# Application of radiocarbon and other tracers to separating urban biogenic and fossil carbon emissions.

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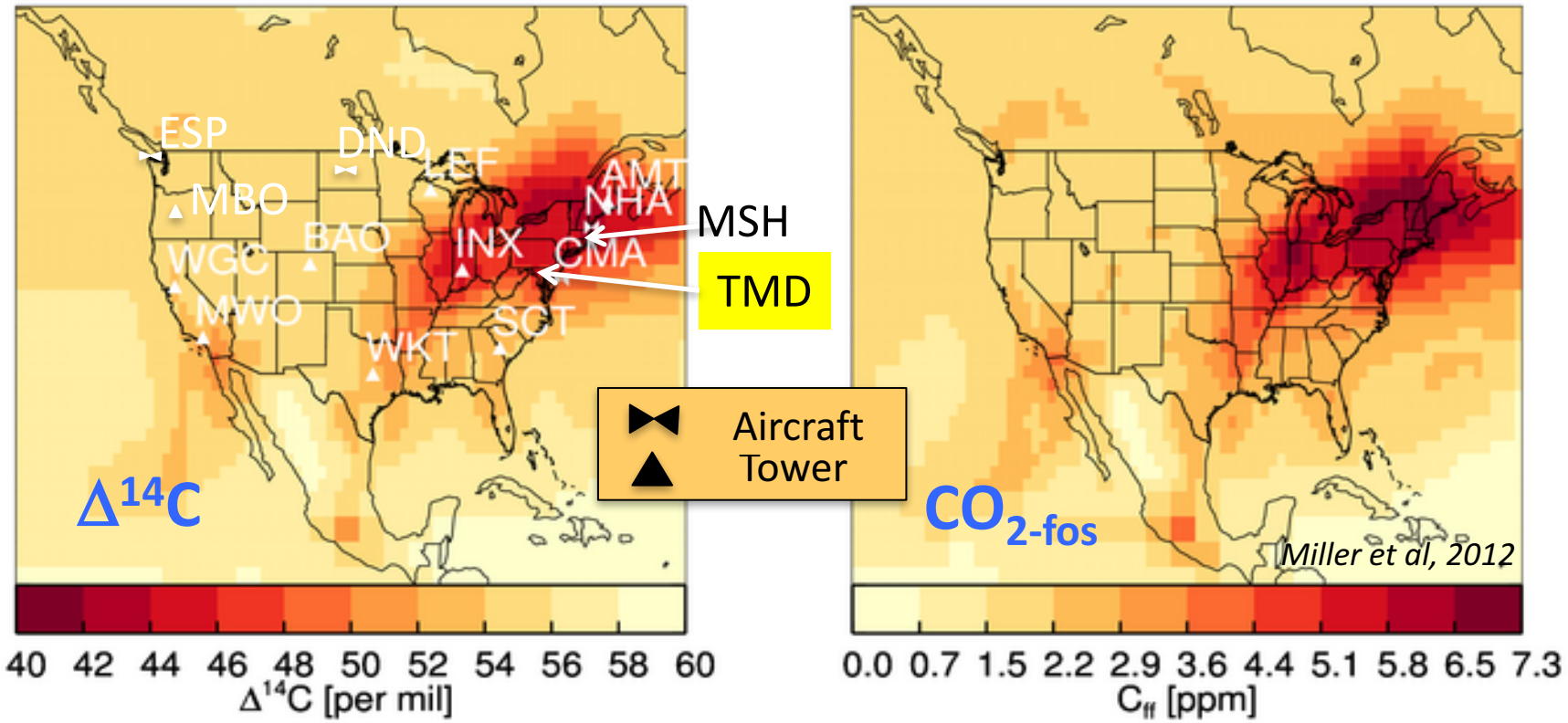
CO2 Urban Synthesis Workshop

Nov. 6 – 7, 2017

1. NOAA/GMD 2. CU/CIRES

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

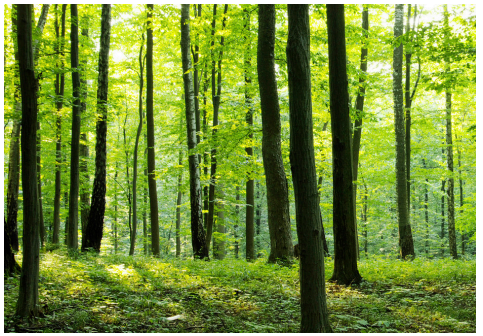
**-2.5 per mil $\Delta^{14}C$ = 1 ppm $CO_2$-fossil**




*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 $\Delta^{14}C$.



$CO_2xs$

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

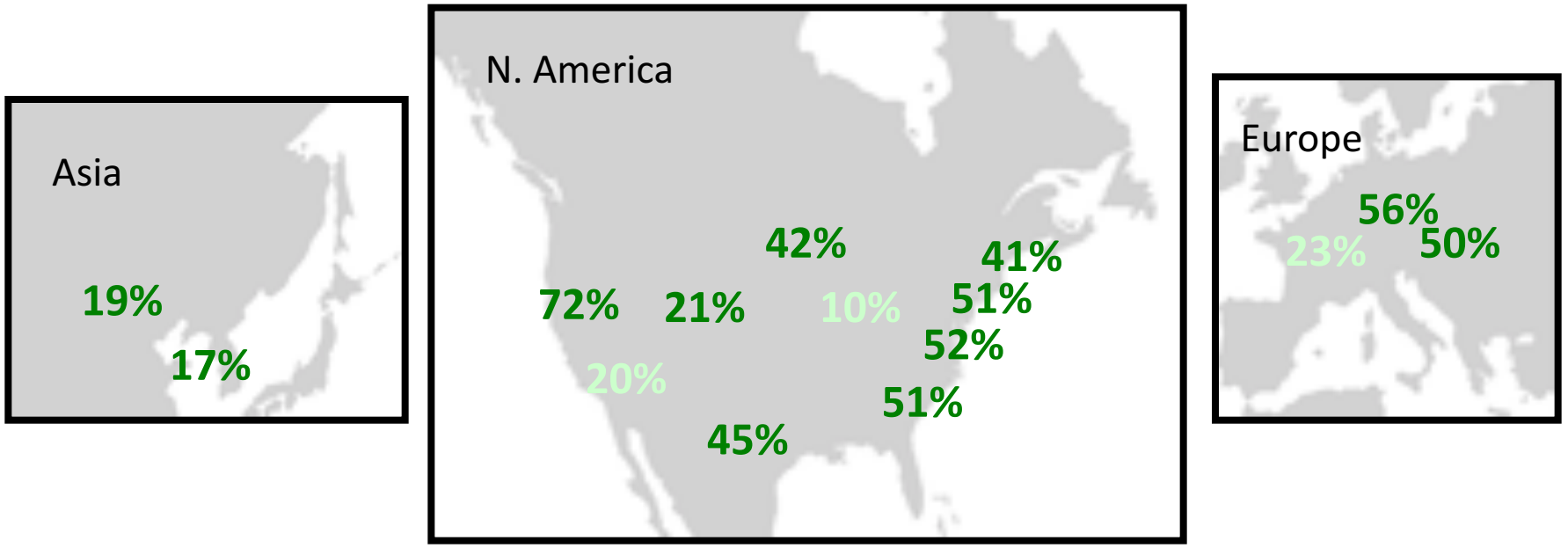
$$(\Delta \times C)_{obs} = (\Delta \times C)_{bg} + (\Delta \times C)_{fos} + \text{minor}$$

Bio has no/little influence

# Air sampling and 14C measurement

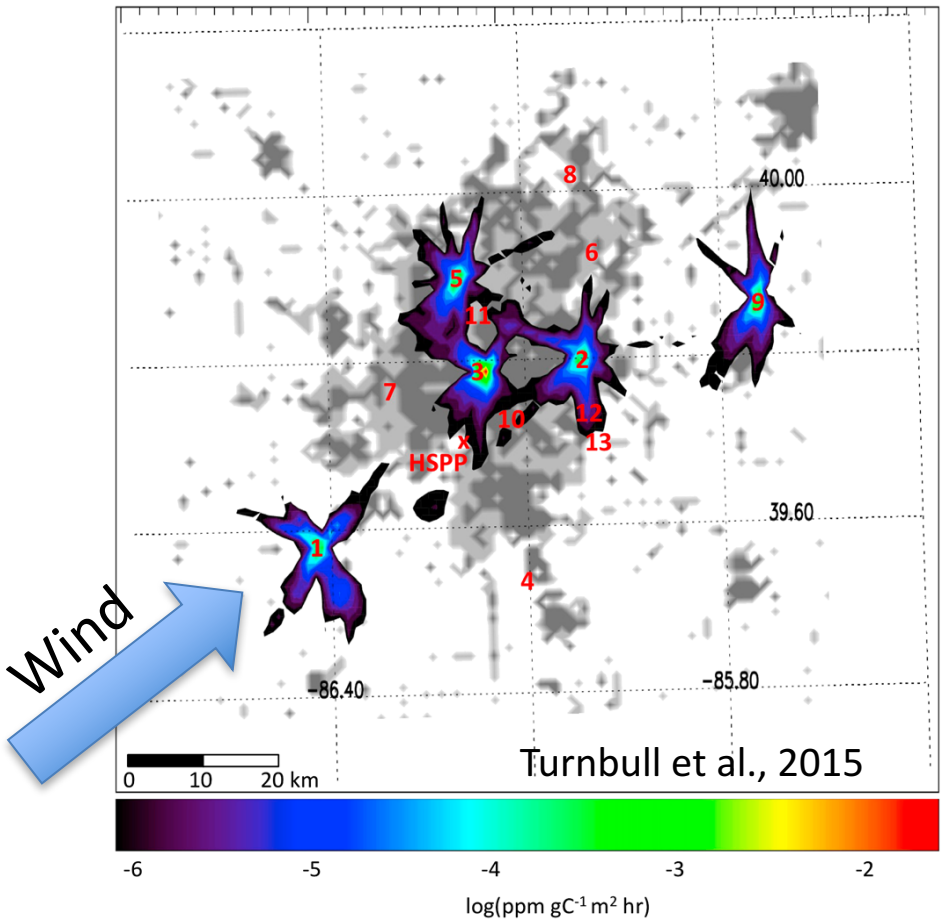
1. We need ~2 L of air for high precision, so we dedicate air from one NOAA “PFP” flask.
2. Extraction of pure $CO_2$ and graphitization at U. of Colorado (Scott Lehman);
3. Accelerator Mass Spectrometer (AMS) analysis, with precision of 1.7 per mil at U. of California, Irvine.

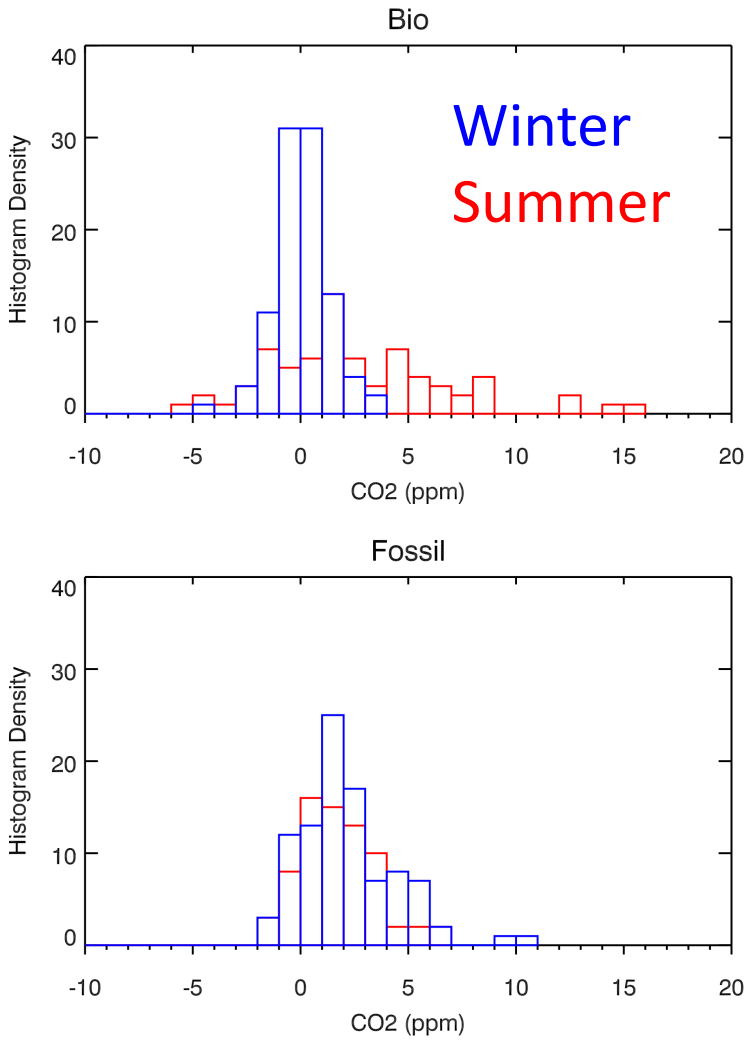
# Wintertime biospheric $CO_2$ fraction averages ~50% for regions; ~ 20% for cities



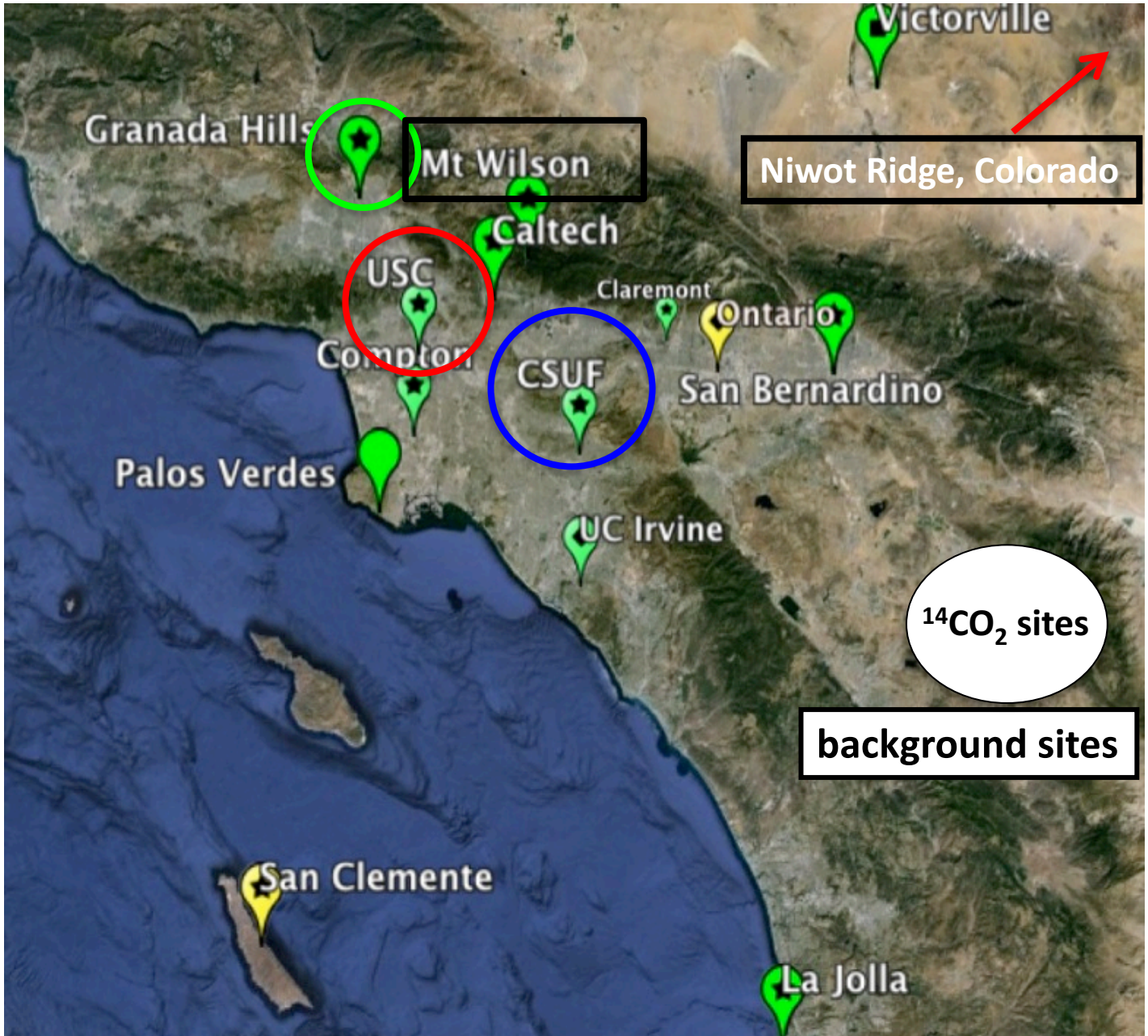

Thanks to: K. Rozanski, M. Zimnoch (Poland); I. Levin (Germany); Morgan Lopez(France); L. Zhou (China); Korea-China Center for Atmos. Res.

# Radiocarbon Monitoring in Indianapolis

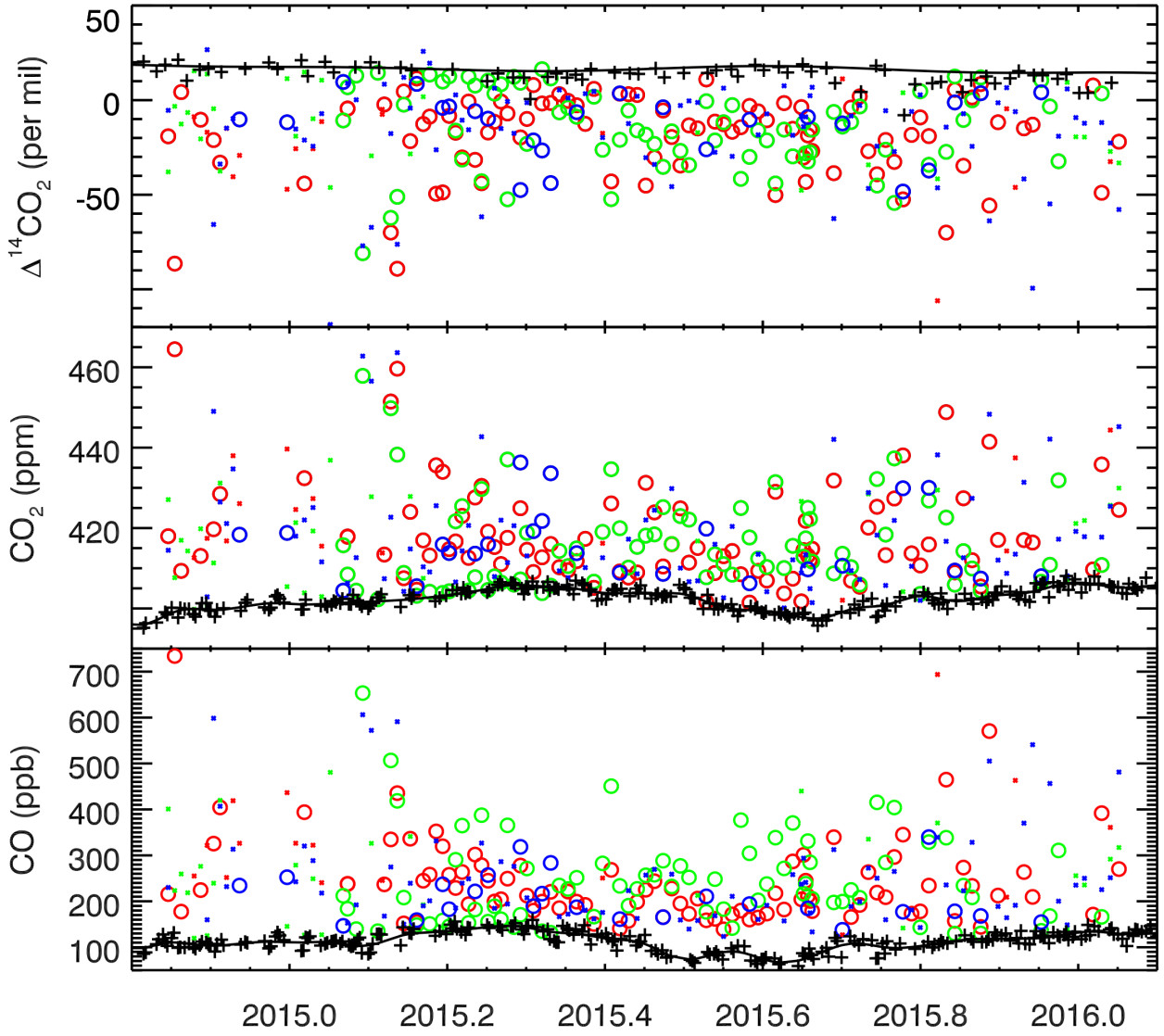


# LA Basin $^{14}CO_2$ sampling sites



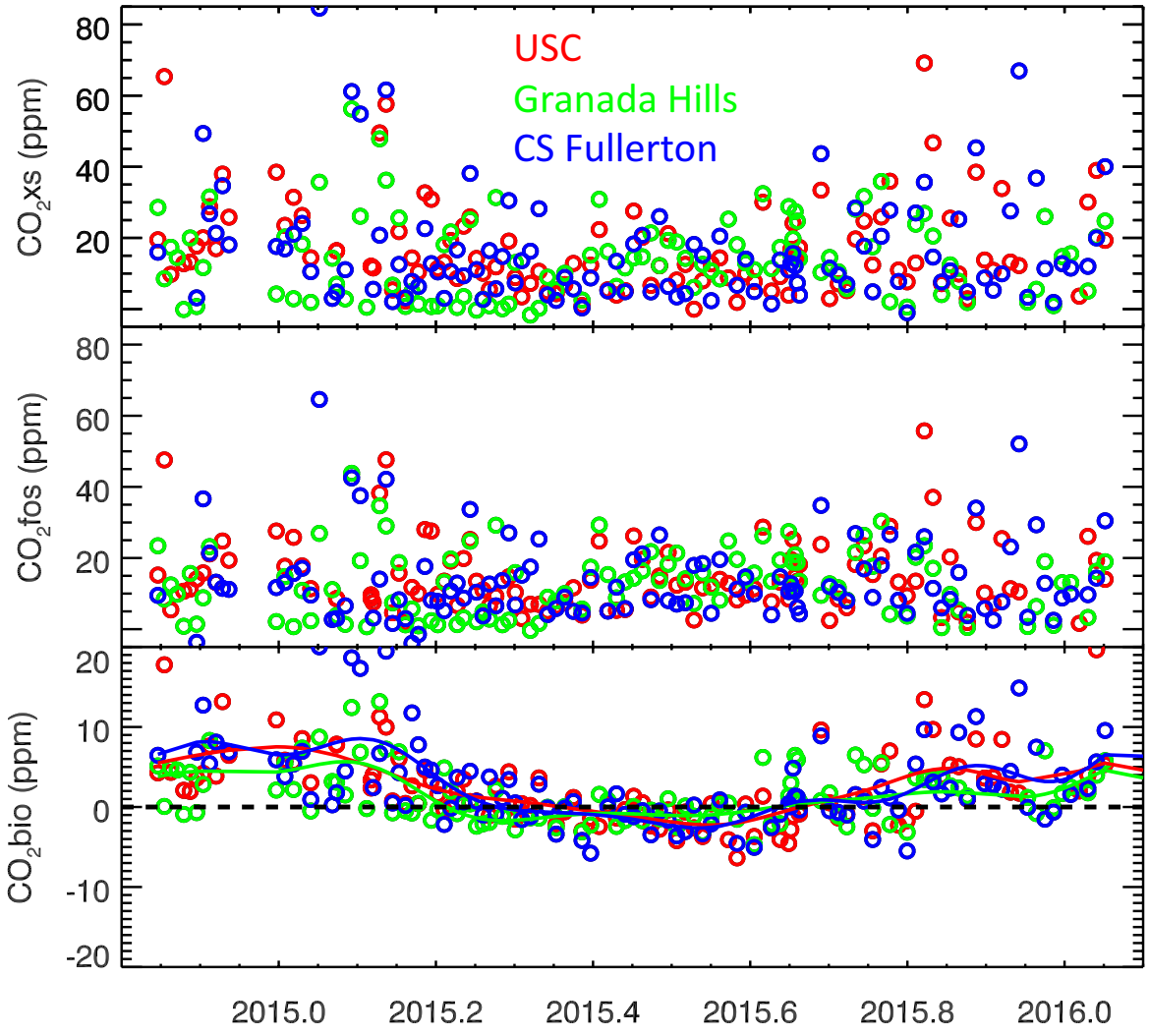
# $CO_2$ and $^{14}CO_2$ data show large variations with a clear fossil fuel contribution.




**100 per mil!!**
**~ 40 ppm fos. CO2.**

Background
(NWR, MWO)
USC
Granada Hills
CS Fullerton

# Biospheric contribution to total $CO_2$ is substantial.



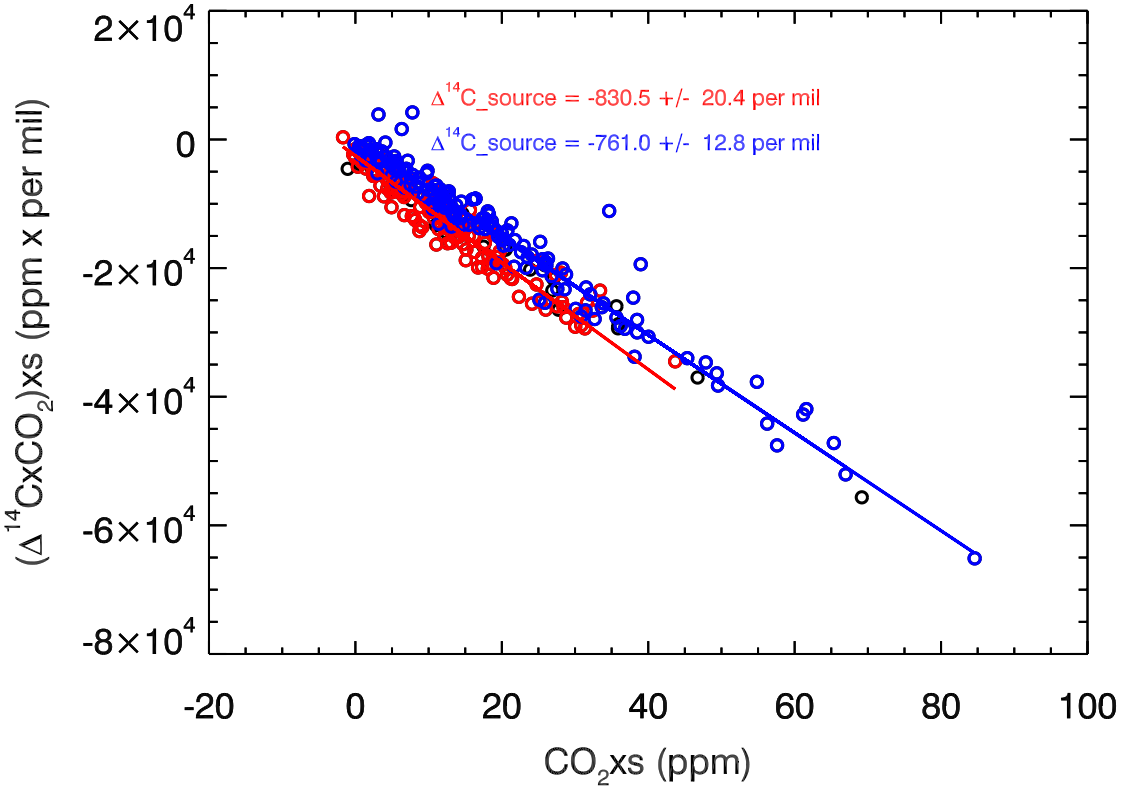

→ Larger enhancements in winter – less vertical mixing

→ 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.



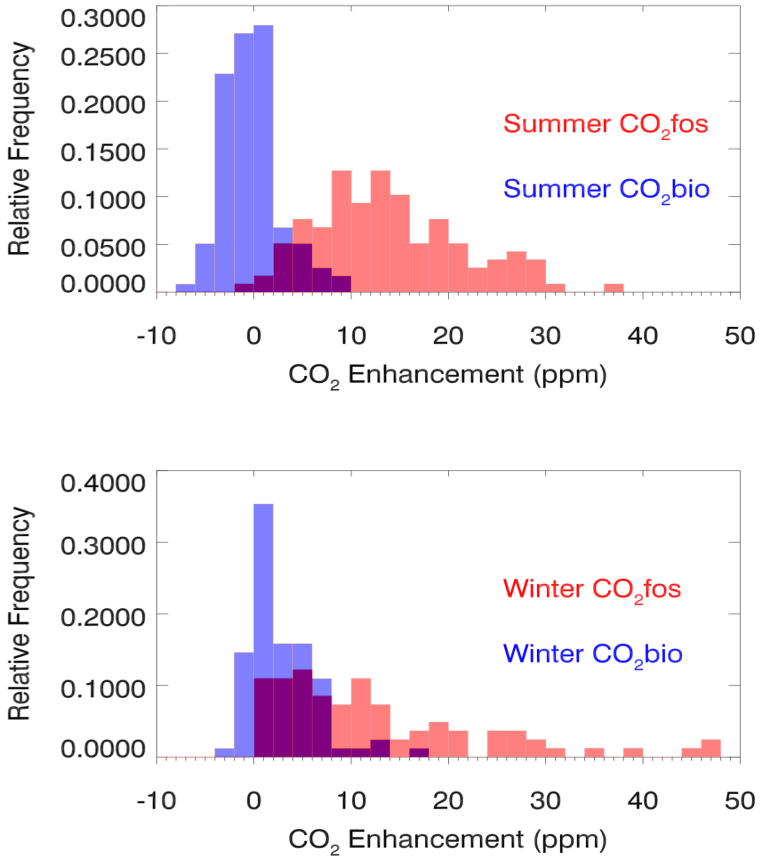

***Why is $CO_2$bio so high?***

- Ethanol in gasoline (~ 3 %)
- Human Respiration (~ 5 %)
- Livestock Respiration (< 1%)
- Urban ecosystems 10-15%: parks, lawns, golf courses, etc. ?

Winter: -760 per mil → $CO_2$xs is 24% biogenic

Summer: -830 per mil → $CO_2$xs is 17% biogenic

# Biogenic contribution appears highly seasonal



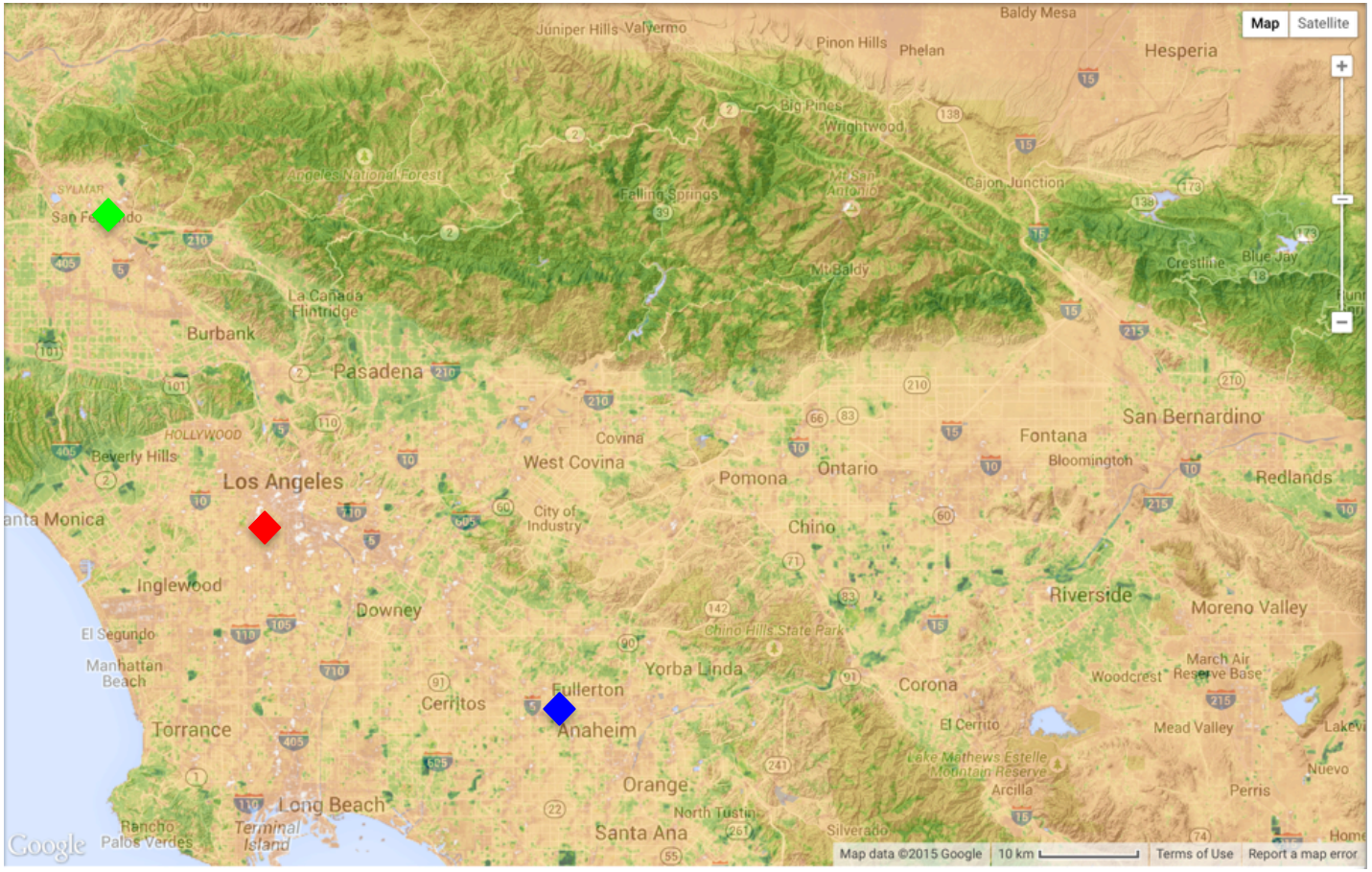
# How productive are urban ecosystems?

→ "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)* LA lawns up to 15 umol/m2/s in summer.

→ Harvard forest summer respiration fluxes are similar

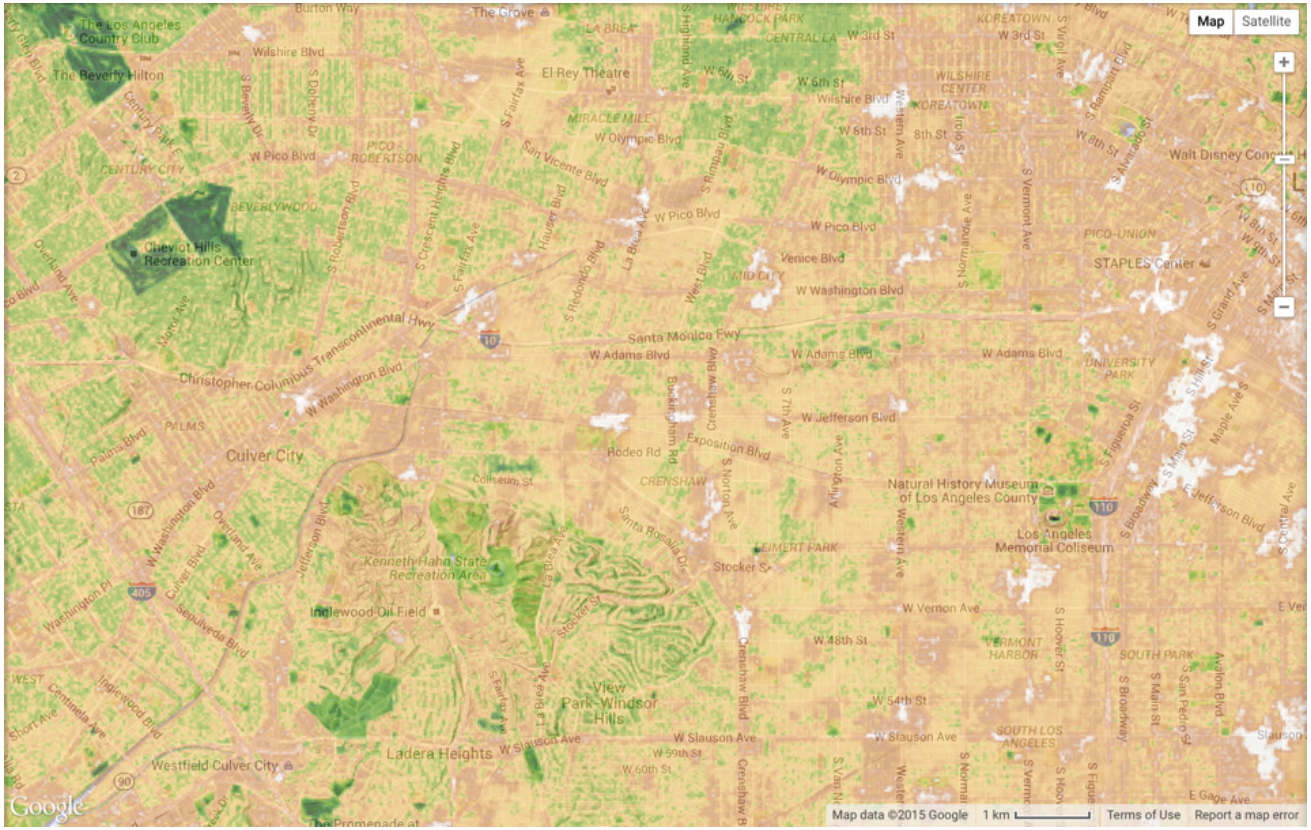
→ These fluxes would require ~1/8th of LA to be covered by lawns (and golf course, parks, etc.) to explain our observations. ***Is this realistic?***

# LANDSAT 30 m EVI



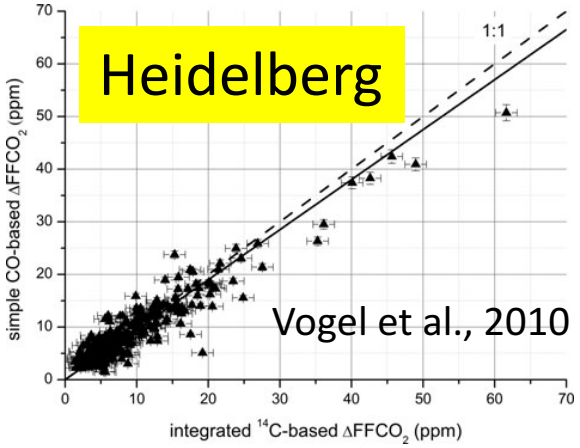

→ Distribution of green appears to be somewhat decoupled from people and roads, but still widespread.

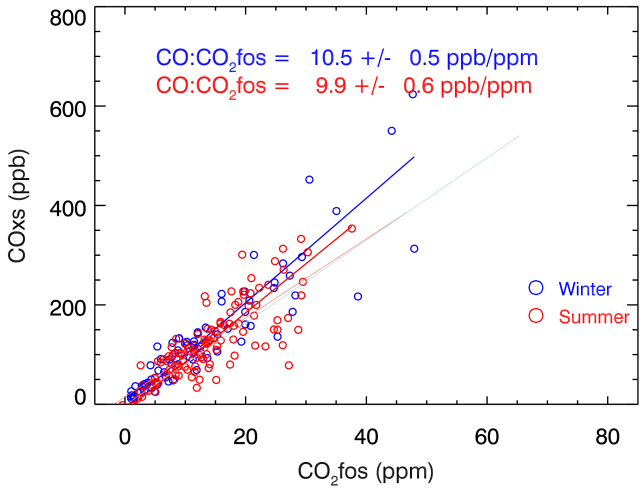
# LANDSAT 30 m EVI zoomed in shows even more.




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

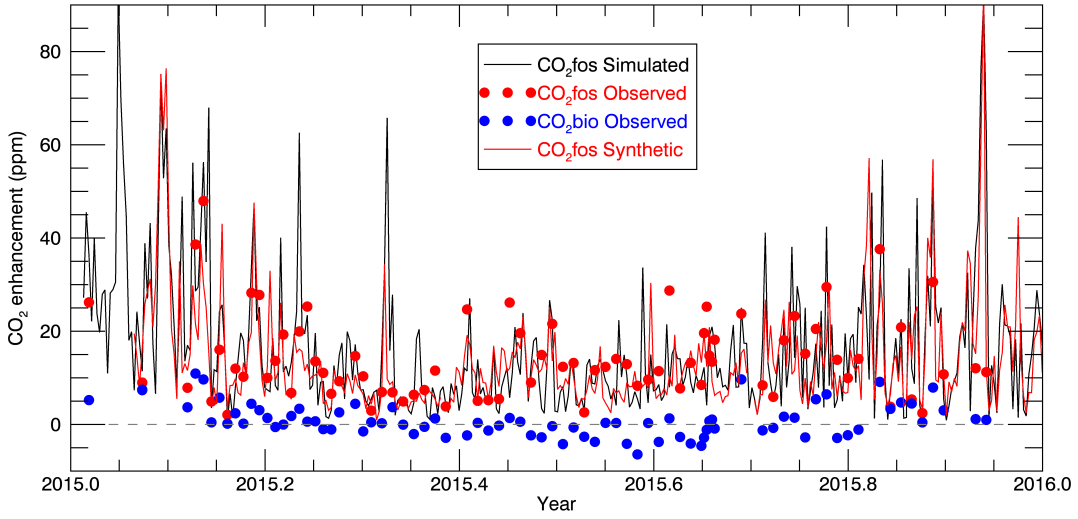
# We can leverage $^{14}C$ measurements to create a pseudo-continuous $CO_2$fos time series.



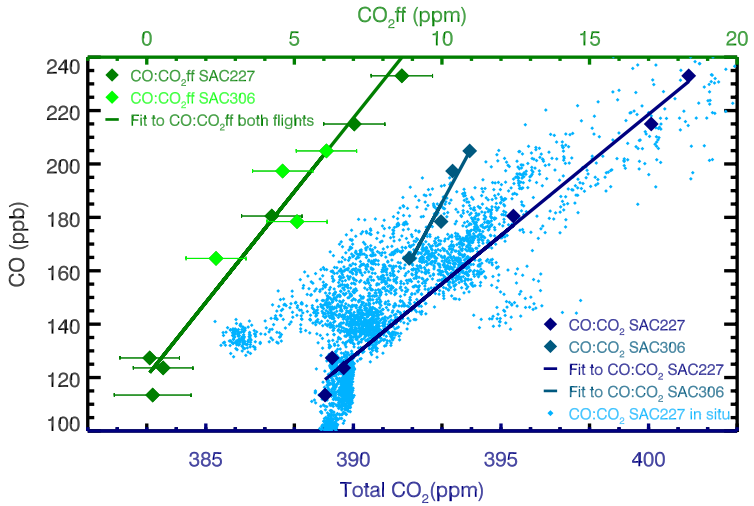



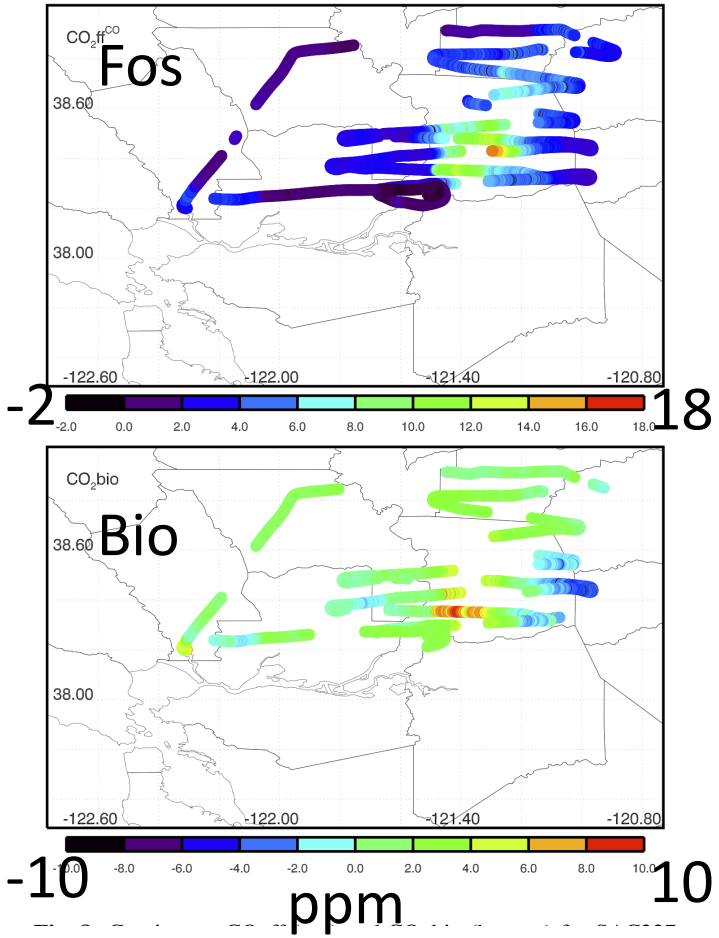

a. COxs:$CO_2$ff ratios are fairly consistent in LA (here for USC)

b. Applying these to the USC COxs time series allows us to create a "synthetic" record of $CO_2$fos at much higher frequency.



# Using radiocarbon and CO to separate fossil and biogenic CO2 above Sacramento

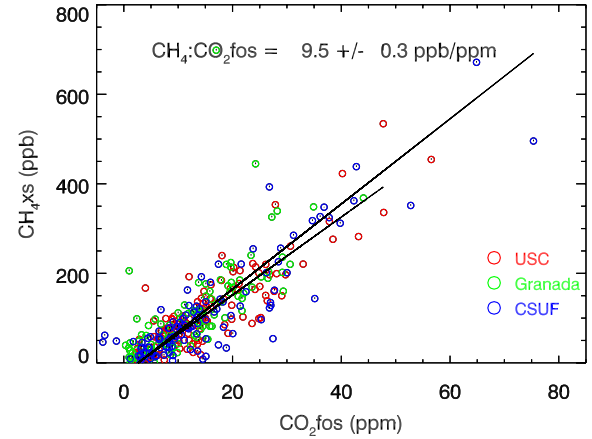


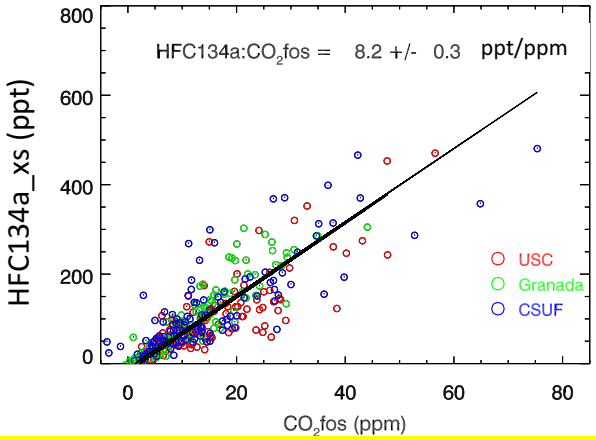




- After isolation of fossil fraction, CO:CO2ff is consistent across days.
- This ratio is then applied to continuous CO measurements.

Turnbull et al., ACP, 2011

# Using X:$CO_2$ff ratios we can estimate emissions for X, X=CH4 and HFC-134a, and other gases



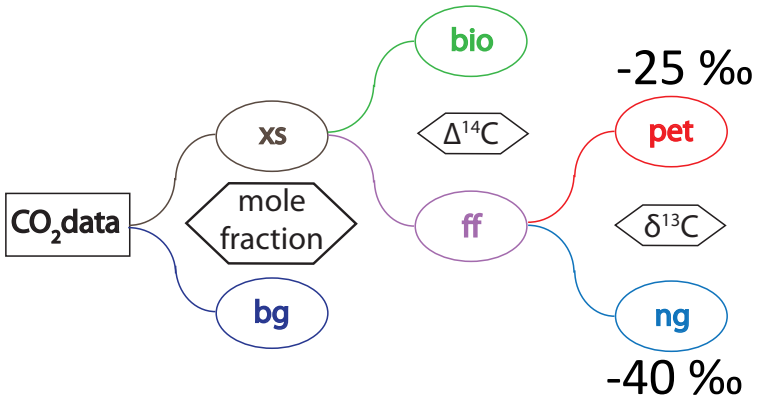

Emission Ratio x FF inventory
= Emissions of "Gas X"

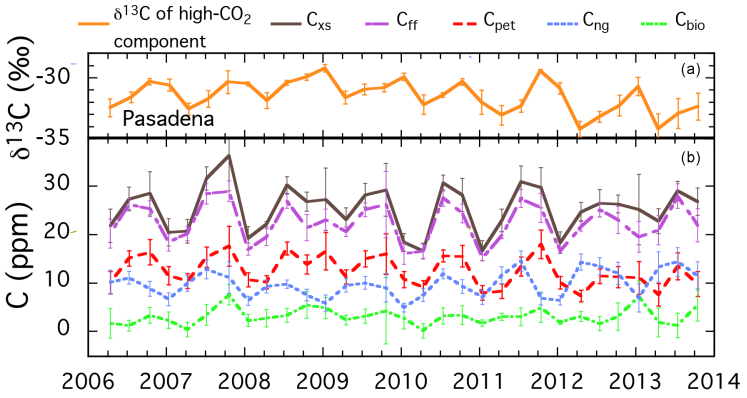
$F_{ff}$ ~ 3.6 x $10^{13}$ gC/yr (Vulcan 2.2, four county total)

| Gas | LA Basin Emissions |
|---|---|
| $CH_4$ | 460 Gg $CH_4$/yr |
| HFC-134a | 2.5 Gg HFC-134a/yr |

Note: Using C_tot instead of C_fos will impose a (seasonal) bias in tracer ratio methods (e.g. Pieschel et al., 2013; Wong et al., 2016)

# $\delta^{13}C$: Natural Gas vs. coal & oil

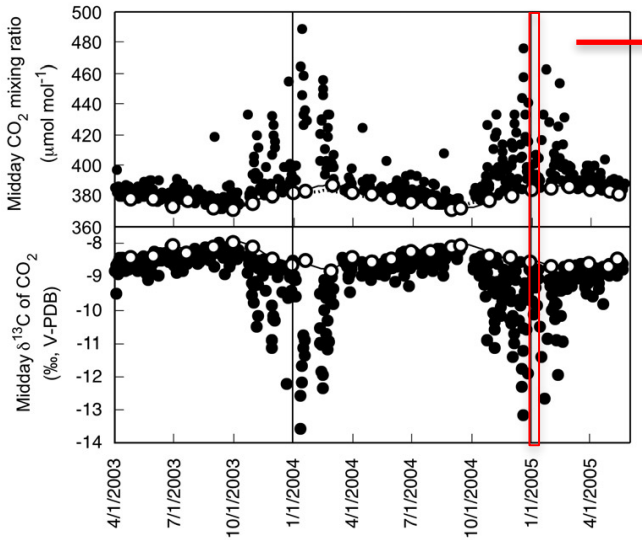


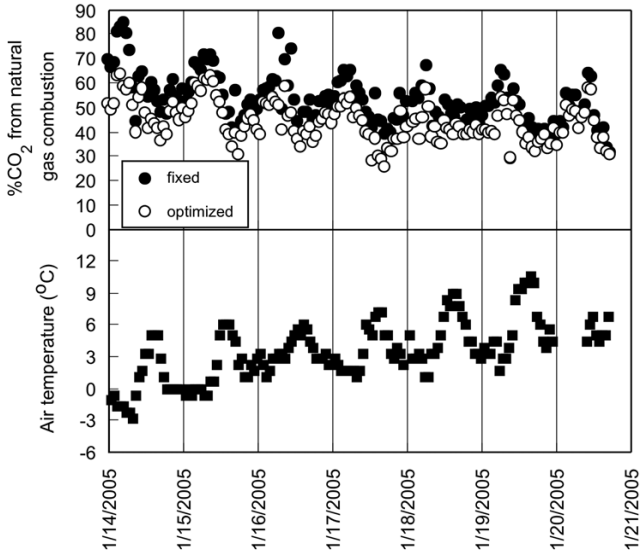

Newman et al, ACP, 2016

$CO_2$

$\delta^{13}C$




Nat. Gas %




Pataki et al, JGR, 2006

# Summary and implications

1. **$CO_2$xs ≠ $CO_2$fos, even in L.A.**
2. Remote-sensing and in situ approaches for urban $CO_2$ fluxes need to account for biospheric $CO_2$.
3. $CO_2$bio varies throughout the year, and likely year to year.
4. Continued and widespread measurement of urban biosphere fluxes will be required to isolate the fossil fuel emissions signal.
5. $CO_2$fos:CO ratios will also change with time requiring $^{14}C$ to be measured going forward.

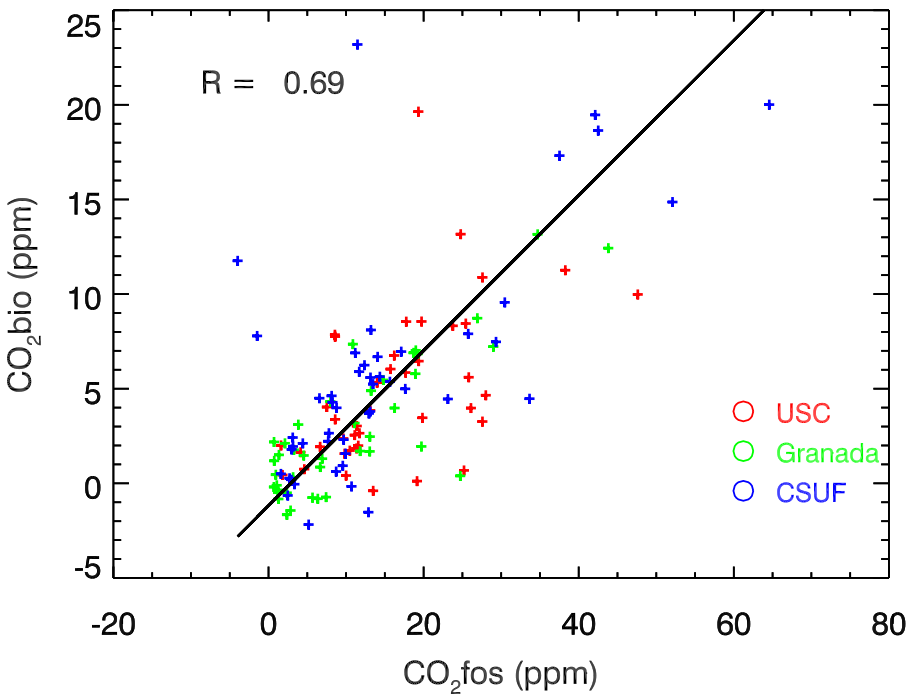
# Challenges and Opportunities

1. Use of other tracers such as CO:
    1. How stable or model-able are the Gas-X:14C ratios?
    2. For example: a) Power plants and diesels have little or no CO; b) off road vehicles have lots; c) biogenic CO can be significant.
    3. Generally in cities, emissions are not truly co-located.
2. Multi-tracer approaches may be tough *in* cities due to poor source mixing but better further away. This means they may work better for megalopoli, which is still a worthy goal.
3. Multi-tracer approaches may work for sectoral apportionment if source signatures and their time variations are known.
4. Dilution of emissions into concentrations: **50 ppm CO2 changes in a day are *NOT* due to emissions changes!**
5. **... But, can using multiple tracers help deal with transport uncertainties?**

# Other measurements

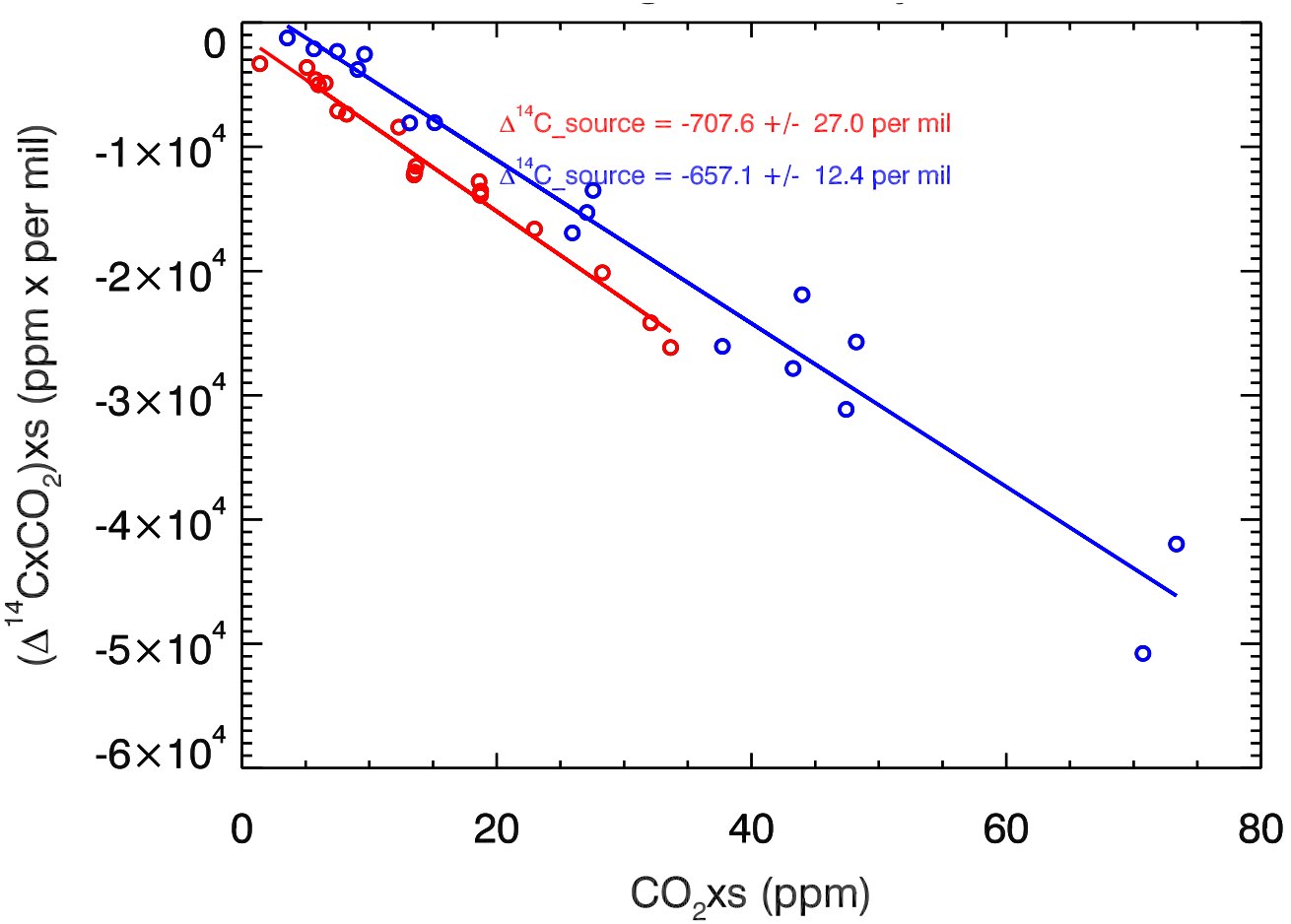
- In situ Tracers:
  - Pollutants (HCs, NOx), halo-carbons, O2:N2
- Remotely sensed GHGs from: OCO-2, -3*, GeoCarb*, Tropomi
- Plant chorlophyll fluorescence: same satellites

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



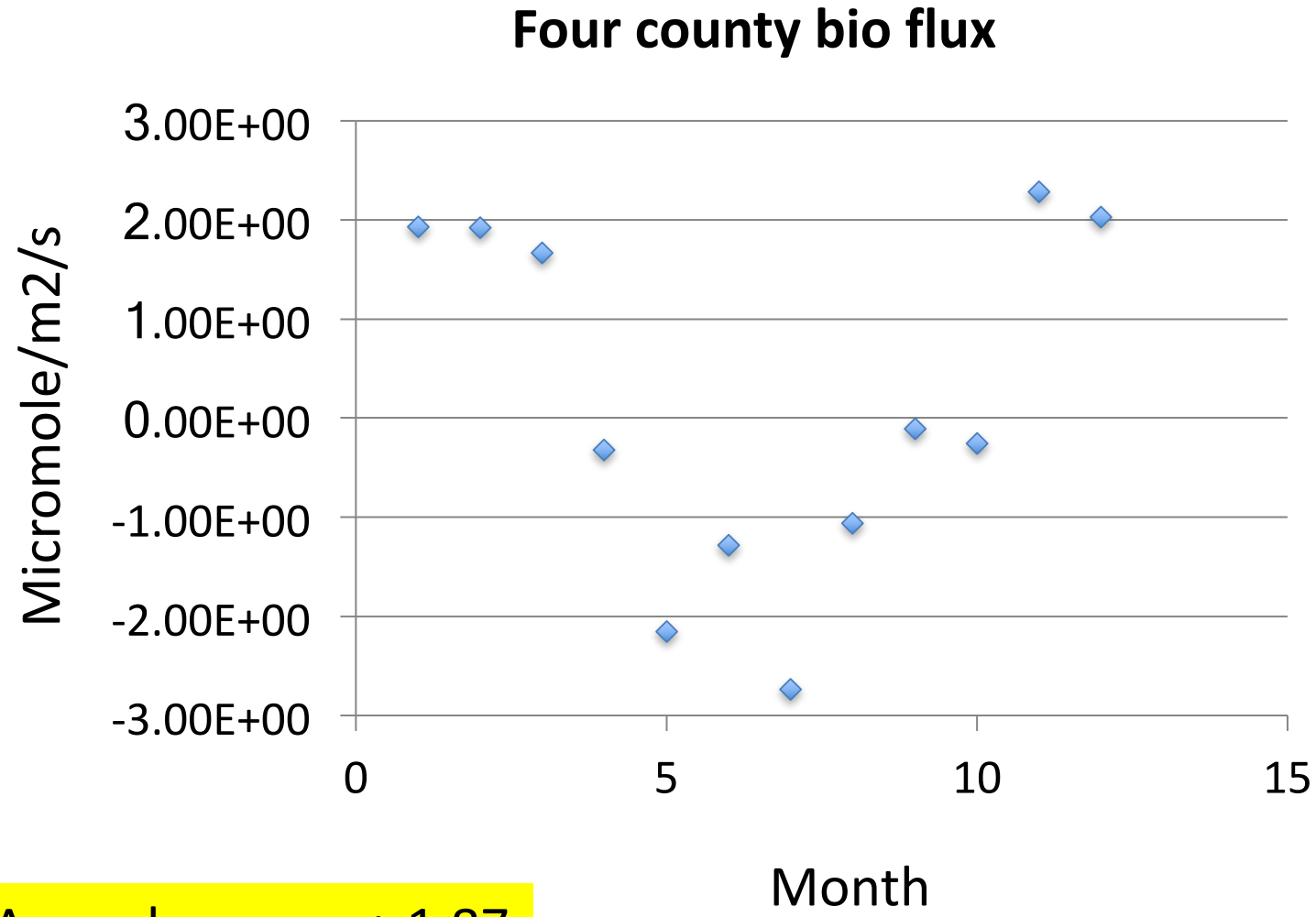

- Fossil fuels (and ethanol), and human population are similarly distributed throughout the Basin.
- Urban ecosystems may also be.
- N.B.: Correlation is analyzed in winter to avoid near zero $CO_2$bio signal resulting from net photosynthesis.

# Nighttime signals show more biogenic signal and small signals overall.




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

# Same approach to calculate Bio flux




Annual mean = + 1.87