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]

1. NOAA/GMD 2. CU/CIRES 3. CU/INSTAAR 4. NASA/JPL 5. CalTech
6. Earth Networks

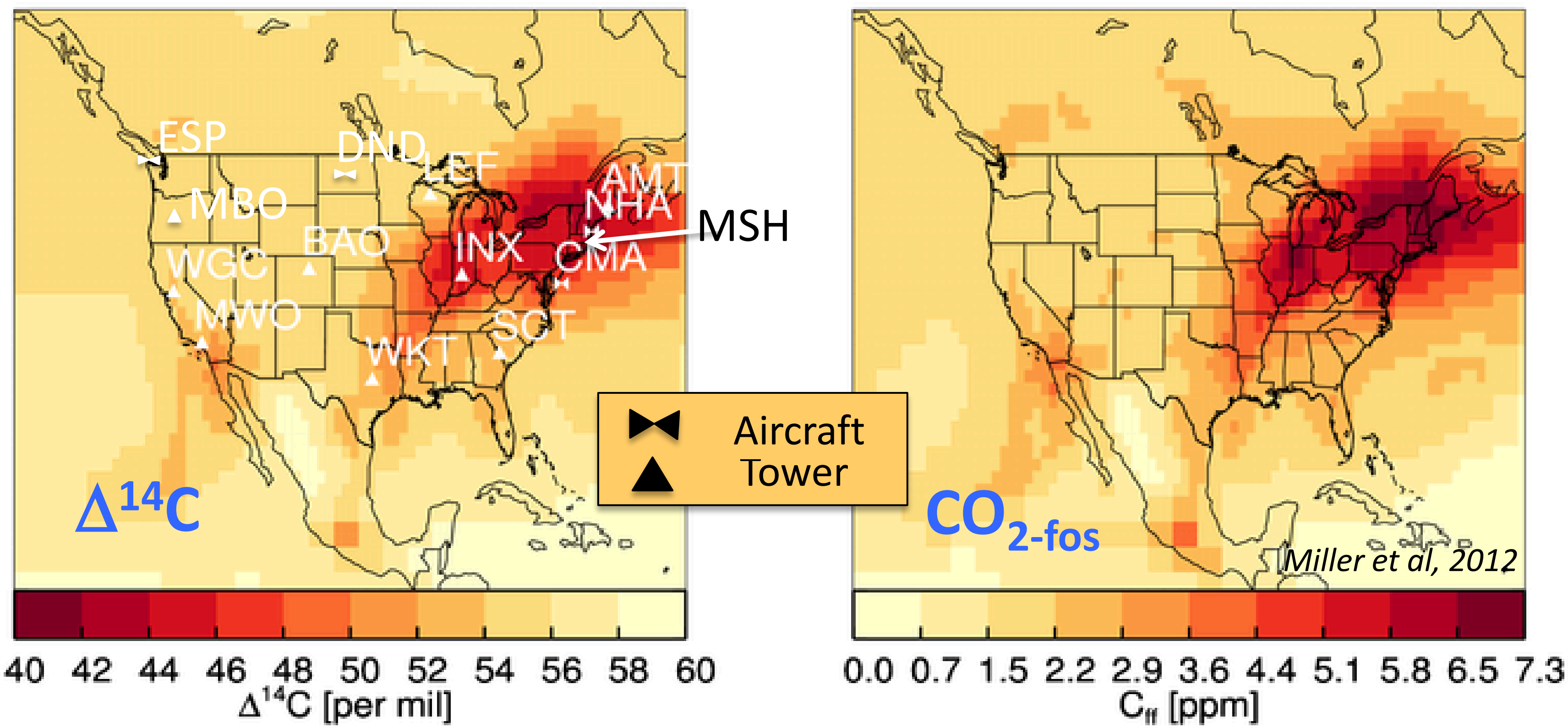
“Megacities” Goals and Approach

“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

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

CO_2xs

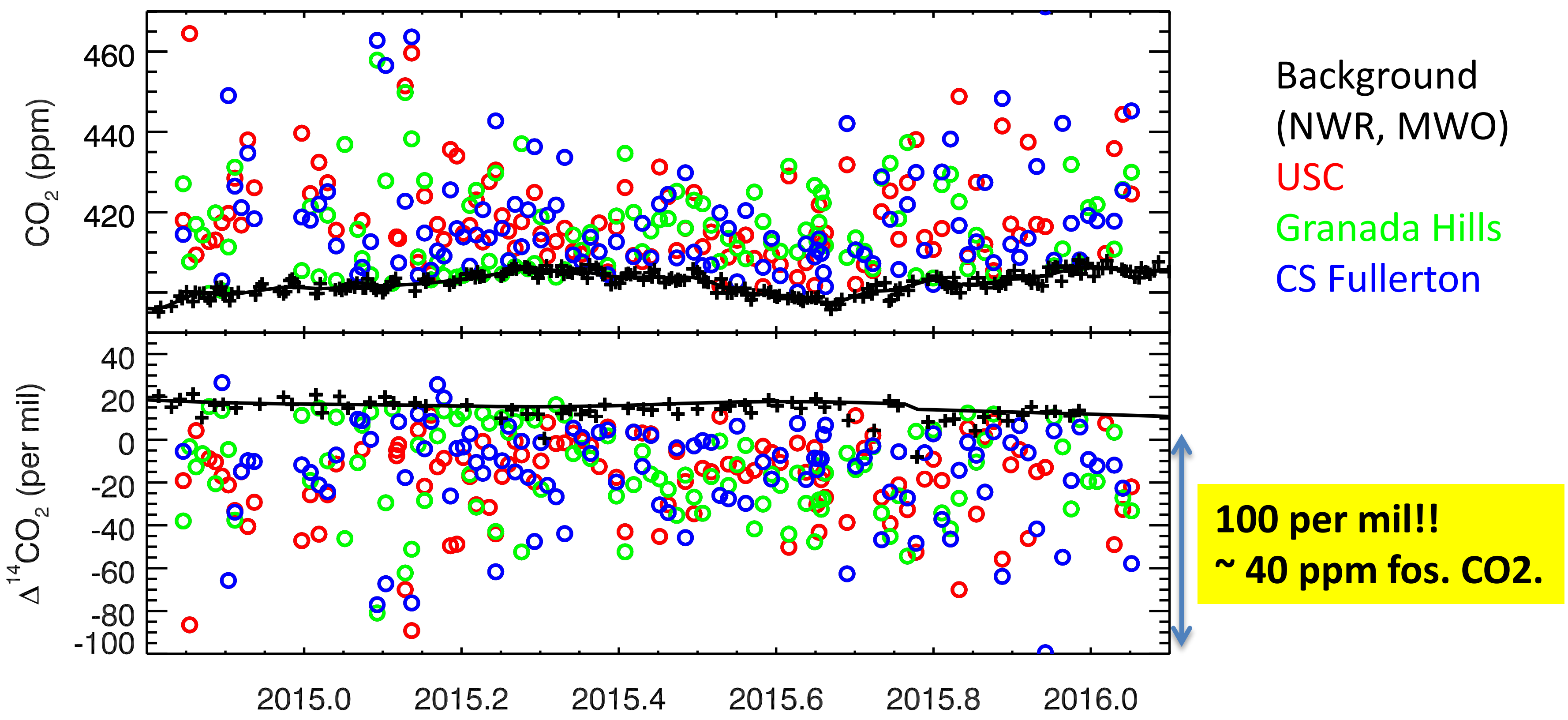
$$C_{obs} = C_{bg} + \boxed{C_{fos} + C_{bio}}$$

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

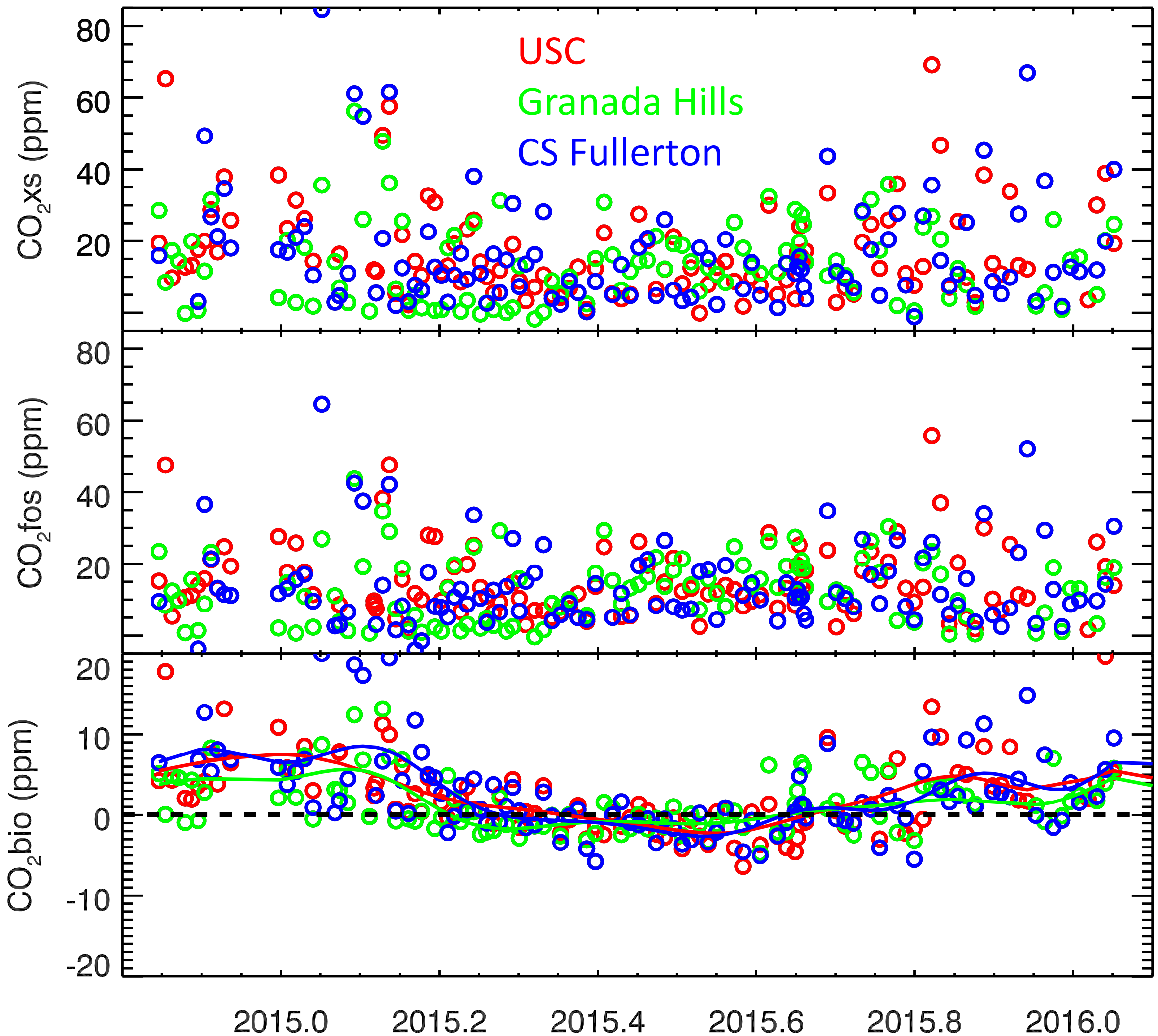
Bio has no influence

LA Basin $^{14}CO_2$ sampling sites
Victorville
Niwot Ridge, CO
background sites
Granada Hills
Mt Wilson
Caltech
USC
Claremont
Ontario
Compton
CSUF
San Bernardino
Palos Verdes
UC Irvine
San Clemente
La Jolla

CO_2 and $^{14}CO_2$ data show large variations with a clear fossil fuel contribution.

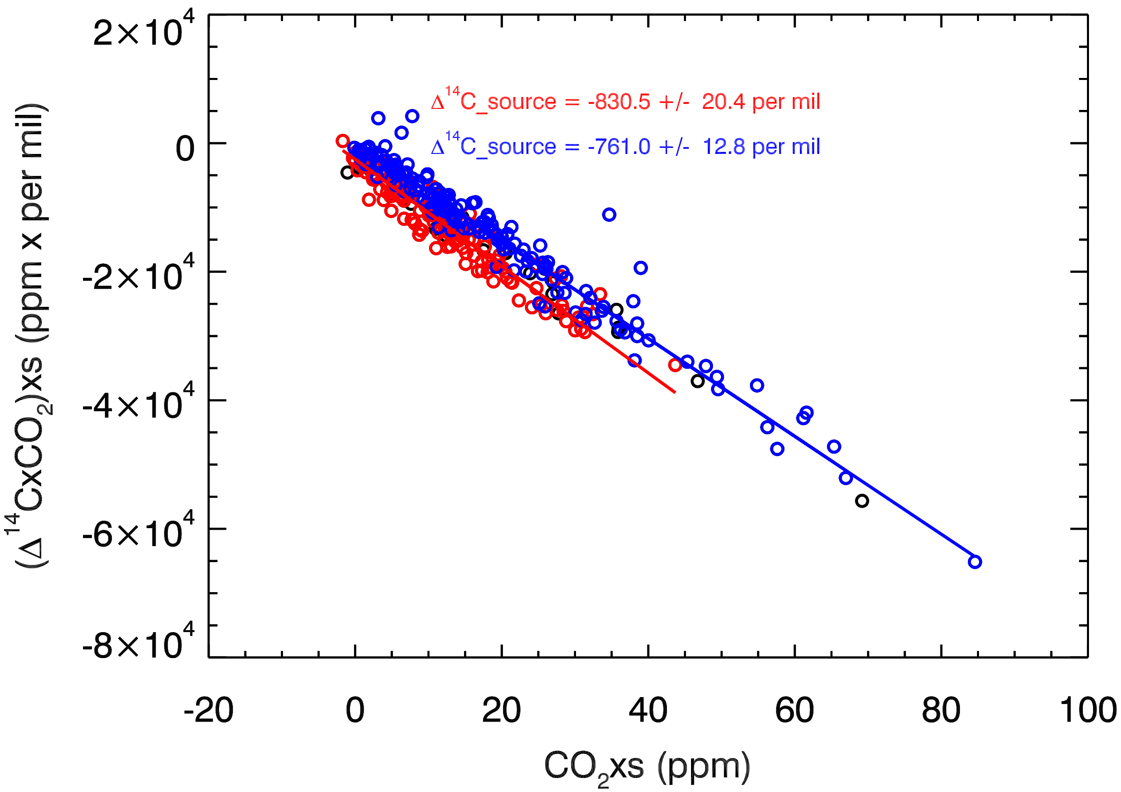


Biospheric contribution to total CO_2 is substantial.



- → 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_2xs,bio and fos are likely dominated by changes in mixing.

Isotopic mixing analysis also shows substantial biospheric contribution throughout the year.



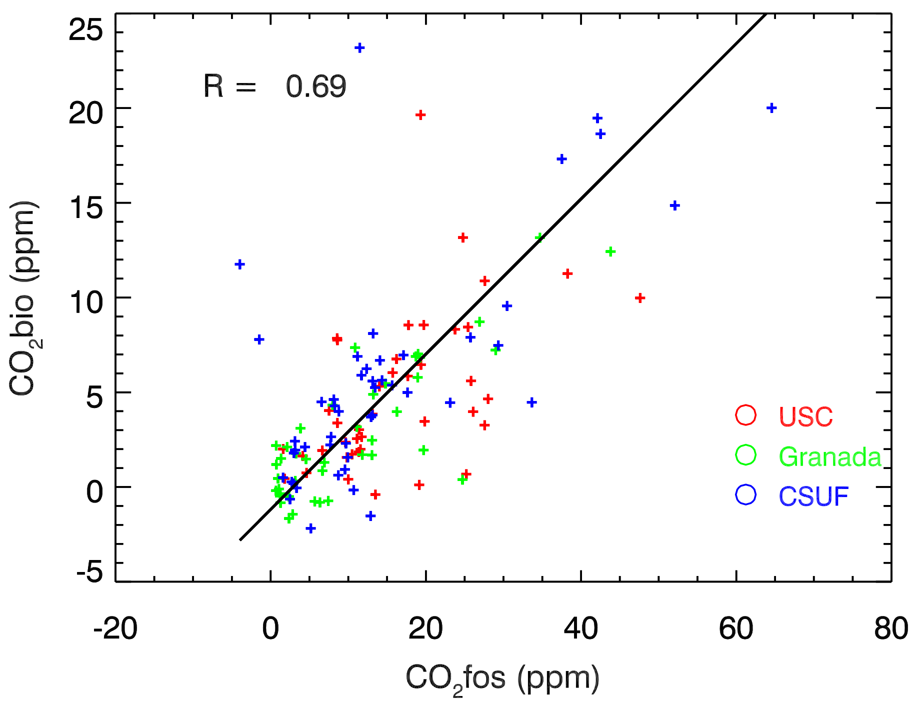
Why is CO_2bio so high?

- Ethanol in gasoline (~ 3 %)
- Human Respiration (~ 5 %)
- Urban ecosystems 10-15% ?

Winter: -760 per mil → CO_2xs is 24% biogenic

Summer: -830 per mil → CO_2xs is 17% biogenic

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 CO_2bio signal resulting from net photosynthesis.

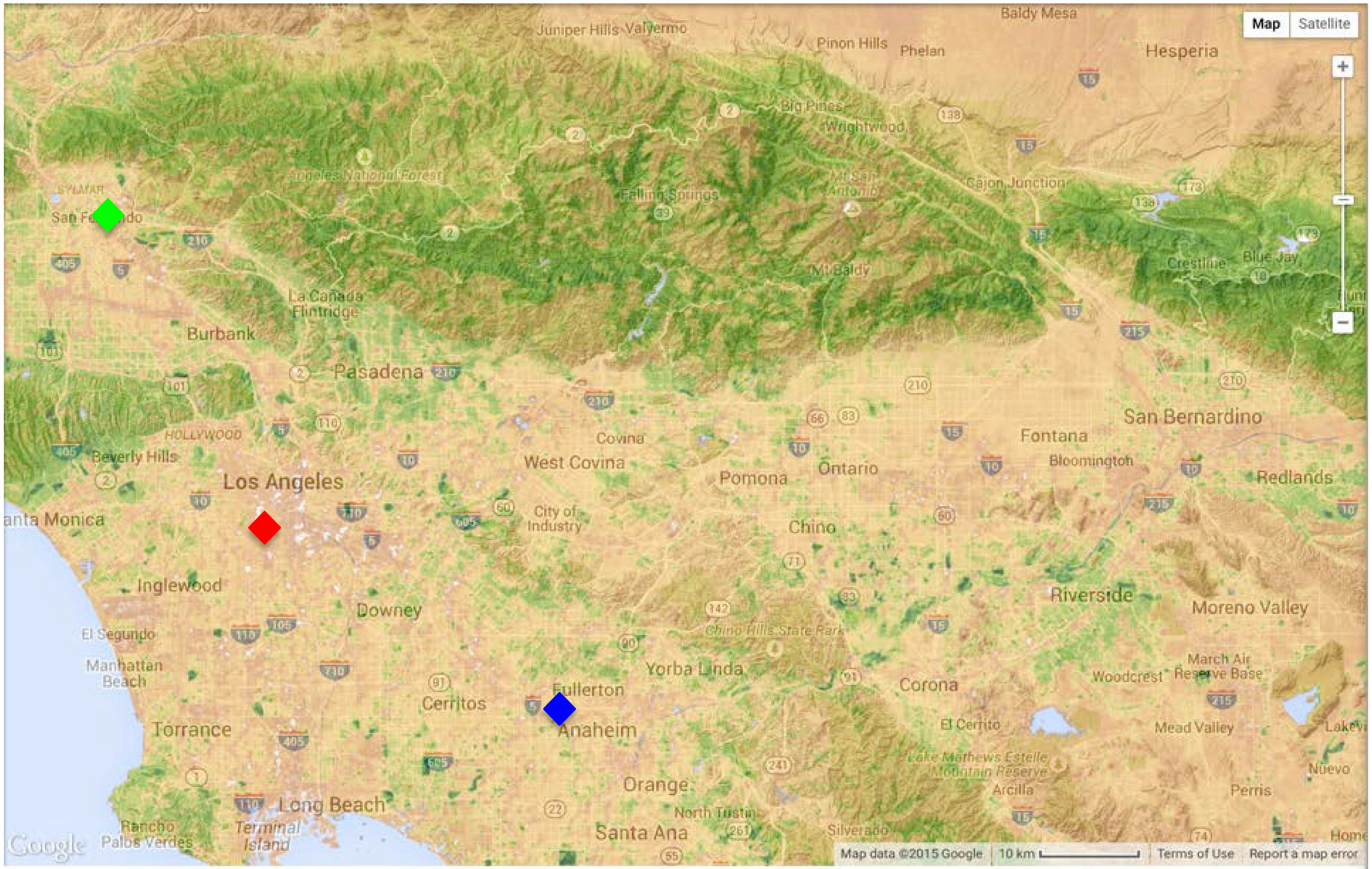
How productive are urban ecosystems?

→ "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.

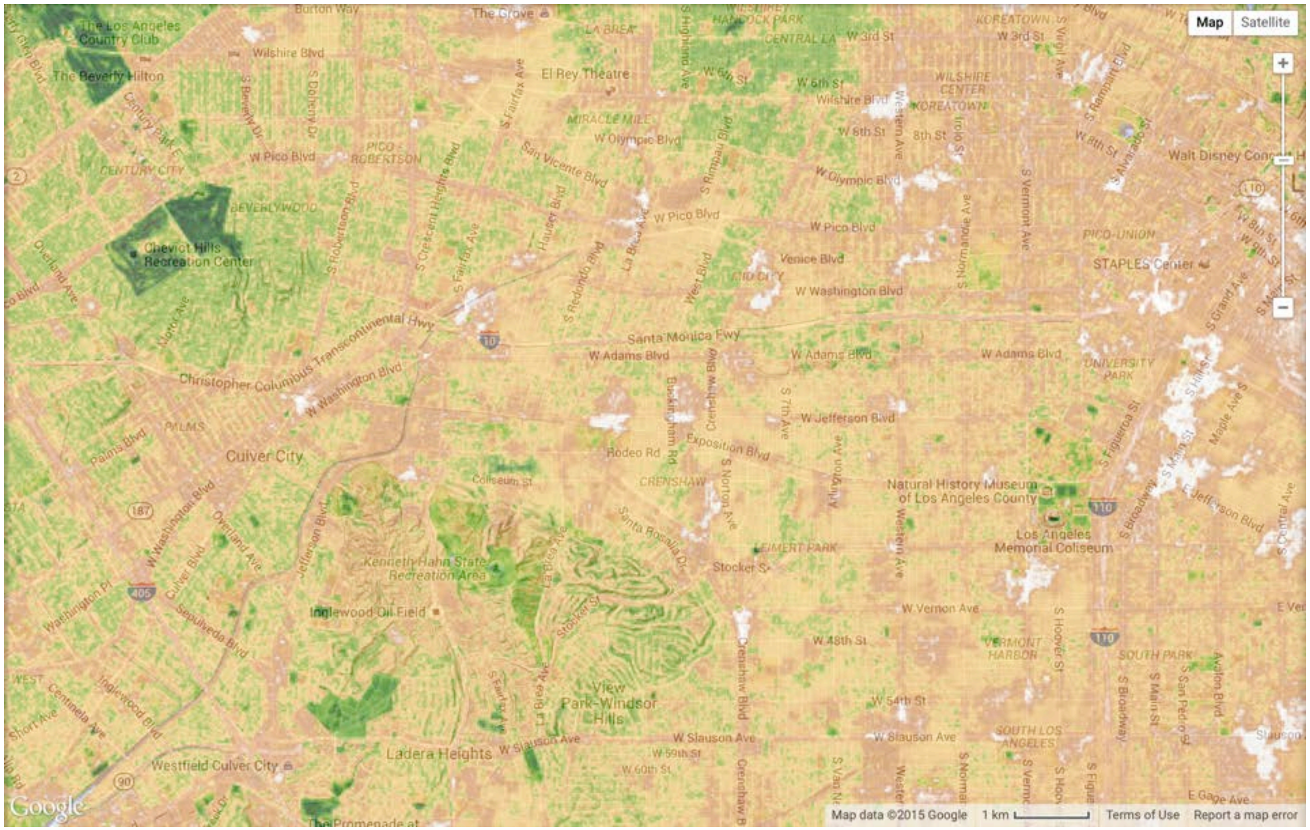
→ These fluxes would require ~1/10th of LA to be covered by lawns (and golf course, parks, etc.) to explain our observations. ***Is this realistic?***

LANDSAT 30 m EVI



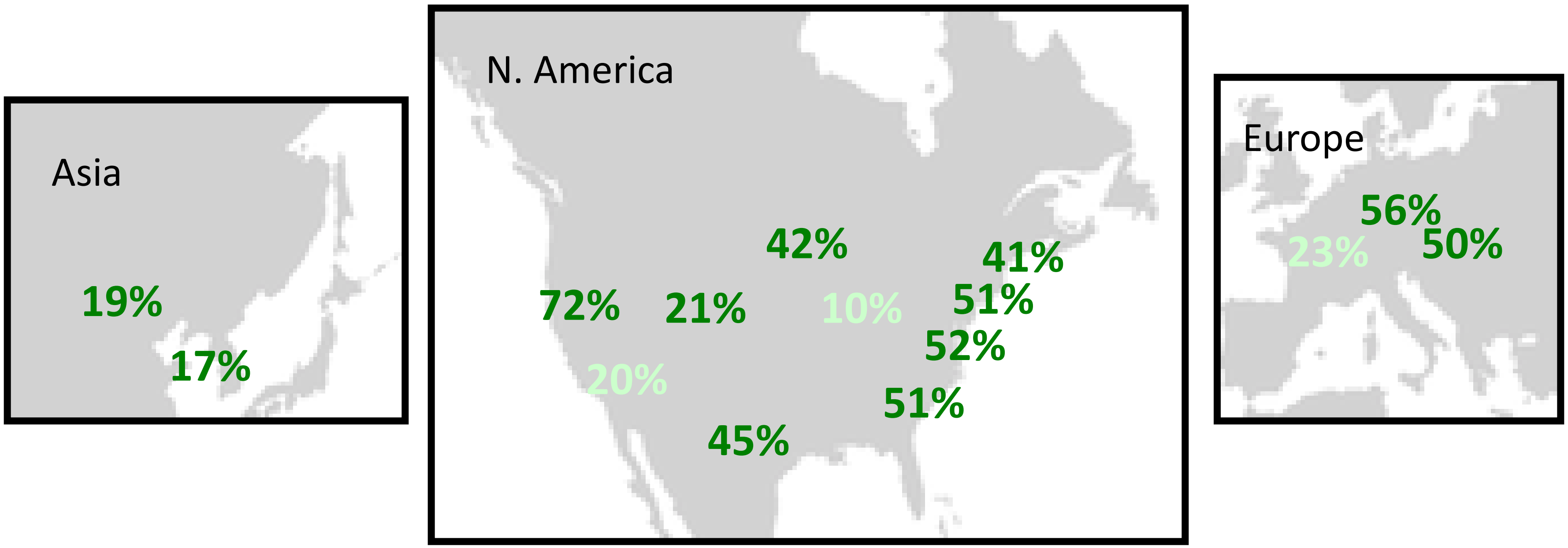
→ Distribution of green appears to be somewhat decoupled from people and roads, but still widespread.

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

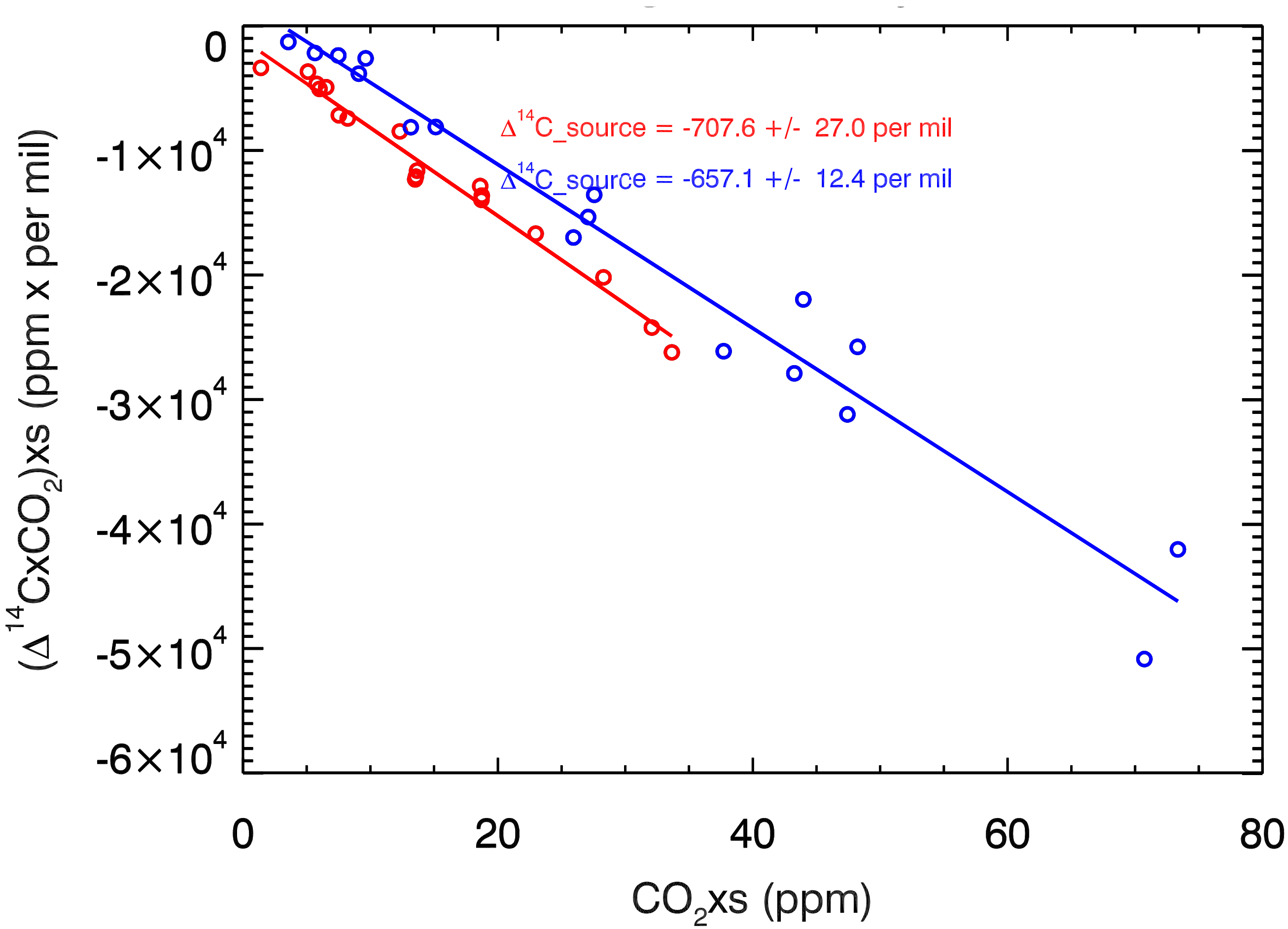


Thanks to: K. Rozanski, M. Zimnoch (Poland); I. Levin (Germany); Morgan Lopez(France); L. Zhou (China); Korea-China Center for Atmos. Res.

Summary and implications

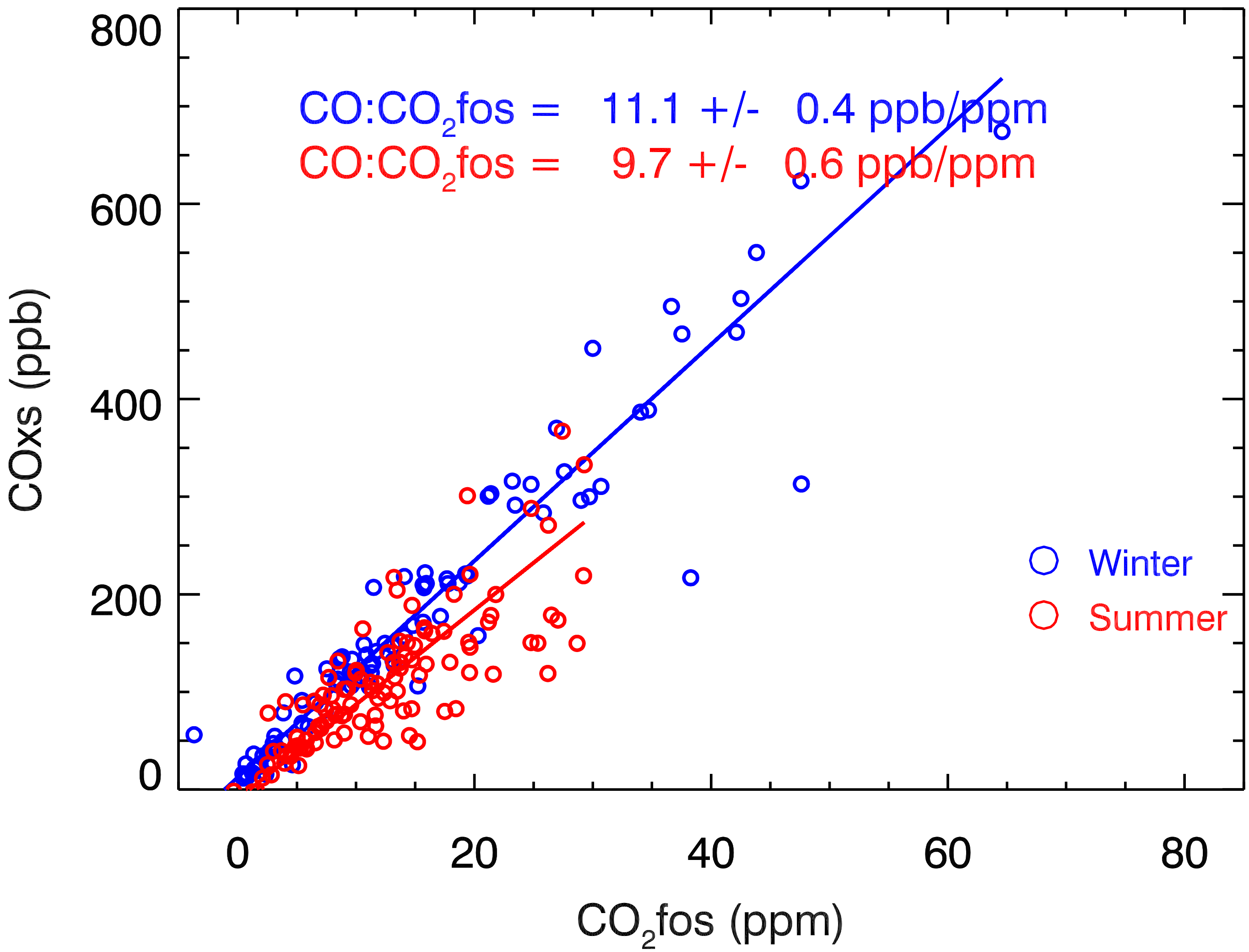
1. **CO_2xs ≠ CO_2fos, even in L.A.**
2. Remote-sensing and in situ approaches for urban CO_2 fluxes need to account for biospheric CO_2.
3. CO_2bio varies throughout the year, but it will likely vary year to year, and its ratio with CO_2fos will likely trend with emissions reductions.
4. Continued and 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.



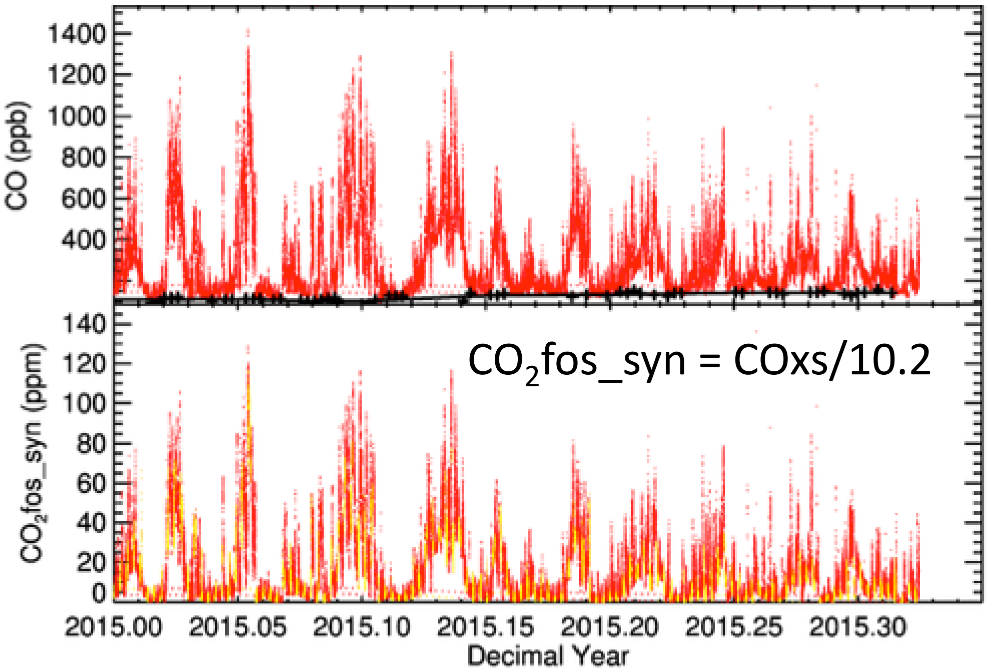
Differences may reflect suppressed atmospheric mixing at night with lower fossil emissions.

$CO:CO_2$ correlations – CO_2fos Summer v. Winter



Transforming *in situ* CO to CO_2ff

Granada Hills in situ data

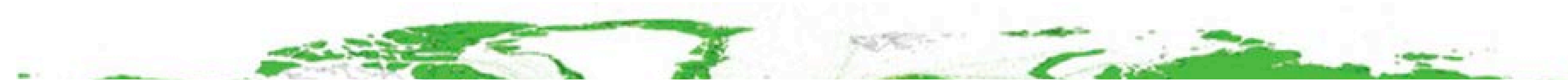


- Just an example, for now…
- Yellow represents mid-day hours – i.e. only when our CO/CO_2fos values are valid.
- Evidence for diurnal variability in CO:CO_2

→ Huuuge signals, but are they too big?

Why Megacities?

Large emissions and large signals. But…



Population (Millions)	GHG Emissions (M tCO_2e)
1. China: 1,192	1. USA: 7,107
2. India: 916	2. China: 4,058
3. 50 Largest Cities: 500	**3. 50 Largest Cities: 2,606** *

Duren and Miller, Nat. C.C., 2012

der picture of LA with multiple obs systems.

Megacity > 10 million; 2010 = 22 cities; 2025 = 38 cities

LA is ~ 17 million

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