Urban CO_2 Emissions from the Los Angeles Basin: Assessing chemistry and dynamics using the suite of tracers measured aboard the CalNex WP-3 Aircraft

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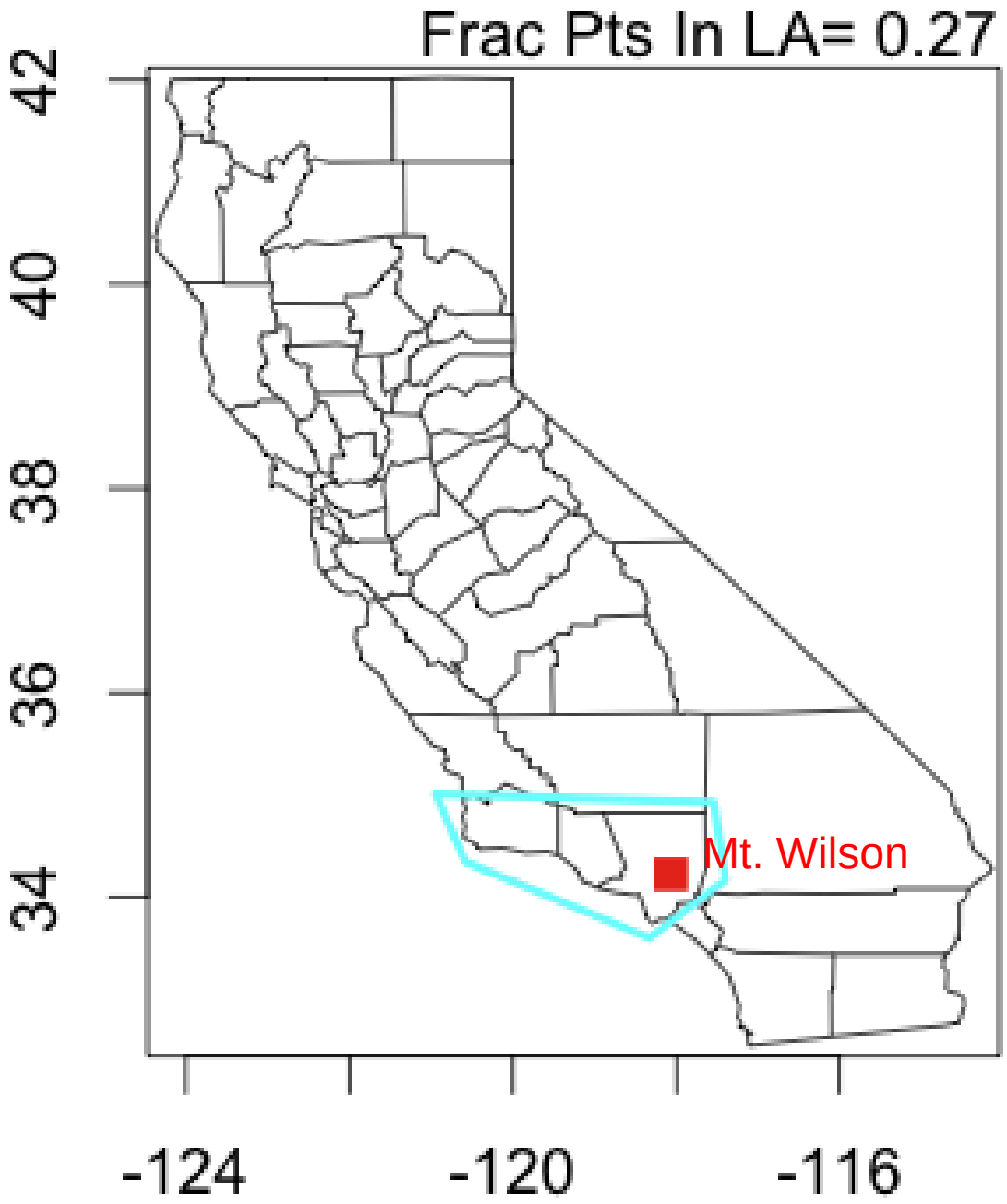
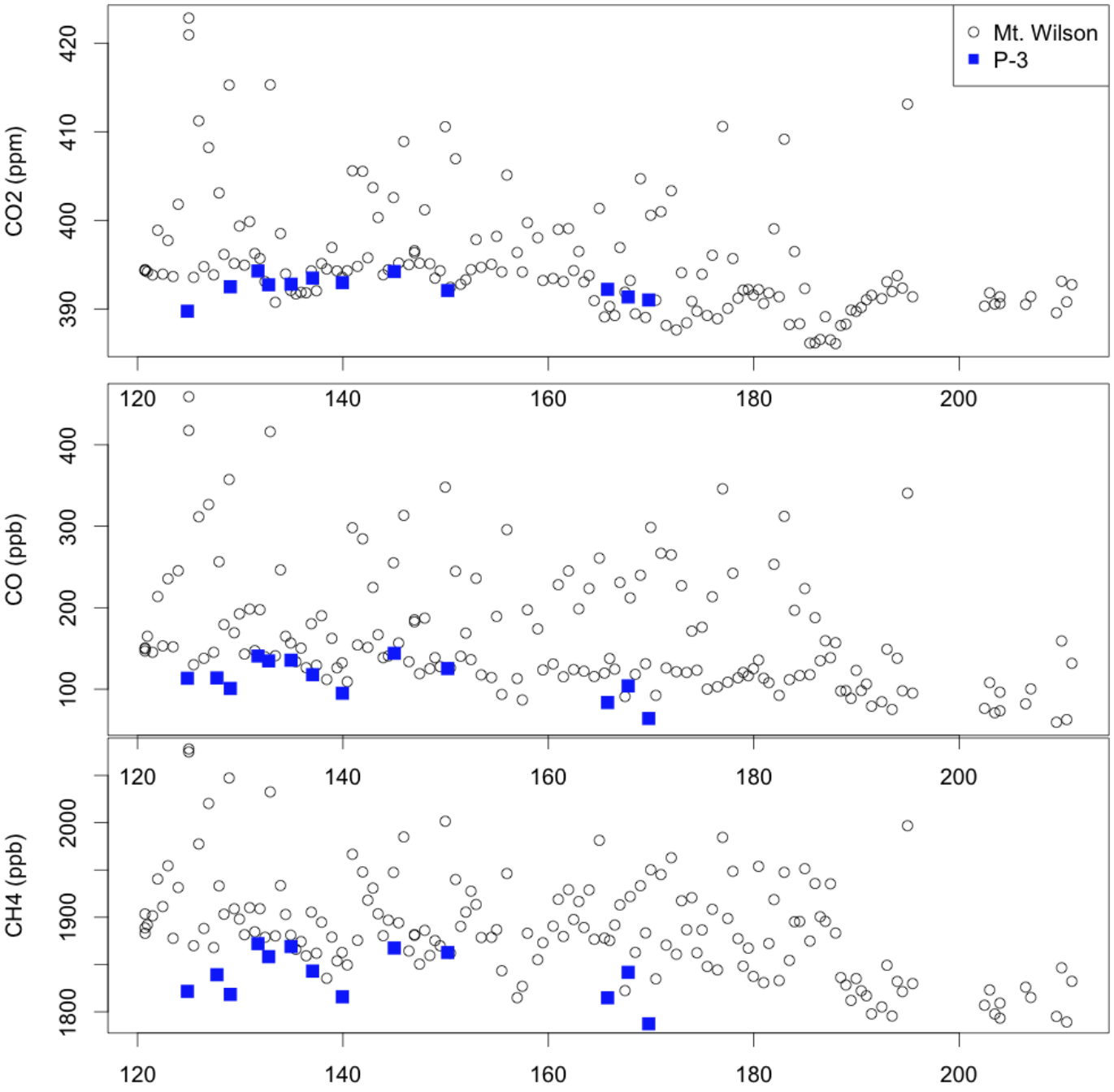
Goals for studying CO_2 and other GHGs in CalNEX

- ***Use of CO_2 as the primary metric of combustion influence***

- ***Test ideas of how to measure changes in total emissions over time (treaty verification)***

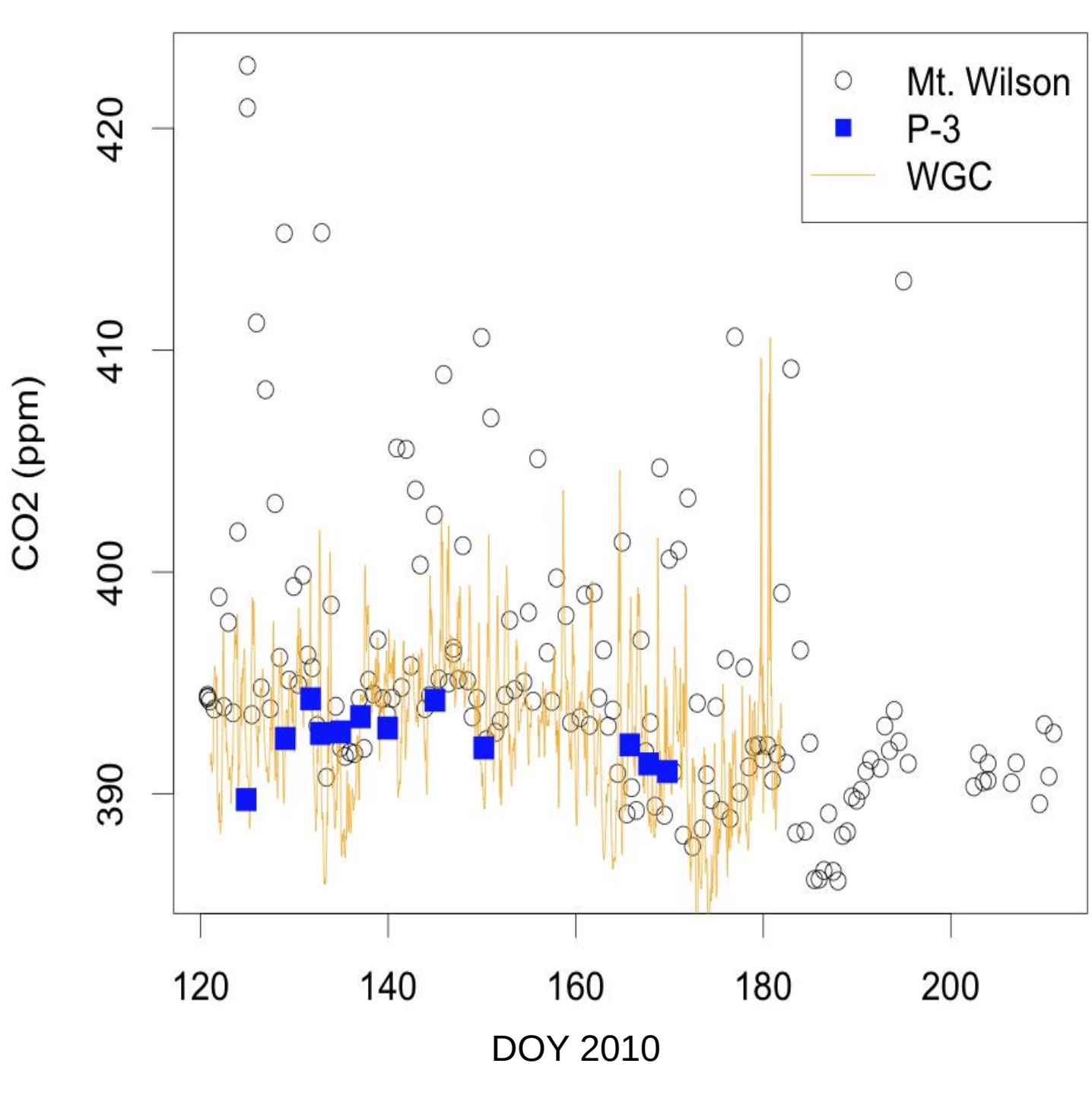
- ***Use CO_2 as a model validation tool***

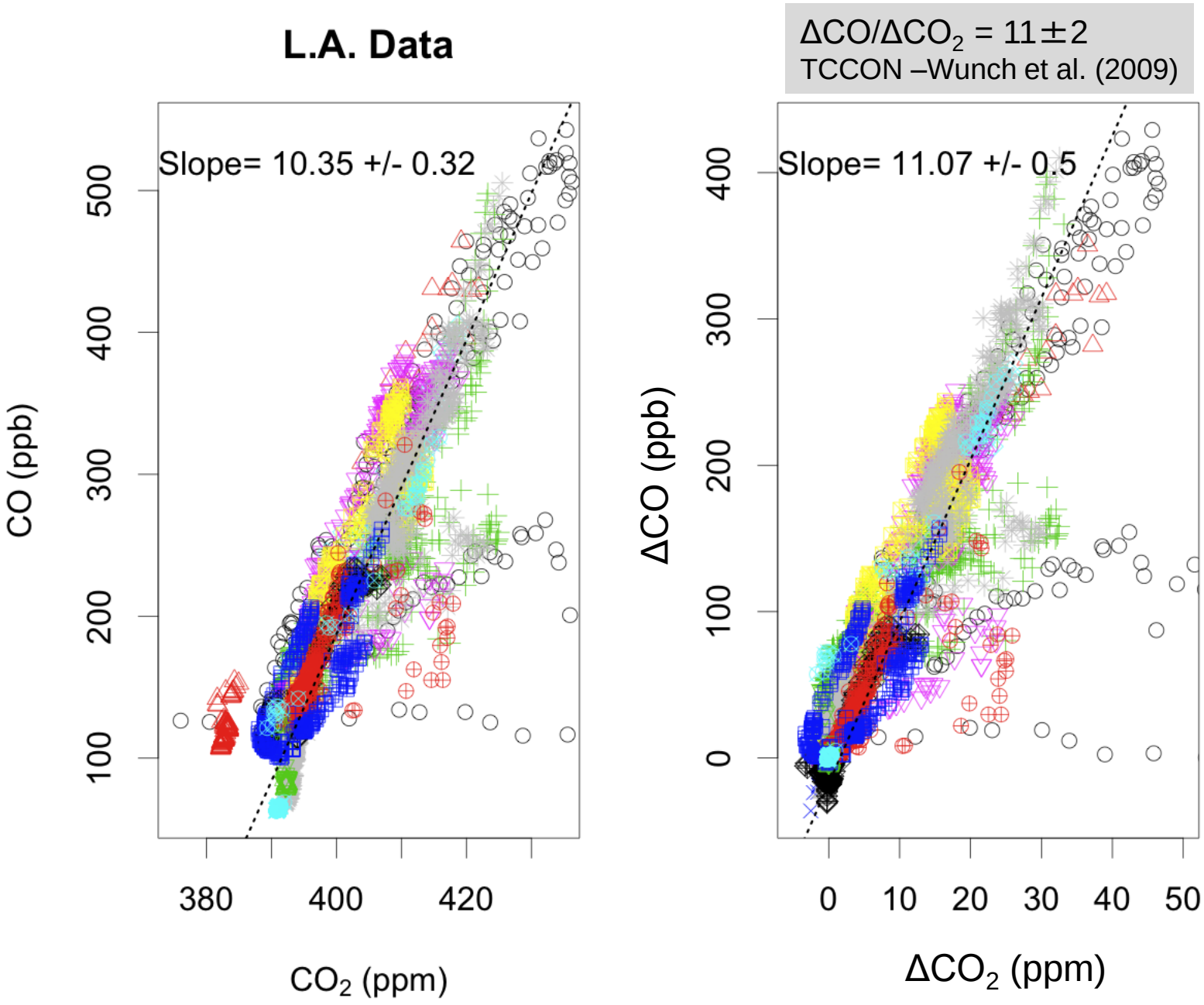

Frac Pts In LA= 0.27
42
40
38
36
34
-124
-120
-116
Mt. Wilson



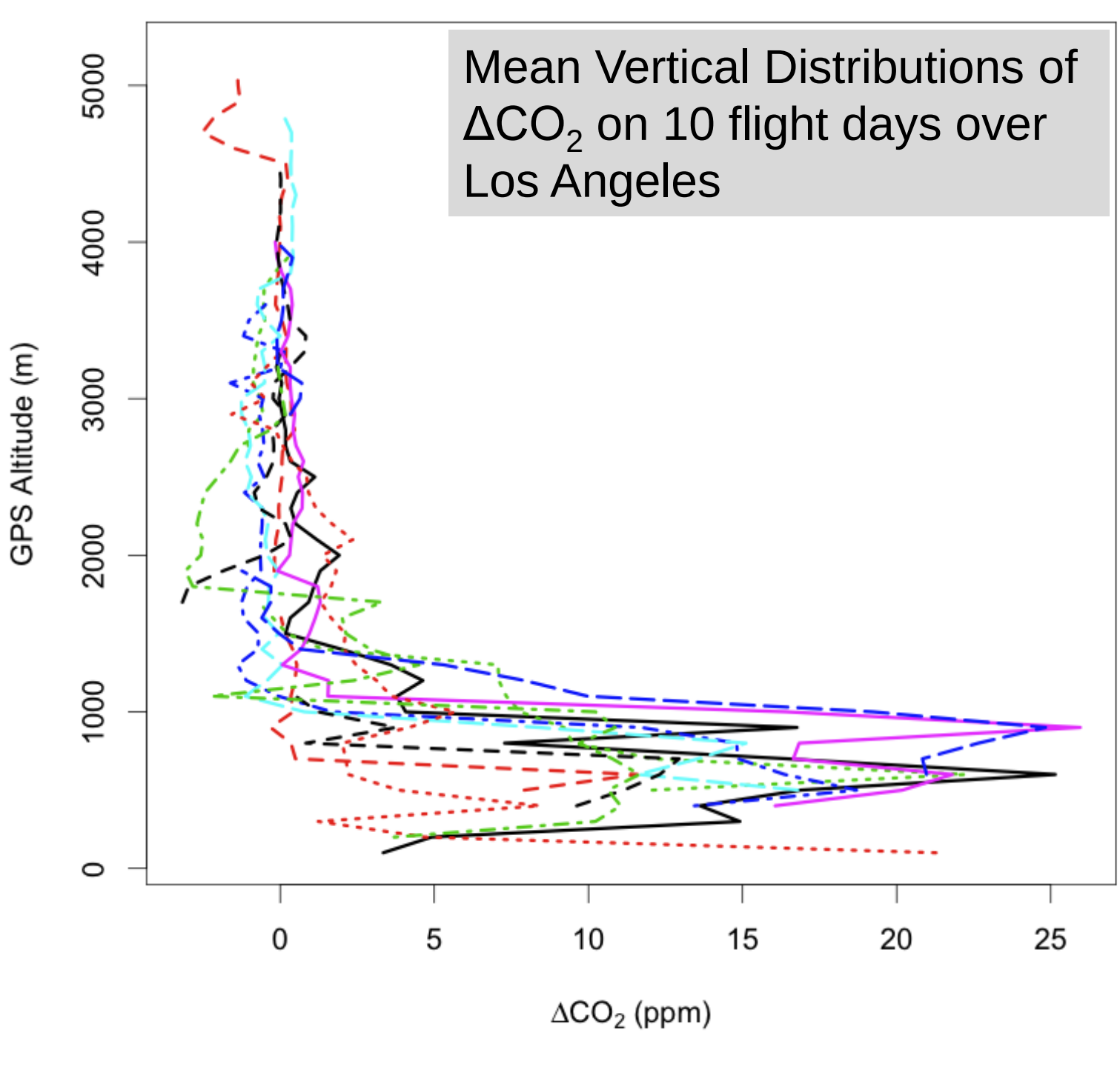
Background CO_2, CO, CH_4 concentrations:

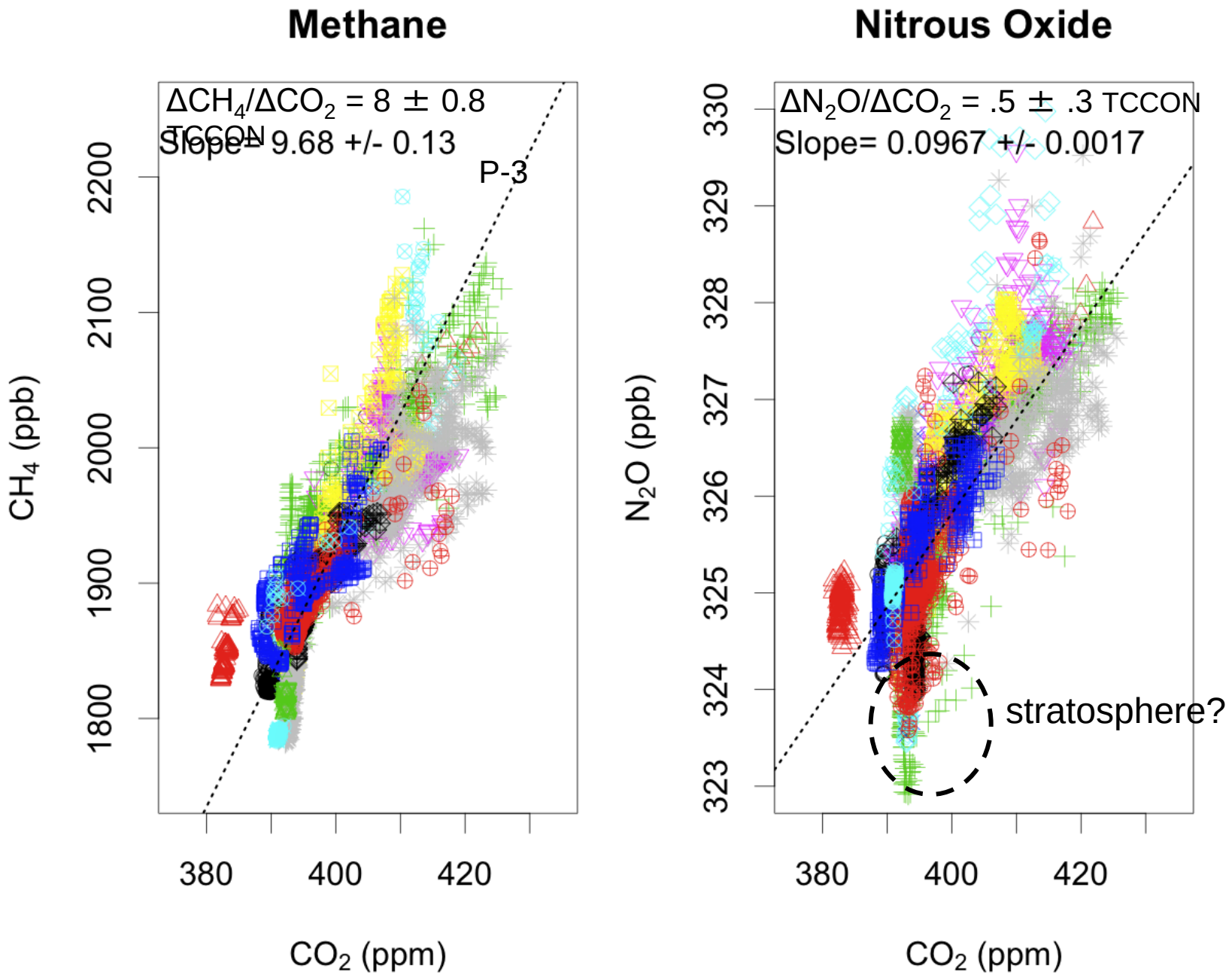
Mt. Wilson vs from the P-3

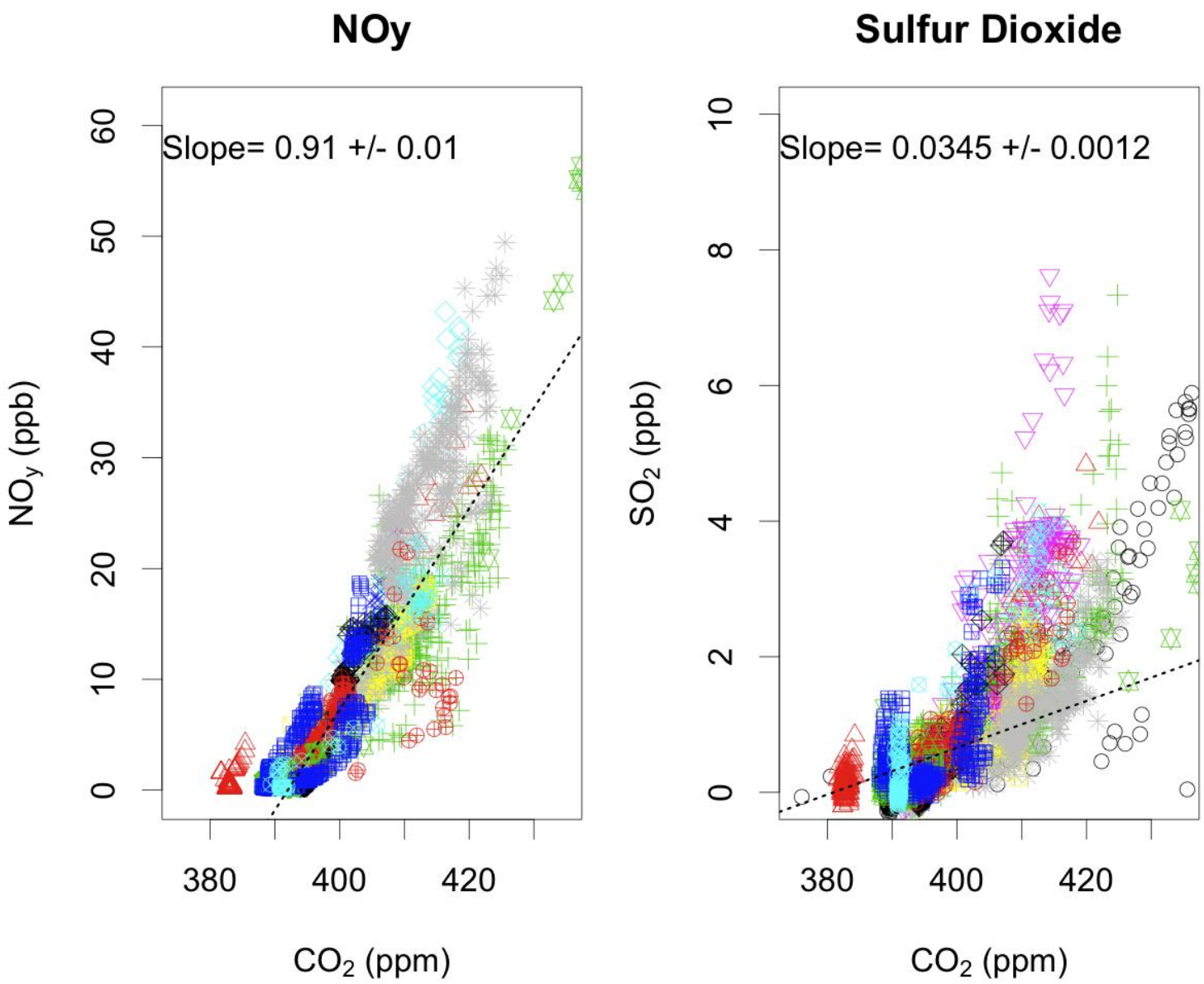

Mt. Wilson
P-3
WGC
CO2 (ppm)
420
410
400
390
120
140
160
180
200
DOY 2010



Uniformity an artifact of an aged mix of sources?


Mean Vertical Distributions of ΔCO2 on 10 flight days over Los Angeles
GPS Altitude (m)
0
1000
2000
3000
4000
5000
0
5
10
15
20
25
ΔCO2 (ppm)


Methane
ΔCH4/ΔCO2 = 8 ± 0.8
TCCON
Slope= 9.68 +/- 0.13
P-3
CH4 (ppb)
1800
1900
2000
2100
2200
380
400
420
CO2 (ppm)
Nitrous Oxide
ΔN2O/ΔCO2 = .5 ± .3 TCCON
Slope= 0.0967 +/- 0.0017
N2O (ppb)
323
324
325
326
327
328
329
330
stratosphere?
380
400
420
CO2 (ppm)


NOy
Slope= 0.91 +/- 0.01
NO_y (ppb)
0
10
20
30
40
50
60
380
400
420
CO_2 (ppm)
Sulfur Dioxide
Slope= 0.0345 +/- 0.0012
SO_2 (ppb)
0
2
4
6
8
10
380
400
420
CO_2 (ppm)

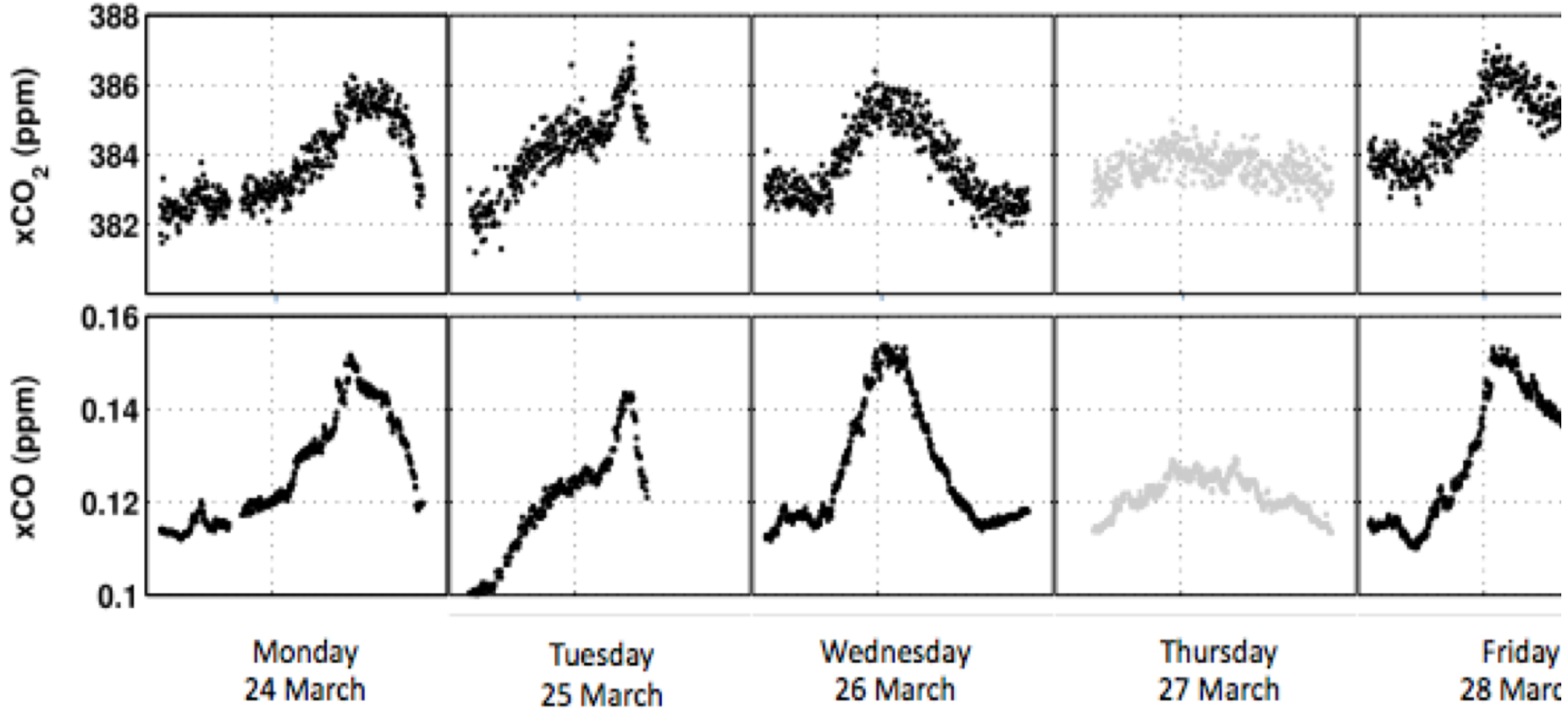
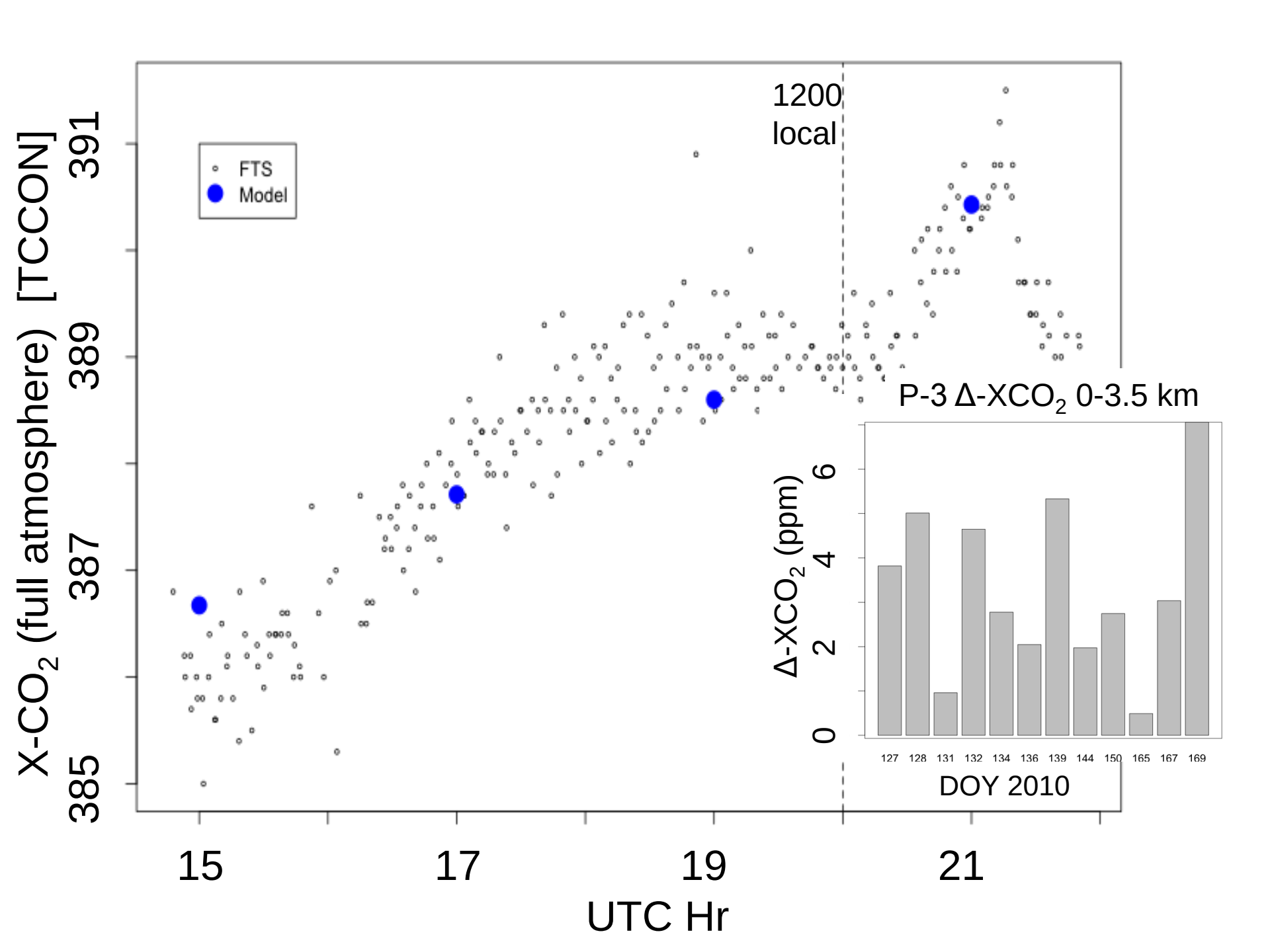
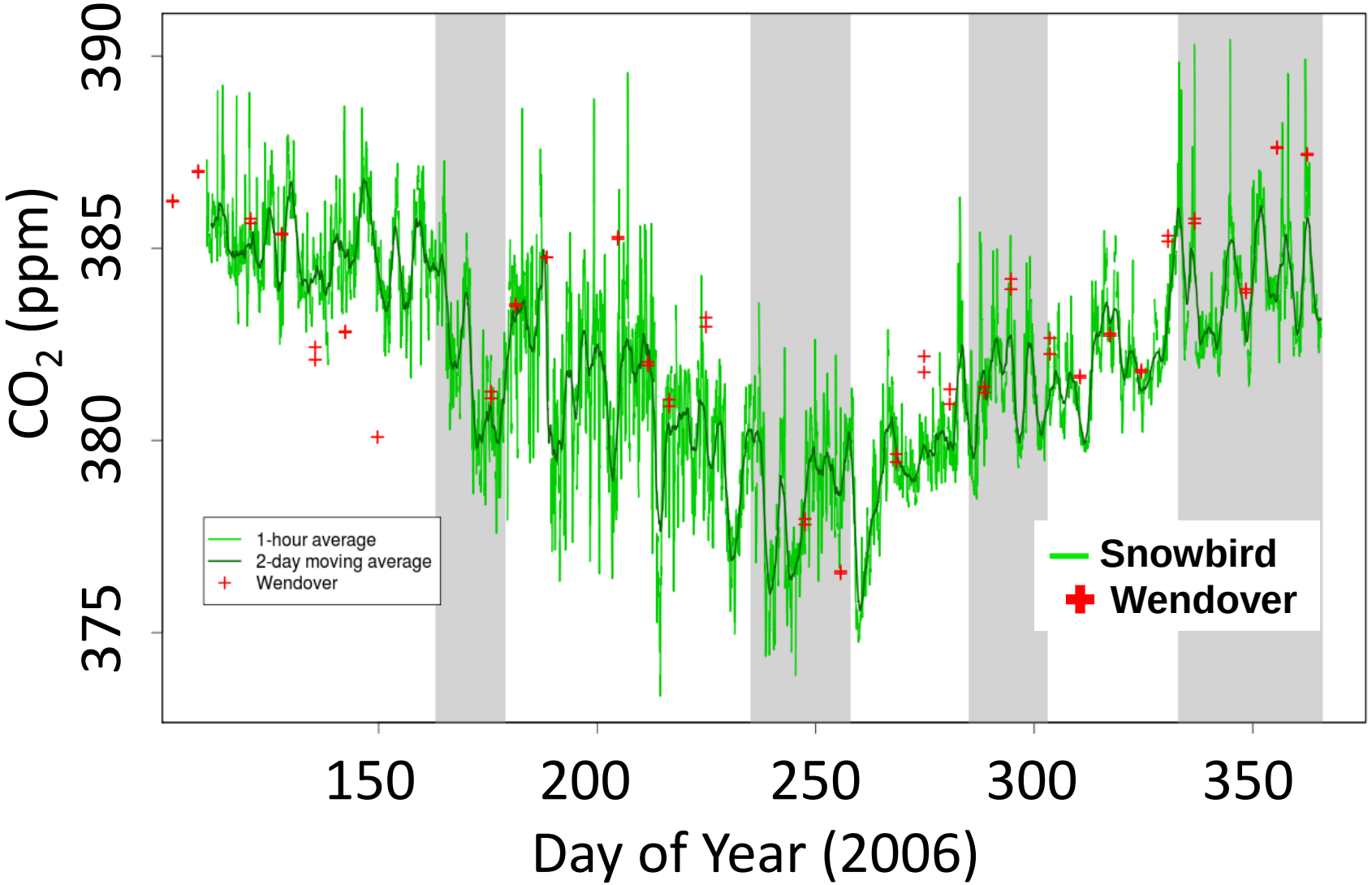


Figure 20. Column CO_2 over Los Angeles from the Total Carbon Column Observation Network (TCCON) for five days in March, 2008. Three of the four days show strong diurnal variation associated with urban emissions while the March 27 data show much smaller variations due to the air originated from the Mojave Desert. Note that there is no data recorded at night, and the solid vertical lines represent the time between 7 PM and 7 AM. (Source: Wunch et al. 2009)


X-CO2 (full atmosphere) [TCCON]
385
387
389
391
FTS
Model
1200
local
15
17
19
21
UTC Hr
P-3 Δ-XCO2 0-3.5 km
Δ-XCO2 (ppm)
0
2
4
6
127
128
131
132
134
136
139
144
150
165
167
169
DOY 2010

Salt Lake City: A contrast site vs. Los Angeles

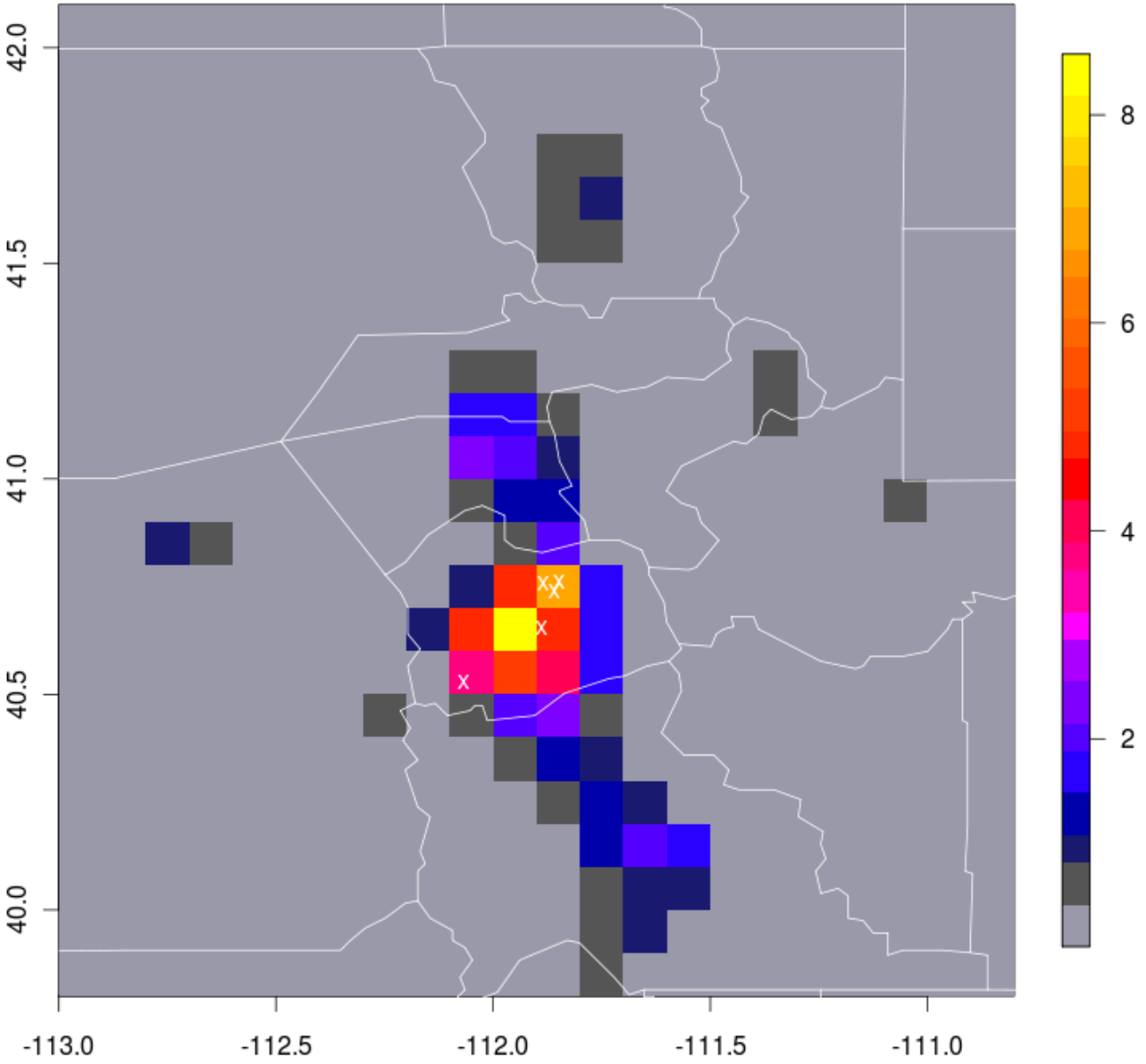
Locations of urban measurement sites in the Salt Lake Valley. Photos show placement & locale.



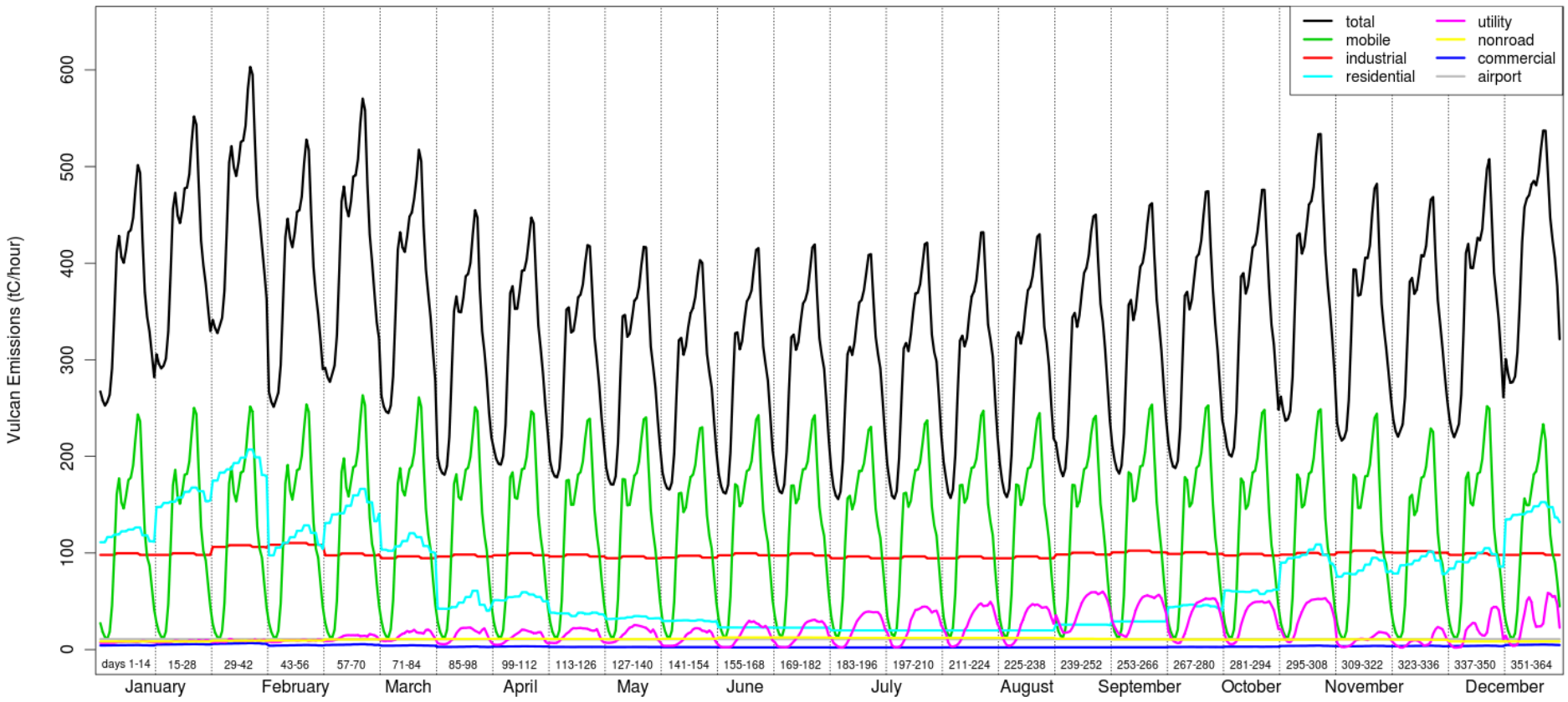
Variation of background air entering the SLC Valley

Data from Britt Stephens

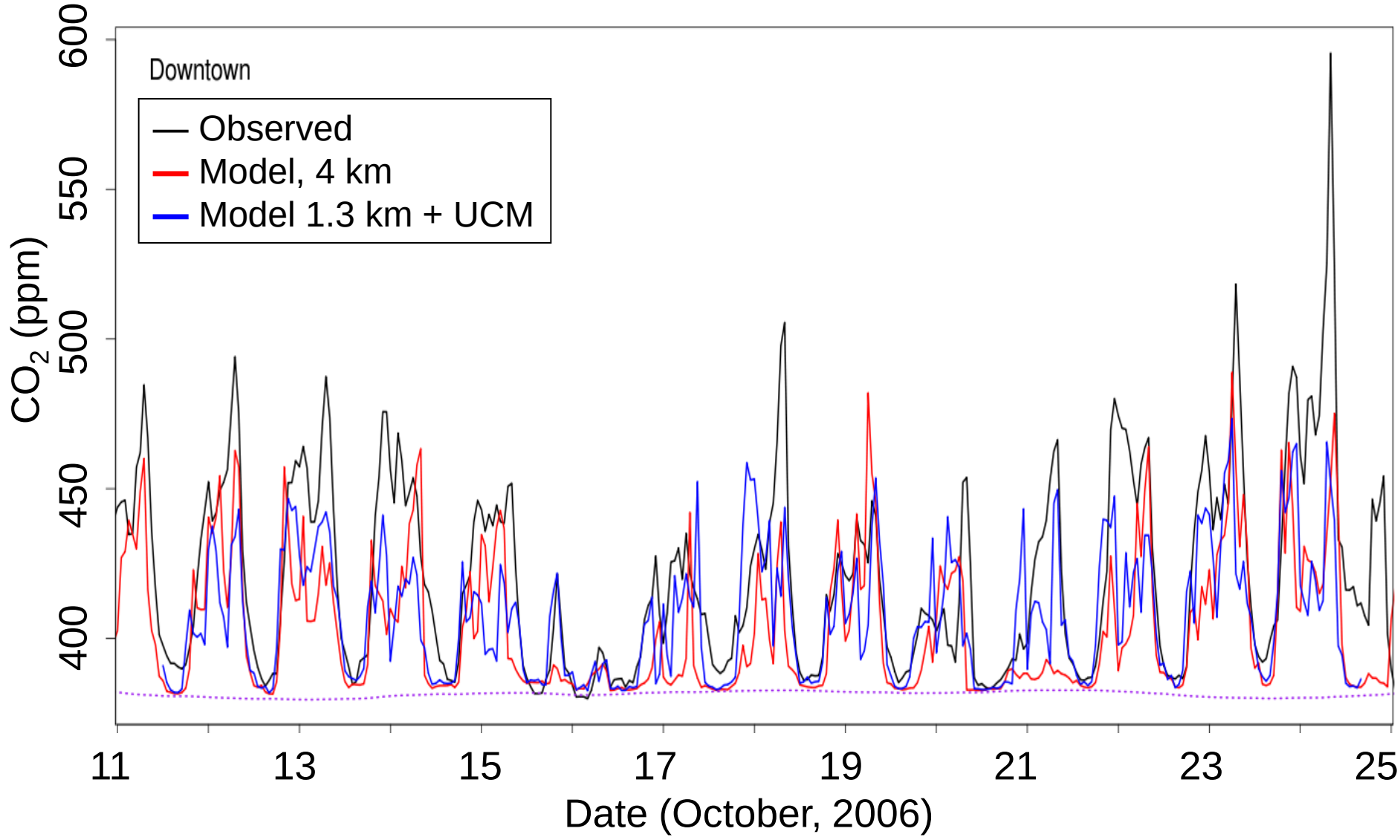
SLC CO_2 (Vulcan emissions in μmole/m^2/s)

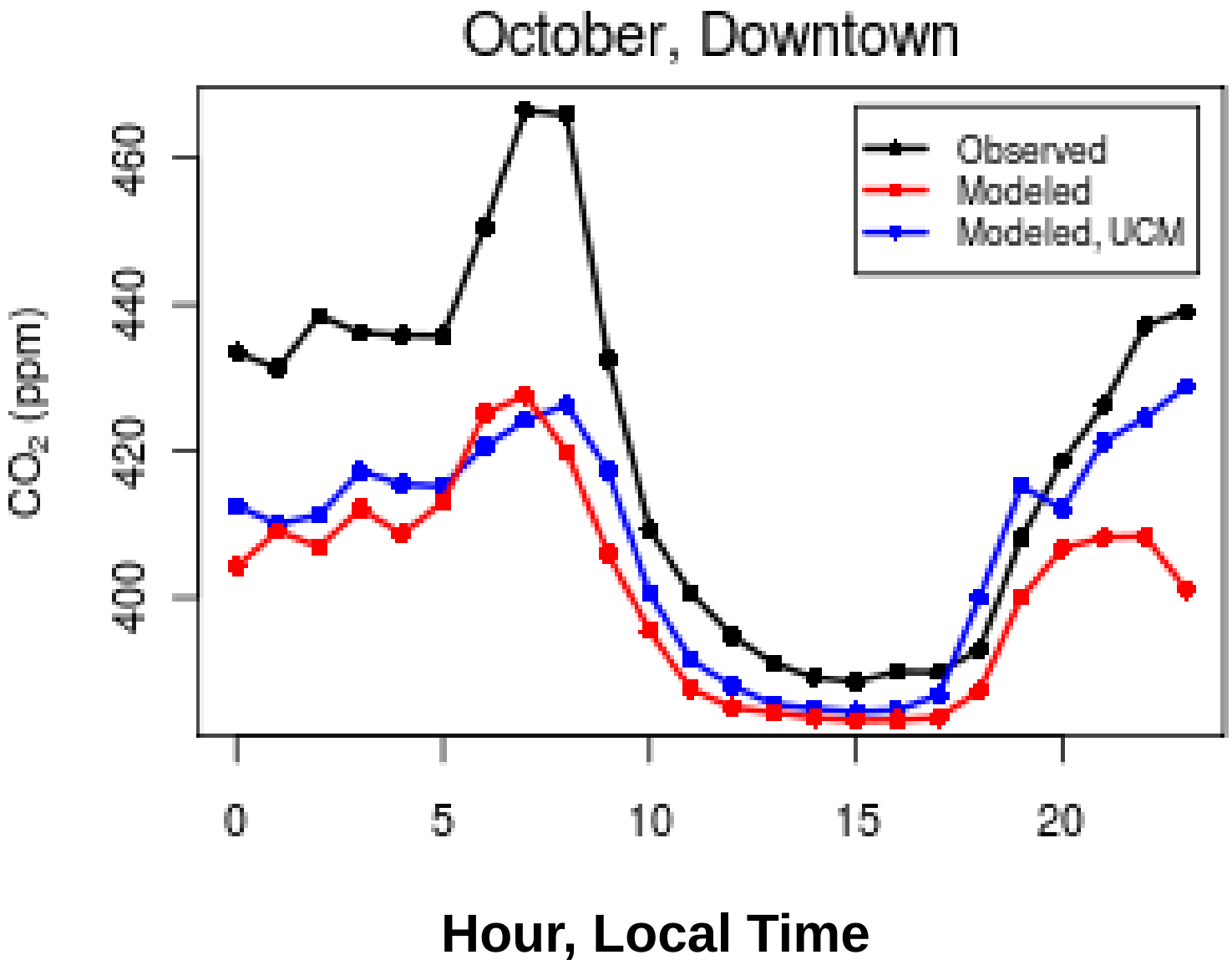


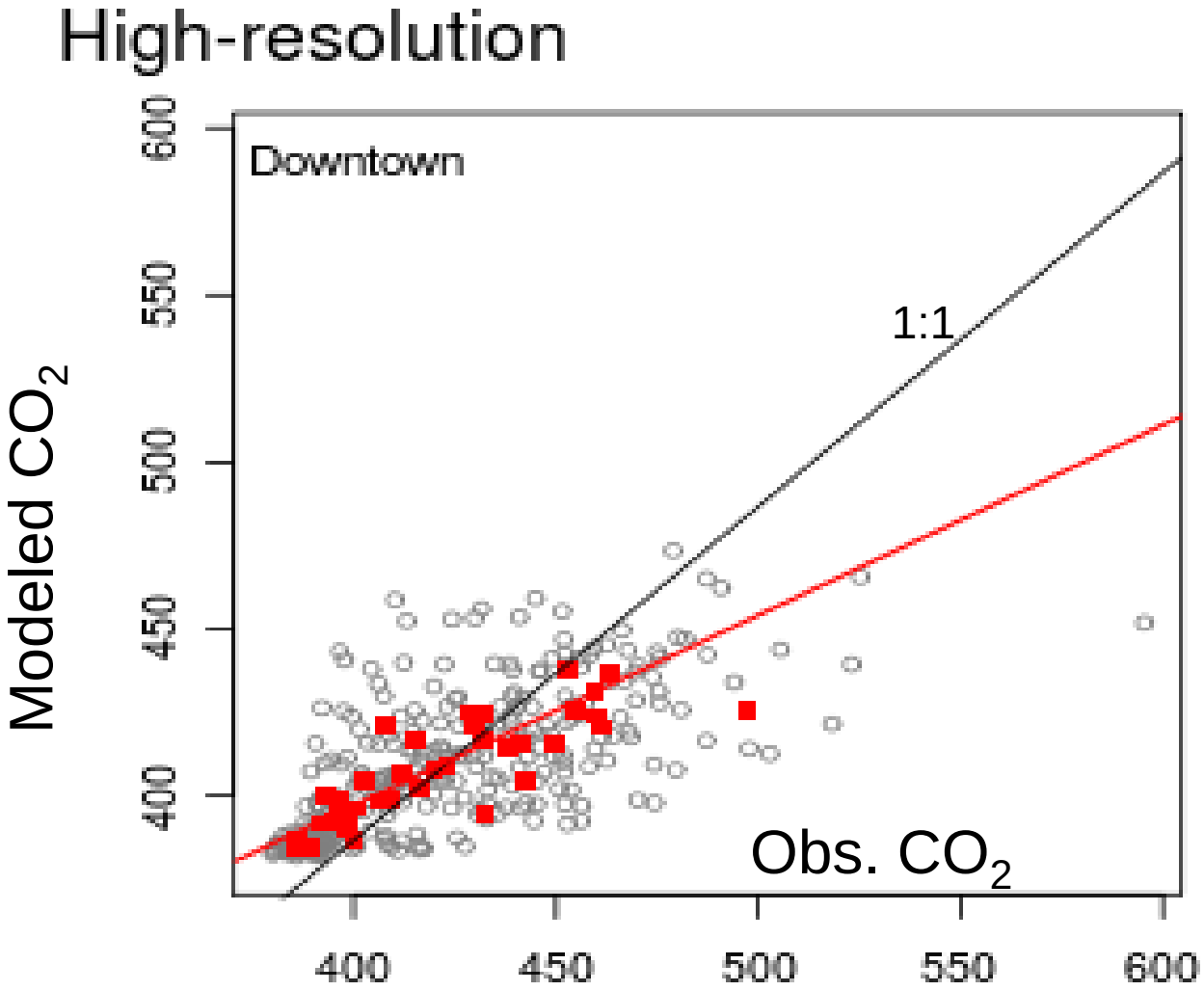
SLC CO_2 (Vulcan emissions in tonne C/hr)



Observed and Modeled CO_2 concentrations, Salt Lake City (Downtown)




October, Downtown
Observed
Modeled
Modeled, UCM
CO_2 (ppm)
400
420
440
460
0
5
10
15
20
Hour, Local Time

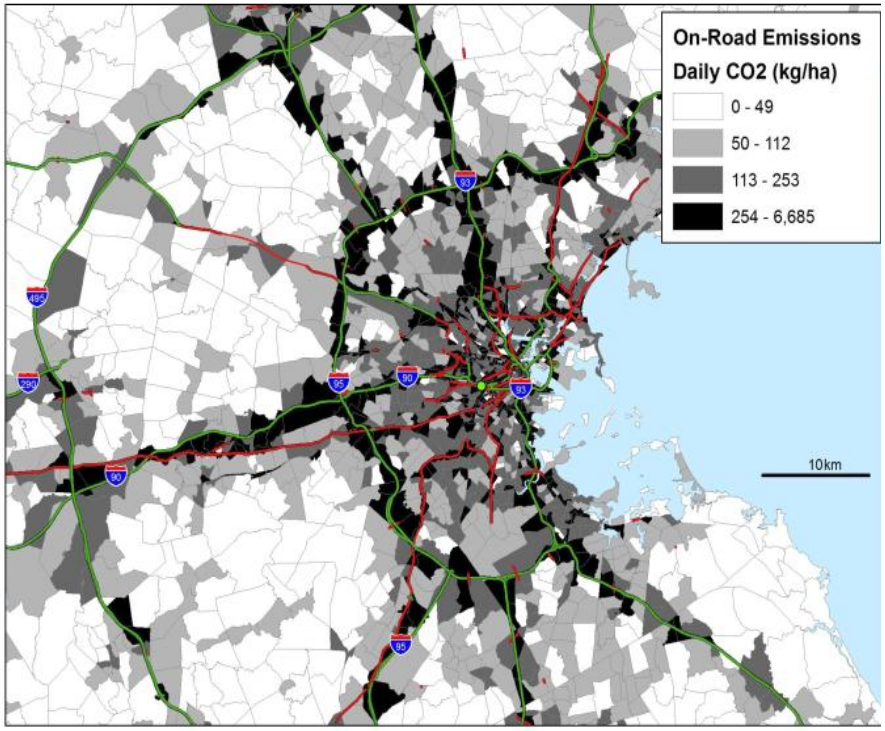


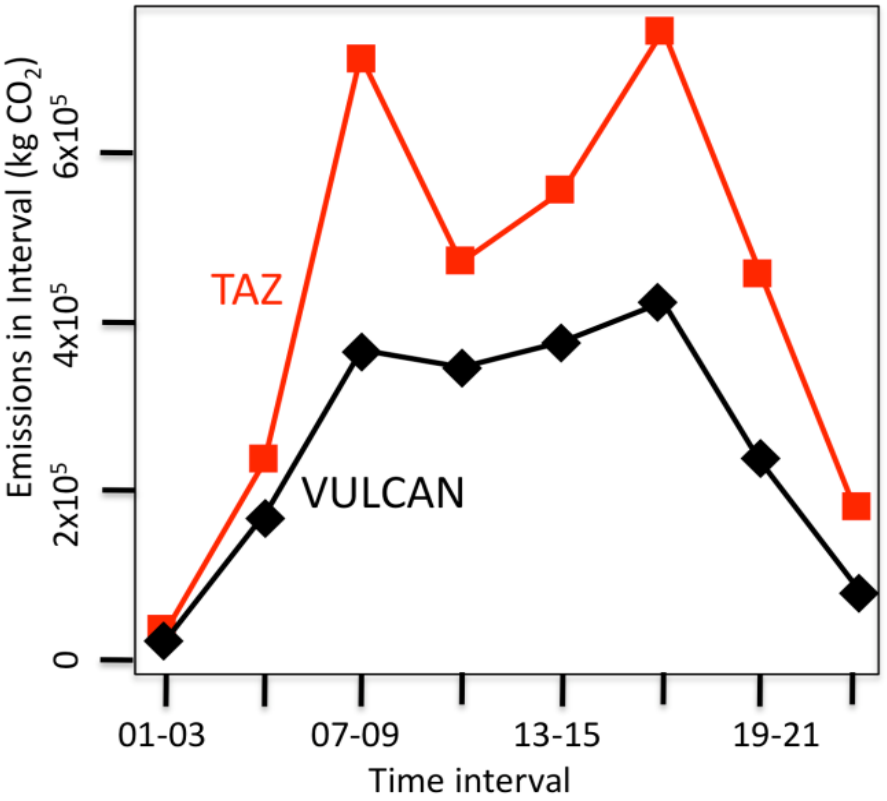
Obs. vs model CO_2 at 3 sites in Salt Lake City, Oct. 2006, from hi-resolution model (1.3 km, urban canopy). Hourly points in **gray** and 8-hour averages in **red**. Line is SMA fit to 8-hour data.

Inventory correction factors for Salt Lake City

Model Configuration	Site	SMA Slope (±95% CI)	Scaling Factor
High-Resolution / UCM	Downtown	0.57 (0.11)	1.76 (0.44)
	Neighborhood	0.54 (0.09)	1.84 (0.27)
	Junior High	0.54 (0.10)	1.86 (0.28)

How could the inventory be so far off ??





The effect of inhomogeneous spatial distribution of emissions on aggregated source models.

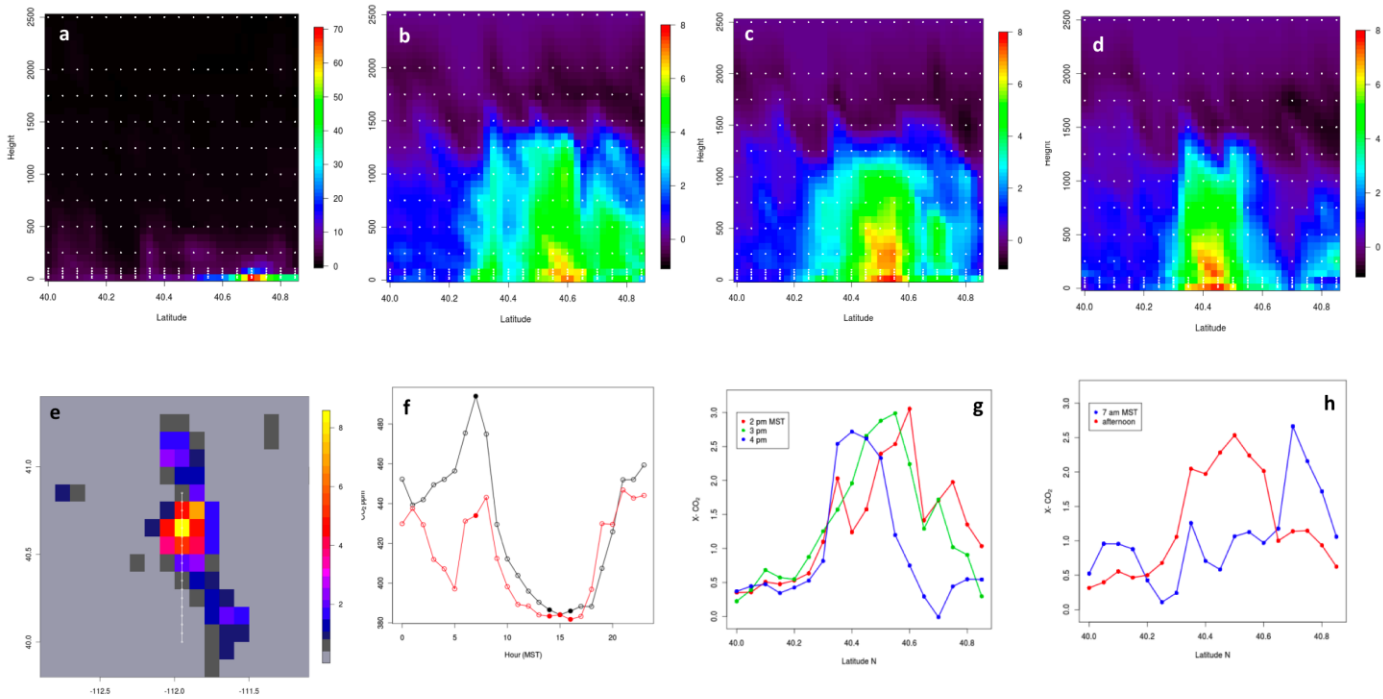


Figure 19. (**a-d**) Vertical distributions of CO_2 (ppm) over Salt Lake City according to the high-resolution model on October 12, 2006, at 7 am, 3, 4, and 5 pm MST (left to right). (**e**) Location of the north-south transect for the vertical model runs, relative to total Vulcan emissions (kt C) for one week in October. (**e**) Observed and simulated surface CO_2 at the Downtown site on October 12, 2006. The four hour that were modeled in the vertical are highlighted. (**g-h**) CO_2 enhancements above background, integrated through the vertical column (g) for three afternoon hours and (h) for a morning hour versus the average of the afternoon hours.

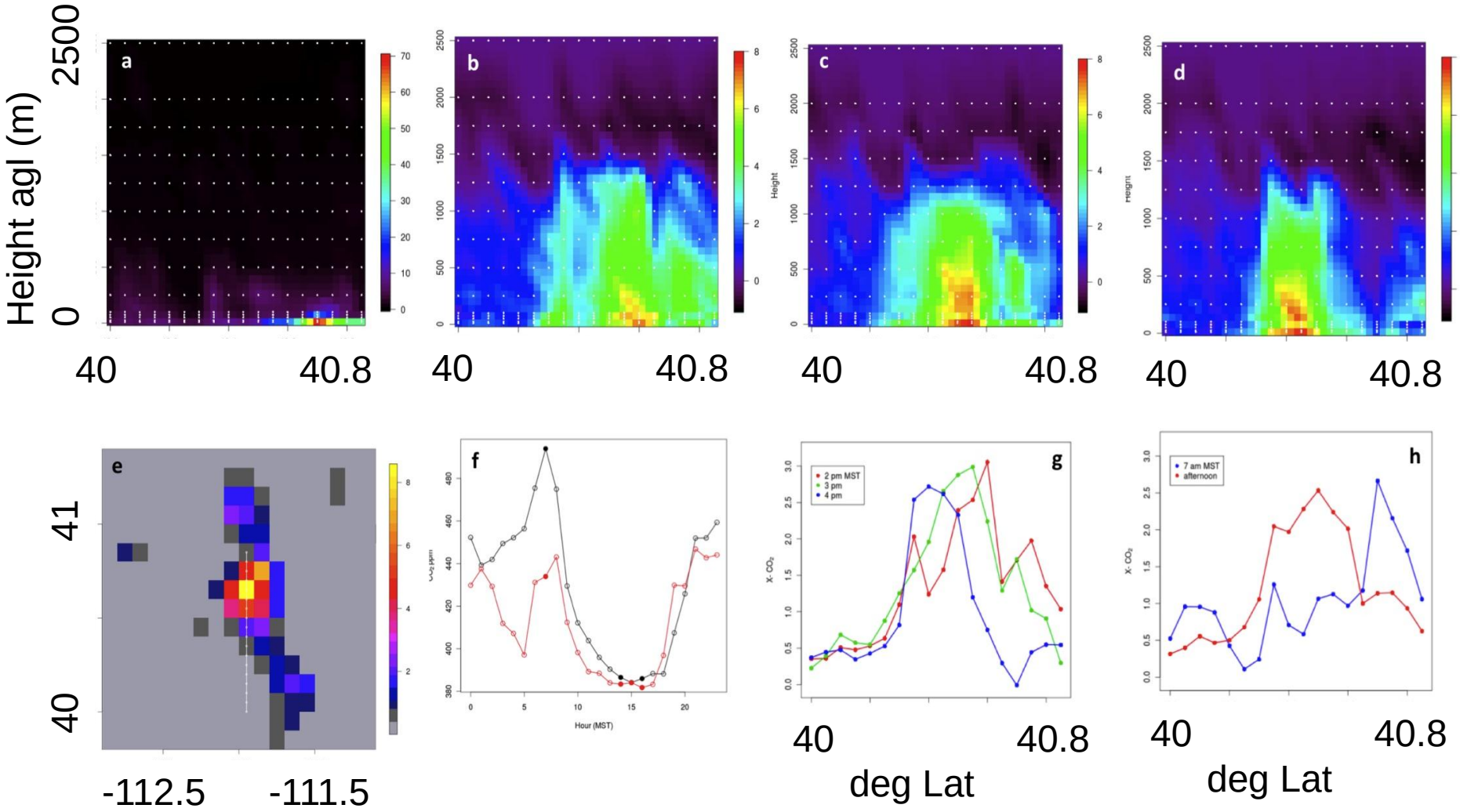
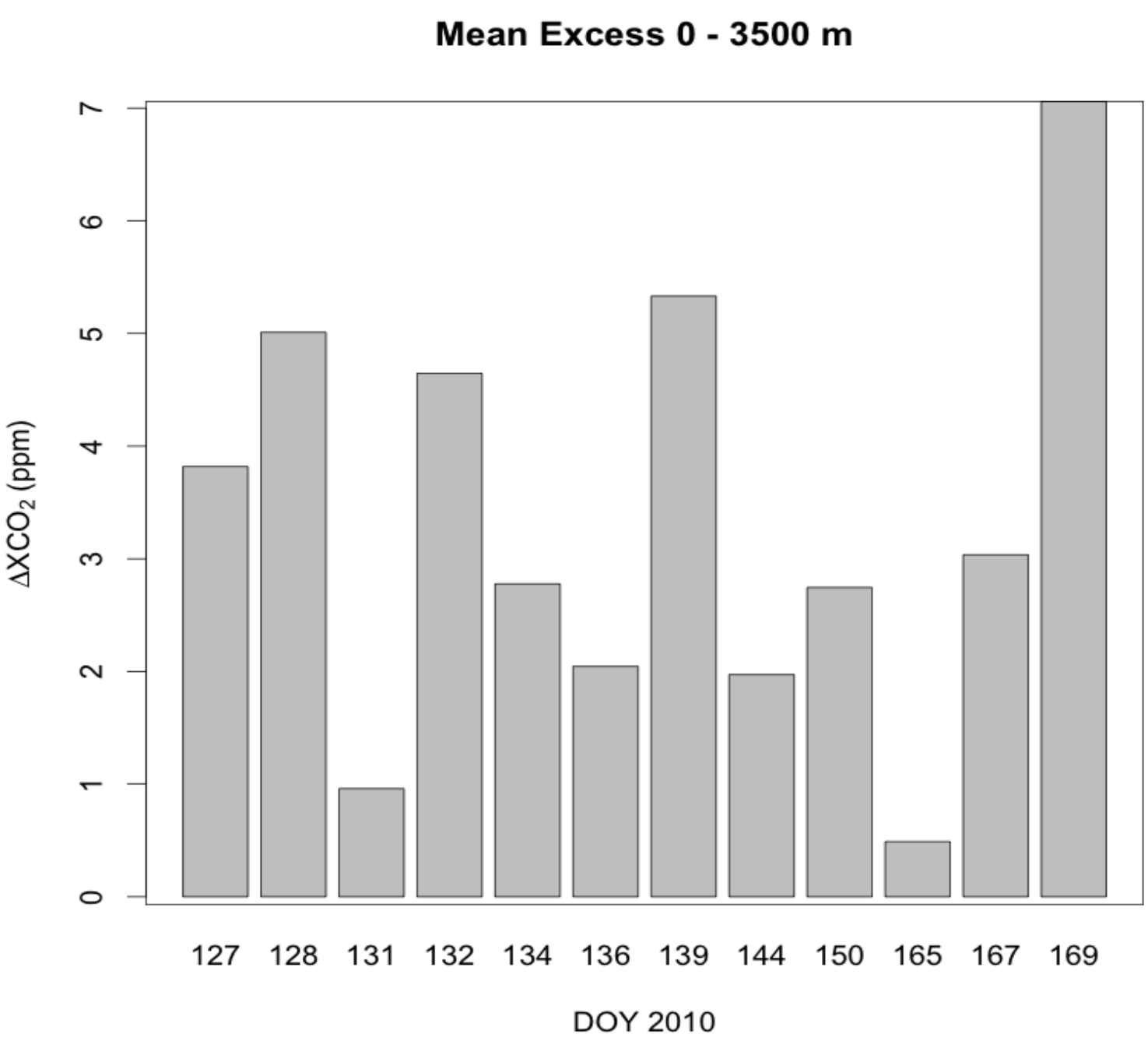
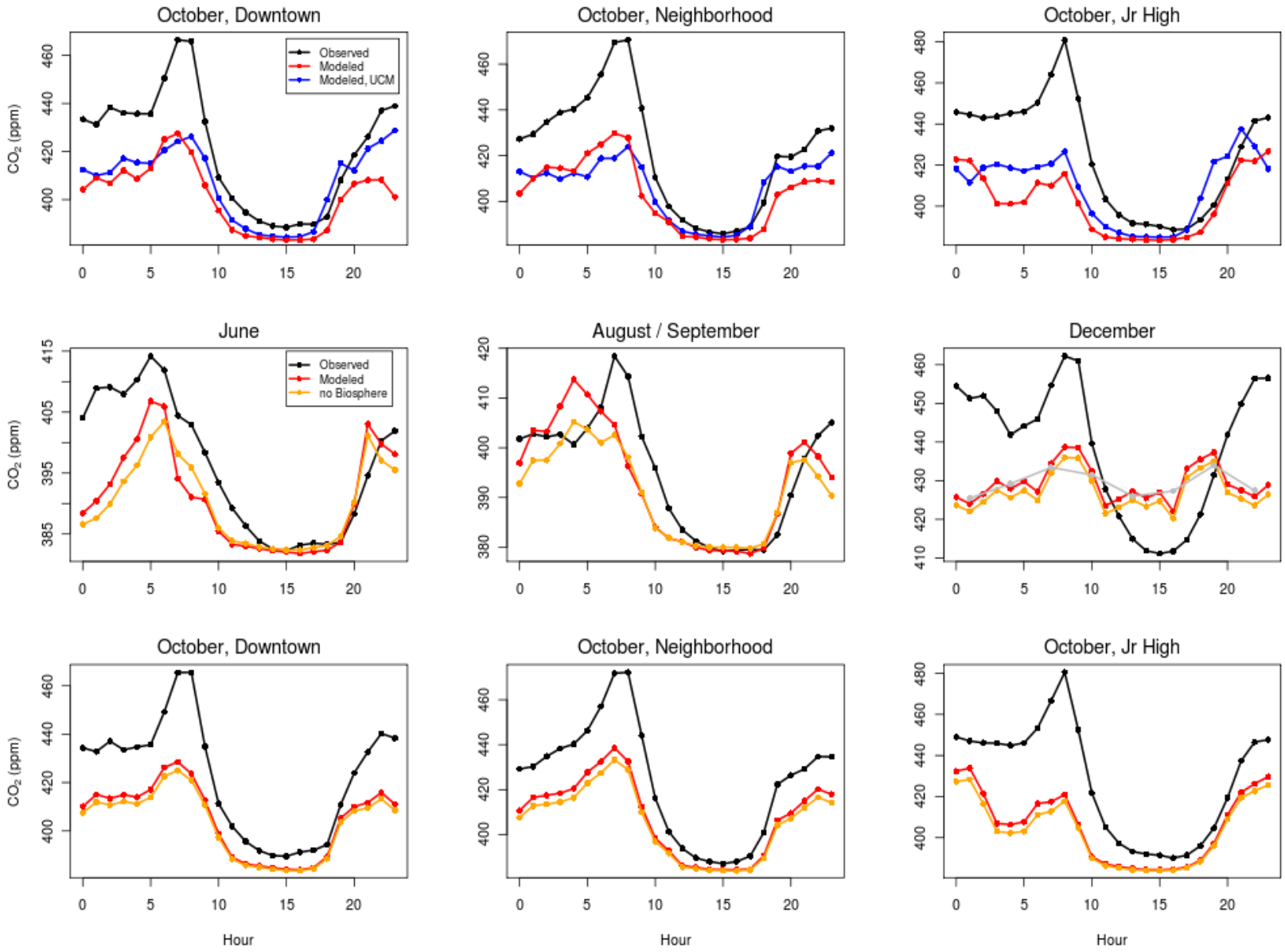


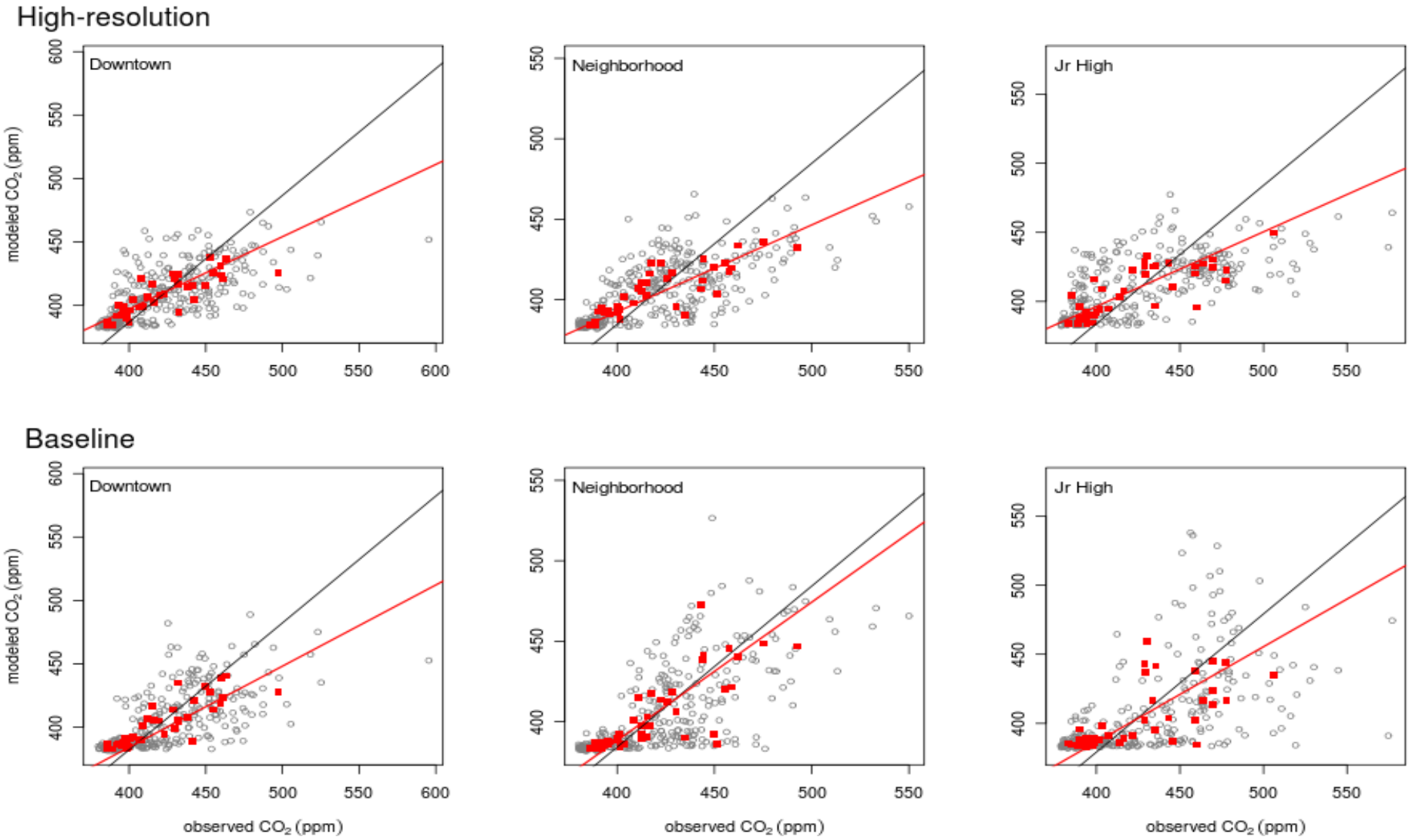
Figure 19. (**a-d**) Vertical distributions of CO_2 (ppm) over Salt Lake City according to the high-resolution model on October 12, 2006, at 7 am, 3, 4, and 5 pm MST (left to right). (**e**) Location of the north-south transect for the vertical model runs, relative to total Vulcan emissions (kt C) for one week in October. (**e**) Observed and simulated surface CO_2 at the Downtown site on October 12, 2006. The four hour that were modeled in the vertical are highlighted. (**g-h**) CO_2 enhancements above background, integrated through the vertical column (g) for three afternoon hours and (h) for a morning hour versus the average of the afternoon hours.

Summary of results

- CO_2 is an excellent tracer of combustion influence in Los Angeles, with overwhelming dominance of fossil fuels and an aged mix of basin-wide sources.
- Methane emission rates are large.
- Total column measurements are most likely to provide independent verification of emission rates.
- Detailed modeling of CO_2 or other long-lived emissions in urban areas requires *a priori* knowledge of source spatial and temporal distributions, not usually available. *Less important in Los Angeles than in most other cities.*


Mean Excess 0 - 3500 m
ΔXCO2 (ppm)
0
1
2
3
4
5
6
7
127
128
131
132
134
136
139
144
150
165
167
169
DOY 2010


October, Downtown
October, Neighborhood
October, Jr High
Observed
Modeled
Modeled, UCM
June
August / September
December
Observed
Modeled
no Biosphere
October, Downtown
October, Neighborhood
October, Jr High
CO2 (ppm)
Hour



Obs. vs model CO_2 at 3 sites in Salt Lake City, Oct. 2006. *Top row*: model and obs. from hi-resolution model (1.3 km, urban canopy). *Bottom*: 4 km baseline model. Hourly points in **gray** and 8-hour averages in **red**. Lines are SMA fits to 8-hour data.