Significant biospheric CO_2 fluxes in the Los Angeles Basin revealed by atmospheric radiocarbon ($^{14}CO_2$)

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

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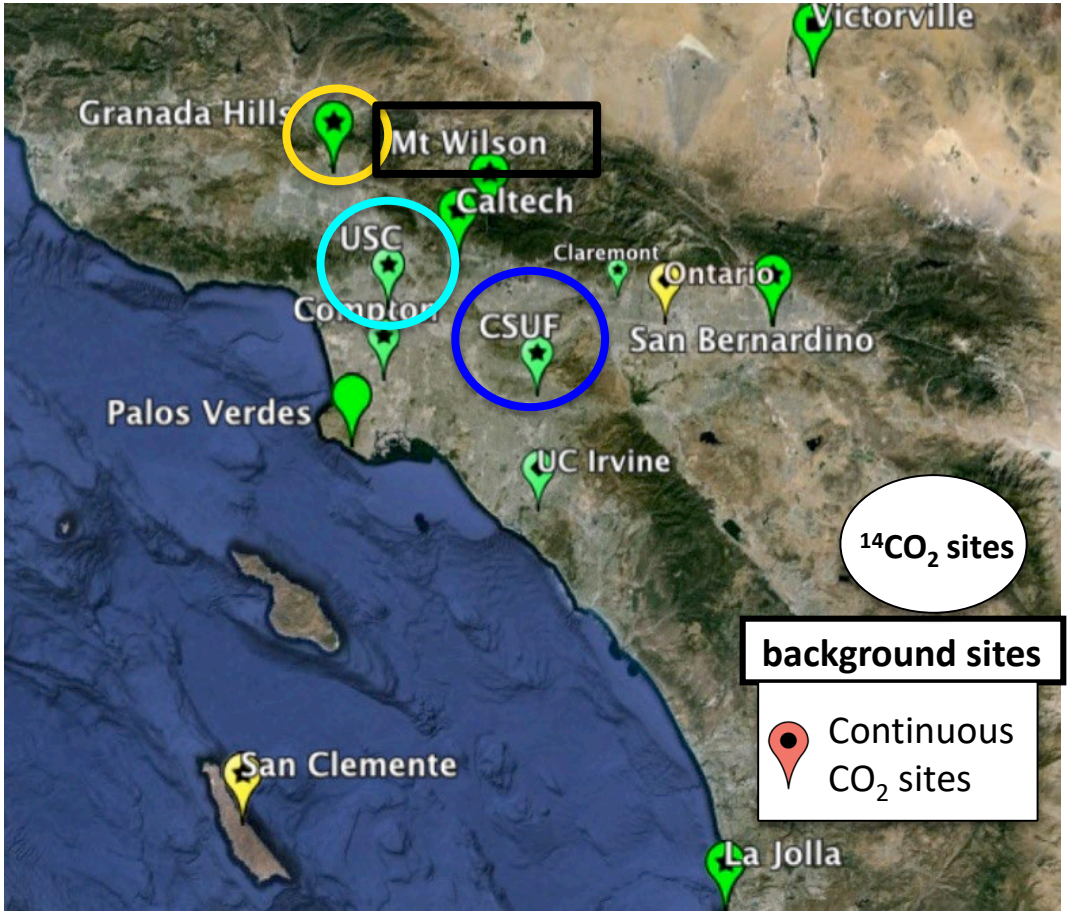
LA Basin $^{14}CO_2$ sampling sites



- → Most sites have in situ CO_2, CH_4 and CO with eventual goal of calculating fluxes.
- → Three sites had 3x/week flask sampling in 2015
- → Goal with flasks was to separate total CO_2 into fossil and biogenic fractions.

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

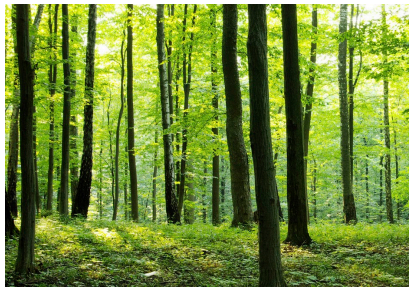
1. Produced via cosmic rays; absorbed by photosynthesis; decay with a half-life of ~6000 yrs.
2. **→ Fossil fuels have no ^{14}C; but $^{14}C_{bio}$ ~ $^{14}C_{atmos.}$**
3. **→ CO_2 variations can be split into bio and fossil using ^{14}C.**
4. Low concentrations: $[^{14}CO_2]$ ~ 400 x 10^{-18} mol/mol; 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_{ff} and C_{bio}.

CO_2xs

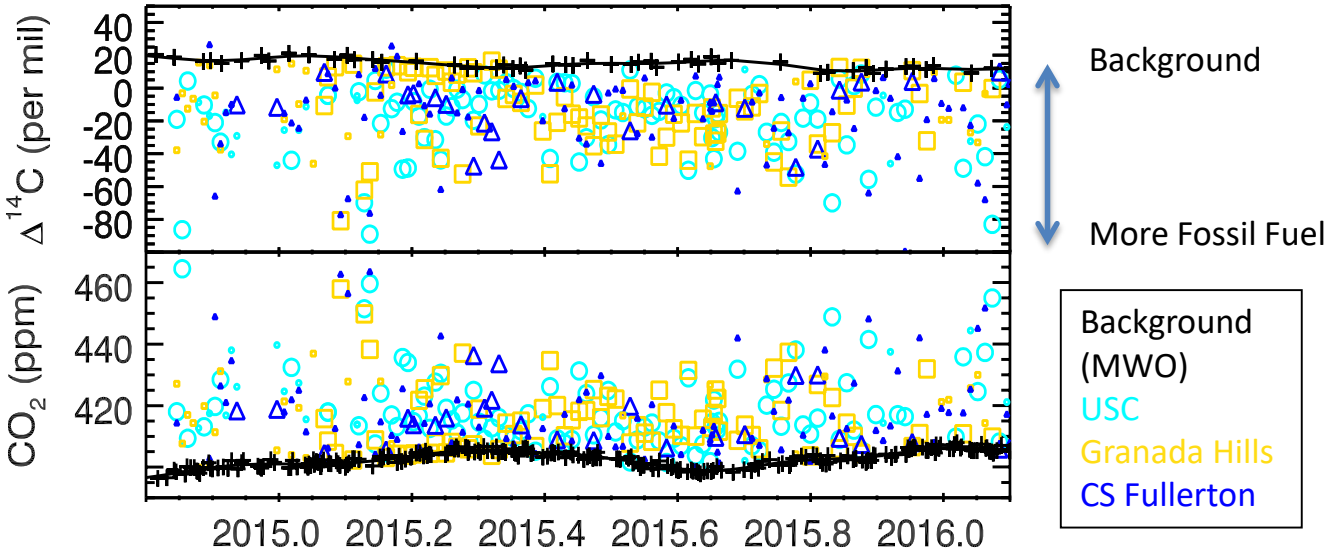
$$C_{obs} = C_{bg} + C_{ff} + C_{bio}$$

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

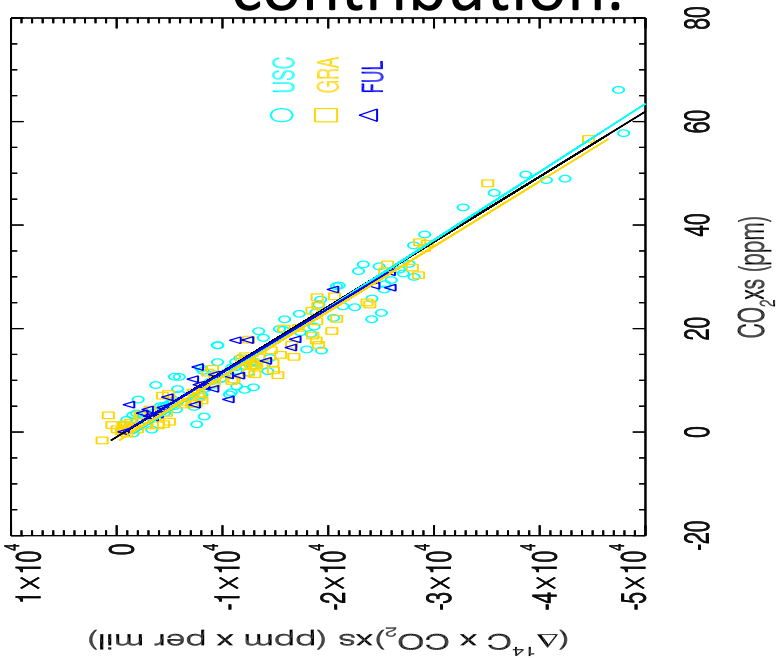


Atmospheric ^{14}C
(~ 0 per mil)

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



Isotopic mixing analysis shows substantial biogenic contribution.

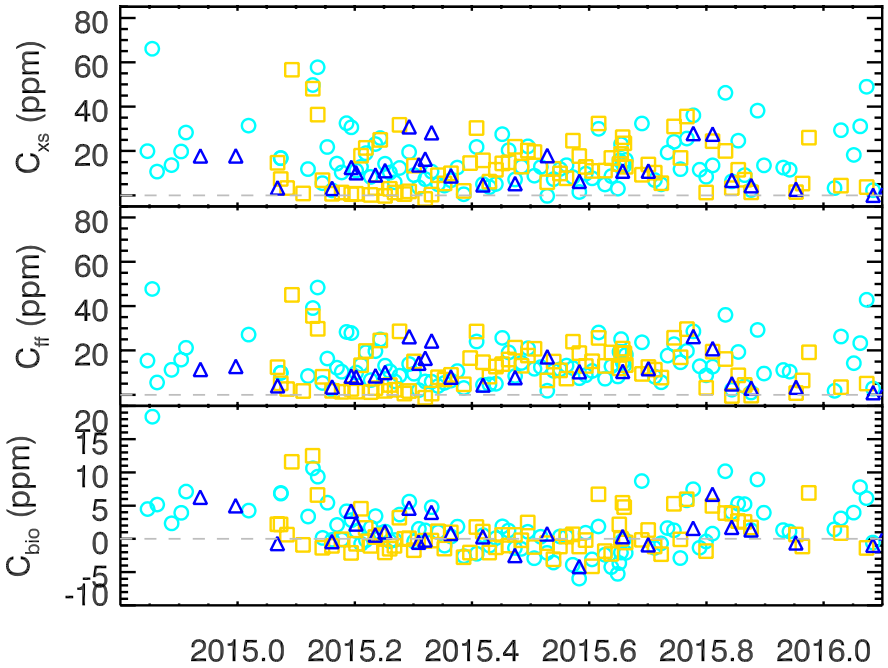


Pure fossil slope = -1000 per mil

Slope (Isotopic source) = -783 per mil → CO_2xs is ~ 20% biogenic

Biospheric contribution to total CO_2 is substantial.

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



- → C_{xs} and C_{ff} are highly correlated, yet the residual C_{bio} has a coherent signal.
- → Seasonally varying biosphere contribution with summer uptake.
- → Variability in CO_2xs,bio and fos are likely dominated by changes in mixing.

C_{bio} has a lot of biofuel and human respiration

Sector	Fossil (TgC/yr)	Bio (TgC/yr)
Residential	2.85	0.37
Commercial	2.46	0.11
Industrial	11.48	1.91
Electricity Production	5.47	0.81
On-road	19.47	1.50
Other	3.99	0.01
Total	45.72	4.72

State of CA inventory and Vulcan 3.0

Biofuel:Fossil-Fuel Emission Ratio = 0.10

So. Cal. Population	Respiration+Excretion (TgC/year)	Fossil emissions (TgC/yr)
18,609,235	2.62	45.21

Human Bio:Fossil Emission Ratio = 0.06

Total Bio:Fossil Emission Ratio = R_{bio} = 0.16

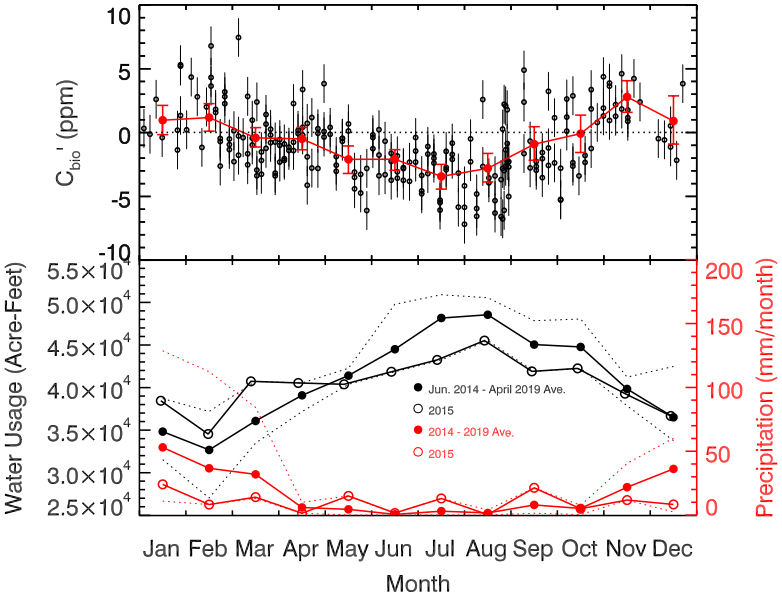
For each sample, we define

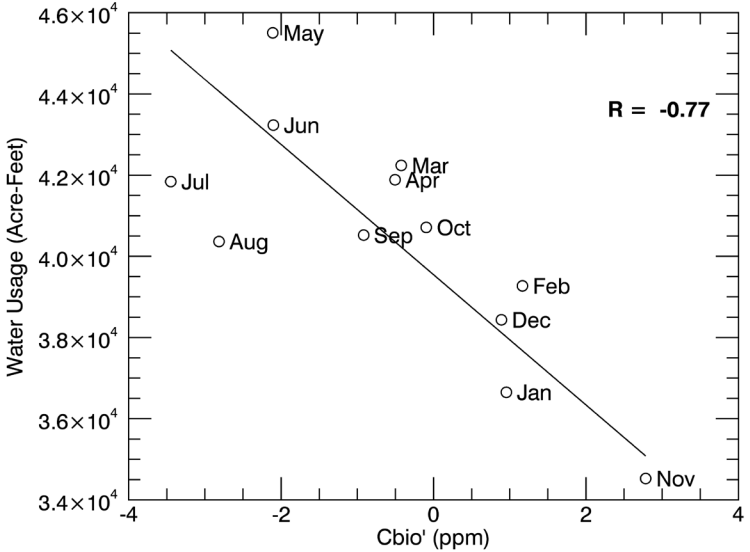
$$C_{bio}' = C_{bio} - R_{bio} \times C_{ff}$$

which captures the signal of the urban biosphere.

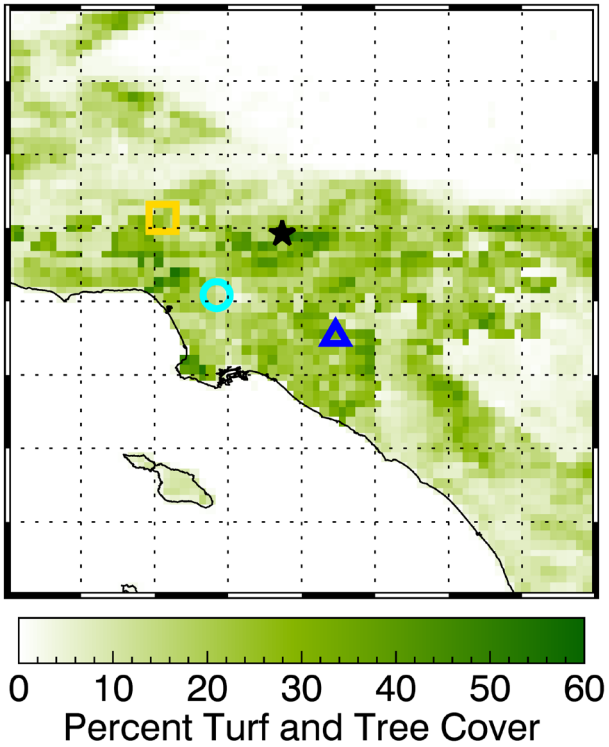
→ $C_{bio}' \sim C_{bio}$ - 2 ppm

C_{bio}' has clear seasonality that correlates with city water use, not rainfall.





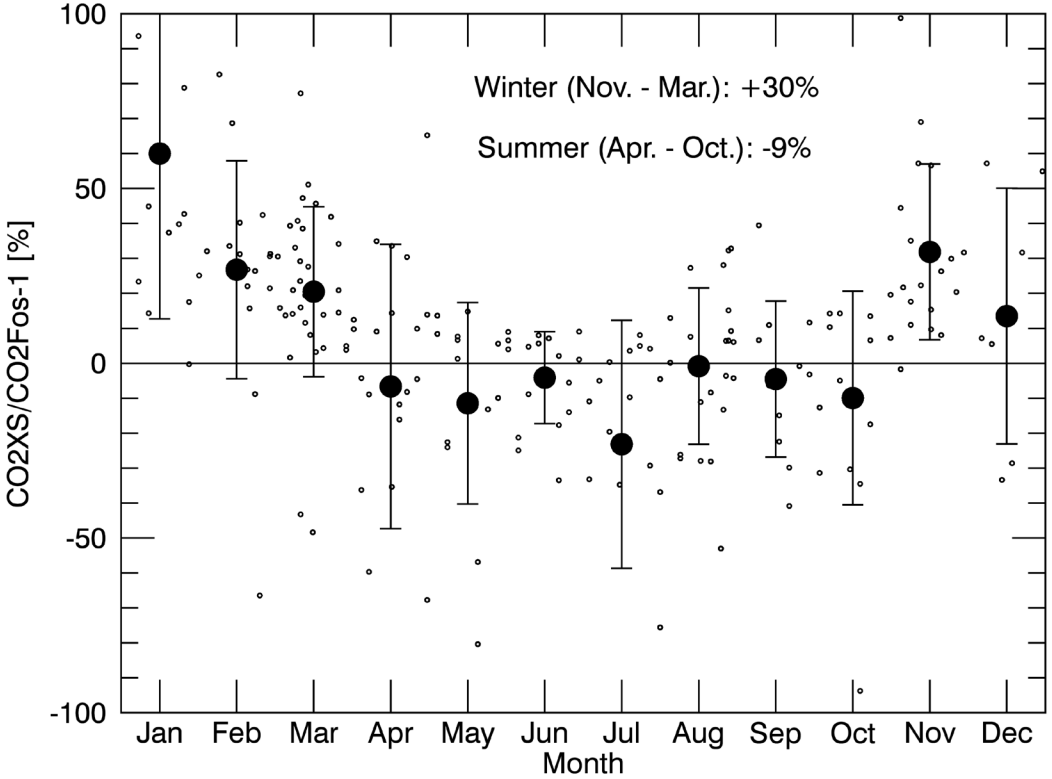
Is such a large urban biospheric signal realistic?



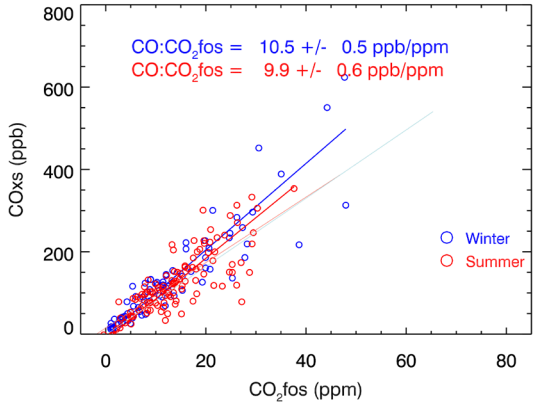
- ~14% tree + turf in our footprint
- McPherson et al., 2011
  - 12% irrigated lawn cover
  - 21% tree cover
- Urban ecosystems: parks, lawns, golf courses, etc.
  - Within footprint of observations
  - **Only urban ecosystems can explain negative C_{bio}**
  - Surrounding unmanaged ecosystems
    - Fluxes mostly out of phase with urban observations.
    - Generally outside footprint.

MODIS VCF and AVIRIS flights (Wetherly et al., 2018)

Assuming all CO_2 enhancement is fossil leads to seasonally varying errors.

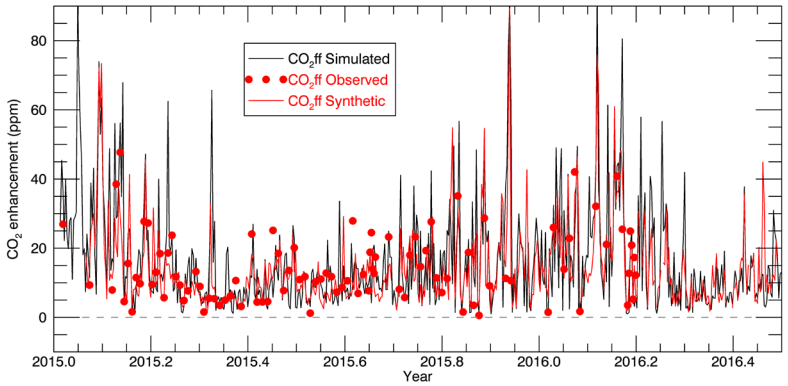


We can transform ^{14}C data to create a synthetic continuous CO_2ff time series using continuous CO.



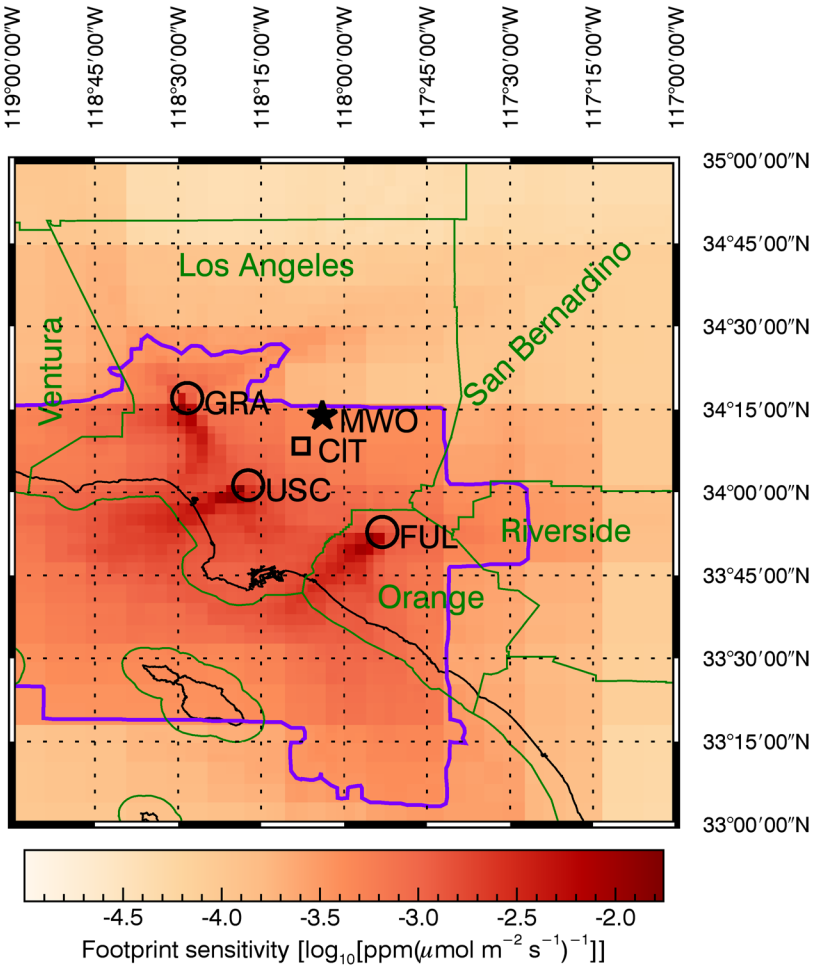
a. COxs:CO_2fos (R_{CO}) ratios from flasks ~ 10 ppb/ppm.
b. CO_2fos_synthetic = COxs_continuous/R_{CO}
c. Agrees reasonably well with Hestia fluxes convolved with WRF-STILT footprints (CO_2fos_simulated): R=0.69; slope=0.81

Note: ~10% bias if R_{CO} calculated with CO_2xs instead of CO_2ff



Summary and implications

1. LA CO_2bio is seasonal and appears to be controlled by irrigation.
2. CO_2xs provides a seasonally biased view of CO_2ff.
    1. Remote-sensing and *in situ* approaches for urban CO_2 fluxes need to account for biospheric CO_2.
3. Continued and widespread measurement of urban biosphere fluxes will be required to isolate the fossil fuel emissions signal, even for generally dry (or cold) areas. **Some combination of ^{14}C, CO and urban biosphere modeling will probably be required.**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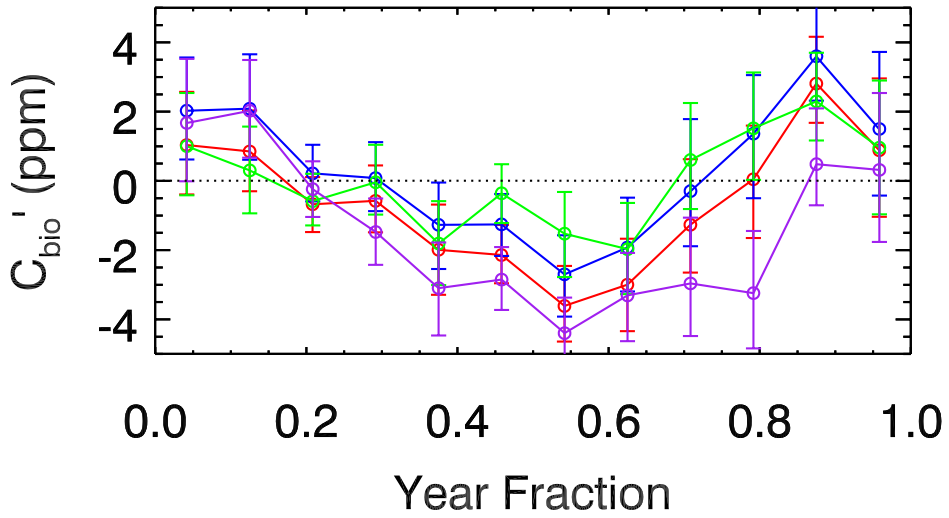
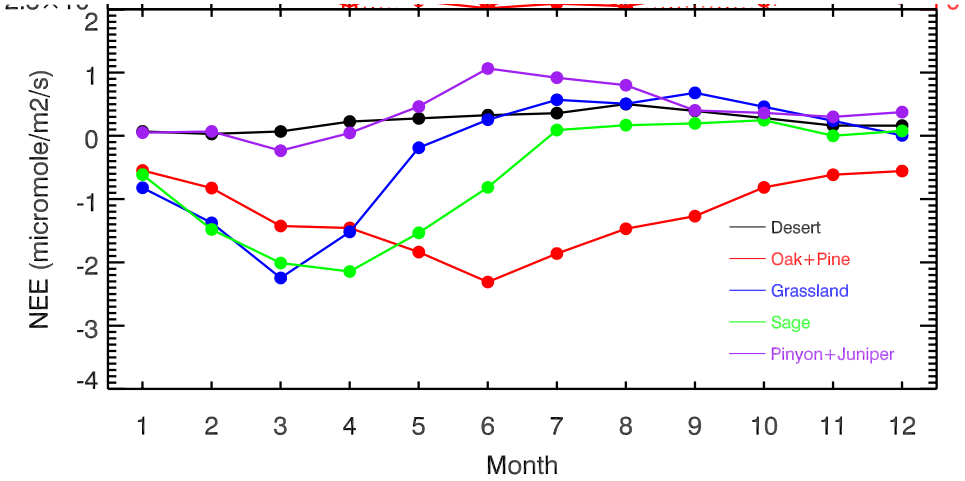
33°45′00″N
33°30′00″N
33°15′00″N
33°00′00″N
Los Angeles
Ventura
San Bernardino
Riverside
Orange
GRA
MWO
CIT
USC
FUL
-4.5
-4.0
-3.5
-3.0
-2.5
-2.0
Footprint sensitivity [log10[ppm(μmol m−2 s−1)−1]]

C_{bio}' Sensitivity Tests



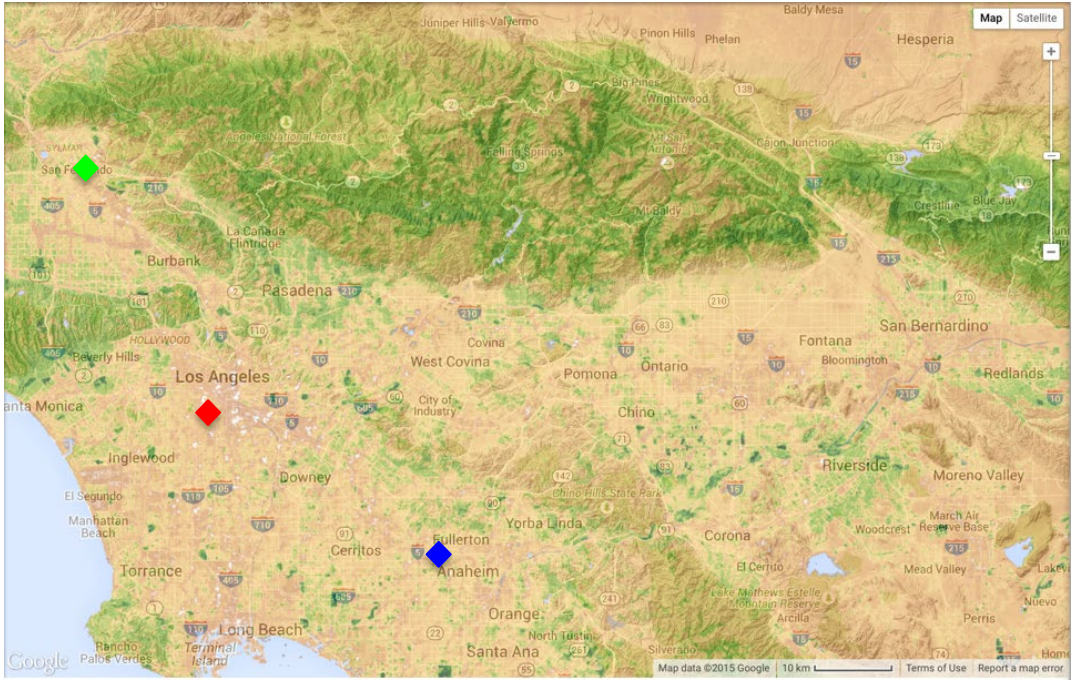
Red=control; Blue=on-road-only ER;
Green=NWR background; Purple=BRW 14C background.

'Natural' ecosystem eddy-fluxes

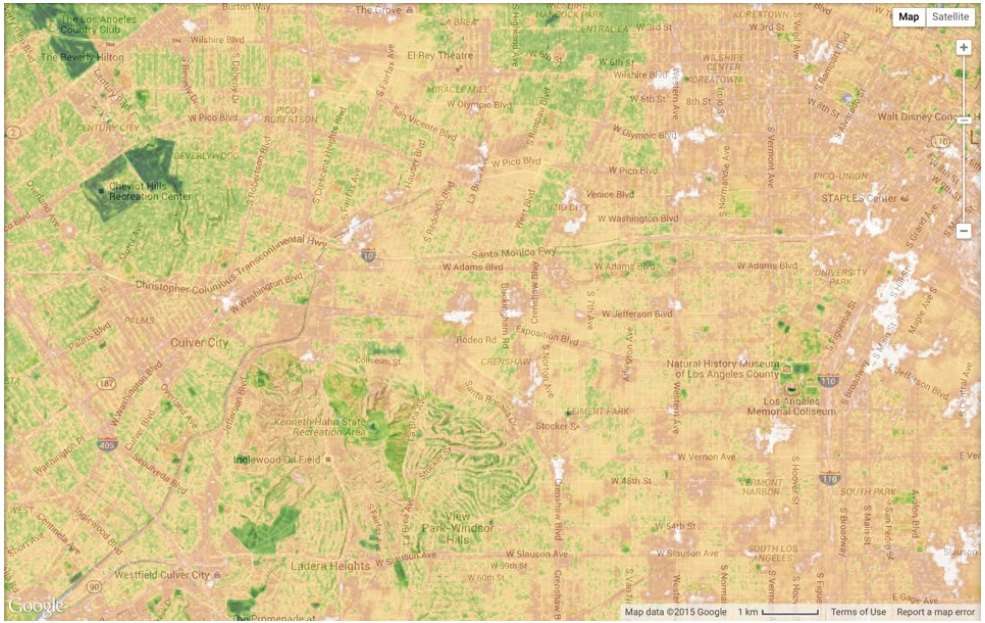


Southern California Climate Gradient study sites, Ameriflux, M Gouldern PI

LANDSAT 30 m Vegetation (EVI)

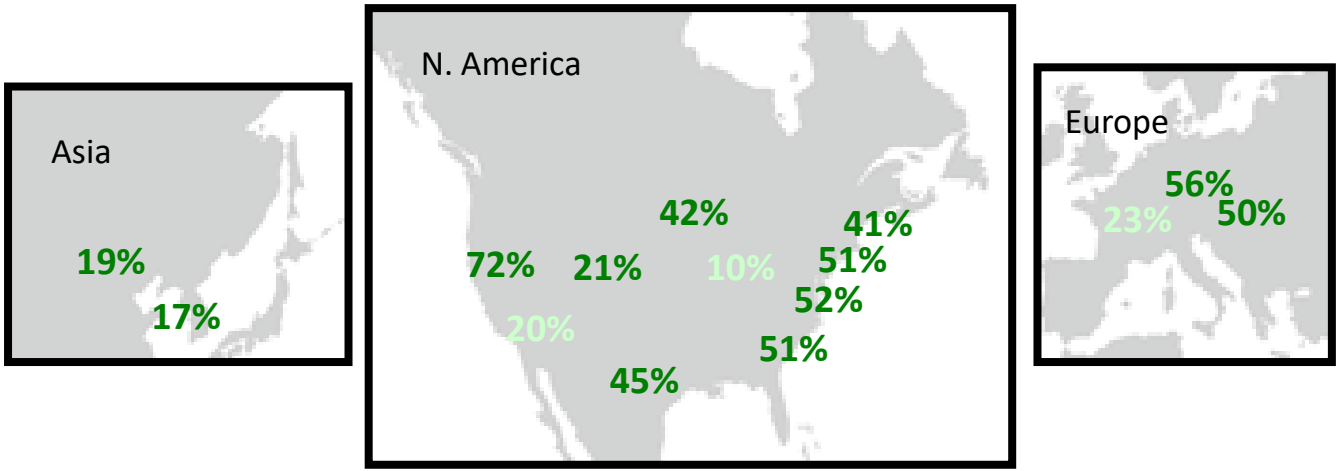


LANDSAT 30 m EVI zoomed in shows even more.



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

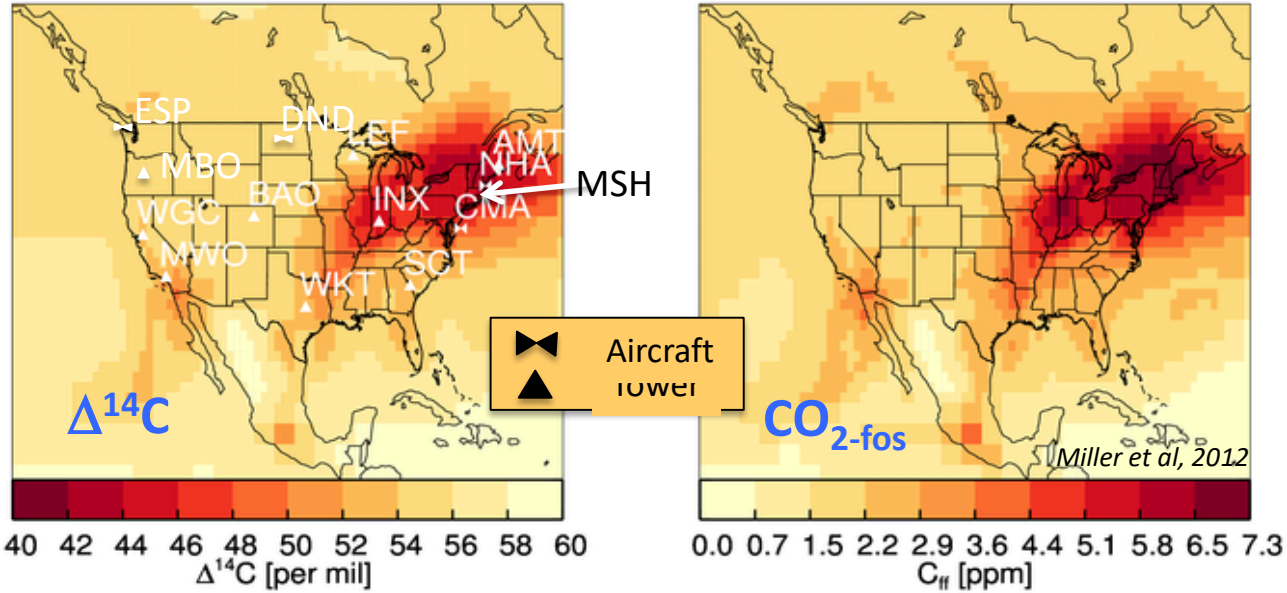
Wintertime biospheric CO_2 fraction averages ~50% for regions; ~ 20% for cities



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

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