

Bridging Carbon Cycling and Air Quality Studies using $^{14}\text{CO}_2$

John B. Miller, Scott Lehman, Steve
Montzka, Colm Sweeney, Pieter Tans,
Jocelyn Turnbull

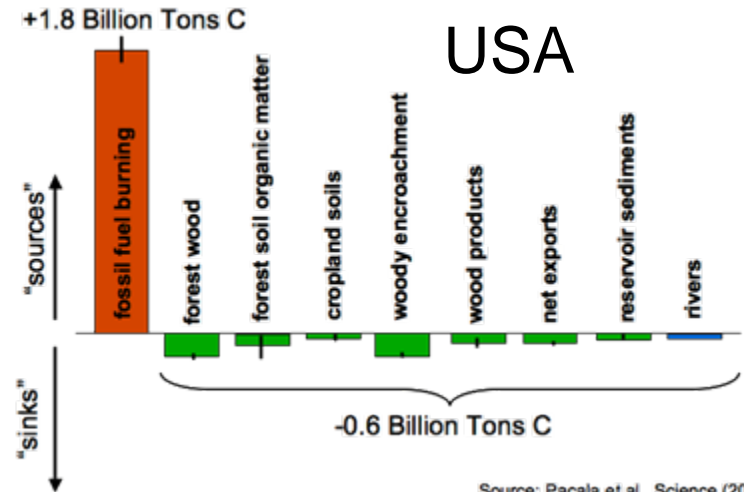


Fossil Fuel and $\Delta^{14}\text{C}$

IPCC 95th %ile!

Global

QuickTime™ and a decompressor are needed to see this picture.



Source: Pacala et al., Science (2001)
+ CarbonTracker

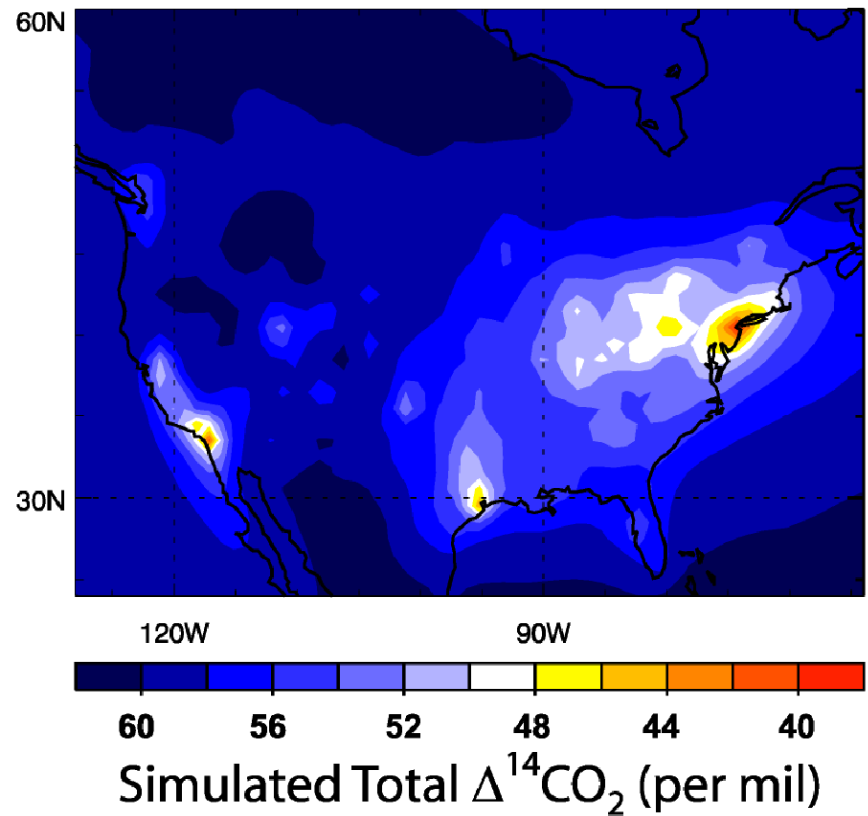
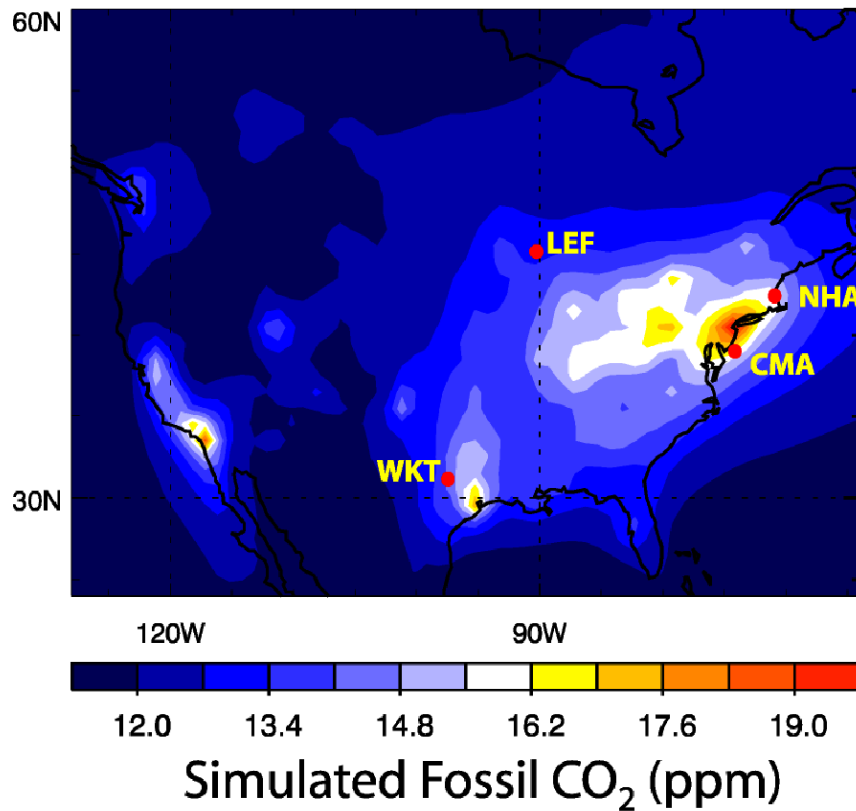
- ^{14}C is, by definition, absent from fossil fuels, and thus an excellent tracer for Fossil Fuel emissions.

Isotopic Notation

$$\Delta^{14}C = \left[\frac{(^{14}C/C)_{sam}}{(^{14}C/C)_{std}} - 1 \right] \times 1000$$

$\Delta_{ff} = -1000$ per mil; $\Delta_{atm} \sim +55$ per mil

Simulated Fossil Fuel CO₂ and $\Delta^{14}\text{C}$



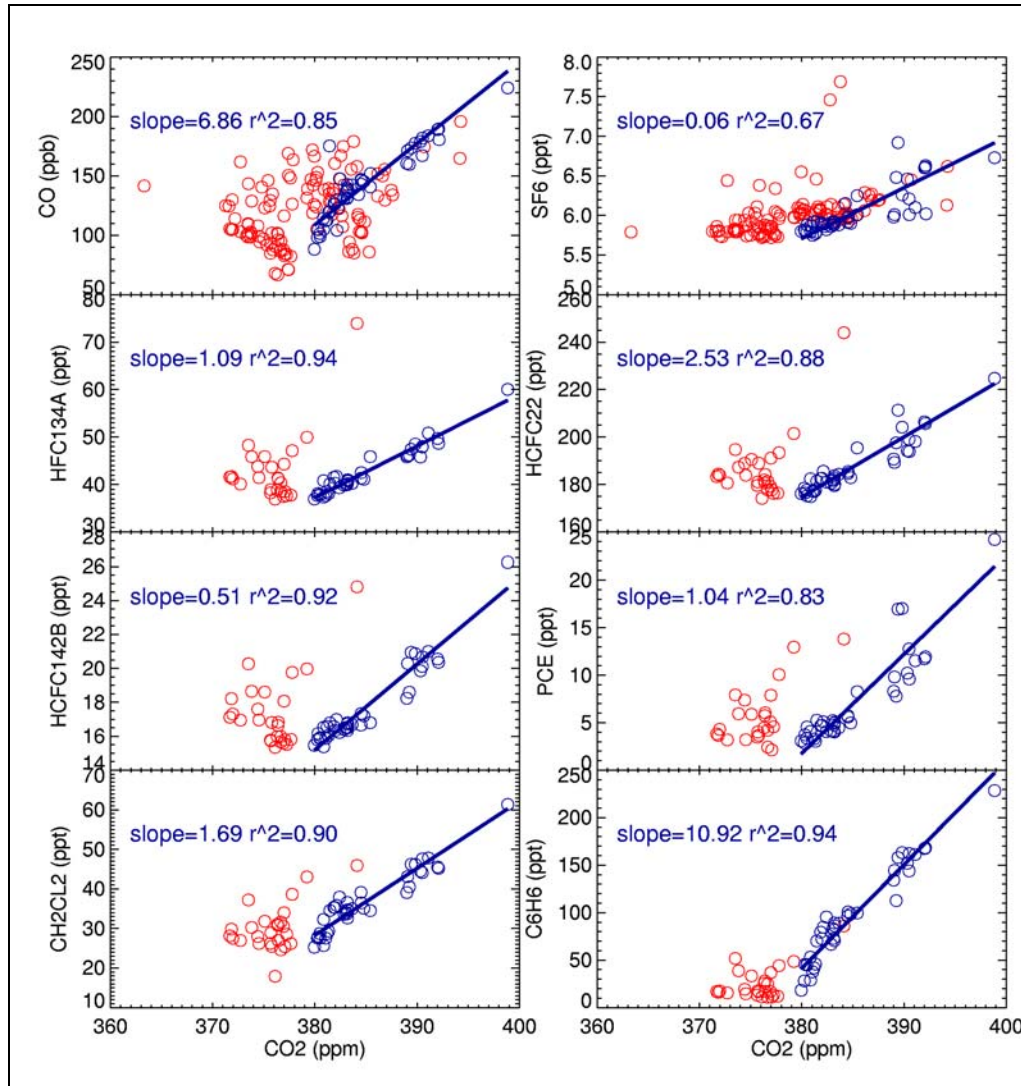
Airborne sampling



QuickTime™ and a decompressor are needed to see this picture.

QuickTime™ and a decompressor are needed to see this picture.

CO₂ v. Anthropogenic Tracers



Hypotheses

H1: Lack of summer correlation due to CO₂ NEE. Using ¹⁴CO₂ instead of CO₂ will improve correlation.

H2: NEE also non-zero in winter. Using ¹⁴CO₂ will change the slope.

East Coast CO₂ and Δ¹⁴C (NHA + CMA)

2004

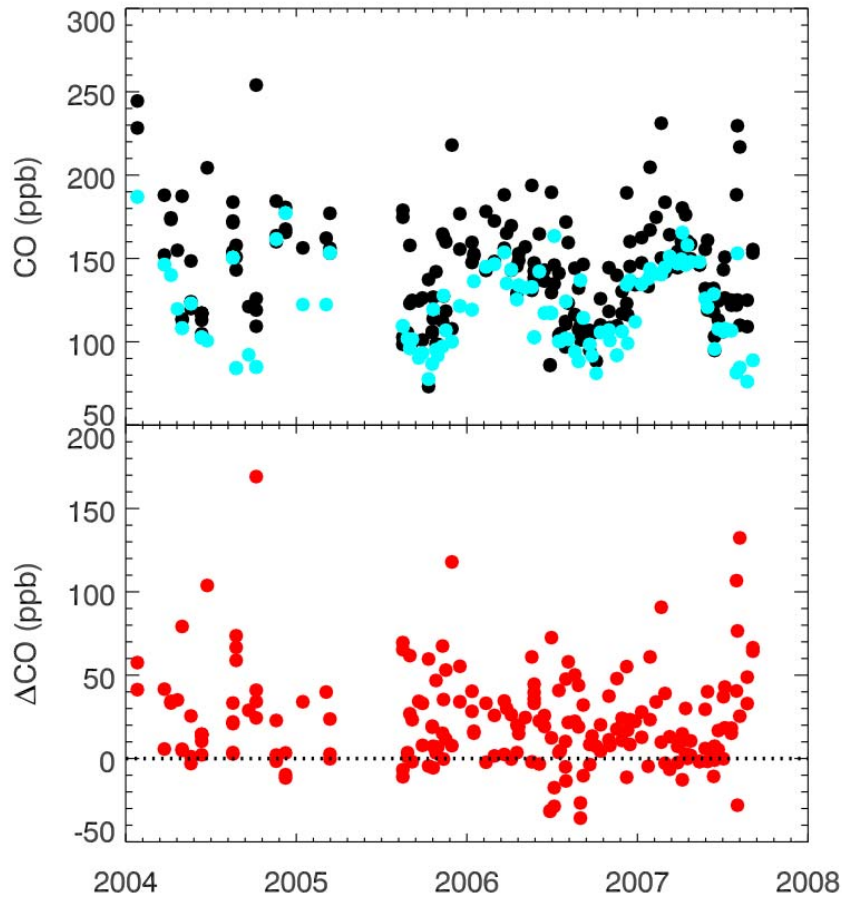
2008

$$C_{\text{obs}} = C_{\text{bg}} + C_{\text{fos}} + C_{\text{bio}}$$

$$(\Delta C)_{\text{obs}} = (\Delta C)_{\text{bg}} + (\Delta C)_{\text{fos}}$$

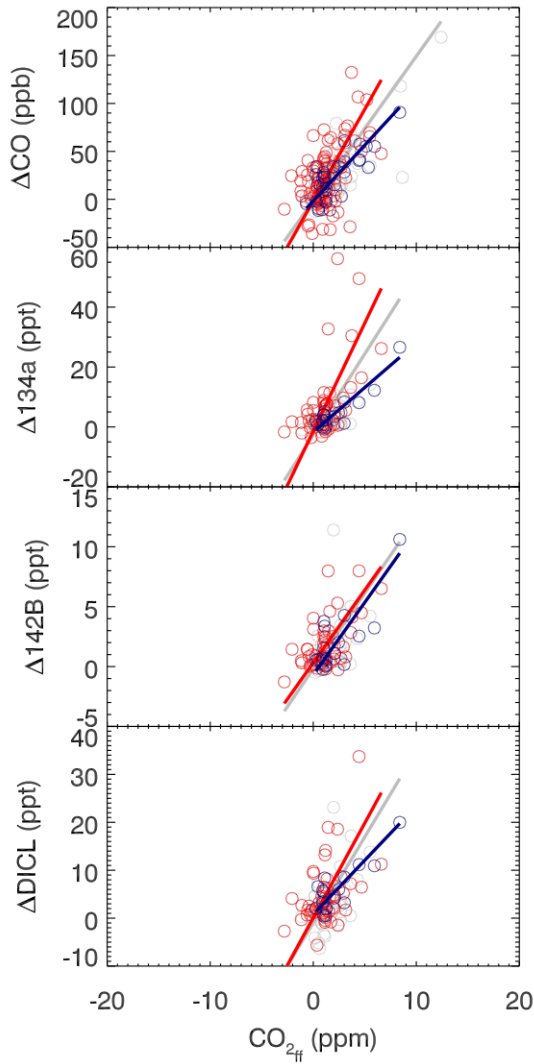
QuickTime™ and a
decompressor
are needed to see this picture.

PBL and Free Troposphere CO



$$C_{\text{obs}} = C_{\text{bg}} + C_{\text{net_source}}$$

C_{ff} v. $C_{\text{net_source}}$



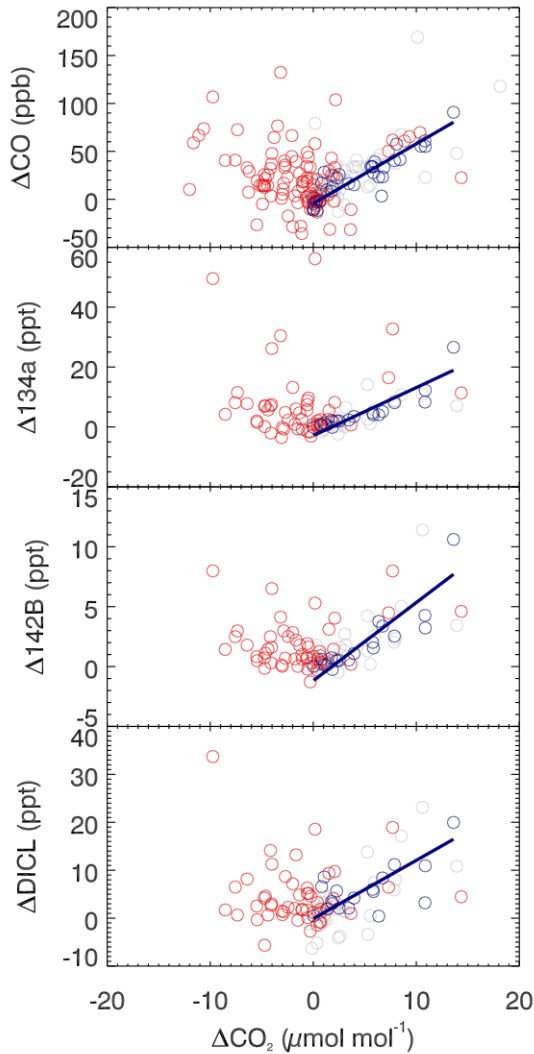
$m=19$ ppb/ppm
 $m=12$ ppb/ppm

$m=7.2$ ppt/ppm
 $m=3.0$ ppt/ppm

$m=1.2$ ppt/ppm
 $m=1.2$ ppt/ppm

$m=4.0$ ppb/ppm
 $m=2.3$ ppb/ppm

Red=Summer; Blue=Winter



$m=6.2$ ppb/ppm

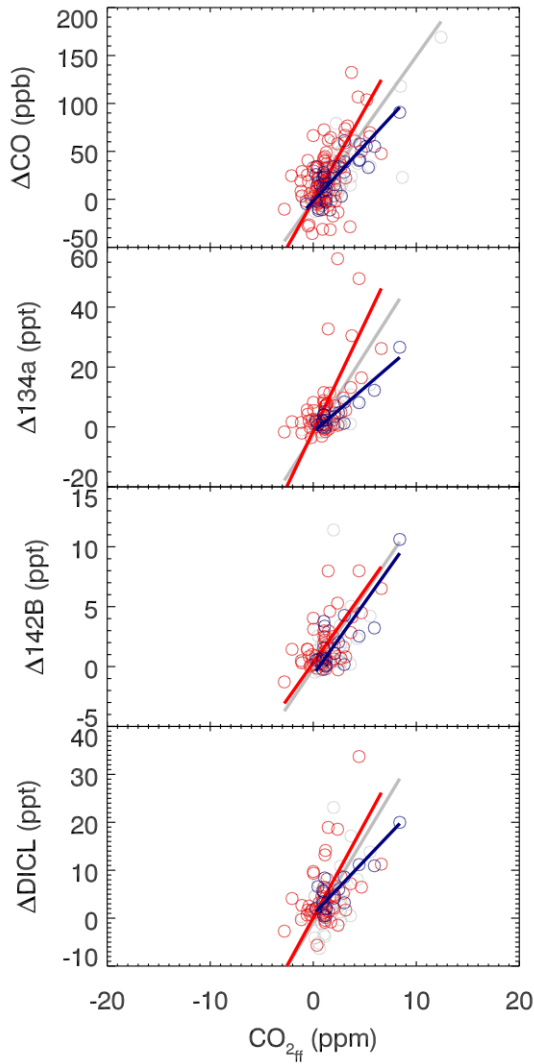
$m=1.6$ ppt/ppm

$m=0.7$ ppt/ppm

$m=1.2$ ppt/ppm

H1 and H2 confirmed!

Red=Summer; Blue=Winter



$m=19$ ppb/ppm
 $m=12$ ppb/ppm

$m=7.2$ ppt/ppm
 $m=3.0$ ppt/ppm

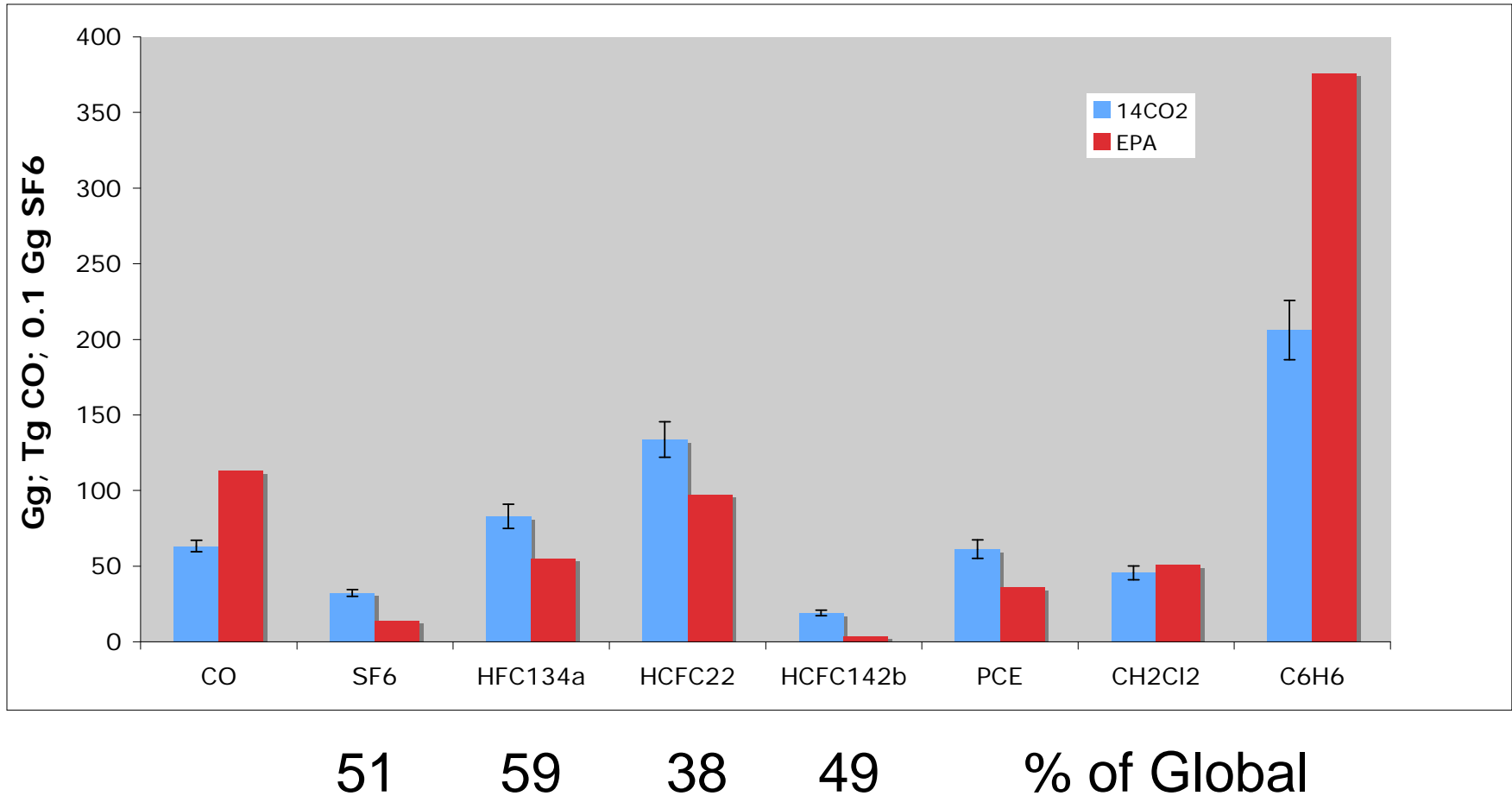
$m=1.2$ ppt/ppm
 $m=1.2$ ppt/ppm

$m=4.0$ ppb/ppm
 $m=2.3$ ppb/ppm

$$m_{\text{gas}} \times E_{\text{ff}} = E_{\text{gas}}$$

Red=Summer; Blue=Winter

USA Emission Estimates



Caveats

- Relatively few ^{14}C data
- Some old emission inventories
- Seasonal covariance between FF and tracer emissions \Rightarrow $\sim 5\%$ high bias
- Limited domain with high S:N
 - Evidence for spatial emission ratio variability.

NHA+CMA 'Footprint'

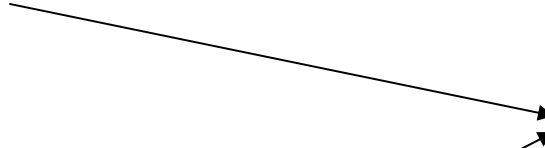
QuickTime™ and a
decompressor
are needed to see this picture.

PBL Residence Time

Future Calculations

Inventory

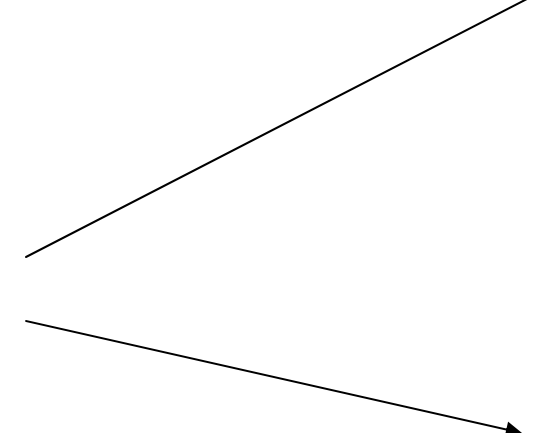
QuickTime™ and a decompressor are needed to see this picture.



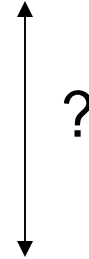
Bottom-up Estimate

Footprint

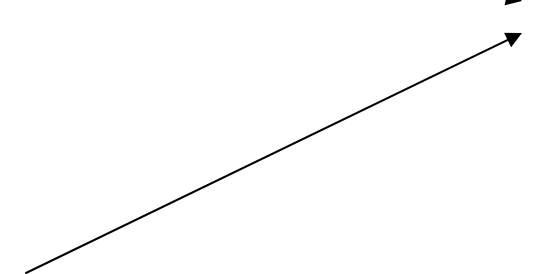
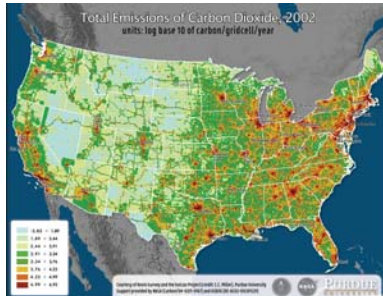
QuickTime™ and a decompressor are needed to see this picture.



Top-down Estimate



Fossil Fuel Emissions



Conclusions

- $^{14}\text{CO}_2$ allows the partitioning of CO_2 into fossil fuel and biological components.
- $^{14}\text{CO}_2$ offers great promise as a tool to calculate regional and seasonal emissions of anthropogenic gases.
- At low ranges, correlating with total CO_2 appears to result in a low bias.
- Many species appear to exhibit significant seasonal emission cycles.