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]

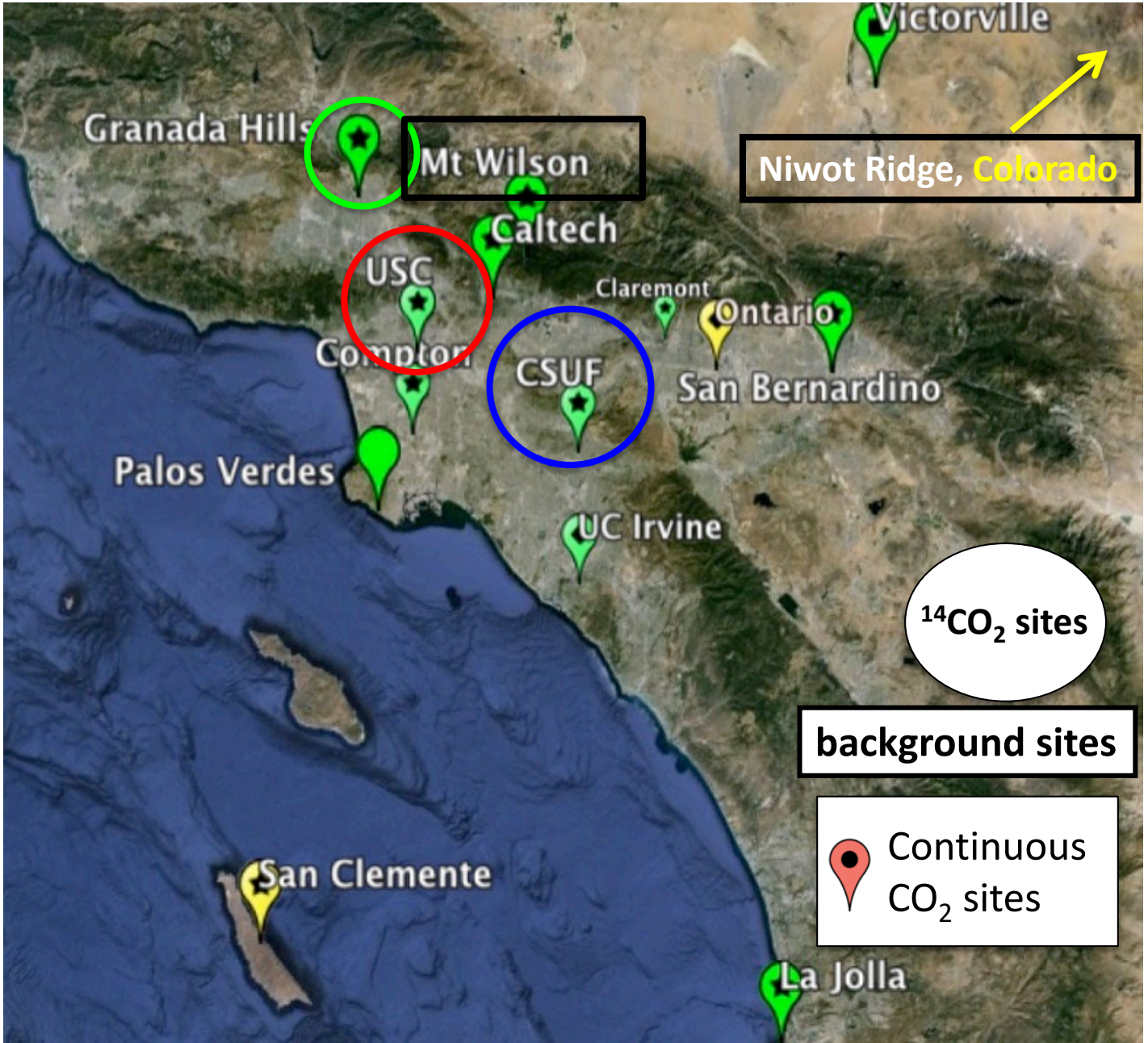
1. NOAA/GMD 2. CU/CIRES 3. CU/INSTAAR 4. NASA/JPL 5. CalTech
6. Earth Networks

LA Megacities goals and our hypotheses

"Develop and demonstrate measurement 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. Despite a large network of CO_2 observations, quantifying CO_2 variations difficult without understanding biogenic contributions.
2. Biogenic contributions difficult without ^{14}C.

LA Basin $^{14}CO_2$ sampling sites



What you need to know about radiocarbon (^{14}C)

1. Produced via cosmic rays; absorbed by photosynthesis; decay with a half-life of ~6000 yrs.
2. **Thus, fossil fuels have no ^{14}C; but $^{14}C_{bio} \sim {}^{14}C_{atmos.}$**
3. **CO_2 variations can be split into bio and fossil using ^{14}C.**
4. Precious: $[^{14}CO_2] \sim 400 \times 10^{-18}$; measured by Accelerator MS on 2 liters of air.
5. $^{14}C/C$ expressed as $\Delta = [(^{14}C/C)/R_{std} - 1]1000$ in "per mil"

Measurements of local and background CO_2 and $\Delta^{14}C$ allow us to determine C_{fos} and C_{bio}.

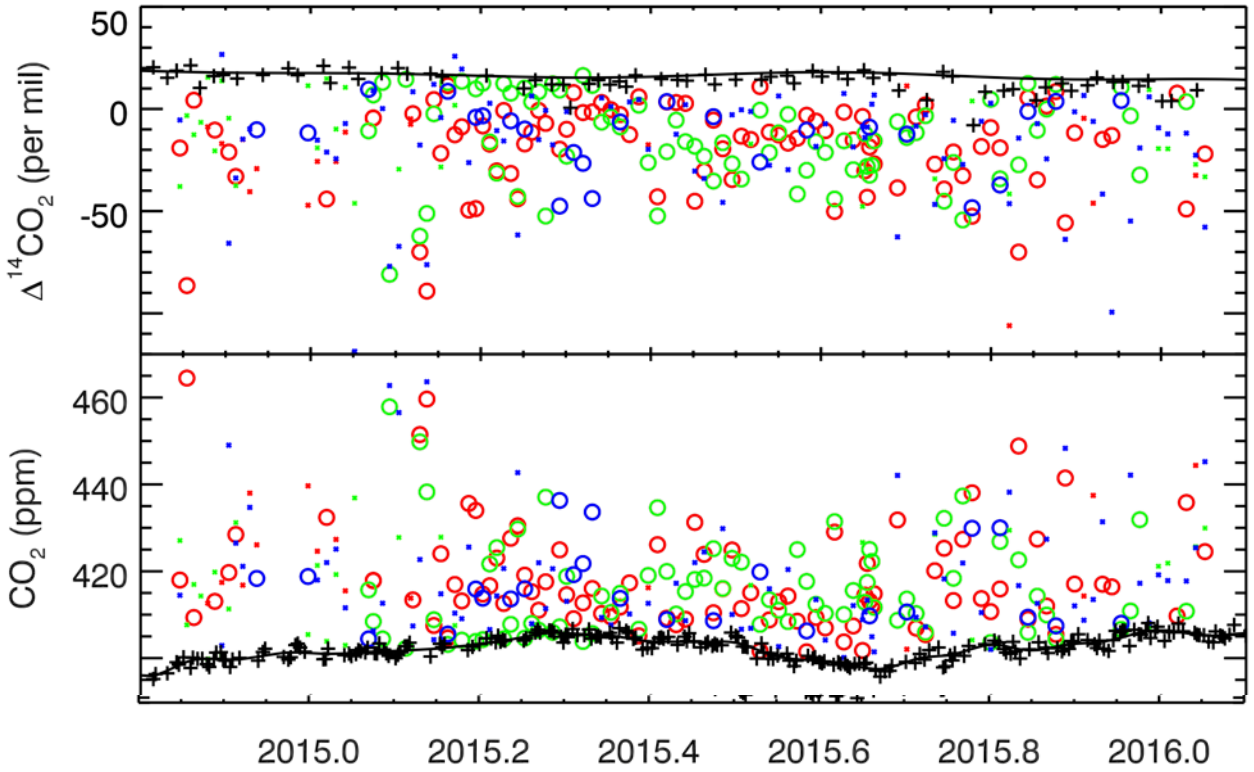
CO_2xs

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

No ^{14}C
(-1000 per mil)

~Atmospheric ^{14}C
(~ 40 per mil)

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



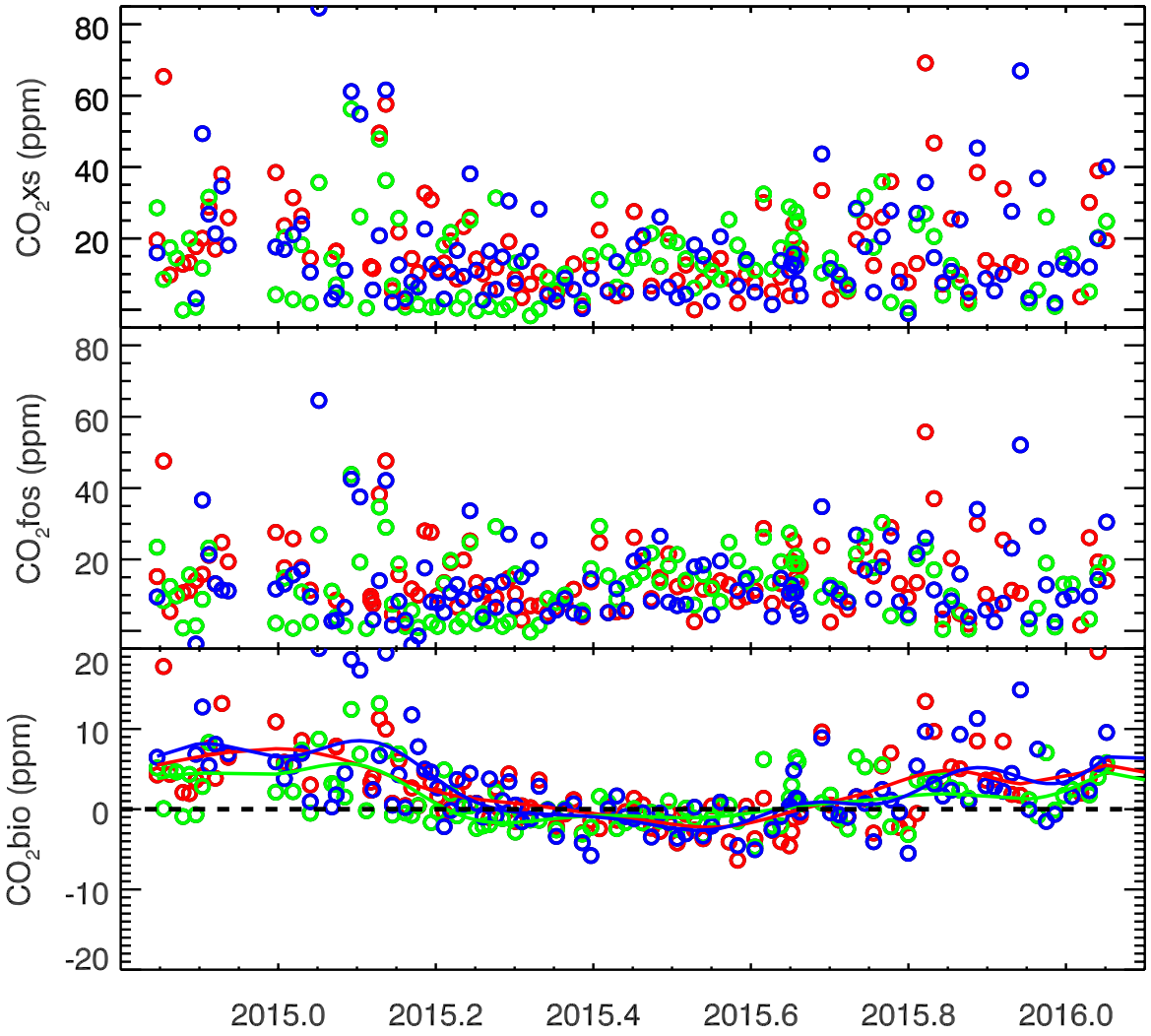
Background

More Fossil Fuel

Background
(NWR, MWO)
USC
Granada Hills
CS Fullerton

Biospheric contribution to total CO_2 is substantial.

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



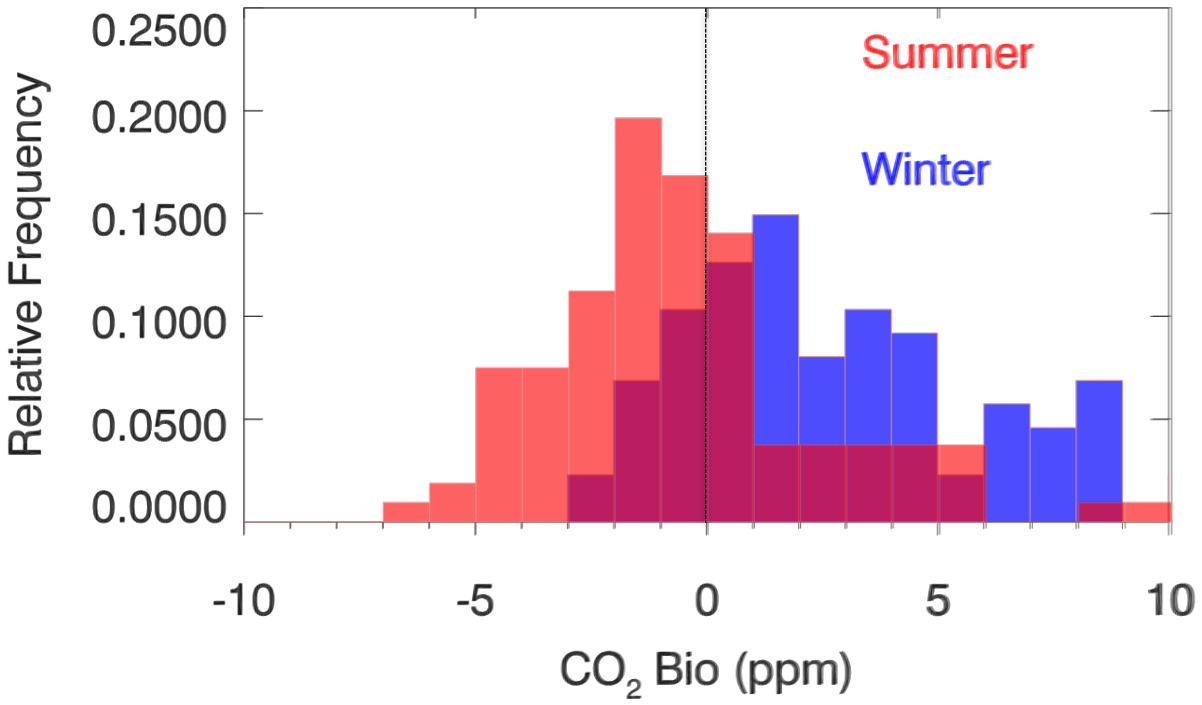
→ Larger enhancements in winter – less vertical mixing.

→ Seasonally varying biosphere contribution with summer uptake.

→ Summer biosphere drawdown is likely underrepresented because of enhanced mixing.

→ Variability in CO_2xs,bio and fos are likely dominated by changes in mixing.

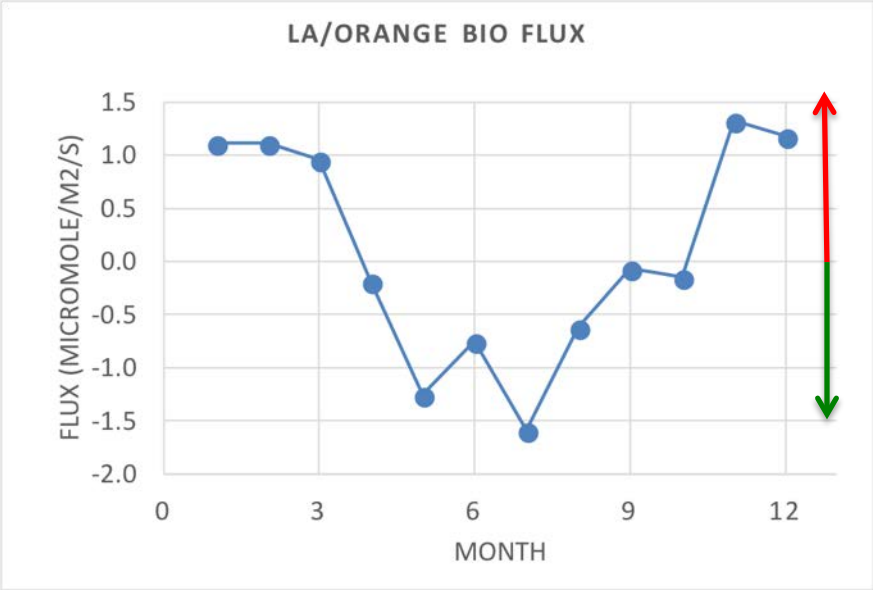
Biogenic contribution appears highly seasonal



Why is CO_2bio so high?

1. Ethanol in gasoline ~ 3% of fossil fuel emissions
2. Human respiration ~ 5%
3. Livestock respiration << 1%
4. → Urban ecosystems: parks, lawns, golf courses, forests
5. **Only urban ecosystems can explain negative C_{bio}**

Use fossil fuel inventory to estimate bio flux



Source

Sink

$F_{bio} = C_{bio}/C_{fos} \times F_{fos}$

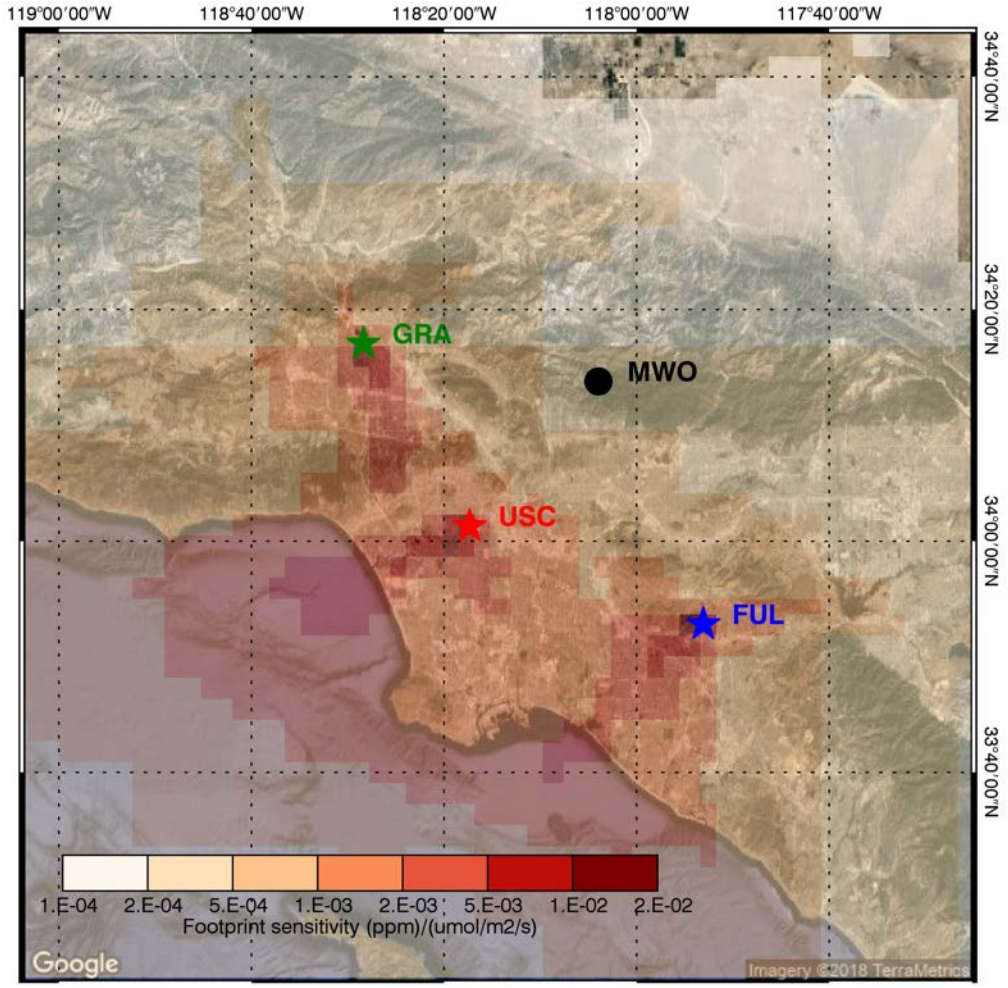
Data Inventory (Vulcan)

- Allows separation of atmospheric mixing and emissions.
- Annual mean flux (NEE) ~ neutral (different than C_{bio}).
- Seasonal minimum is in summer, not spring, as expected for Mediterranean climate.
- This suggests managed ecosystems (e.g. lawns) are driving C_{bio}, not native grass and forest ecosystems.

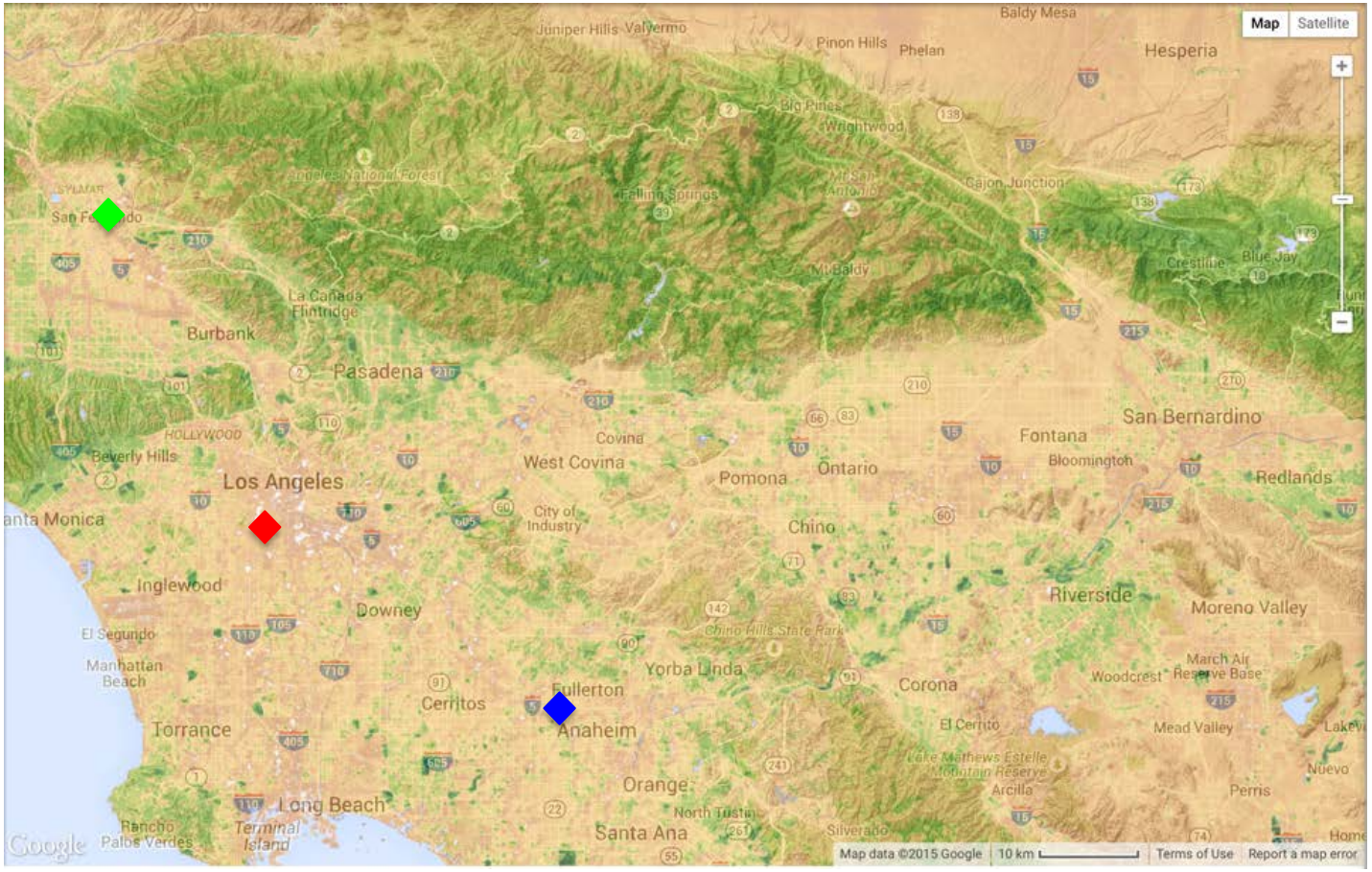
Summary and implications

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, and likely year to year. → Trend detection will be difficult.
4. Continued and widespread measurement of urban biosphere fluxes will be required to isolate the fossil fuel emissions signal.

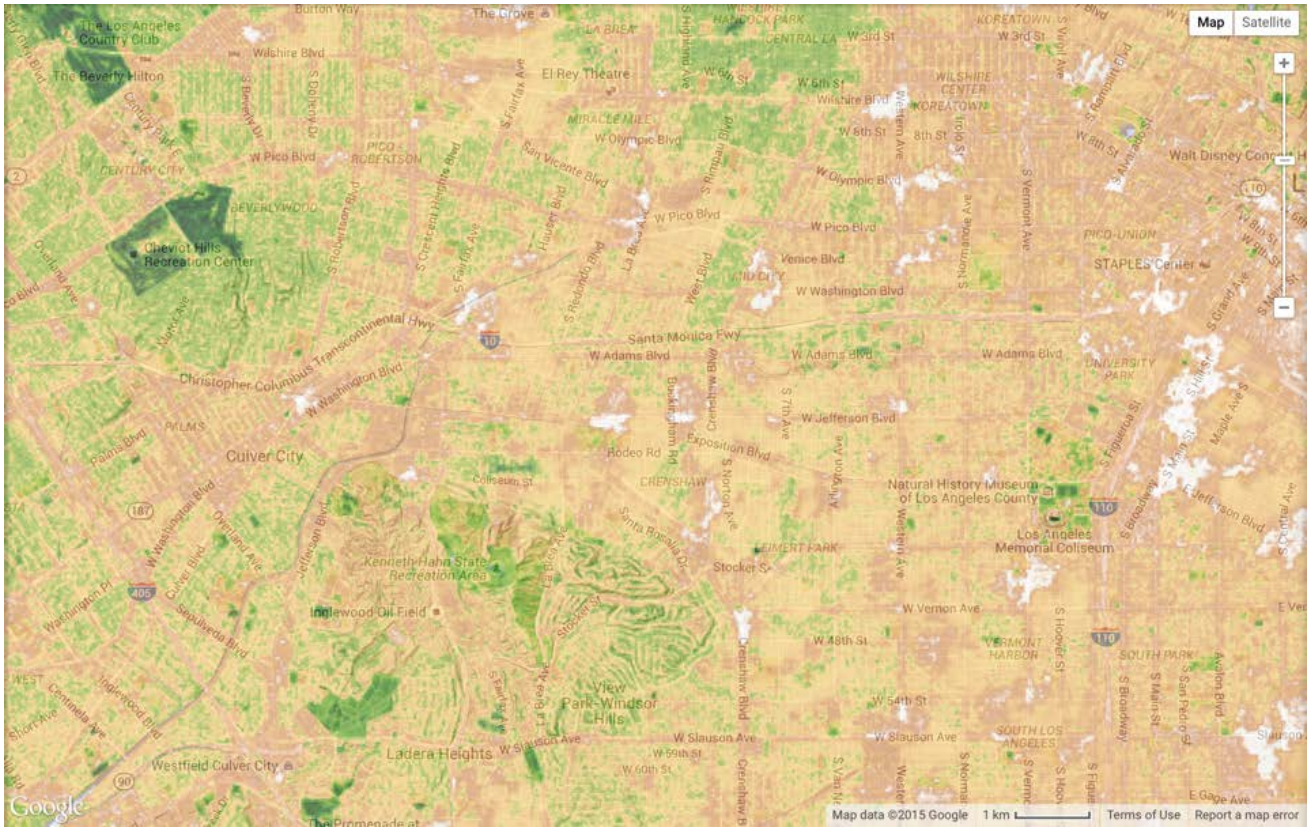
Footprints


119°00′00″W
118°40′00″W
118°20′00″W
118°00′00″W
117°40′00″W
34°40′00″N
34°20′00″N
34°00′00″N
33°40′00″N
GRA
MWO
USC
FUL
1.E-04
2.E-04
5.E-04
1.E-03
2.E-03
5.E-03
1.E-02
2.E-02
Footprint sensitivity (ppm)/(umol/m2/s)
Google
Imagery ©2018 TerraMetrics

LANDSAT 30 m Vegetation (EVI)

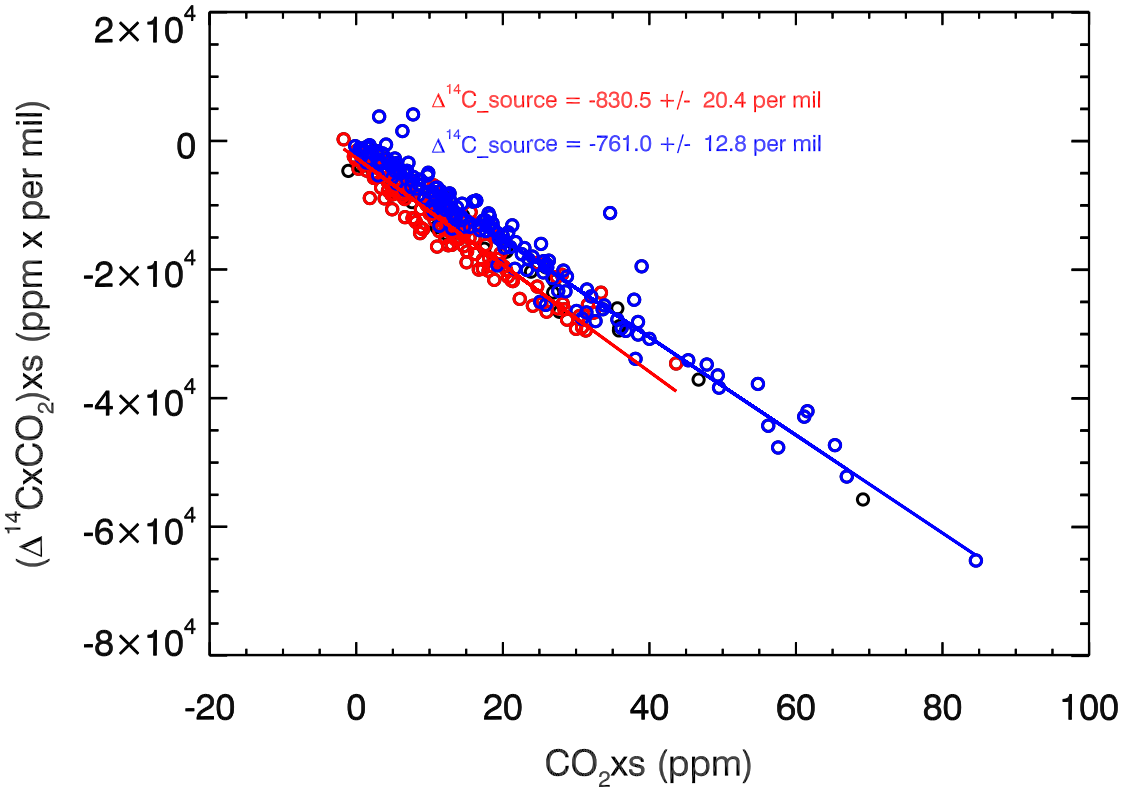


LANDSAT 30 m EVI zoomed in shows even more.



→ Google Earth (~50 cm) shows yet more.

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

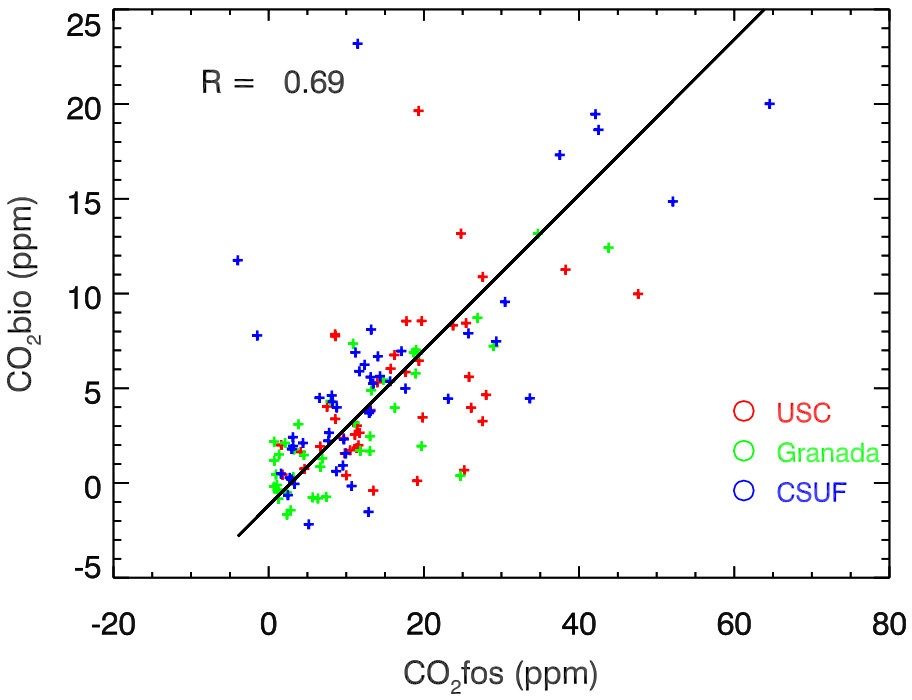


Pure fossil: -1000 per mil

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

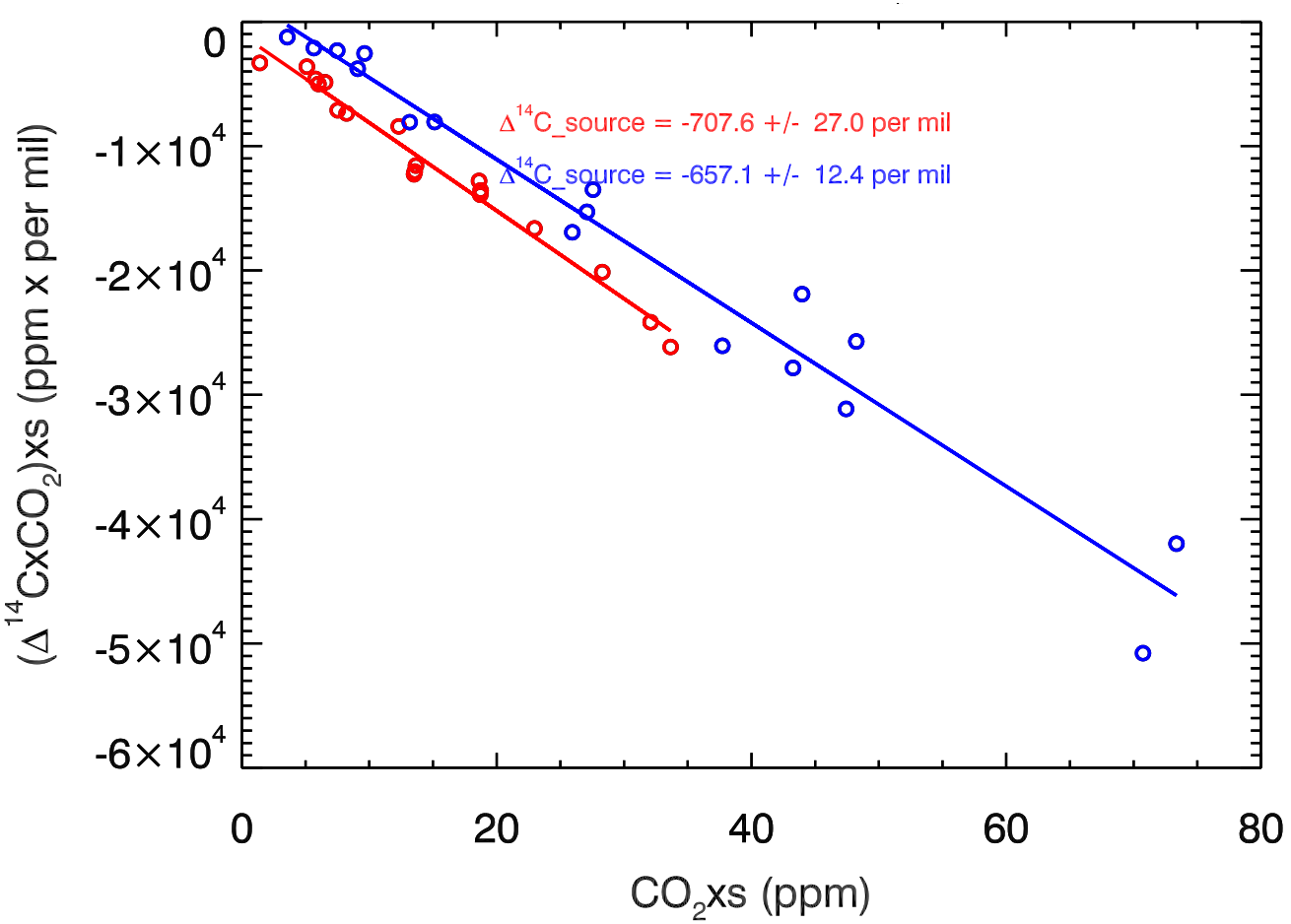
Summer: -830 per mil → CO_2xs is 17% biogenic

High correlation of Bio and Fossil components consistent with co-located distributed sources.



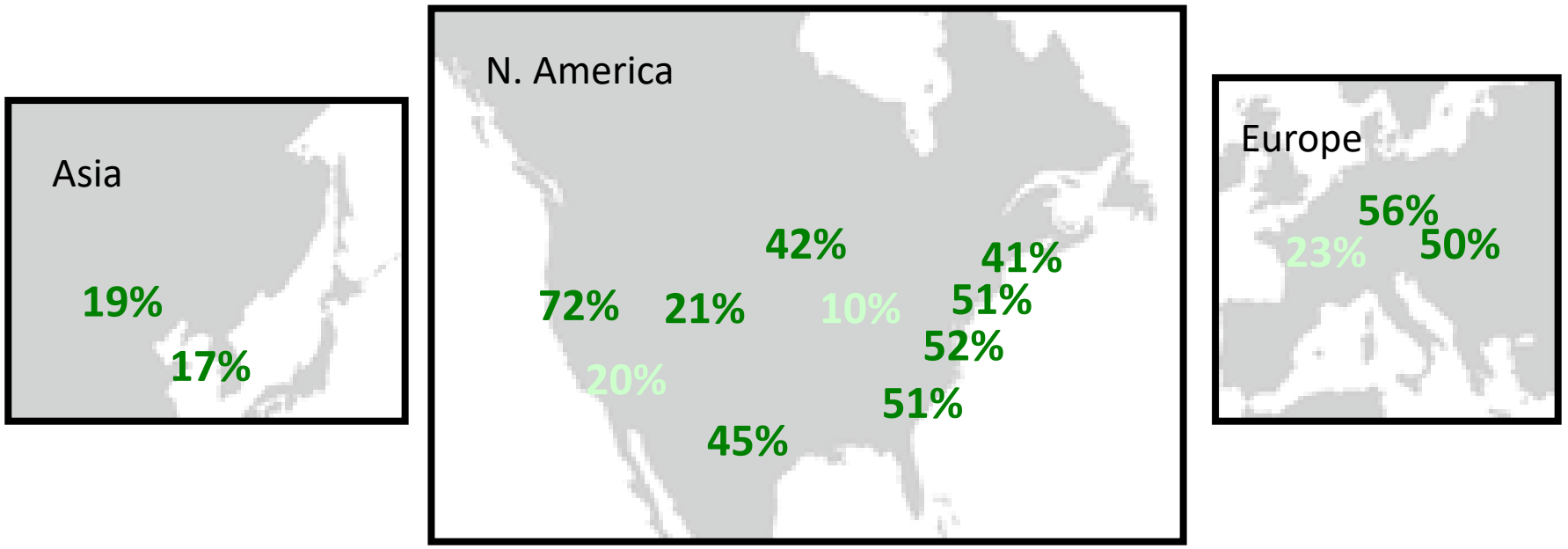
- Fossil fuels (and ethanol), and human population are similarly distributed throughout the Basin.
- Urban ecosystems may also be.
- High correlation also suggests urban ecosystems and not mountain forest areas are responsible for Cbio variations.
- N.B.: Correlation is analyzed in winter to avoid near zero CO_2bio signal resulting from net photosynthesis.

Nighttime signals show more biogenic signal and small signals overall.



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

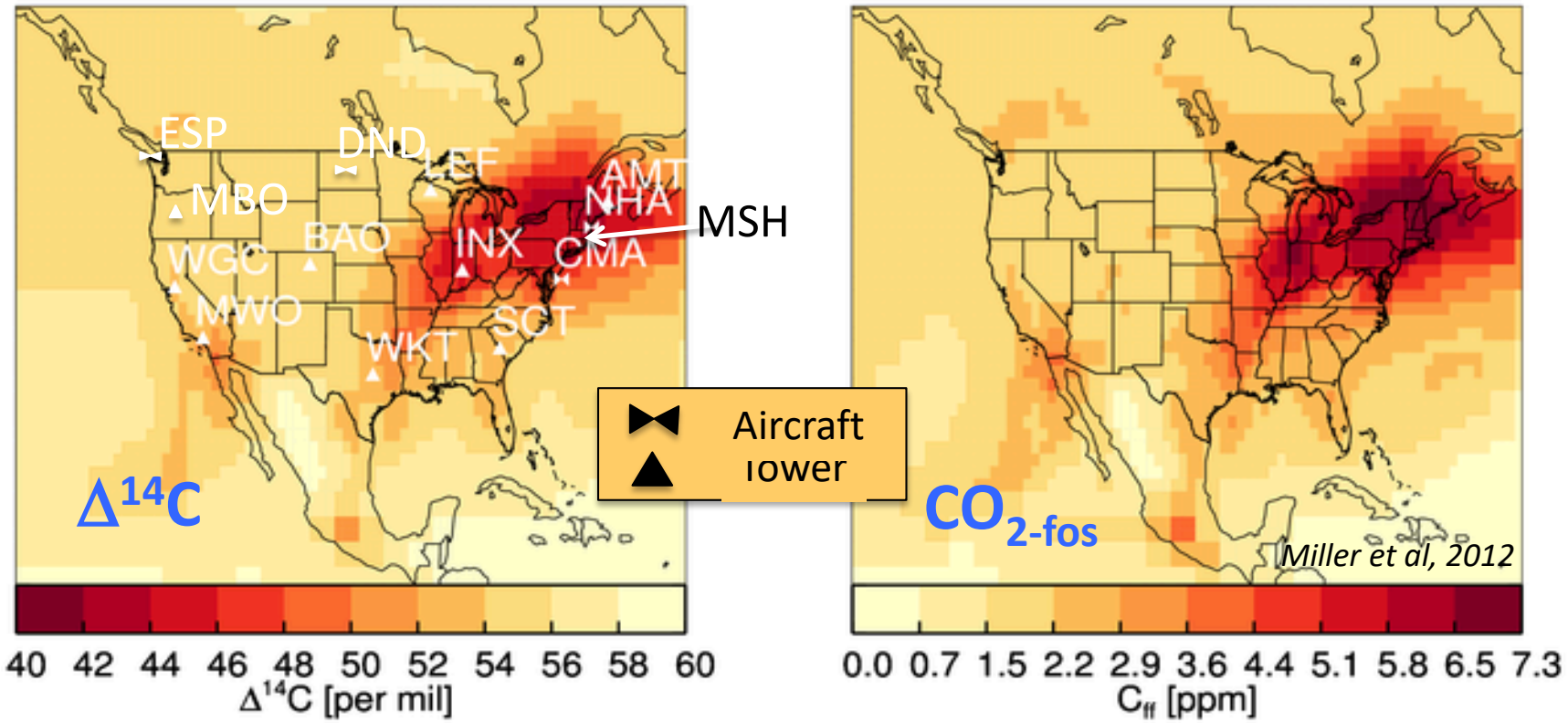
Wintertime biospheric CO_2 fraction averages ~50% for regions; ~ 20% for cities



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

Atmospheric $^{14}CO_2$ looks just like fossil CO_2

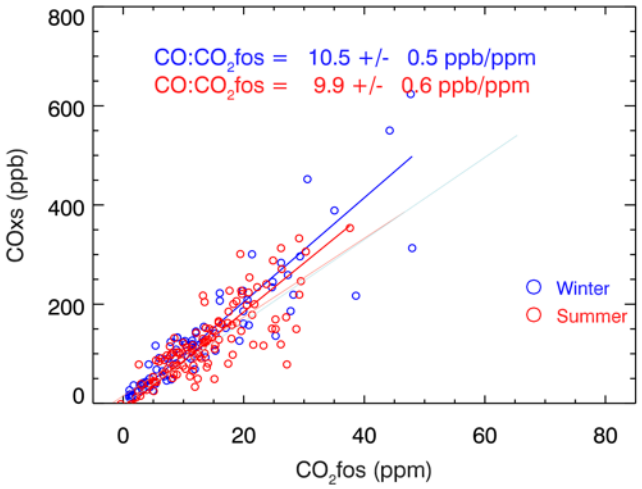
-2.5 per mil $\Delta^{14}C$ = 1 ppm CO_2-fossil



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

Includes only fossil fuel

We can leverage our ^{14}C measurements to create a pseudo-continuous CO_2fos time series.



a. COxs:CO_2ff ratios are fairly consistent (here for USC)

b. Applying these to the USC COxs time series allows us to create "CO_2fos Synthetic"