Estimating US Fossil Fuel CO_2 Emissions from Atmospheric Measurements of CO_2 and $^{14}CO_2$

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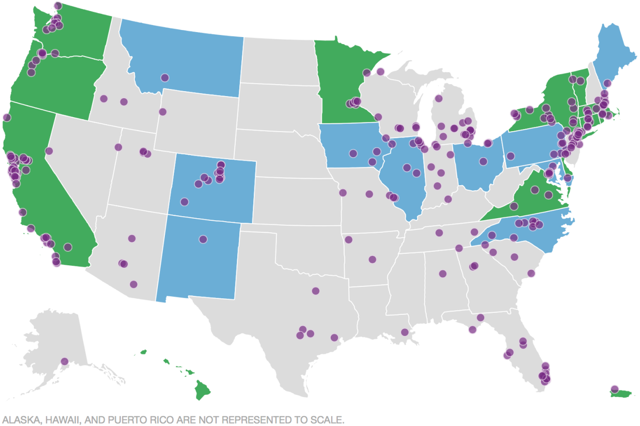
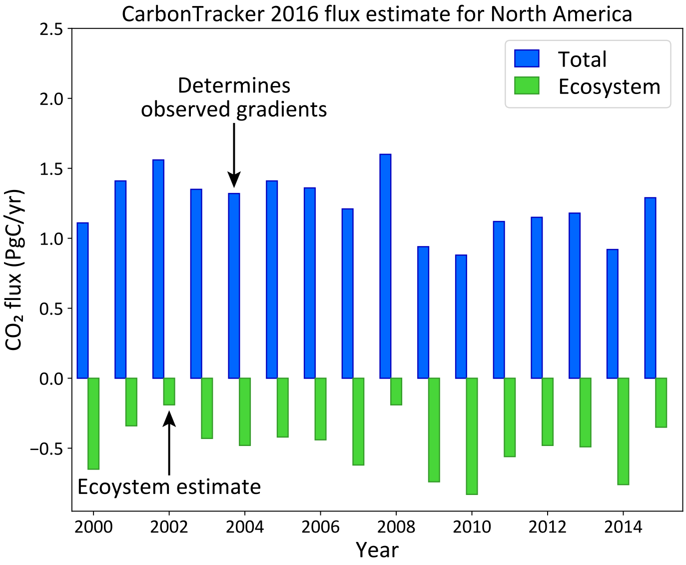
Why track US fossil fuel emissions (1)?



Coalitions like the US Climate Alliance and the Regional Greenhouse Gas Initiative (RGGI) remain committed to emission reductions of the Paris Accord (or more). Regional emissions estimates needed to support these efforts. NOAA GMD has the capability to support the development of independent, atmosphere-based verification methods.

Why track US fossil fuel emissions (2)?



- We are interested in the climate response of land ecosystem (NEE) and ocean fluxes
- CarbonTracker-like CO_2 flux estimation systems solve for NEE from observed atmospheric gradients

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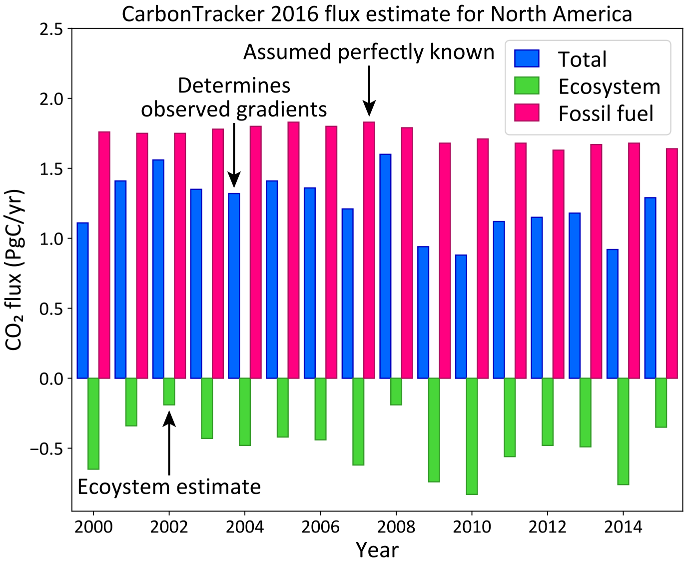
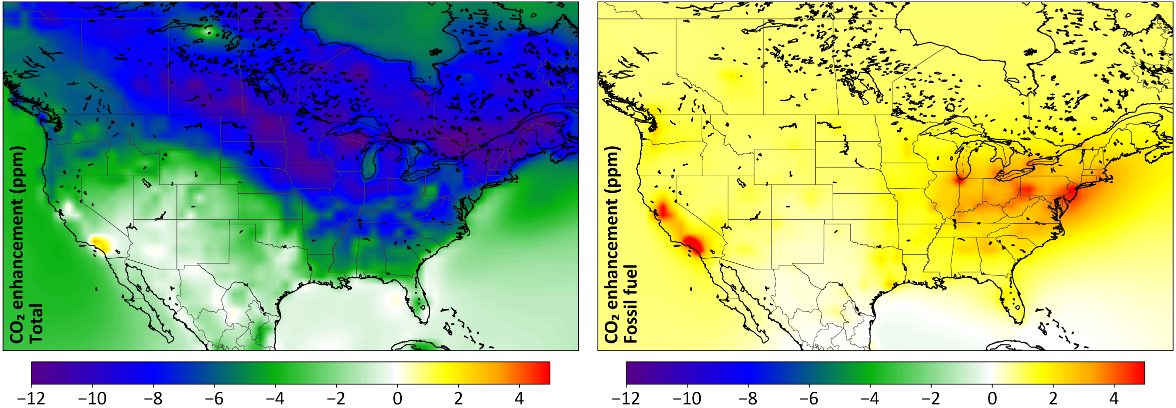


- We are interested in the climate response of land ecosystem (NEE) and ocean fluxes
- CarbonTracker-like CO_2 flux estimation systems solve for NEE from observed atmospheric gradients
- Fossil fuel emissions assumed to be perfectly known
- Errors in FF (especially seasonal) can impact diagnosed NEE anomalies and climate response

Can we track emissions using CO_2 measurements only?

Summer-time mid-afternoon near-surface gradients

Total CO_2 | Fossil fuel derived CO_2



Near-surface gradients of CO_2 are completely different from that of fossil fuel derived CO_2
It is not possible to estimate the latter by measuring the former

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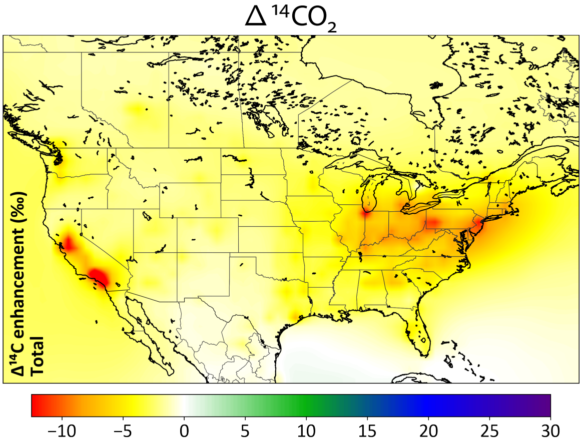
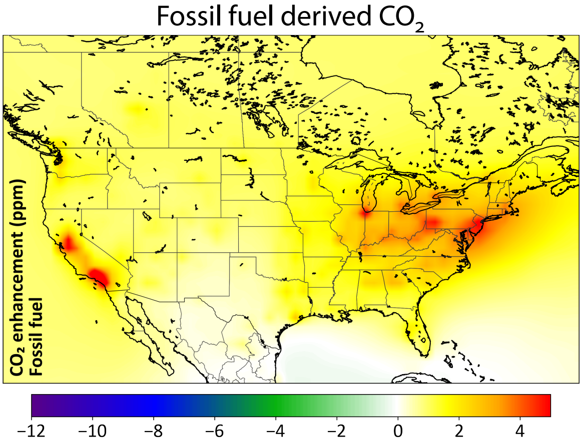
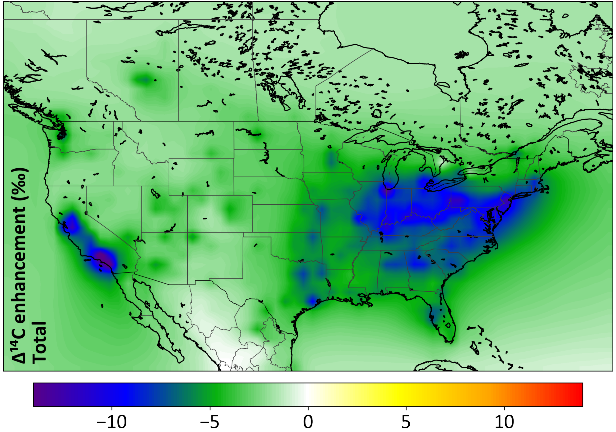




1 ppm fossil fuel CO_2 = -2.5 ‰ in $\Delta\,^{14}CO_2$ (roughly)

Correlation is tight enough to estimate FF CO_2 from $\Delta\,^{14}CO_2$ gradients

Fossil fuel flux is the main driver of $\Delta^{14}CO_2$ gradients over North America



$\Delta^{14}CO_2$ gradients are determined by fossil fuel, cosmogenic production, nuclear production, and oceanic and terrestrial disequilibria

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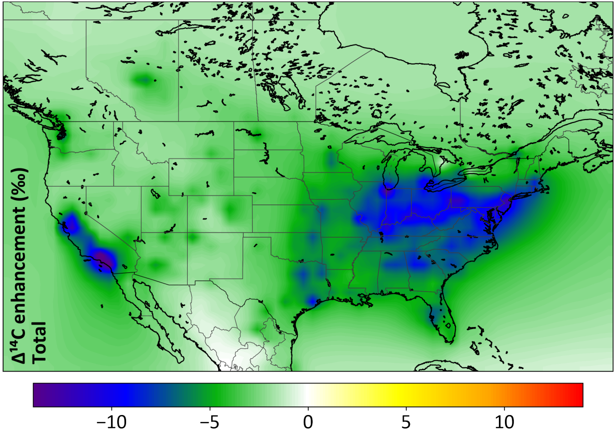

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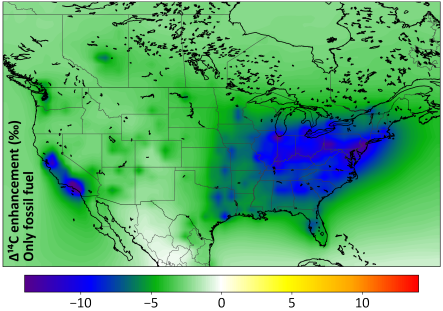
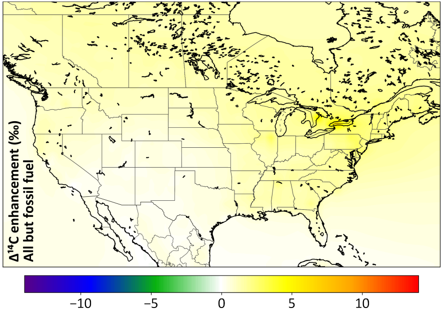
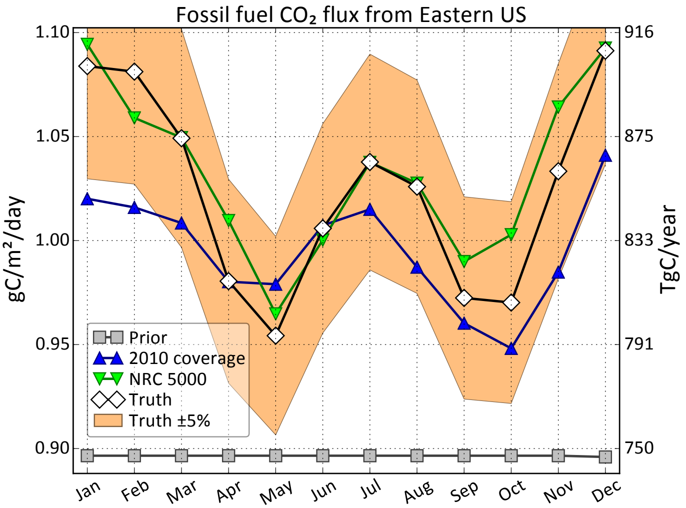
Fossil fluxes



Non-fossil fluxes



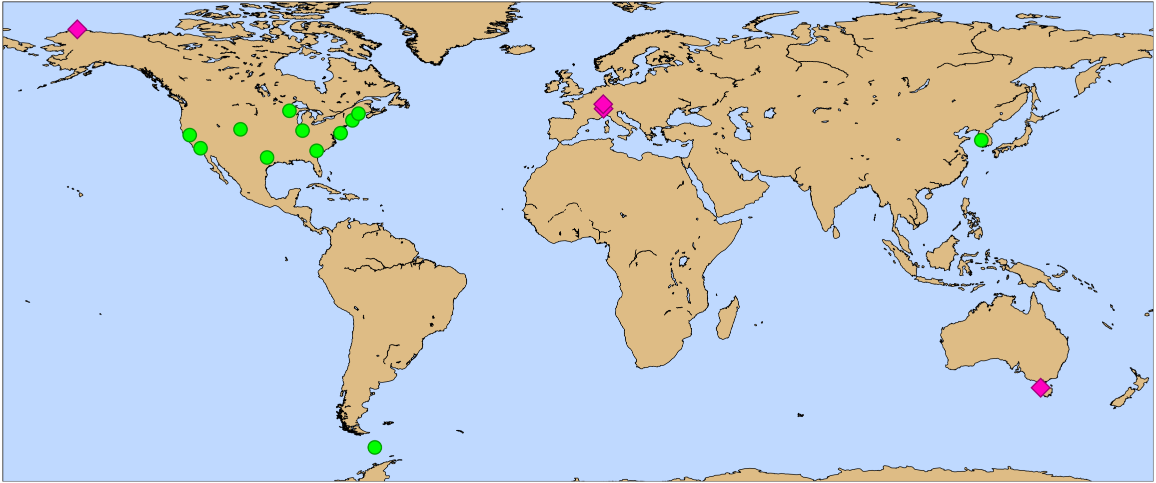
Previous synthetic data (OSSE) results: GMAC 2015



Monthly fluxes over the US and large sub-regions recovered to within ± 5%

Basu et al, ACP (2016)

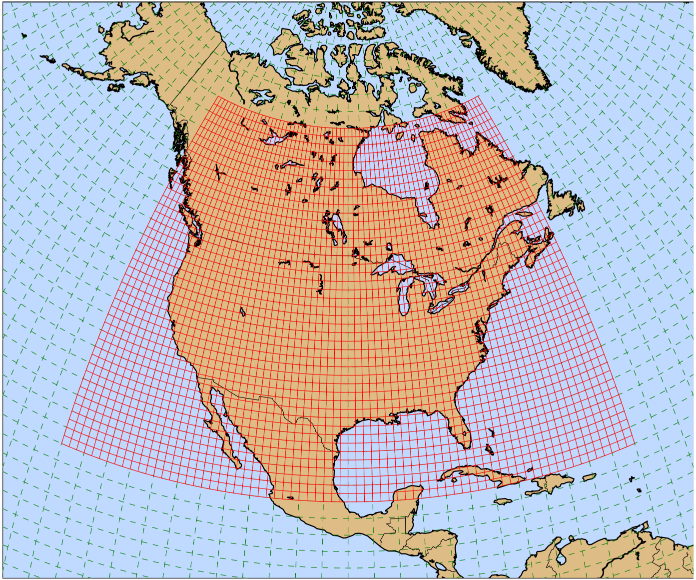
Real $^{14}CO_2$ inversion for 2010: Sites



NOAA GMD/CU INSTAAR (895)

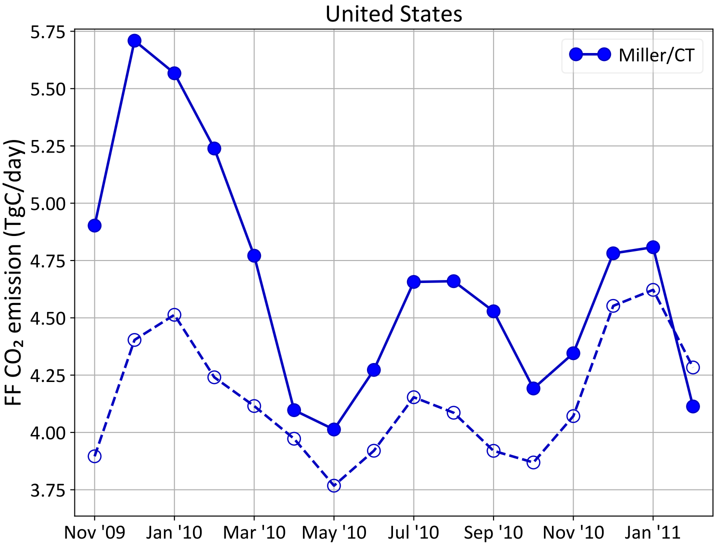
External (89)

Real $^{14}CO_2$ inversion for 2010: Inversion setup



- Fluxes and transport globally at 3°×2°, over the US at 1°×1° to take advantage of higher measurement density
- Goal here is to solve for *regional* fluxes, not megacity-scale fluxes
- Assimilate all QC'd observations representing regional or background signals
- TM5 4DVAR flux estimation framework, from Jul 2009 to Apr 2011, to estimate 2010 emissions

Results: Monthly fluxes



- The inversion suggests larger fluxes and seasonality of FF emissions, with the same phasing as the prior (Blasing, 2005) seasonality

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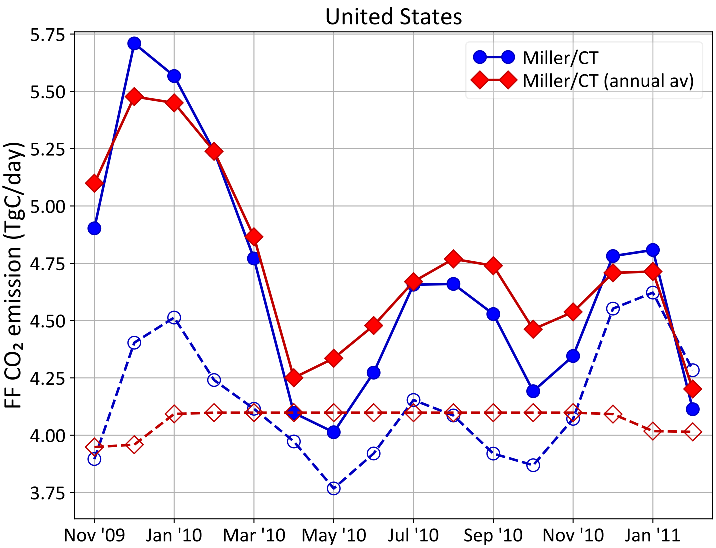

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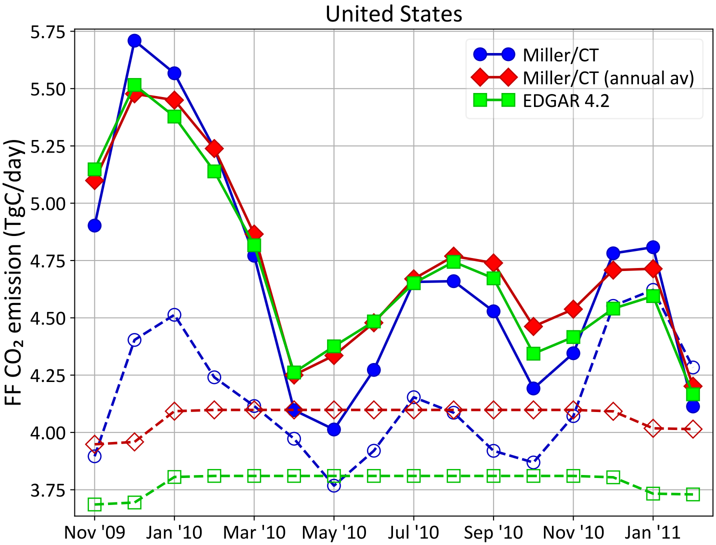
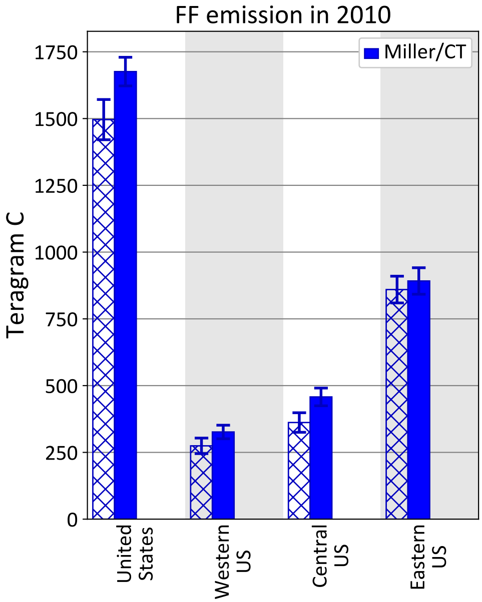


- The inversion suggests larger fluxes and seasonality of FF emissions, with the same phasing as the prior (Blasing, 2005) seasonality
- This is not coming from the prior, rather from the $\Delta^{14}CO_2$ data
- Relatively insensitive to a different prior

Results: Annual totals over the US



- Our inversion suggests 12% higher US fossil fuel emissions in 2010 (1677 TgC) compared to the CDIAC estimate (1497 TgC)
- Considering the 1σ prior and posterior errors, this is a significant adjustment
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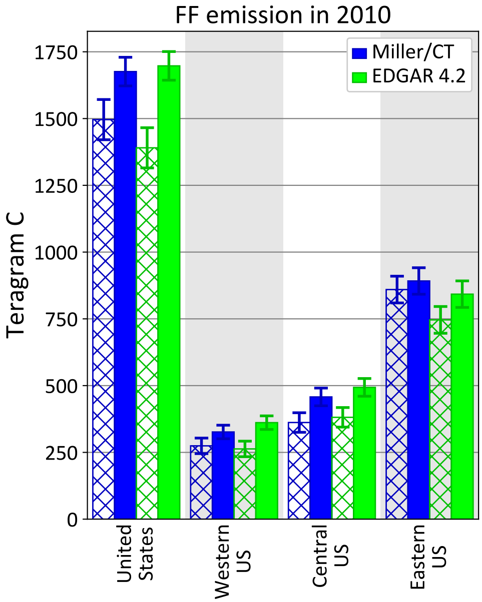

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- Considering the 1σ prior and posterior errors, this is a significant adjustment
- Vulcan 3.0 reports 1632 TgC, only 2.7% away!
- Using a completely different prior, biased low and with different spatial pattern, gives 1698 TgC, so our estimate is relatively insensitive to the prior

Take home points

- NOAA GMD measurement and modeling capabilities can track fossil fuel emissions independent of bottom-up inventory estimates, which remains a priority for many regional initiatives like RGGI
- Previous results suggest that we need an expansion in our ^{14}C measurement network, as recommended by the National Research Council, to obtain robust regional results
- Independently estimating seasonal FF emissions also improves our ability to diagnose biospheric fluxes and their anomalies (*a la* CarbonTracker)
- Inversions of 2010 $^{14}CO_2$ data suggest a US total emission of 1677 ± 54 TgC, significantly higher than inventory estimates for that year
- The $^{14}CO_2$ data imply a larger seasonal variation in FF emissions compared to the Blasing et al (2005) seasonality, even when no prior assumptions are made regarding FF seasonality