Using atmospheric radiocarbon ($^{14}CO_2$) to estimate fossil and biogenic CO_2 fluxes in the LA megacity

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

Project Goals

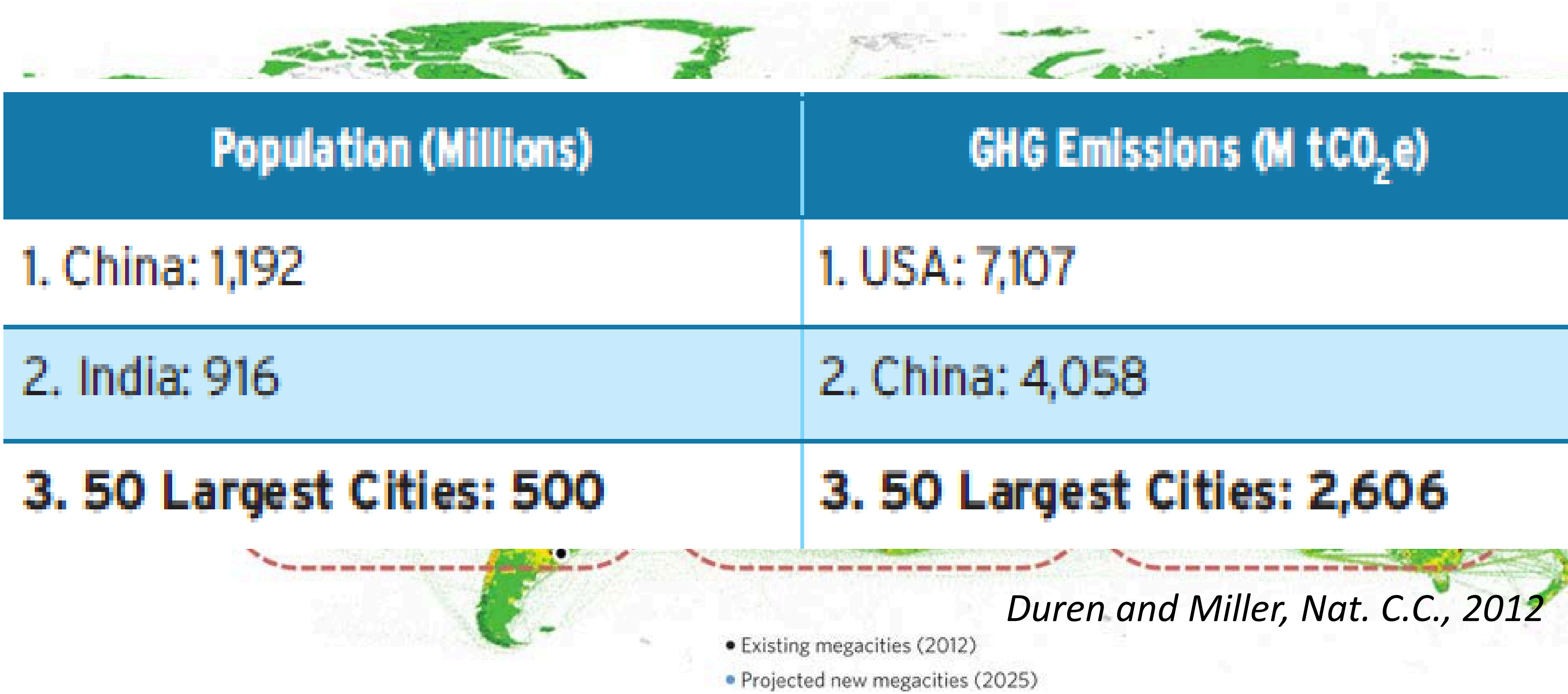
- Ultimately: invert ^{14}C or CO_2fos for FF emissions via CO (and other tracers.)
- Proximately: compare observed CO_2fos to transported inventories.

Outline

- Background on megacities and $^{14}CO_2$
- Results and Analysis
- Conclusions and Future work

Why Megacities?

Large emissions and large signals!



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**

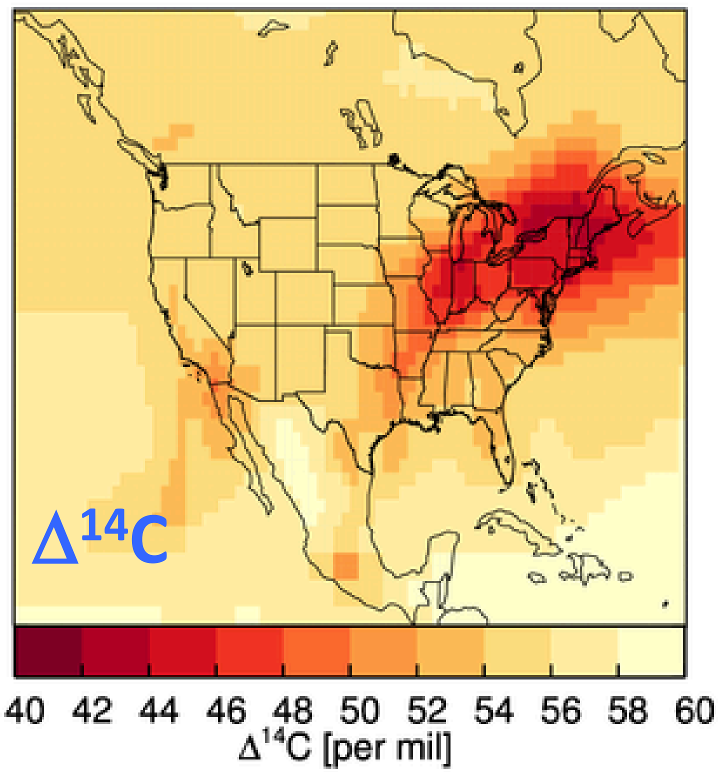
Duren and Miller, Nat. C.C., 2012

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

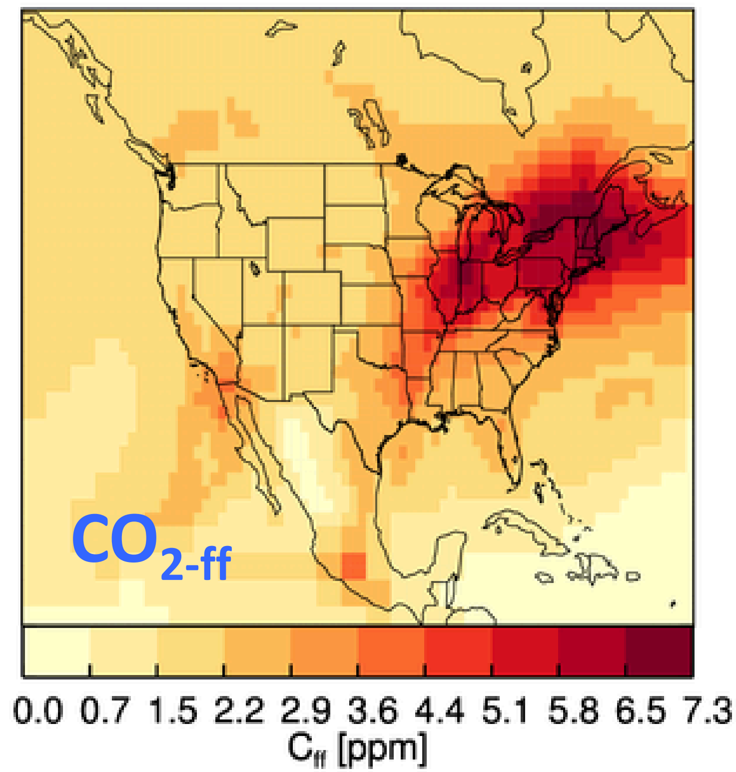
$^{14}CO_2$:$^{12}CO_2$ ($\Delta^{14}C$) is a robust tracer for fossil fuel fluxes: atmospheric $\Delta^{14}C$ looks just like fossil CO_2.

$\Delta^{14}C_{ff}$ = -1000 per mil (i.e. zero ^{14}C)

Scaling: -2.7 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 PBL enhancements (or depletions) can be partitioned into Ecosystem and Fossil fractions.

CO_2xs

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

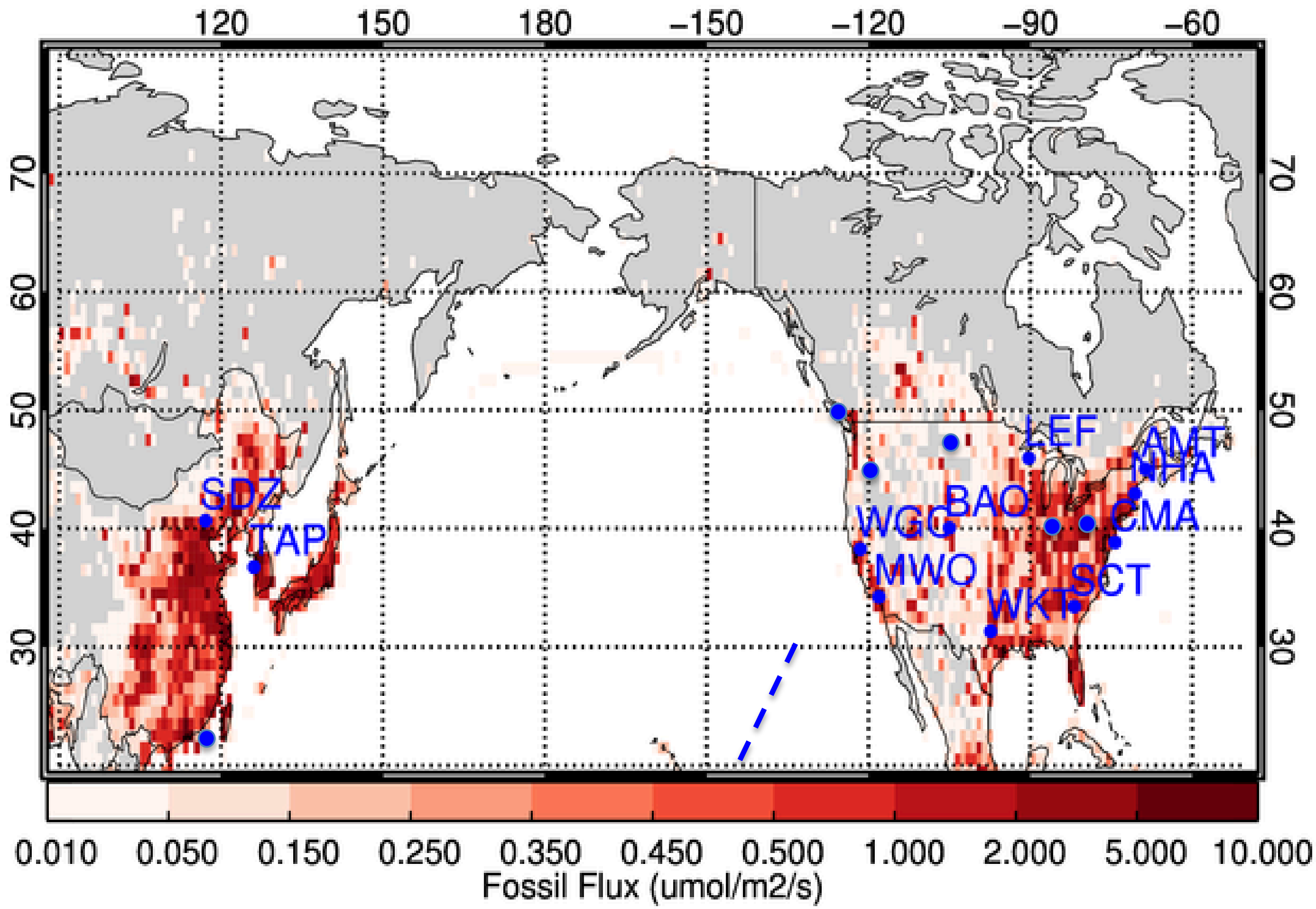
$$(\Delta C)_{obs} = (\Delta C)_{bg} + (\Delta C)_{fos} + \text{minor}$$

Measurement precision = 1.7 per mil → ~ 1 ppm C_{fos}

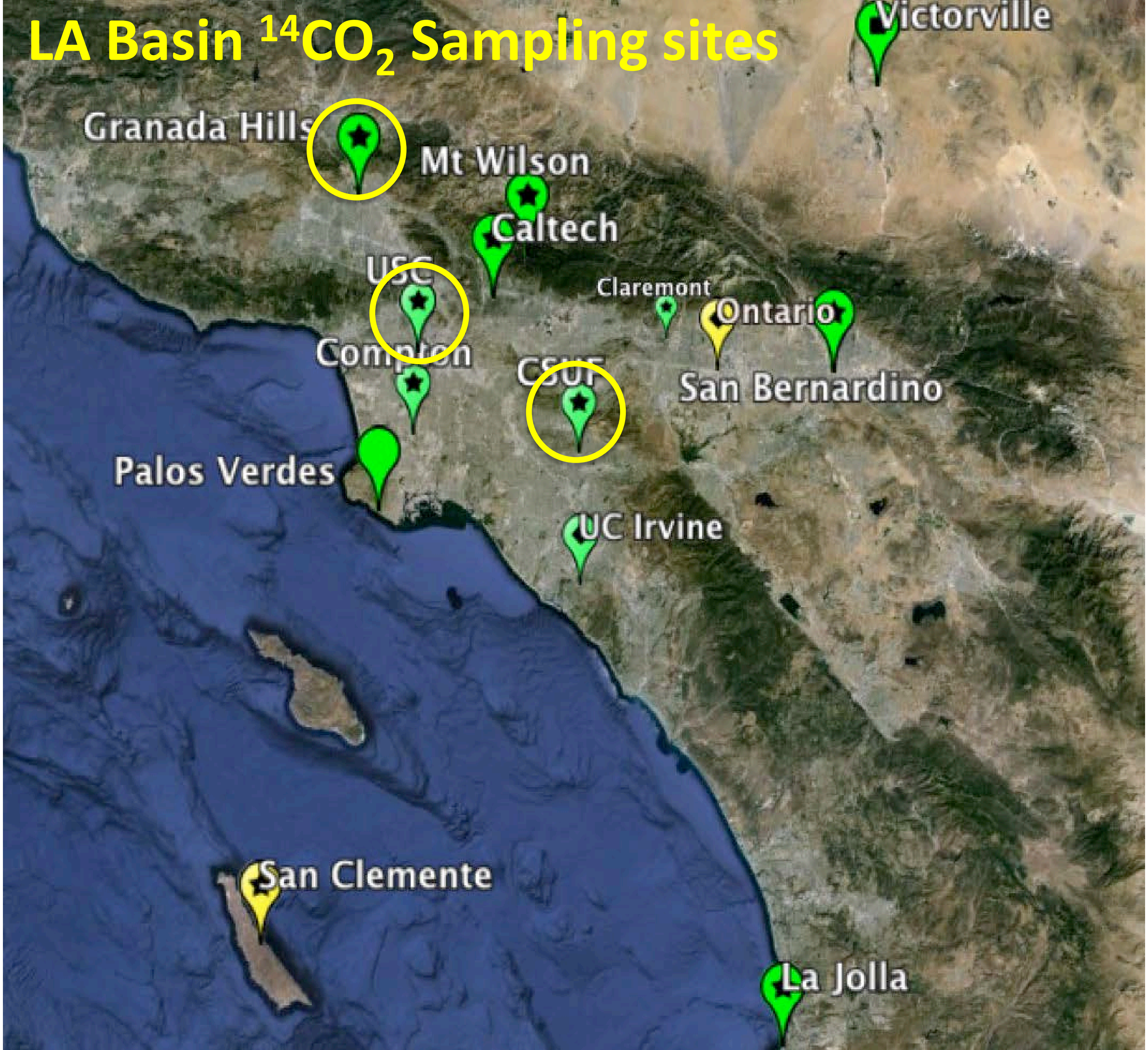
$$\Delta^{14}C = \left[\frac{(^{14}C/C)_{sam}}{(^{14}C/C)_{std}} - 1 \right] \times 1000$$

Δ_{ff} = -1000 per mil; Δ_{atm} ~ +20 per mil

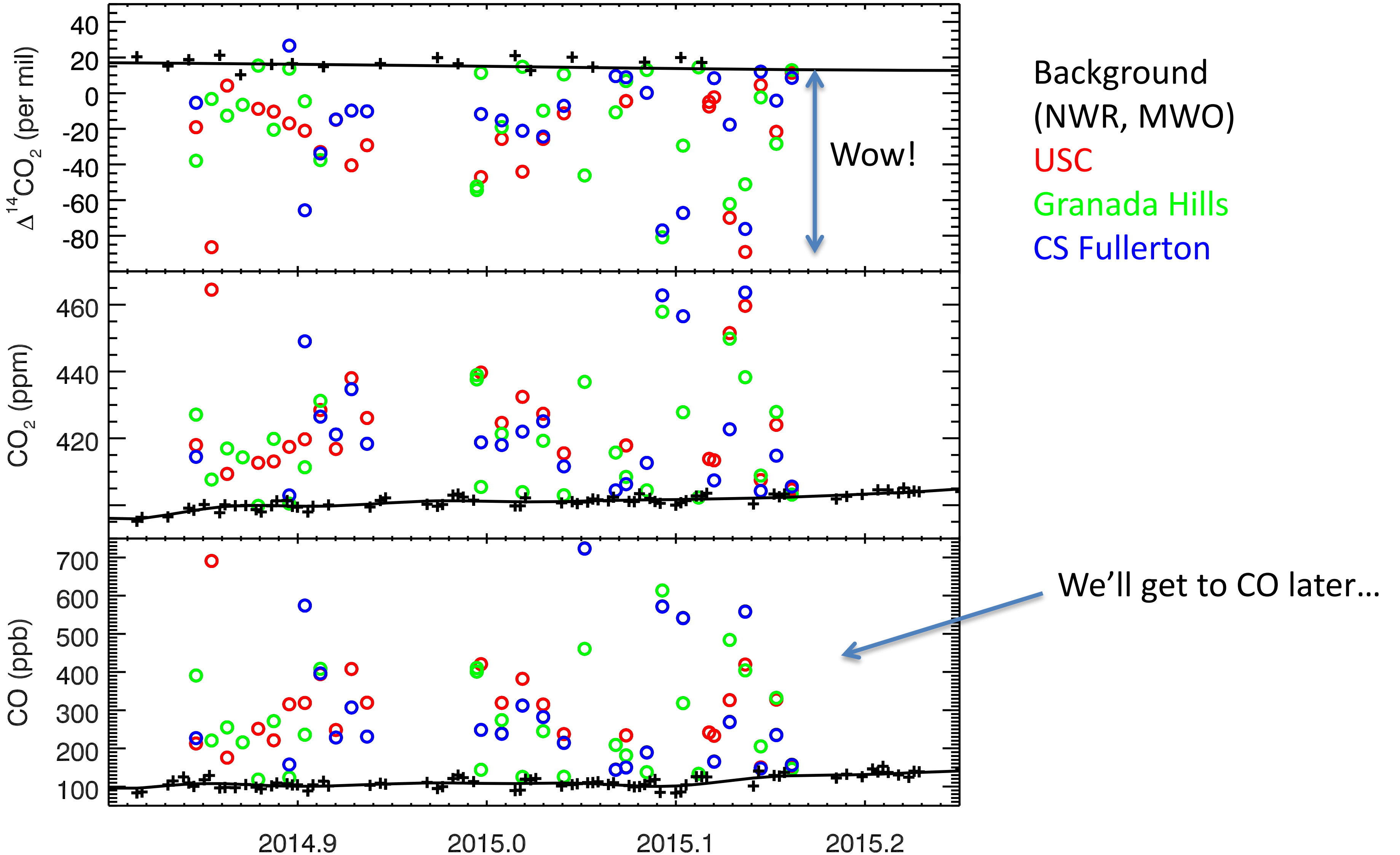
Context: NOAA/INSTAAR $^{14}CO_2$ sites sensitive to significant fraction of Asian and North American emissions



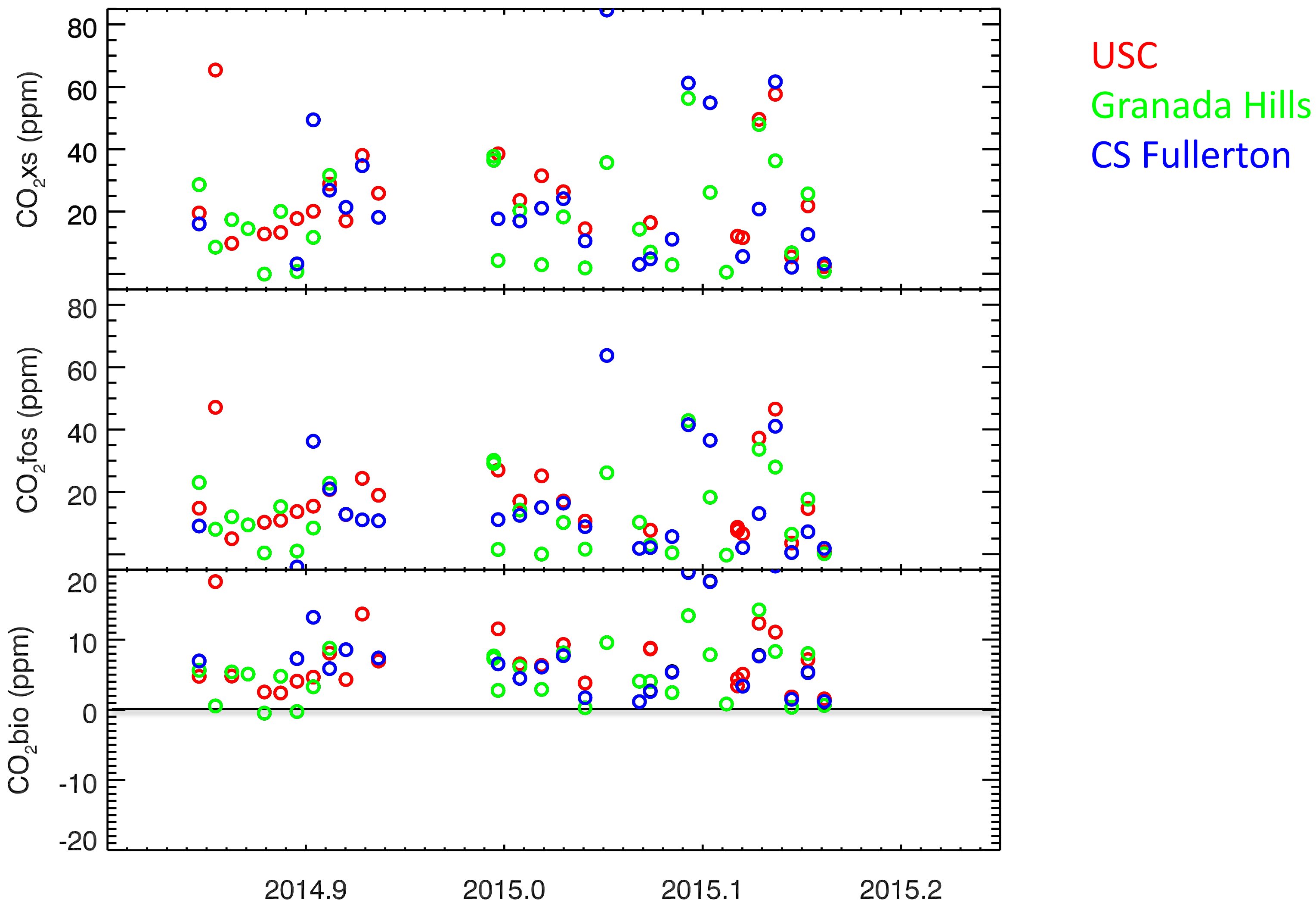
LA Basin $^{14}CO_2$ Sampling sites



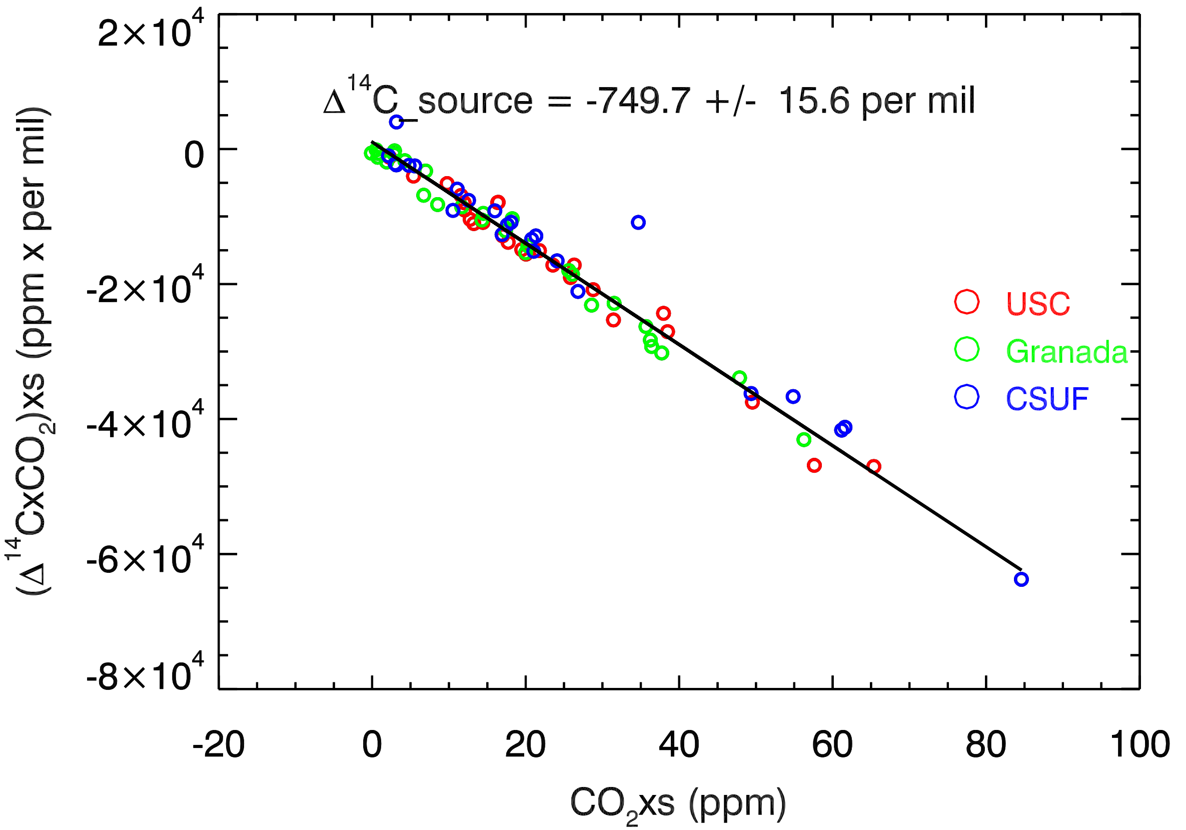
CO_2, CO and $^{14}CO_2$ time series



CO_2xs, fos and bio time series



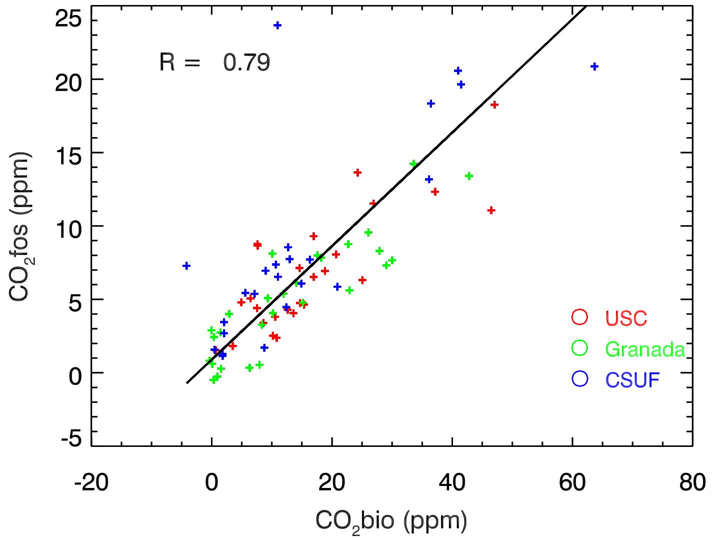
$\Delta^{14}CO_2$-based source analysis



-750 per mil → 25% biological

CO_2fos/bio source analysis

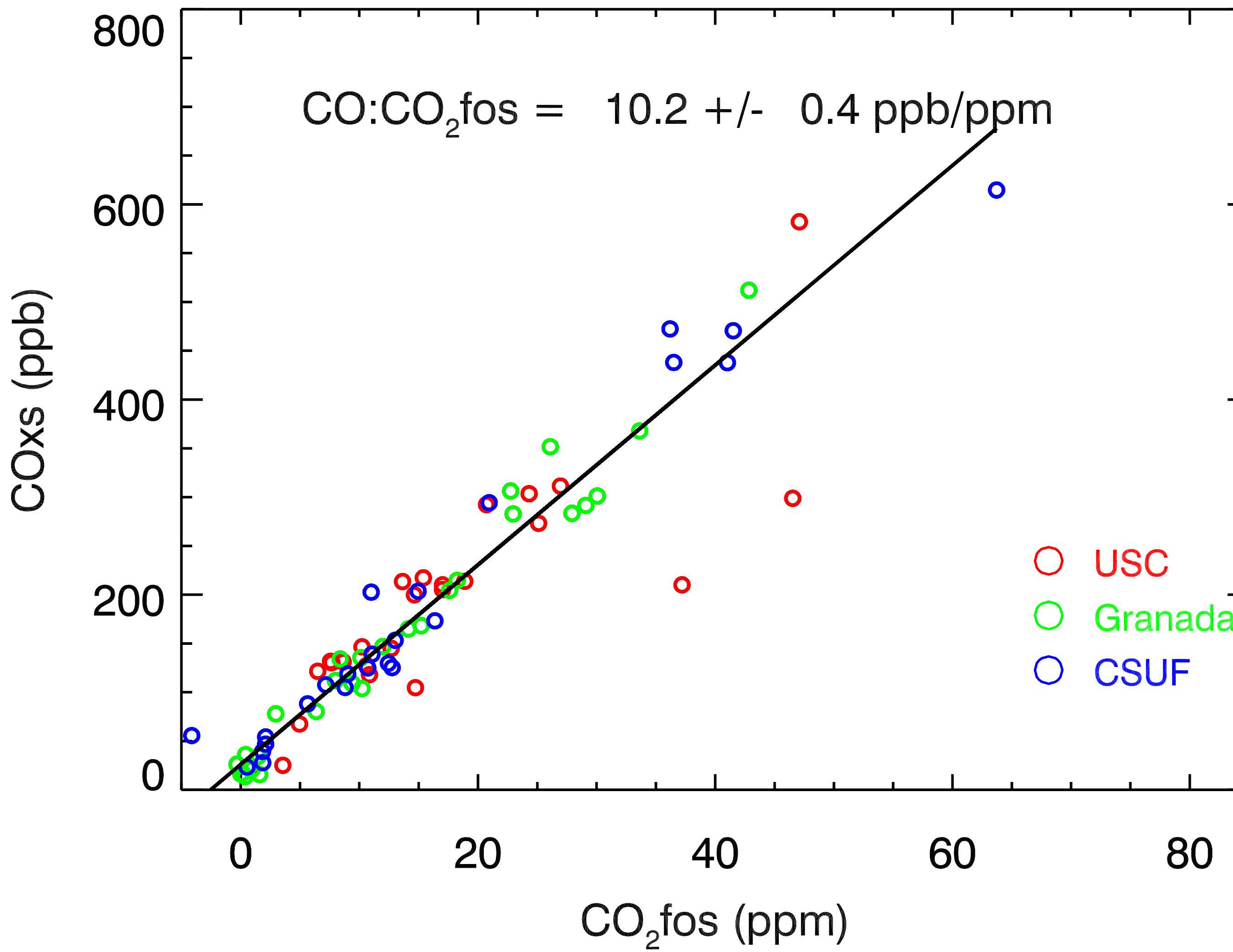
- <CO_2bio/CO_2xs> = 0.27 (-0.09/+0.18)
- Also highly correlated (R = 0.8) → common source location and transport



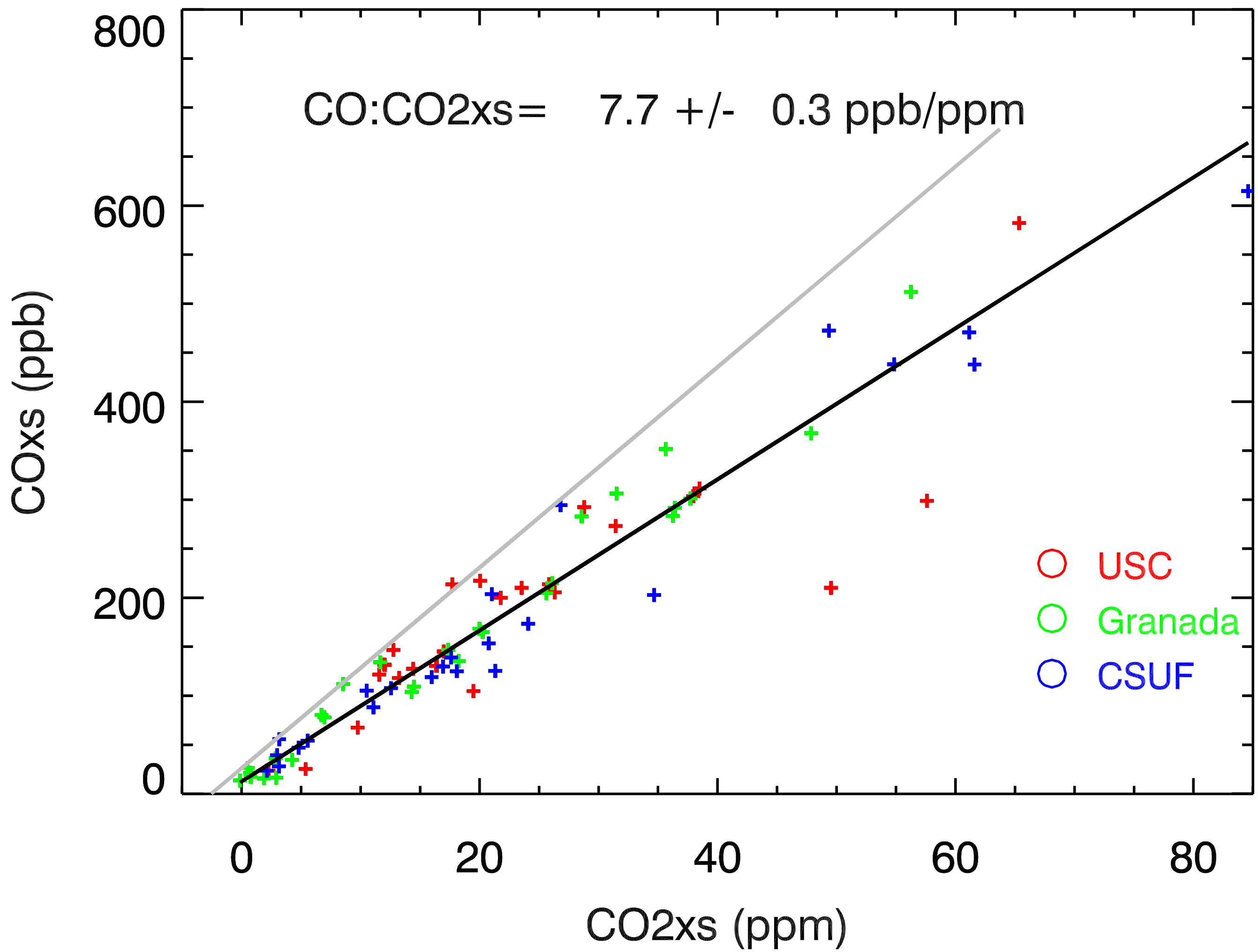
Why is CO_2 bio as high as it is?

- Ethanol in gasoline (10% of 50% of fuel sources)
- Human Respiration (~ 1 % of fuel sources)
- What is the rest? (~ 20%)
- Urban Biosphere?

CO:CO_2 correlations – CO_2fos

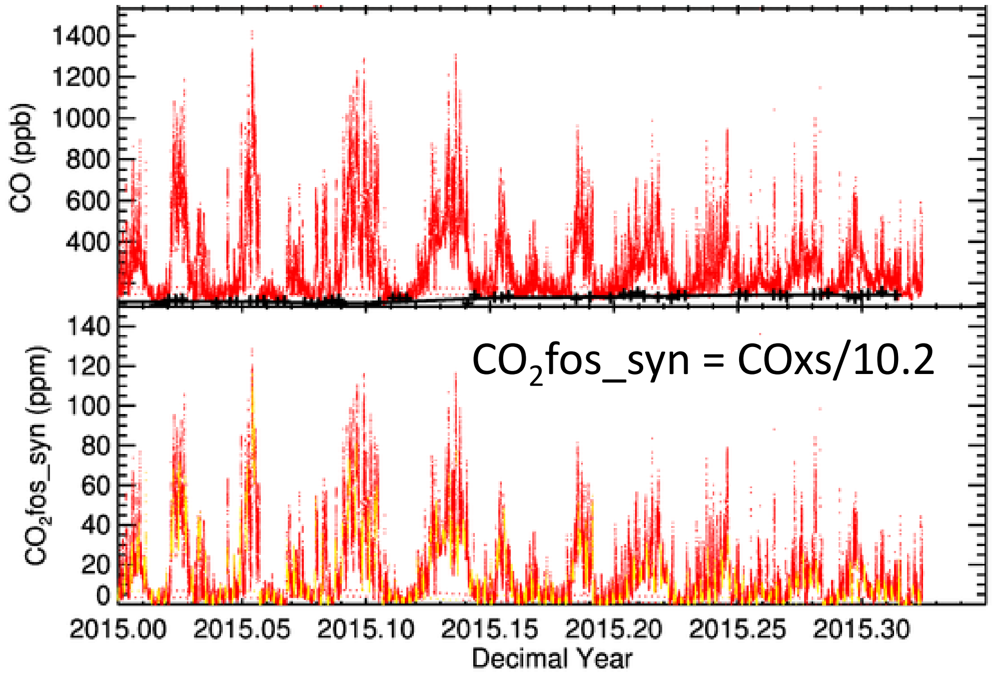


CO:CO_2 correlations – CO_2xs



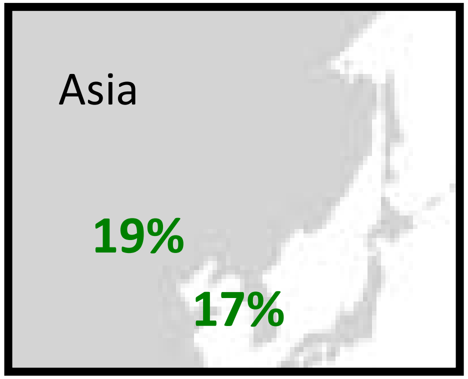
Transforming *in situ* CO to CO_2fos

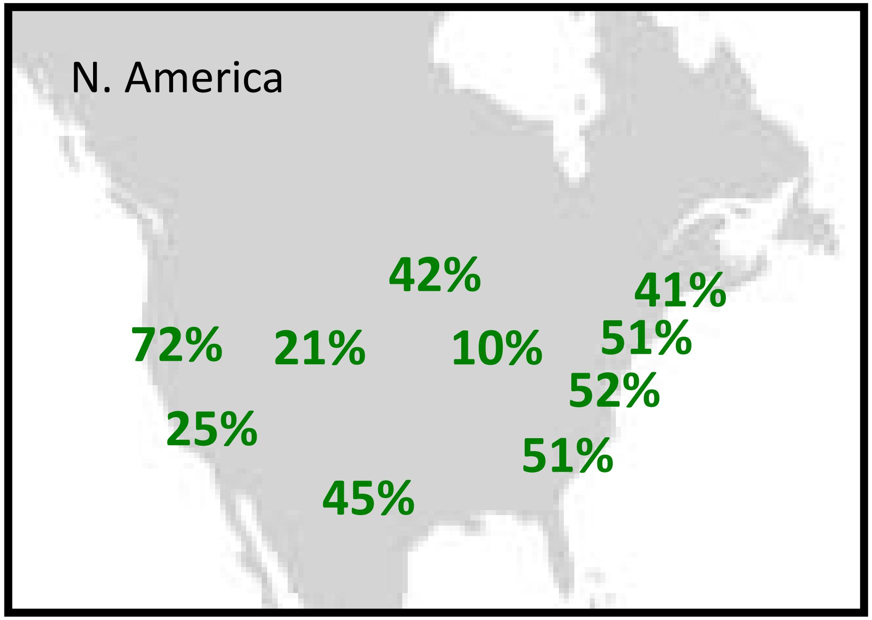
Granada Hills in situ data

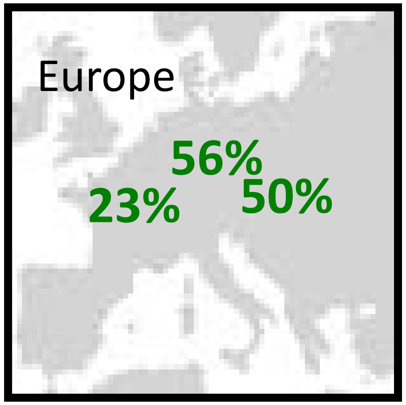


- Just an example, for now…
- Yellow represents mid-day hours – i.e. only when our CO/CO_2fos values are valid.
- Evidence for diurnal variability in CO:CO_2

Wintertime biospheric CO_2 fraction averages ~40% of total CO_2 enhancement.





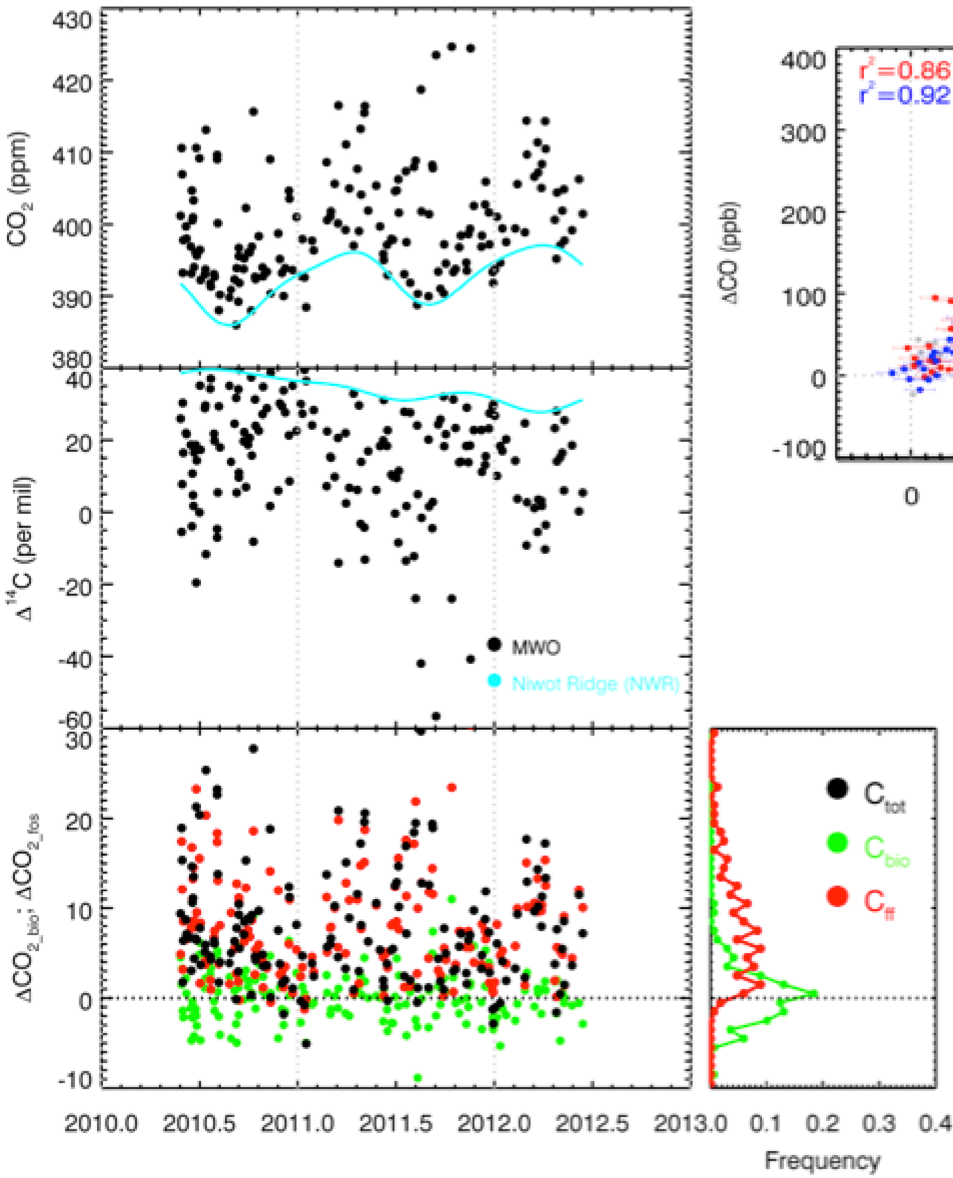


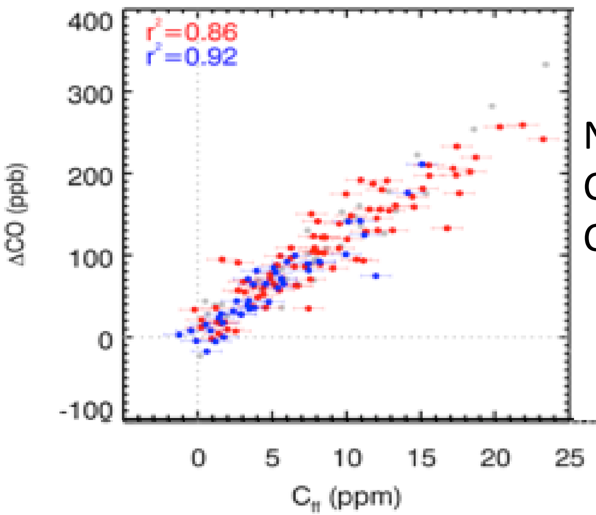
Thanks to: K. Rozanski, M. Zimnoch (Poland); I. Levin (Germany); Morgan Lopez(France); L. Zhou (China); Korea-China Center for Atmos. Res.

Conclusions and Future work

1. **CO_2xs ≠ CO_2ff, even in L.A.**
2. Significant CO_2bio seems to be the rule – not the exception.
3. Remote-sensing and in situ approaches need to account for biospheric CO_2.
4. $\delta^{13}CO_2$ measurements → fuel type partitioning (oil v. gas)
5. Create continuos time series of CO_2fos via CO_2fos:CO ratios.

Mount Wilson Observations of 14C, CO2 and CO

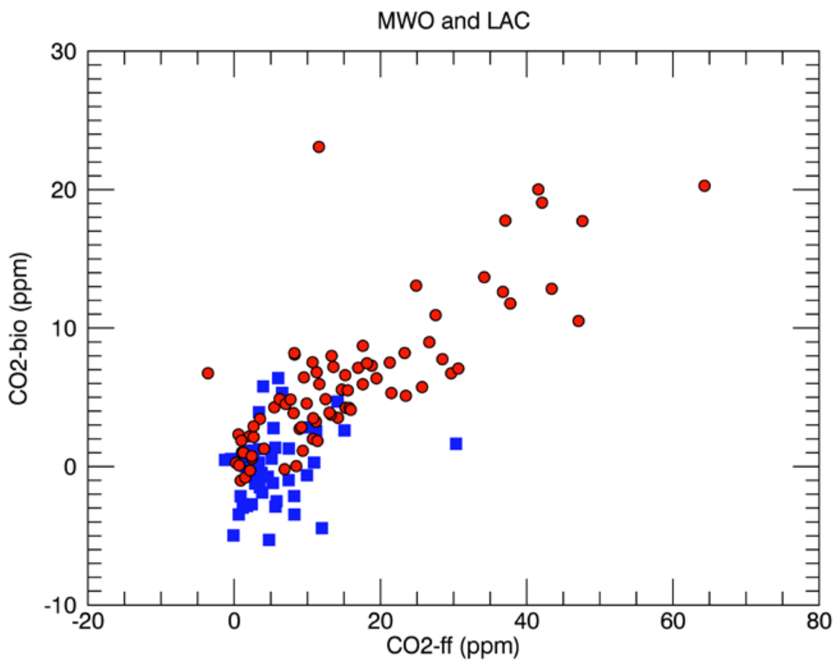




Nov – Feb (2011,2012)
COxs:CO2_ff = 11.9 ppb/ppm
COxs:CO2xs = 9.7 ppb/ppm

Nov – Feb (2011, 2012)
<Cbio/Ctot> = 15% (median)
K.P. intercept = -818 +/-56 per mil

MWO and LA Basin comparison

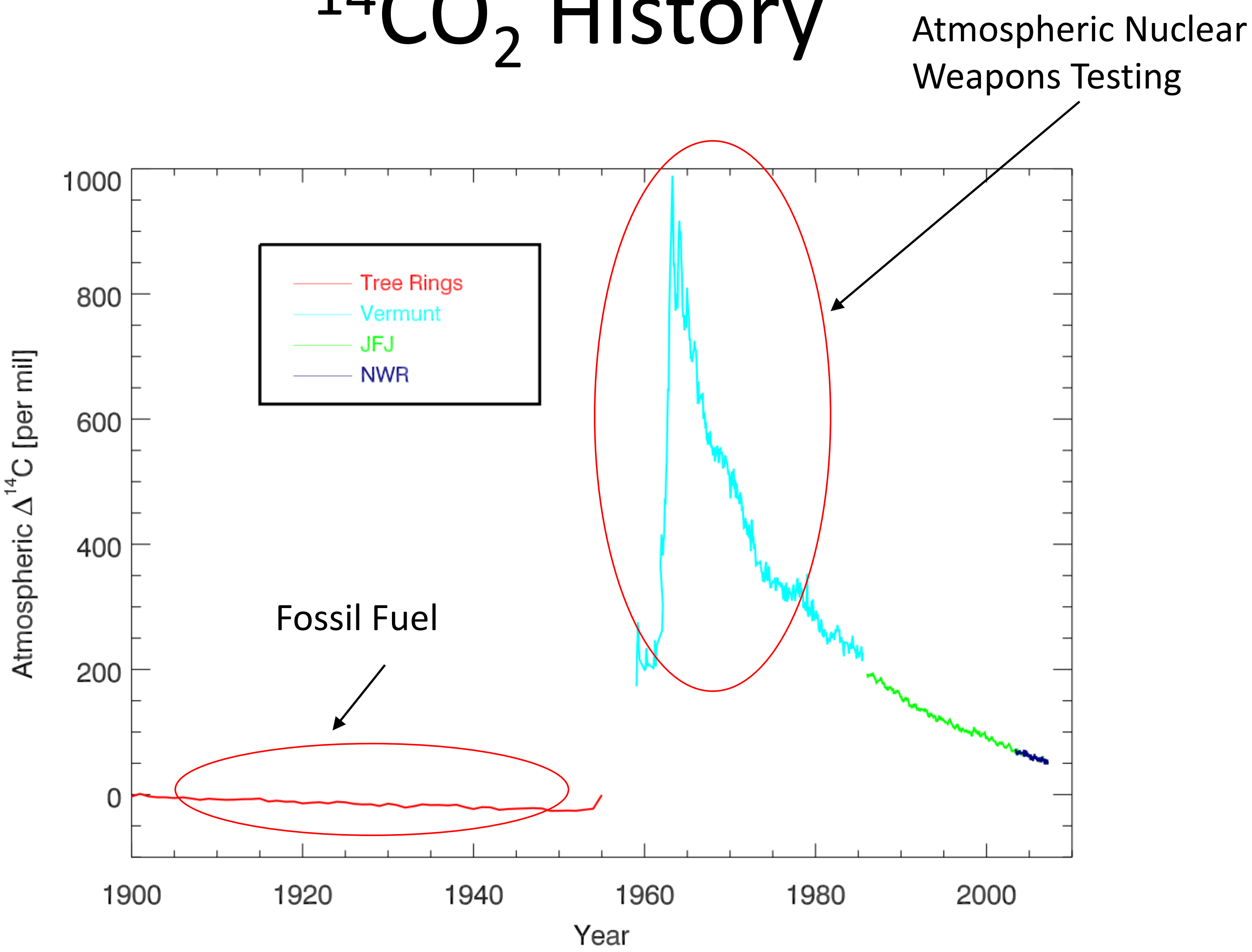


- Both show substantial Cbio, but MWO also shows substantial uptake.
- MWO signals are weaker.
- Differences between CO:CO2xs and CO:CO2ff are consistent with Cbio contributions, but…
- … they are offset. Is this spatial or a time trend in combustion efficiency.

Future work

- Sampling:
  - continue at 3 or 4 days per week for ~ 2 years
  - Add a summer and winter diurnal cycle sampling campaign
  - Switch PFPs to other sites (Compton?, Irvine?, San Bernardino?)
- Measurement and QC:
  - Data flagging using in situ CO_2, CO, ws and wd

$^{14}CO_2$ History



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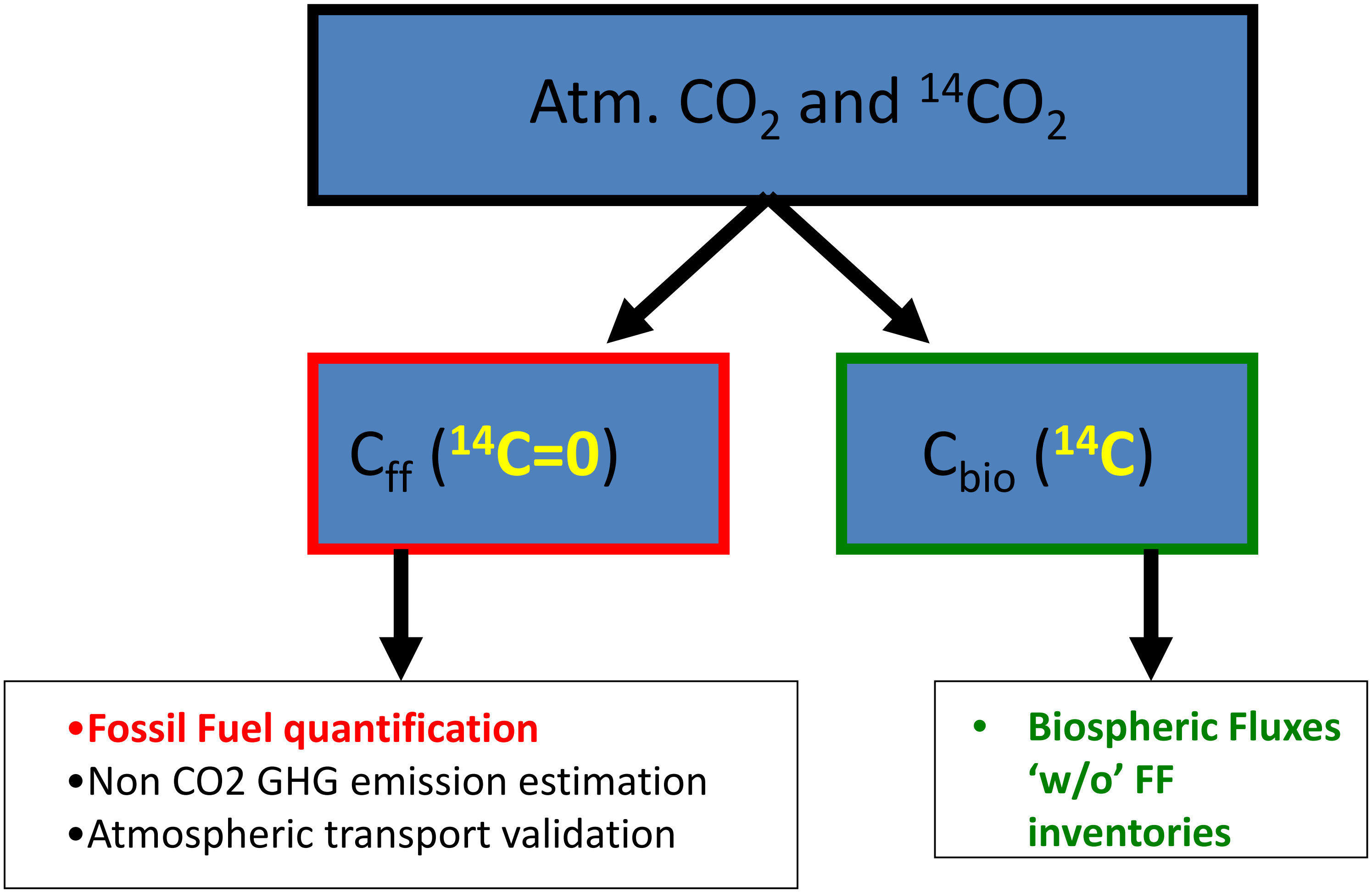
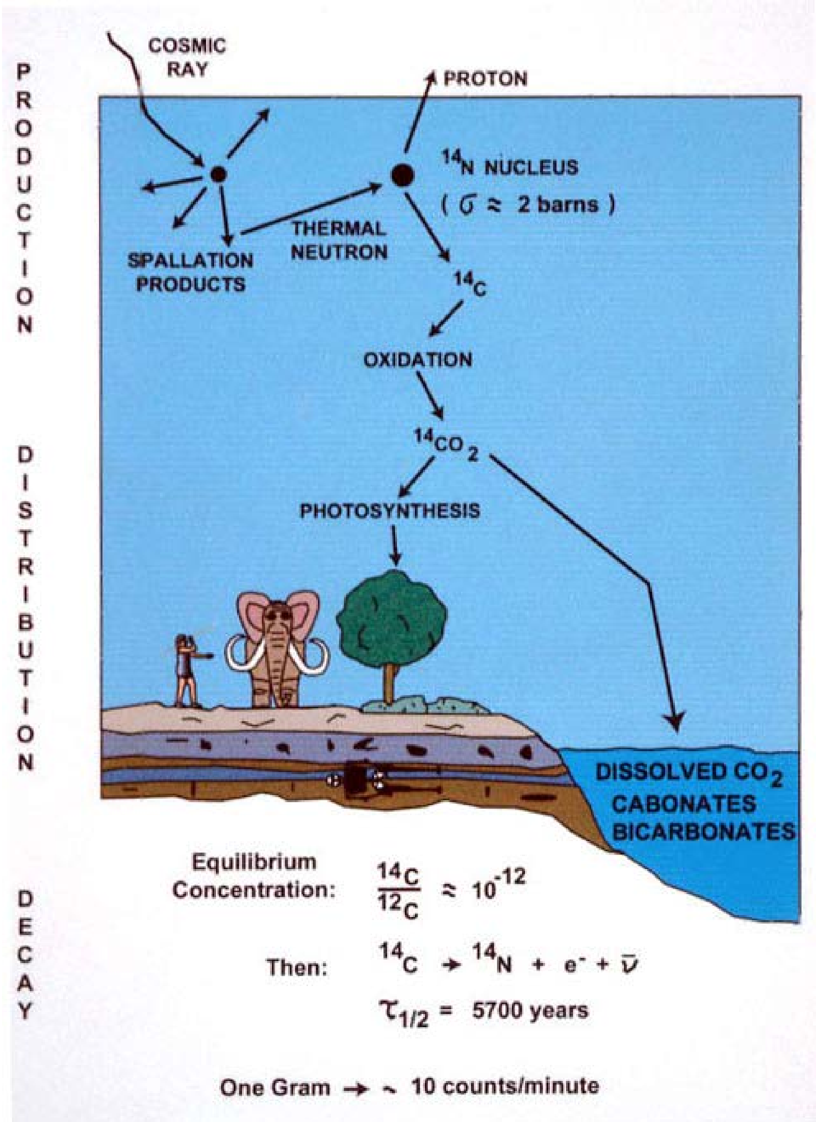


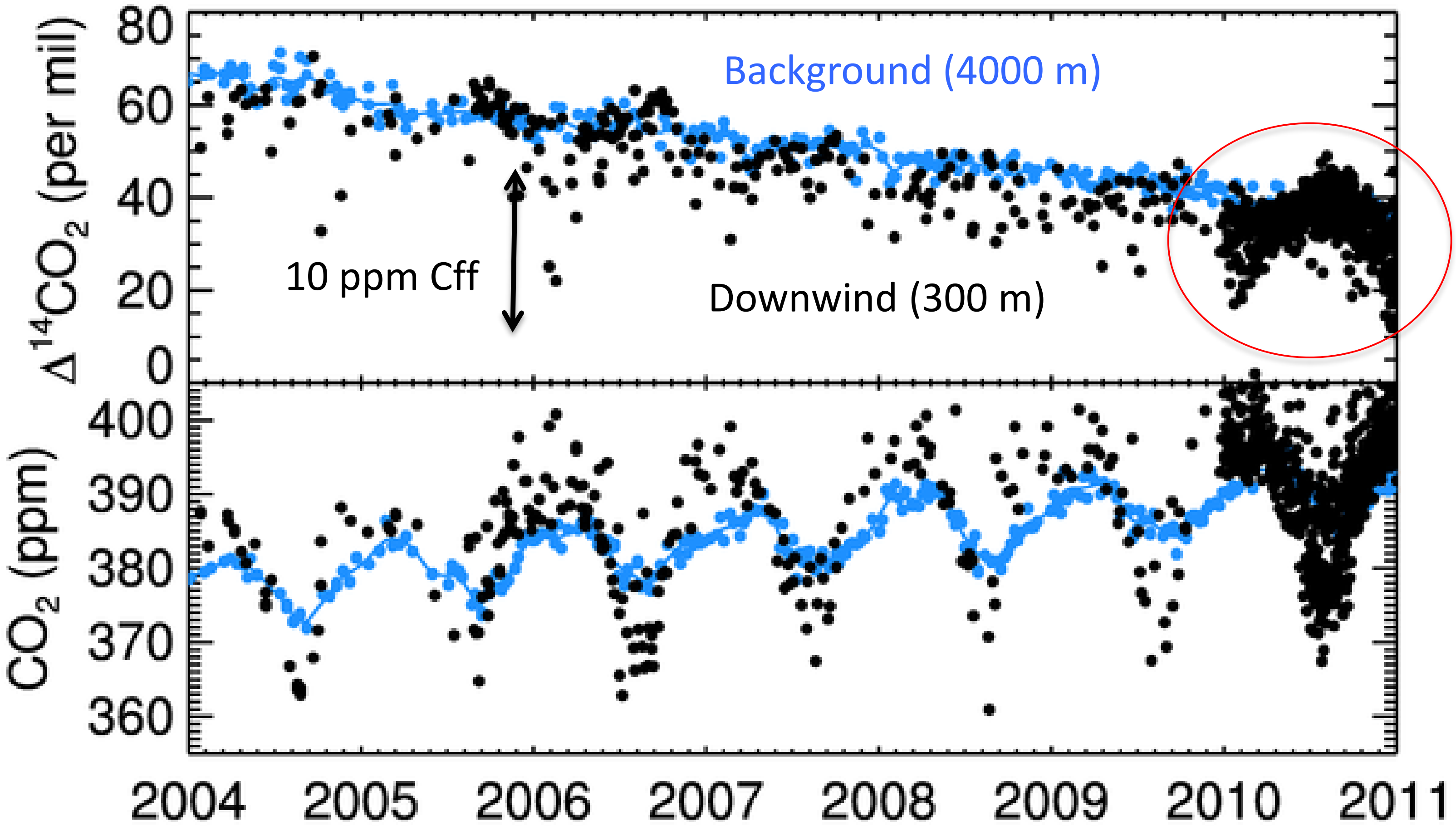
Fossil Fuel and $\Delta^{14}C$



U. Arizona AMS Lab

- ^{14}C is produced from N in the stratosphere by cosmic rays.
- It is oxidized to CO, then CO_2
- ^{14}C has a half-life of ~6000 years.
- Thus, it is absent from fossil fuels, and thus an excellent tracer for these emissions.
- In the USA, minor emissions from nuclear power plants
- Also fluxes associated with gross C fluxes from oceans and terrestrial biosphere.

U.S. lower atmosphere data show expected depletions of ^{14}C



INSTAAR+UCI Measurement Precision

en) = -31.46 ± 1.63

- Measurement made by Accelerator Mass Spectrometry (AMS) at UC Irvine
- Precision = 1.6 per mil
- Accuracy = < 0.5 per mil (based on intercomparison of different labs)

~7 years

Lehman et al, 2013