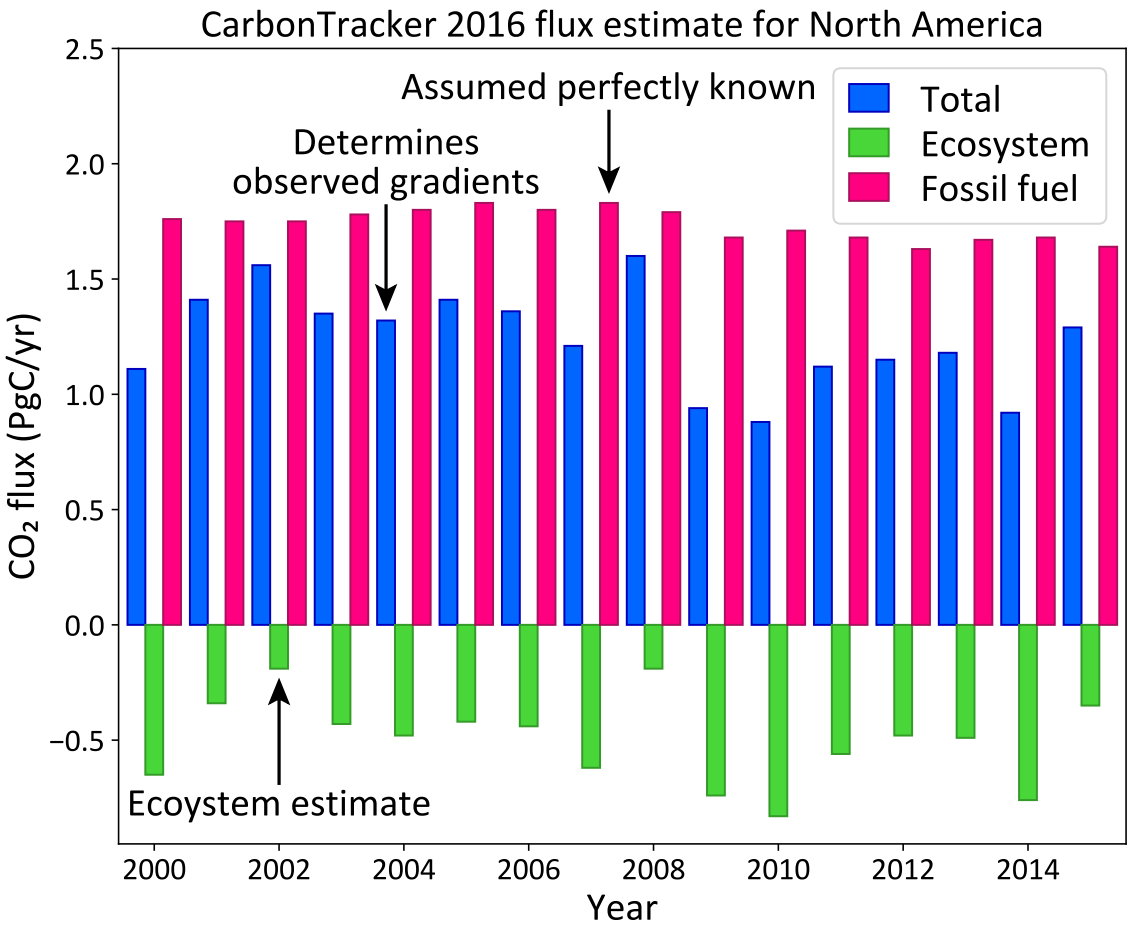
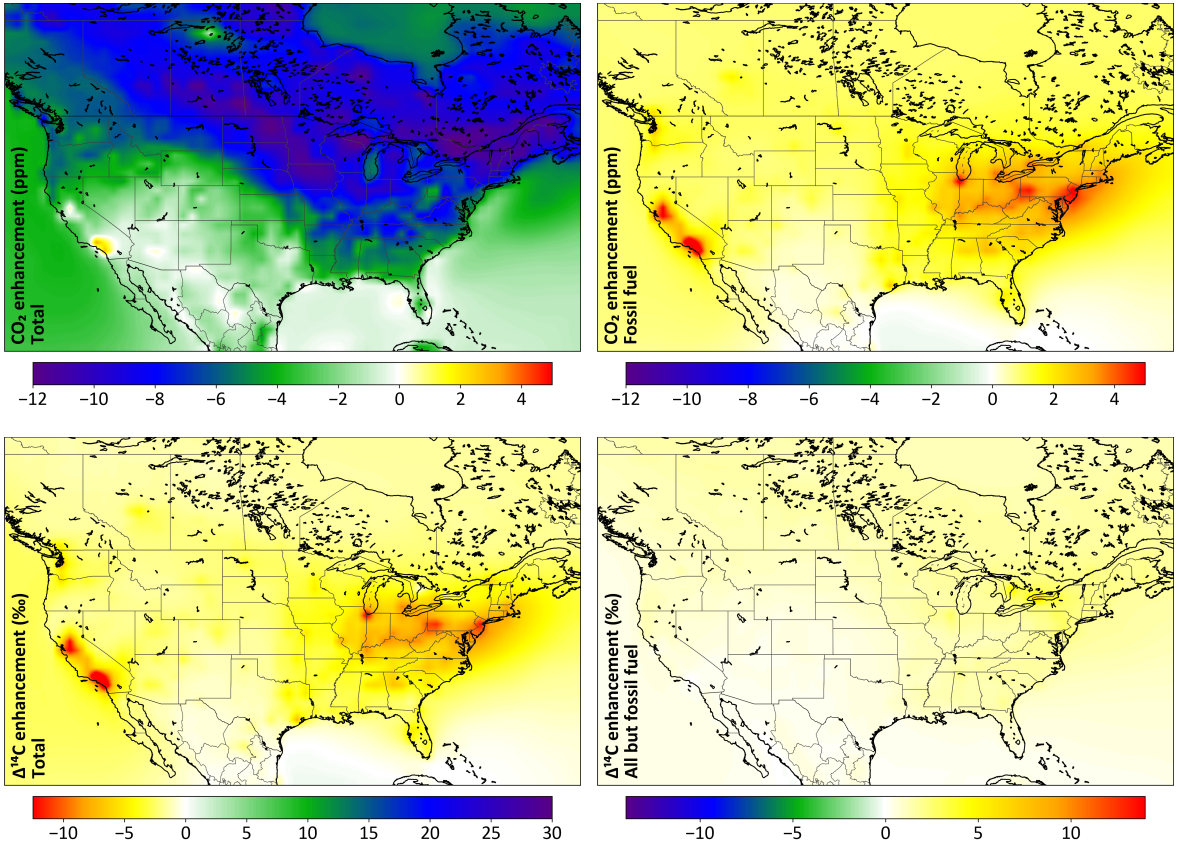


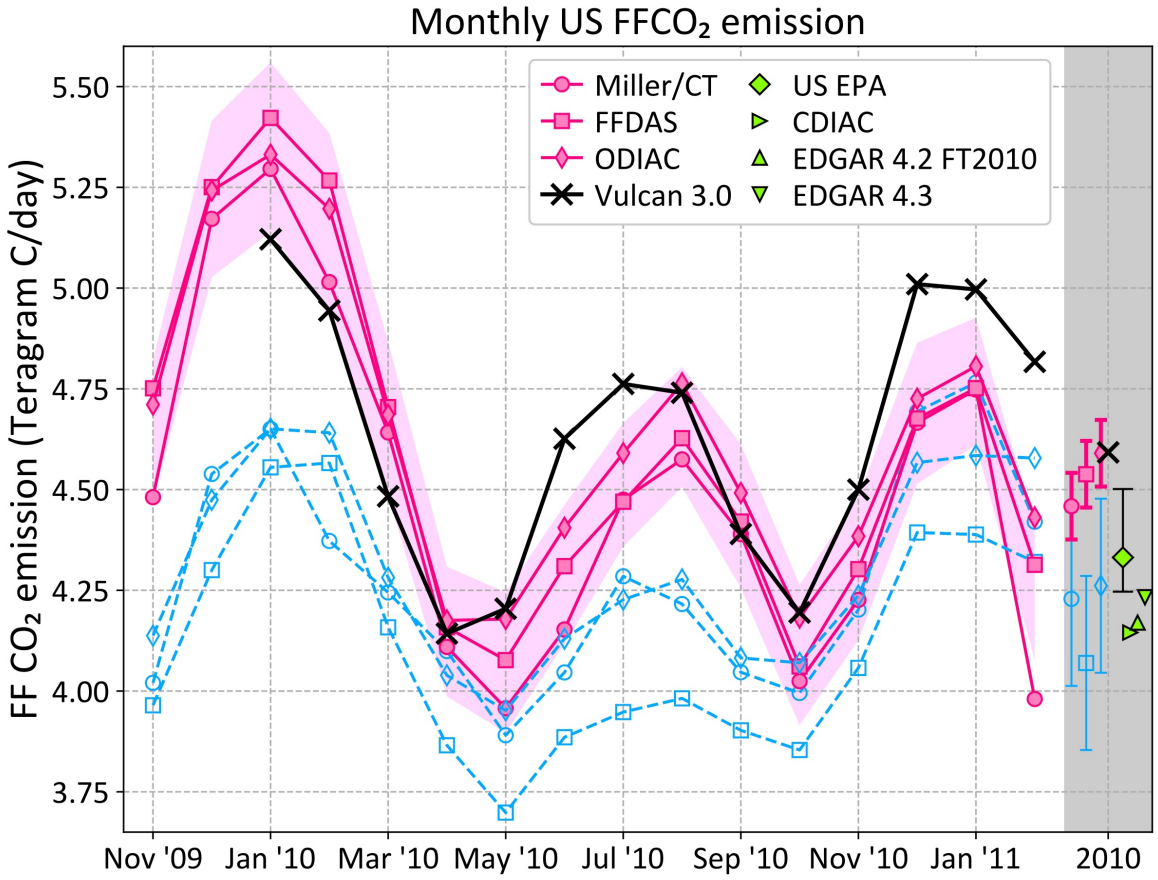
- We want to know the climate response of land ecosystems
- CO_2 flux inversions solve for NEE from observed atmospheric gradients of CO_2
- The fossil fuel contribution to those gradients is assumed to be perfectly known, which is not true at regional, sub-annual scales
- Errors in fossil CO_2 (especially seasonal) will lead to errors in NEE, impacting diagnosed NEE anomalies and the climate response

$\Delta^{14}CO_2$ is an Excellent Tracer of Fossil CO_2



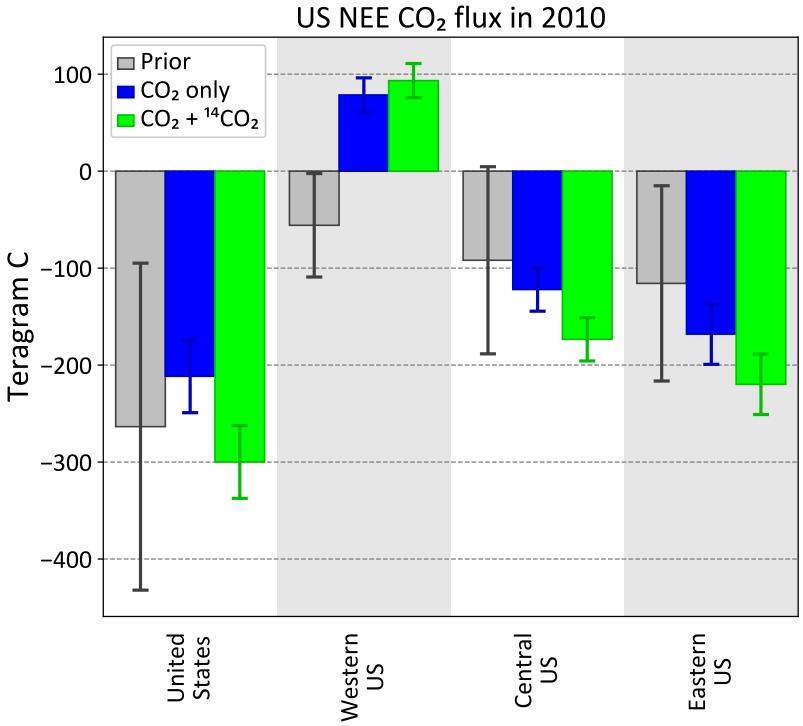
- Gradients of CO_2 over land, whether measured from space or from in situ samples, include the influence of fossil CO_2 emissions and a highly variable biosphere, even in winter
- Recently emitted fossil CO_2 is completely devoid of the radioisotope ^{14}C, and is the primary determinant of continental $\Delta^{14}CO_2$ gradients
- The tight correlation between fossil CO_2 and $\Delta^{14}CO_2$ allows us to construct an atmospheric inversion to derive the former by measuring the latter
- Non-fossil terms in the ^{14}C budget create a negligible gradient

Monthly Fossil CO_2 Fluxes



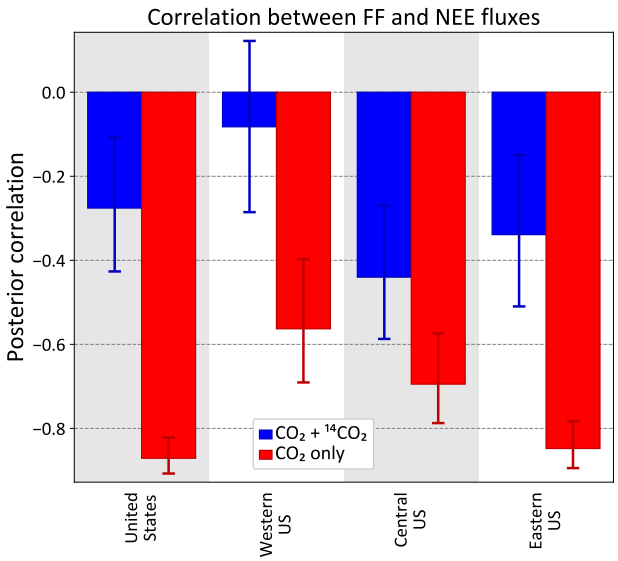
- Current $\Delta^{14}CO_2$ measurement coverage in the US (~900 obs/year) allows us to estimate national monthly fossil CO_2 emissions to within ~5%, and annual totals to within ~2%
- Our estimate is higher than all inventories (including US EPA) except for Vulcan, a US-specific emission data product
- The seasonality is not from the prior, we recover it even if the prior is aseasonal

Impact on NEE Estimate



The addition of $\Delta^{14}CO_2$ data decorrelates NEE and fossil CO_2, with the degree of decorrelation depending on the number of $\Delta^{14}C$ measurements and atmospheric circulation

Our results suggest that errors in the "perfectly known" fossil CO_2 in a CO_2-only inversions can lead to significant biases in the NEE. Since fossil CO_2 is less well-known sub-annually, seasonal errors are likely to be even larger.



The adjustment to US NEE is significant if fossil CO_2 is solved for instead of assumed perfectly known