Unexpected and significant biospheric CO$_2$ fluxes in the Los Angeles Basin revealed by atmospheric radiocarbon ($^{14}$CO$_2$)

John Miller$^{1,2}$, Scott Lehman$^3$, Kristal Verhulst$^4$, Charles Miller$^4$, Riley Duren$^4$, Sally Newman$^5$, Jack Higgs$^1$, Christopher Sloop$^6$, Pat Lang$^1$, Eric Moglia$^{1,2}$

“Megacities” Goals and Approach

“Develop and demonstrate measurements systems capable of quantifying trends in the anthropogenic carbon emissions of the Los Angeles Megacity (target: 10% change in Fossil Fuel CO$_2$ over 5 years).”

1. Difficult without understanding biogenic contributions;
2. Biogenic contributions difficult without $^{14}$C.
3. But general concept for urban emissions monitoring is to measure CO$_2$ assuming that its variations are purely anthropogenic.
Atmospheric $^{14}$CO$_2$ looks just like fossil CO$_2$

-2.5 per mil $\Delta^{14}$C = 1 ppm CO$_2$-fossil

Includes ecosystems, oceans, nuclear power, cosmic rays, fossil fuel.

Includes only fossil fuel

Miller et al, 2012
$CO_2$ variations can be separated into Biogenic and Fossil fractions using $\Delta^{14}C$.

\[ C_{\text{obs}} = C_{\text{bg}} + C_{\text{fos}} + C_{\text{bio}} \]

\[ (\Delta \times C)_{\text{obs}} = (\Delta \times C)_{\text{bg}} + (\Delta \times C)_{\text{fos}} + \text{minor} \]

Bio has no influence
LA Basin $^{14}$CO$_2$ sampling sites

Niwot Ridge, CO

background sites
CO$_2$ and $^{14}$CO$_2$ data show large variations with a clear fossil fuel contribution.

Background
(NWR, MWO)
USC
Granada Hills
CS Fullerton

100 per mil!!
~ 40 ppm fos. CO2.
Biospheric contribution to total CO$_2$ is substantial.

- Larger enhancements in winter – less vertical mixing
- Seasonally varying biosphere contribution with summer uptake.
- Summer biosphere drawdown is underrepresented because of enhanced mixing
- Variability in CO$_2$xs,bio and fos are likely dominated by changes in mixing.
Isotopic mixing analysis also shows substantial biospheric contribution throughout the year.

Winter: -760 per mil $\rightarrow$ CO$_2$xs is 24% biogenic

Summer: -830 per mil $\rightarrow$ CO$_2$xs is 17% biogenic

**Why is CO$_2$bio so high?**

- Ethanol in gasoline ($\sim$ 3%)
- Human Respiration ($\sim$ 5%)
- Urban ecosystems 10-15%?
High correlation of Bio and Fossil components consistent with co-located distributed sources.

- Fossil fuels (and ethanol), and human population are similarly distributed throughout the Basin.
- Urban ecosystems may also be.
- N.B.: Correlation is analyzed in winter to avoid near zero \( \text{CO}_2 \text{bio} \) signal resulting from net photosynthesis.
How productive are urban ecosystems?

→ "Soil respiration (~7 umol/m2/s) ... in urban ecosystems was ...2.5 to five times greater than any other land-use type." (Kaye et al., Global Change Biology (2005))

→ Harvard forest summer respiration fluxes are only ~ 4 umol/m2/s.

→ These fluxes would require ~1/10th of LA to be covered by lawns (and golf course, parks, etc.) to explain our observations. **Is this realistic?**
Distribution of green appears to be somewhat decoupled from people and roads, but still widespread.
LANDSAT 30 m EVI zoomed in shows even more.

→ Quickbird/Google Earth (~50 cm) shows yet more.
Wintertime biospheric CO$_2$ fraction averages
~50% for regions; ~ 20% for cities

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Summary and implications

1. $\text{CO}_2^{xs} \neq \text{CO}_2^{fos}$, even in L.A.

2. Remote-sensing and in situ approaches for urban $\text{CO}_2$ fluxes need to account for biospheric $\text{CO}_2$.

3. $\text{CO}_2^{bio}$ varies throughout the year, but it will likely vary year to year, and its ratio with $\text{CO}_2^{fos}$ will likely trend with emissions reductions.

4. Continued and widespread measurement of urban biosphere fluxes will be required to isolate the fossil fuel emissions signal.
Nighttime signals show more biogenic signal and small signals overall.

Differences may reflect suppressed atmospheric mixing at night with lower fossil emissions.
CO:CO$_2$ correlations – CO$_2$ fos
Summer v. Winter

CO:CO$_2$ fos = 11.1 +/- 0.4 ppb/ppm
CO:CO$_2$ fos = 9.7 +/- 0.6 ppb/ppm
Transforming *in situ* CO to CO$_2$ff

Granada Hills in situ data

- Just an example, for now...
- Yellow represents mid-day hours – i.e. only when our CO/CO$_2$ values are valid.
- Evidence for diurnal variability in CO:CO$_2$

➢ Huuuge signals, but are they too big?
Why Megacities?
Large emissions and large signals. But...

<table>
<thead>
<tr>
<th>Population (Millions)</th>
<th>GHG Emissions (M tCO₂e)</th>
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</thead>
<tbody>
<tr>
<td>2. India: 916</td>
<td>2. China: 4,058</td>
</tr>
<tr>
<td>3. 50 Largest Cities: 500</td>
<td>3. 50 Largest Cities: 2,606</td>
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Megacity > 10 million; 2010 = 22 cities; 2025 = 38 cities
LA is ~ 17 million

*However, this is still only ~ 10% of global emissions.*