Quantifying US Fossil Fuel CO₂ Emissions Using Precise Measurements of $^{14}$C in Atmospheric CO₂

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The current $\Delta^{14}$CO₂ measurement coverage in the US (~900 obs/year) allows us to estimate national monthly fossil CO₂ emissions to within ~5%, and national annual totals to within ~2%.

Continental boundary layer gradients of $\Delta^{14}$CO₂ are primarily determined by recent fossil CO₂ emissions, while gradients of CO₂ include biospheric signals.

https://www.pnas.org/content/117/24/13300
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.
Why Track Fossil CO₂ Emissions?

• We want to know the climate response of land ecosystems

• CO₂ flux inversions solve for NEE from observed atmospheric gradients of CO₂

• 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 CO₂ (especially seasonal) will lead to errors in NEE, impacting diagnosed NEE anomalies and the climate response
Δ¹⁴CO₂ is an Excellent Tracer of Fossil CO₂

- Gradients of CO₂ over land, whether measured from space or from in situ samples, include the influence of fossil CO₂ emissions and a highly variable biosphere, even in winter.
- Recently emitted fossil CO₂ is completely devoid of the radioisotope ¹⁴C, and is the primary determinant of continental Δ¹⁴CO₂ gradients.
- The tight correlation between fossil CO₂ and Δ¹⁴CO₂ allows us to construct an atmospheric inversion to derive the former by measuring the latter.
- Non-fossil terms in the ¹⁴C budget create a negligible gradient.
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
The impact on US NEE estimate is significant if fossil CO₂ is solved for instead of assumed perfectly known.

The addition of Δ¹⁴CO₂ data decorrelates NEE and fossil CO₂, with the degree of decorrelation depending on the number of Δ¹⁴C measurements and atmospheric circulation.

Our results suggest that errors in the “perfectly known” fossil CO₂ in a CO₂-only inversions can lead to significant biases in the NEE. Since fossil CO₂ is less well-known sub-annually, seasonal errors are likely to be even larger.