Quantifying fossil and biospheric CO_2 fluxes in California using ground-based and satellite observations

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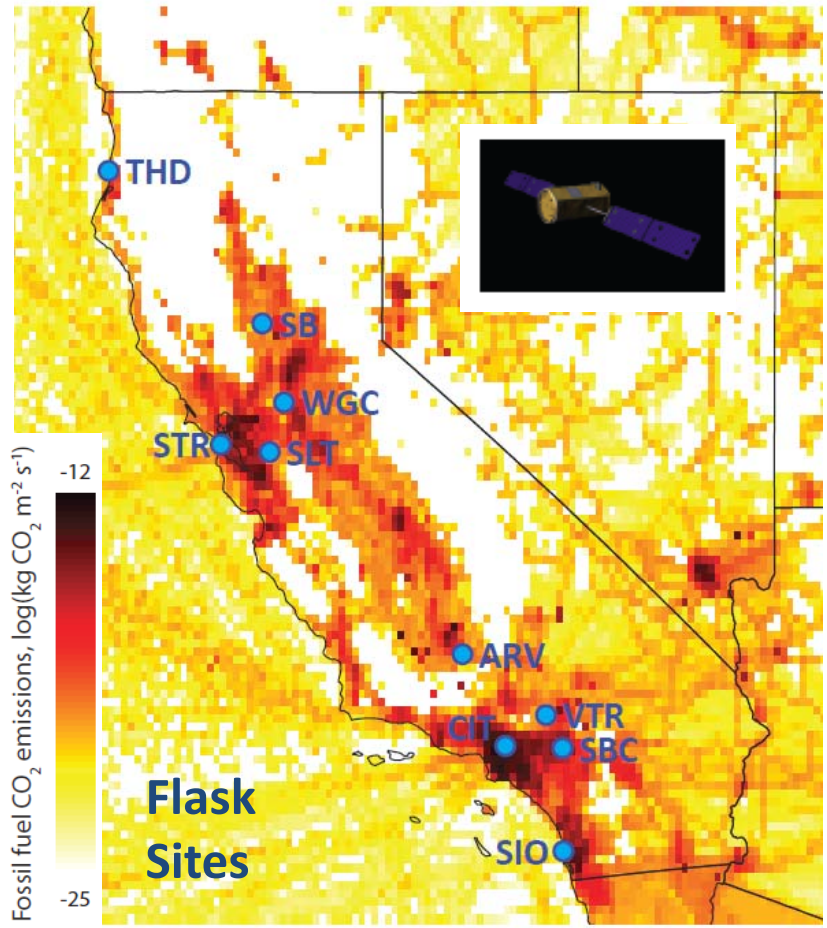


California's "Global Warming Solutions Act"

2006 legislation (AB 32) to reduce GHG emissions 20% by 2020; affirmed by voters in 2010 (Prop 23)

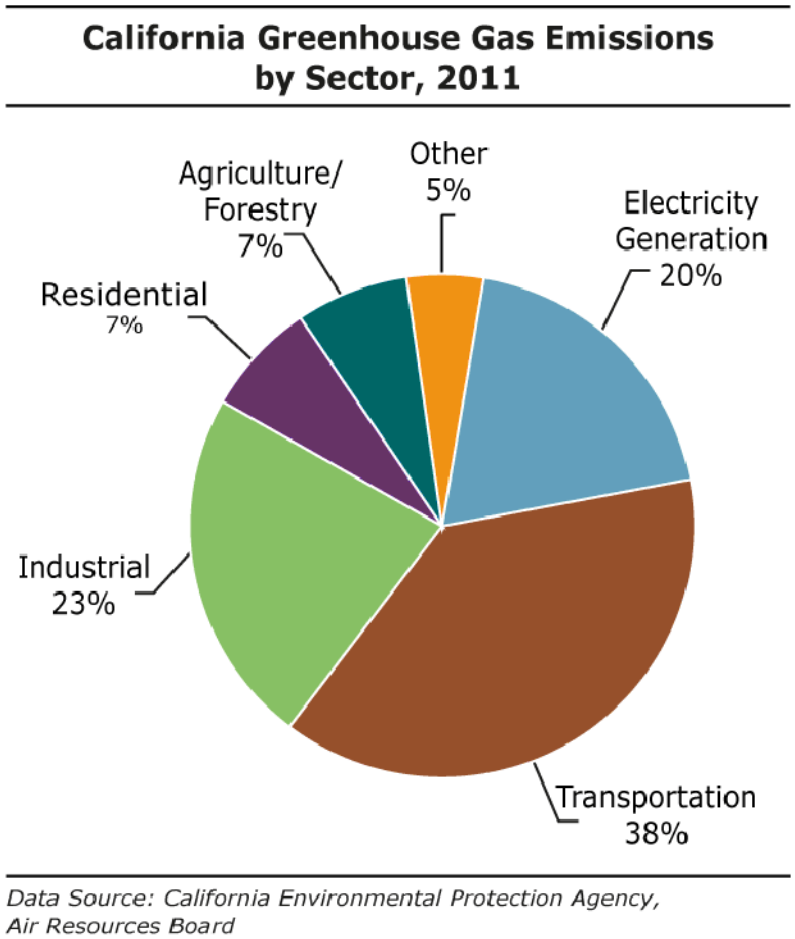
Includes CO_2, CH_4, N_2O, SF_6, HFCs, PFCs, NF_3

Implementation by California Air Resources Board (CARB) and other agencies

New regulations and reporting, cap-and-trade market, auditing/MRV, atmospheric observations (Picarros, LGRs) at 6 sites

http://www.arb.ca.gov/cc/inventory/inventory.htm

California's GHG emissions



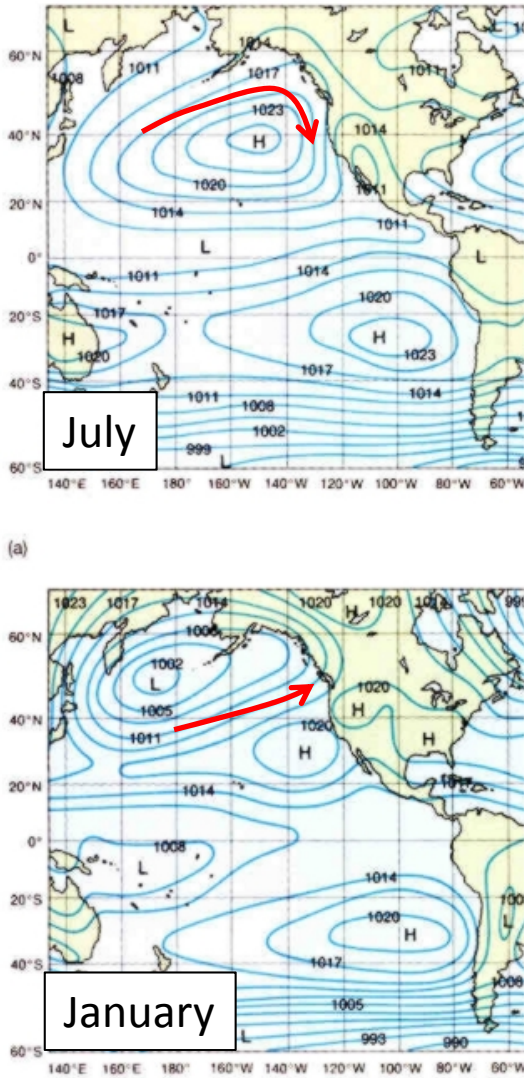
140 MtC eq in 2010 with ~90 % contributed by CO_2

Estimated biospheric CO_2 sink or source of 24 to -15 MtC/yr , depending on year's climate (Potter et al. 2010)

Various bottom-up estimates for $ffCO_2$:

100 MtC CDIAC (2001)
96 MtC Vulcan (2002)
138 MtC EDGAR (2002)
119 MtC CARB (2002)

Typical meteorology: On-shore flow



Santa Ana events bring air off-shore in Southern California in Oct-Mar

NASA MODIS; Mühle et al. 2007

Top-down emissions estimates based on aircraft data in May-June 2010 (CalNex)

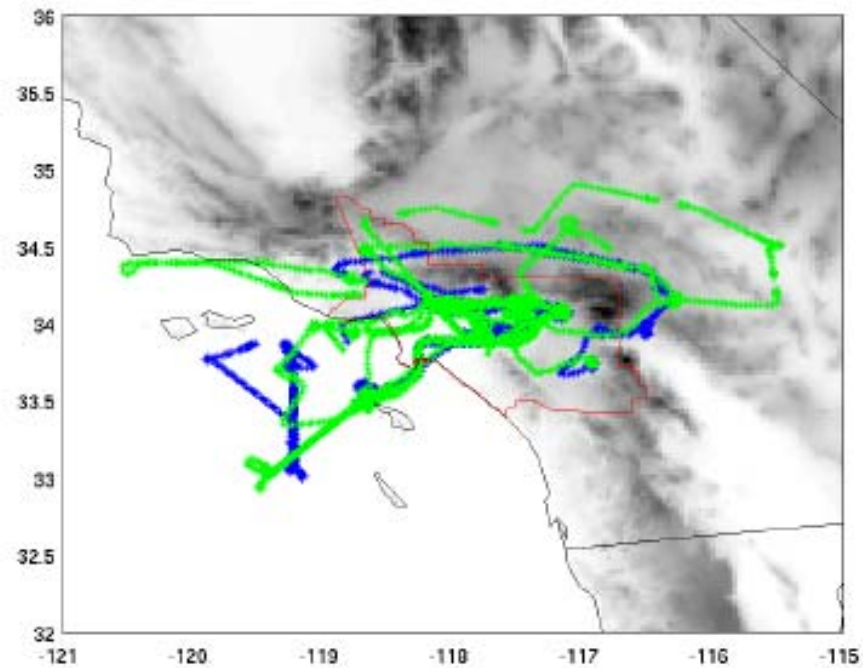
Inversion on CO emissions using WRF and WRF-CHEM with FLEXPART, data from 6 flights

Extended CO results to CO_2 with tracer ratio method, neglecting biospheric effects on CO_2

Uncertainties of 15% in posterior emissions reported

Suggests Vulcan underestimates $ffCO_2$ emissions in Los Angeles by 15-40%

Scaled up to CA, suggests California's emissions are likely to be accurate in CARB (2012)'s inventory, ~25% higher than Vulcan



Brioude et al. 2013

Can we use atmospheric observations to optimize both fossil fuel emissions and biospheric fluxes?

Radiocarbon separates fossil-derived and biospheric CO_2

^{14}C is produced in the atmosphere and participates in carbon cycle, decaying with ~5000 year half-life

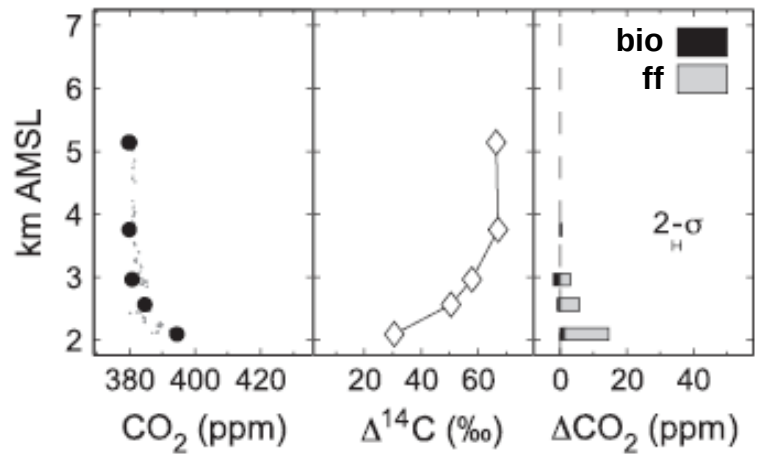
Fossil fuels have no ^{14}C and dilute $^{14}CO_2$

$$CO_2ff = -\frac{CO_2bg\left(\Delta_m - \Delta_{bg}\right)}{\Delta_m - 1000‰} - \beta$$

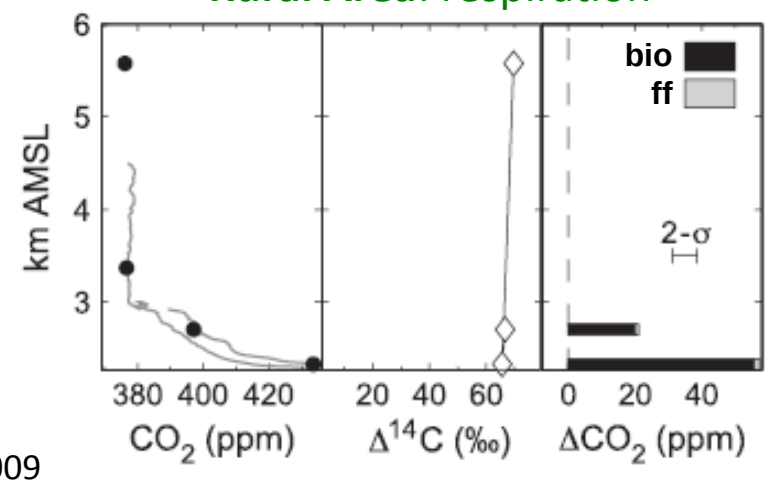
$$CO_2bio = CO_2m - CO_2ff - CO_2bg$$

Linking ^{14}C with CO can provide information on source type, extend temporal coverage of fossil/biospheric separation

Urban Area: fossil fuel emissions



Rural Area: respiration



Examples from Graven et al. 2009

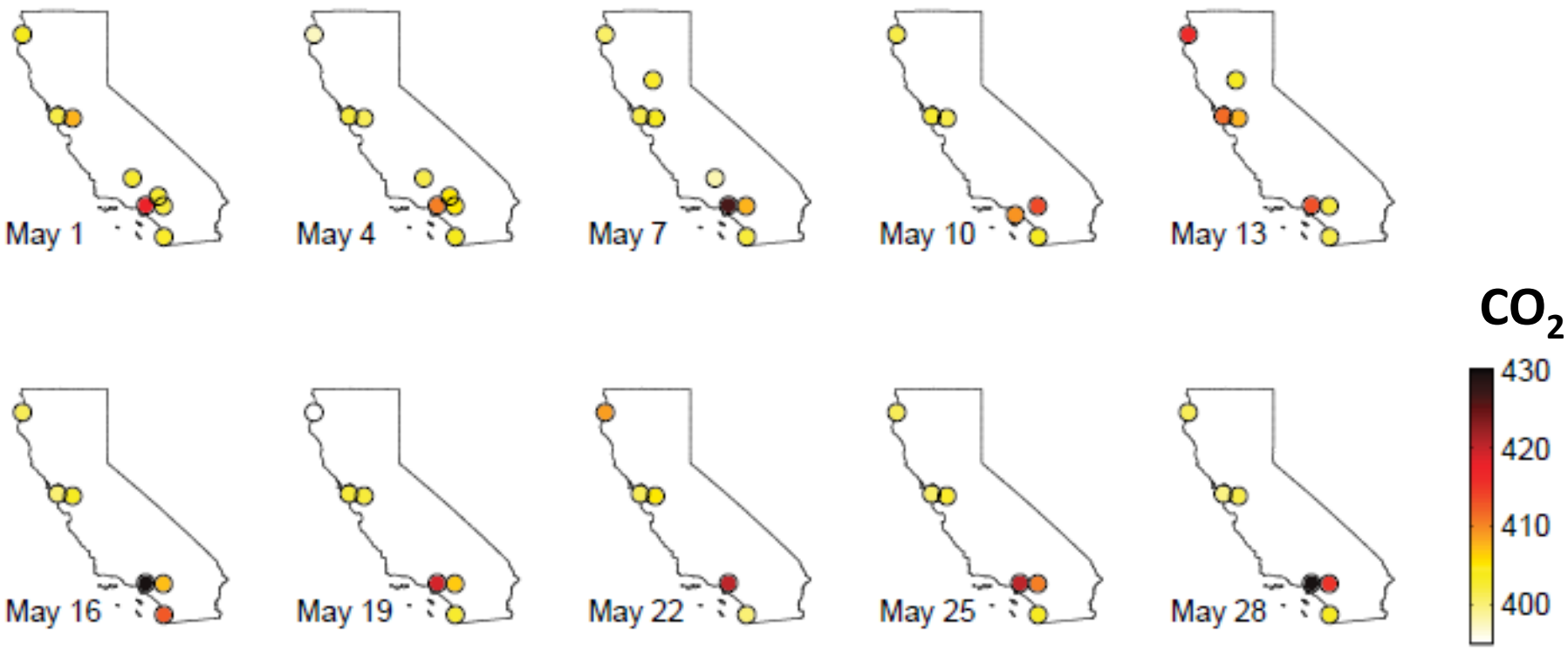
Project objectives

- Observe high resolution CO_2, $ffCO_2$ and $bioCO_2$ gradients in California using column and in situ data, especially ^{14}C
- Develop inversion framework to use data and models to estimate $ffCO_2$ and $bioCO_2$ fluxes in California

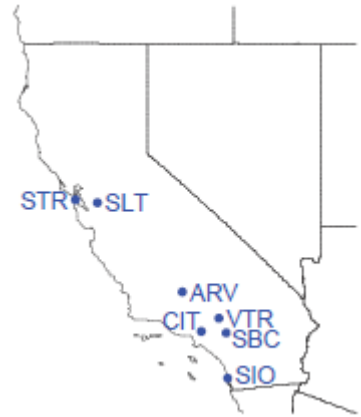
Current progress

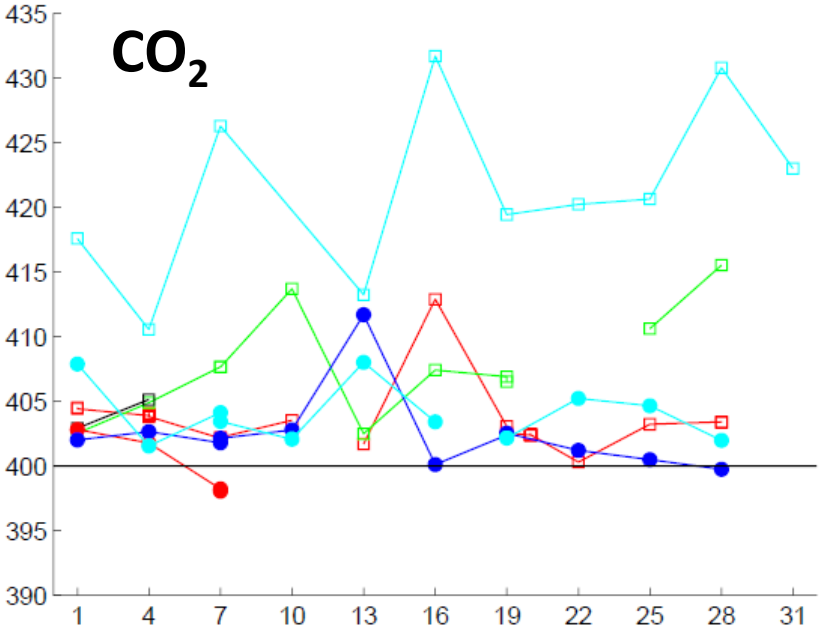
- Field campaign #1 completed in May, ^{14}C analysis ongoing
  Field campaign #2 Oct. 15 through Nov. 14
- Pseudo-data simulations and inversions using flask network and potential OCO-2 columns

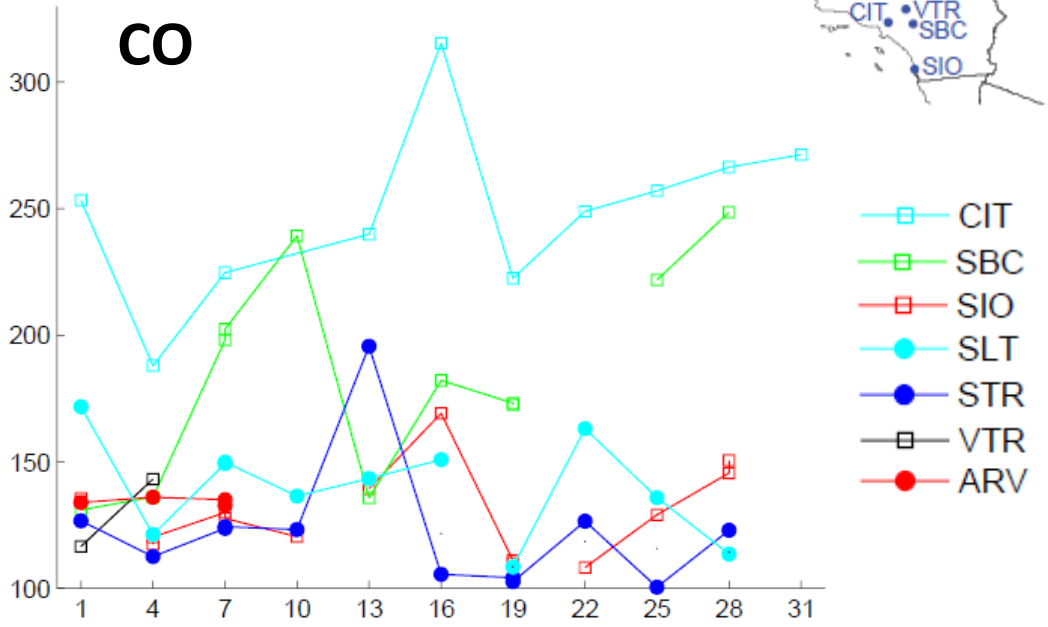
Preliminary flask data from May field campaign



Preliminary flask data shows regional gradients due to fossil fuel and biospheric fluxes and transport

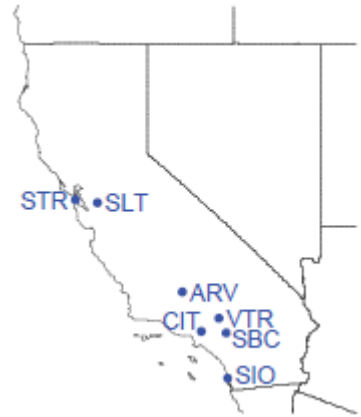


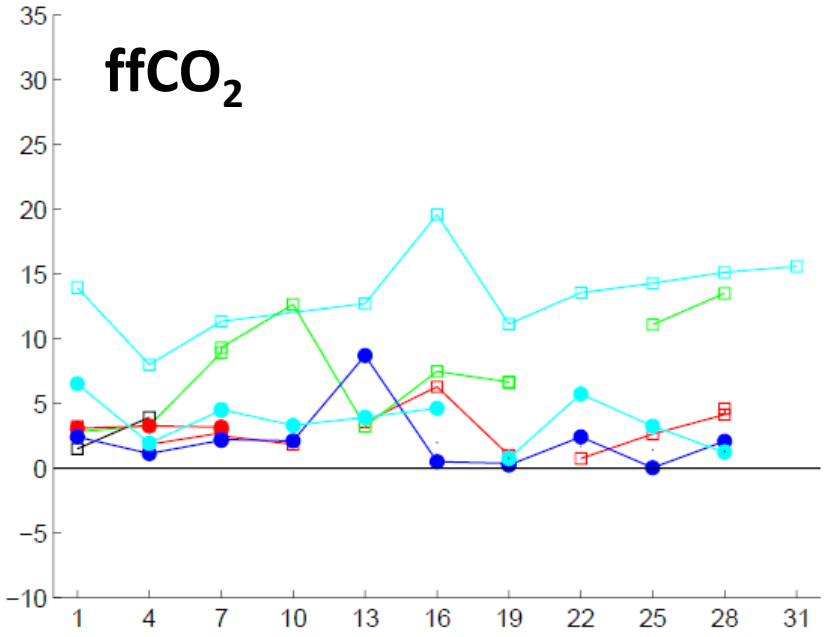


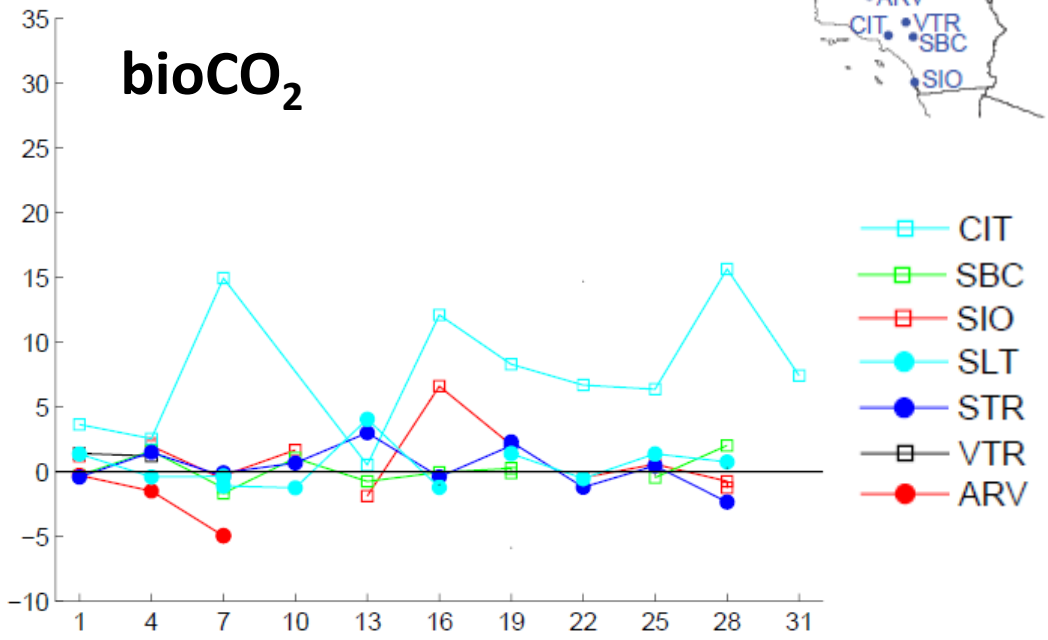


Preliminary results from May campaign

Preliminary flask data shows regional gradients due to fossil fuel and biospheric fluxes and transport







Preliminary calculation assuming $bgCO_2$=400ppm, bgCO=100ppb and $ffCO_2$/ffCO=11 ppm/ppb (Newman et al. 2013)

Pseudodata experiments to test observational constraints

WRF-STILT footprints for flask and potential OCO-2 observation sites

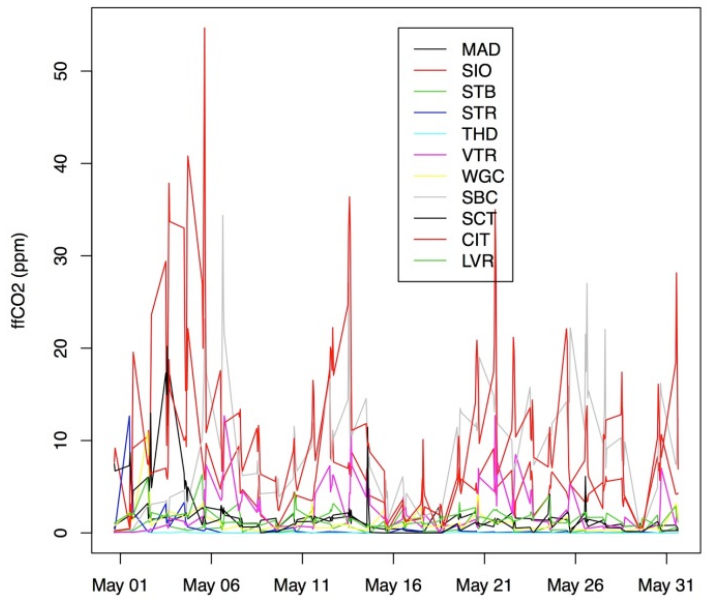
Vulcan $ffCO_2$ and CASA bioCO2 fluxes

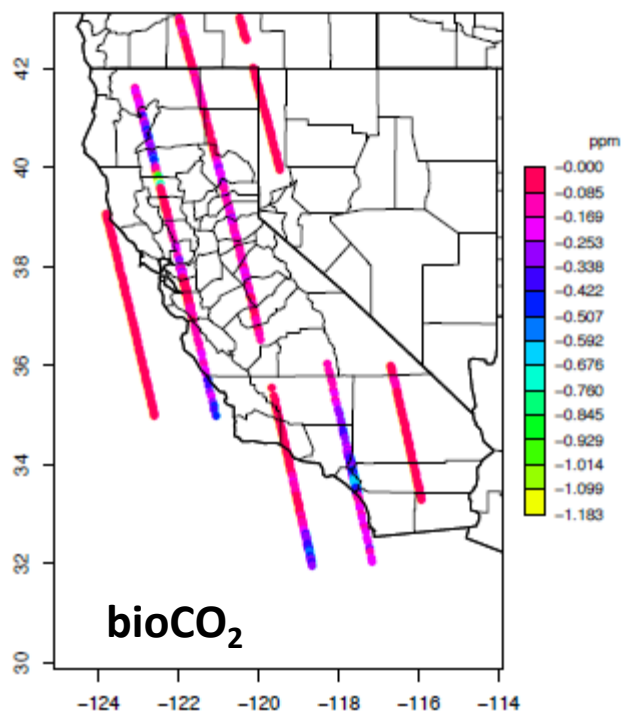
Included random-normal variation of ~25% in region FF fluxes for 1000 member Monte Carlo simulation

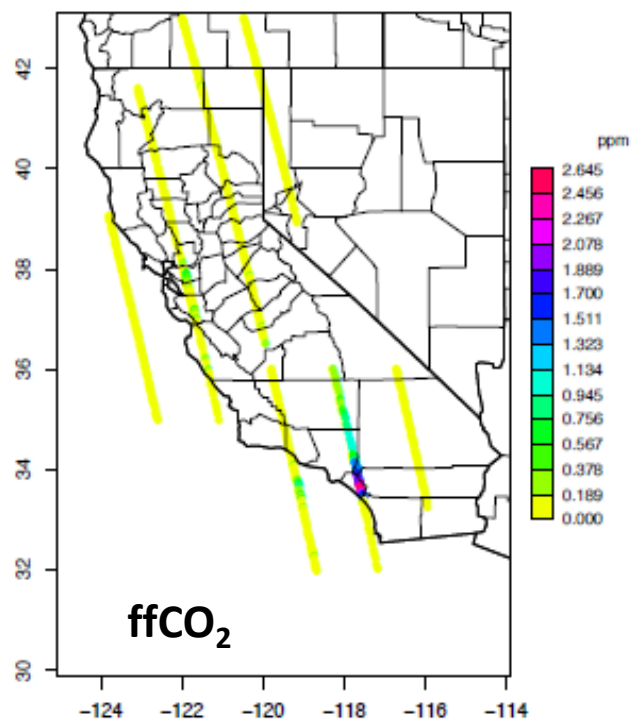
Meas uncertainty 0.7-1ppm, Transport uncertainty 30%

Assuming perfect subtraction of background and biospheric CO_2 for OCO-2

May 2011







Pseudo-data $ffCO_2$ inversion results:

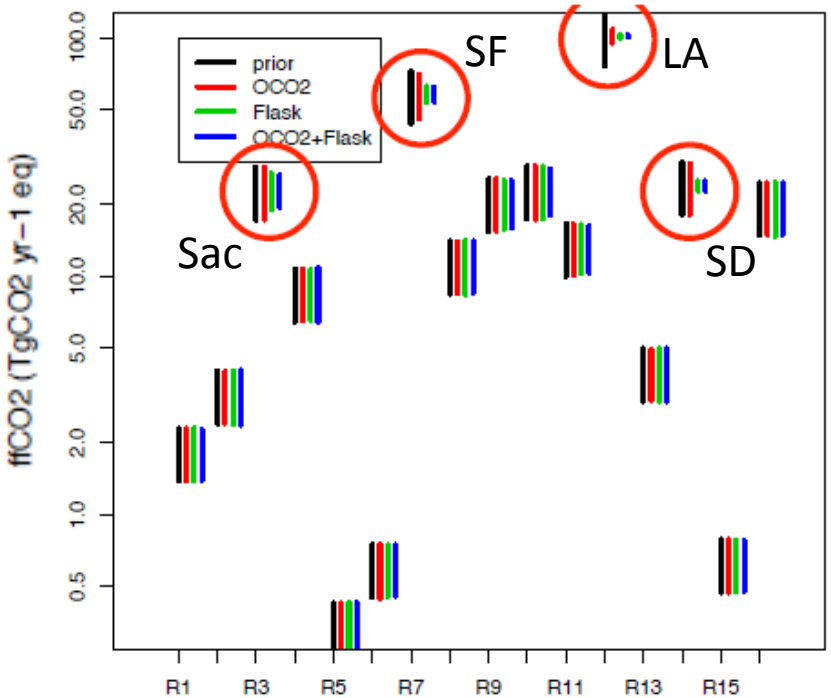
Some constraint with OCO-2 (in LA Basin)

Stronger constraint with flasks (several regions)

Time period & data used:	May 2011, OCO-2 only	May 2011, flasks and OCO-2
Posterior uncertainty ($TgCO_2$/yr)	21	11

Prior total $ffCO_2$ emissions:
317 ± 31 $TgCO_2$/yr (~10%)

May 2011



Summary

- Combining column CO_2 with ground-based observations and models of CO_2 and ^{14}C to study fossil fuel and biospheric fluxes in California
- 1st field campaign shows CO_2 variations related to fossil fuel and biospheric fluxes and transport
- Pseudodata experiments indicate OCO-2 could provide some constraint on fossil fuel emissions in the LA Basin, combining OCO-2 with flask network improves and expands constraint to other regions

Ongoing work

- Radiocarbon analyses for 1st campaign, Full analysis of 2nd campaign
- Development of bioCO_2 component to pseudodata inversion
- Application of inversion to field campaign observations