Top-down estimate of methane emissions in California using a mesoscale inverse modeling technique

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USEPA EI Conference
April 12-16, 2015 San Diego

Background

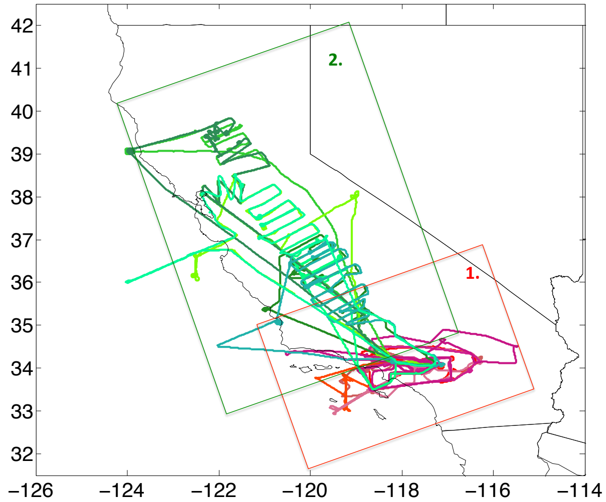
- CH_4 has increased by factor of 2.5 at least since pre-industrial times (IPCC AR5)

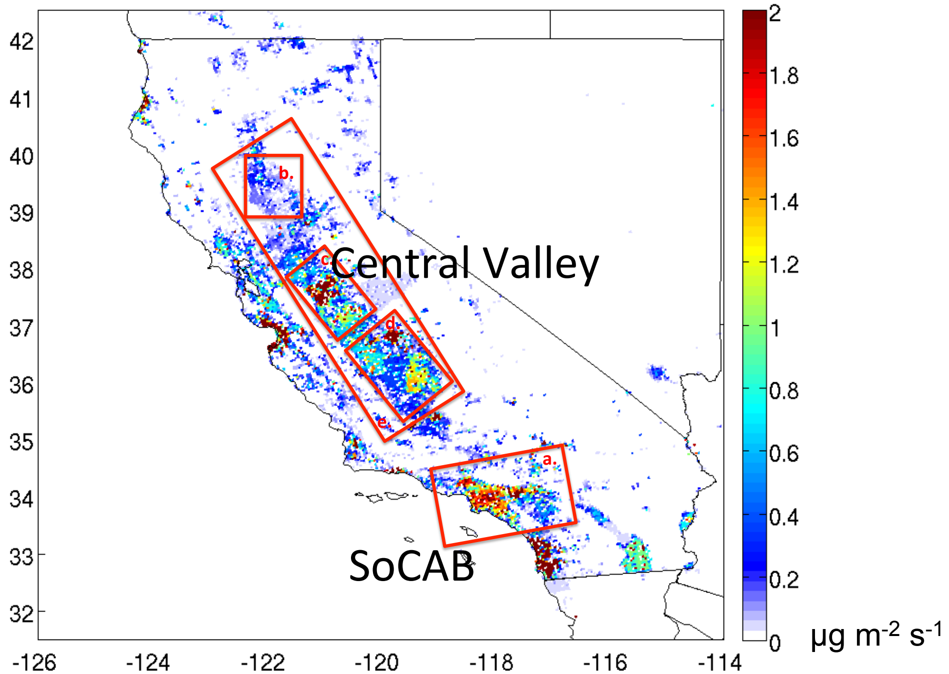
- Shorter lifetime than CO_2 but much higher global warming potential than CO_2

- The change in CH_4 mixing ratio altered the concentrations of OH and ozone in the troposphere and water vapor in the stratosphere

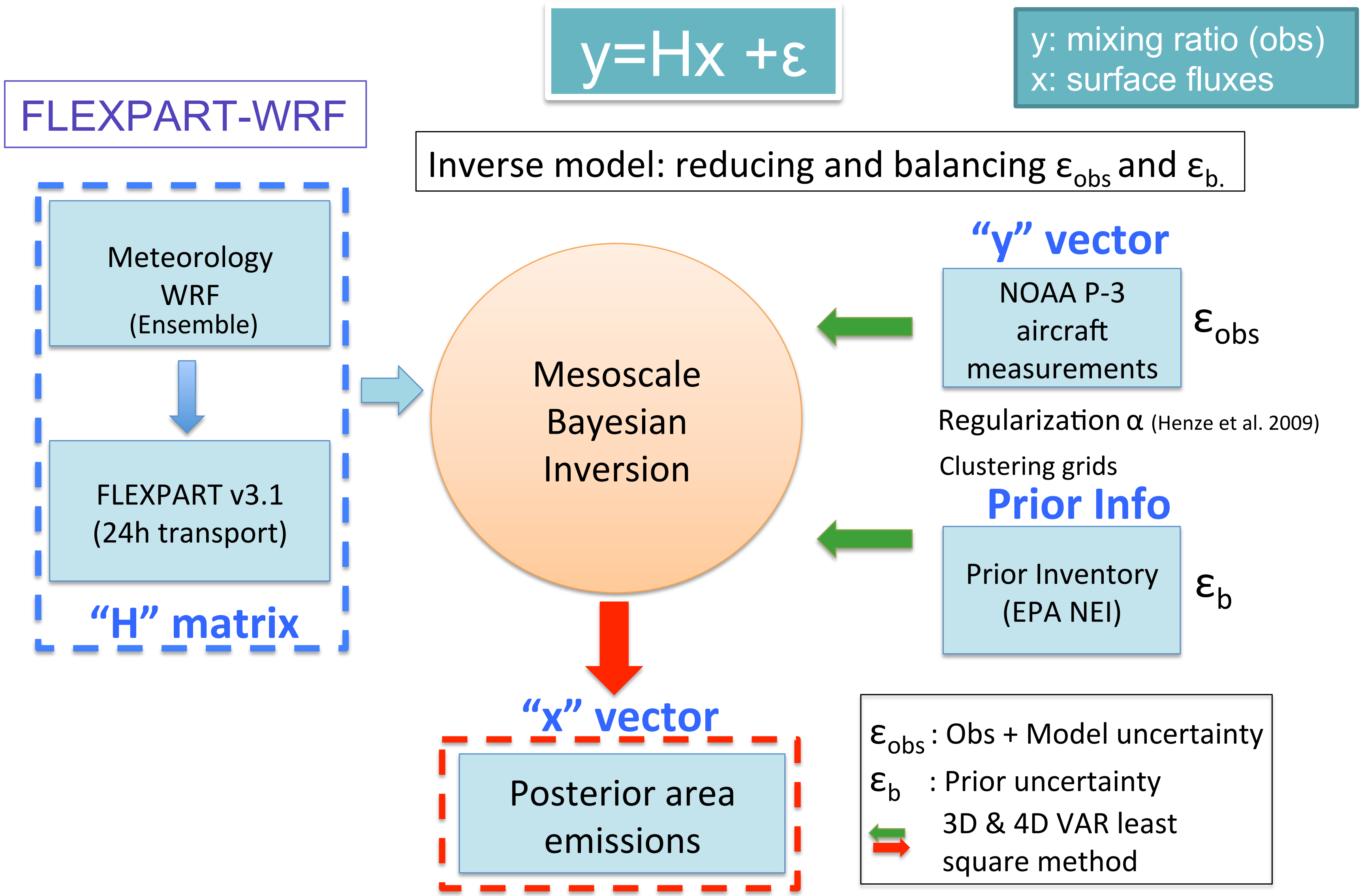
- In California, CH_4 emissions are regulated by Assembly Bill 32

Airborne measurements, CalNex 2010





Lagrangian inverse system in Mesoscale



Bayesian formulation with lognormal distribution

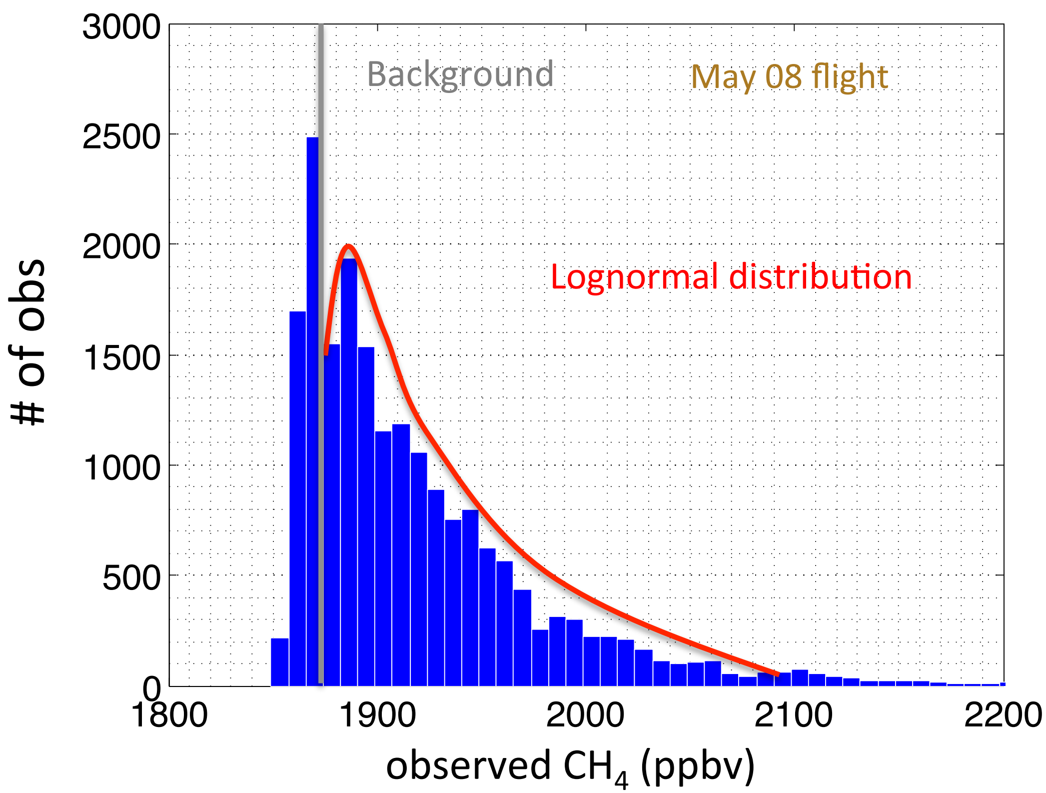
$$J = \frac{1}{2}(\ln(y_o) - \ln(Hx))^T R^{-1}(\ln(y_o) - \ln(Hx)) + \frac{1}{2}(\ln(x) - \ln(x_b))^T B^{-1}(\ln(x) - \ln(x_b))$$

Cost function: J

J obs: $\frac{1}{2}(\ln(y_o) - \ln(Hx))^T R^{-1}(\ln(y_o) - \ln(Hx))$

J prior: $\frac{1}{2}(\ln(x) - \ln(x_b))^T B^{-1}(\ln(x) - \ln(x_b))$

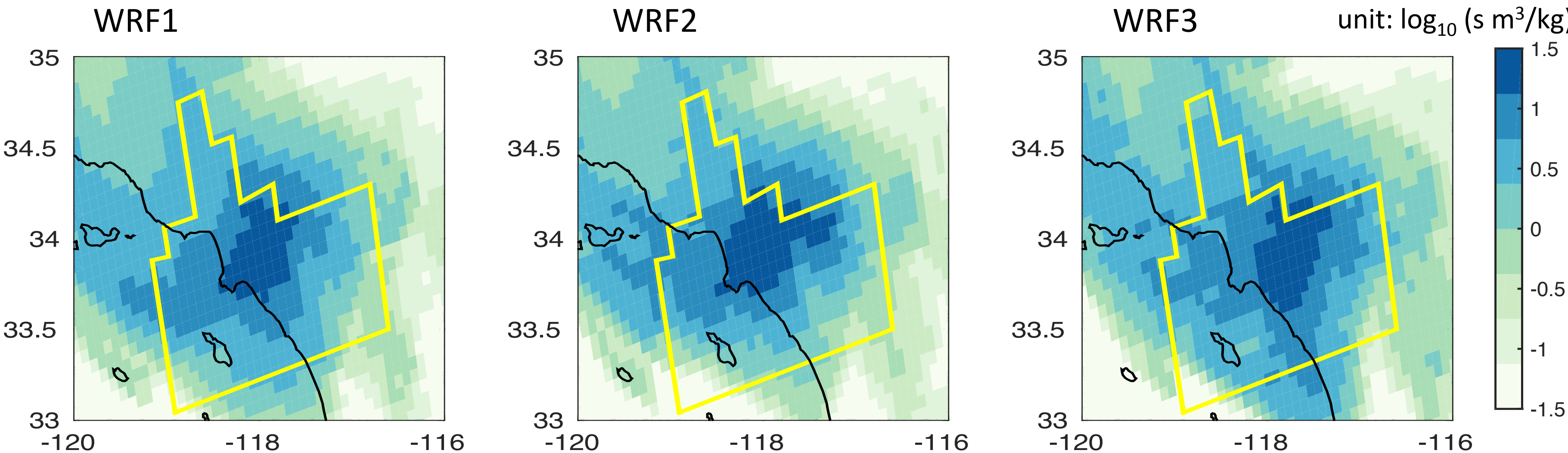
R and B are covariance matrices



- For each flight we give a background value, and a regularization α to reach a good compromise in R and B
- Bootstrapping & Monte Carlo methods
- No negative fluxes, obtain a minimum variance solution and not a likelihood

Brioude et al. 2011, Cui Y Y et al. 2014

Three off-line transport models (FLEXPART-WRF)



Name	Version	Initialization	PBL scheme	Grid Spacing (km)	Vertical levels	LSM, data	Wind field
WRF1	WRF 3.3	ECMWF-ERA	MYJ	4	60	Noah, UCM, MODIS	Time-averaged winds
WRF2	WRF-Chem 3.1	NCEP-GFS	YSU	4	60	Noah	Sigma dot Winds
WRF3	WRF-Chem 3.5	NCEP-GFS	YSU	4	60	Noah, MODIS	Time-averaged winds

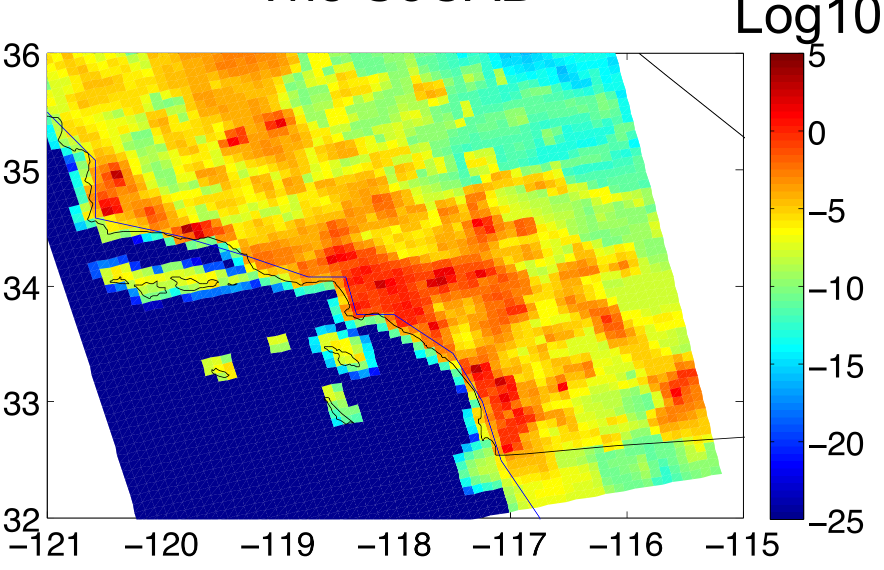
Releasing 10,000 particles every 30 s and every 100 m along flight tracks, backward 24 hrs

Clustering spatially grid cells

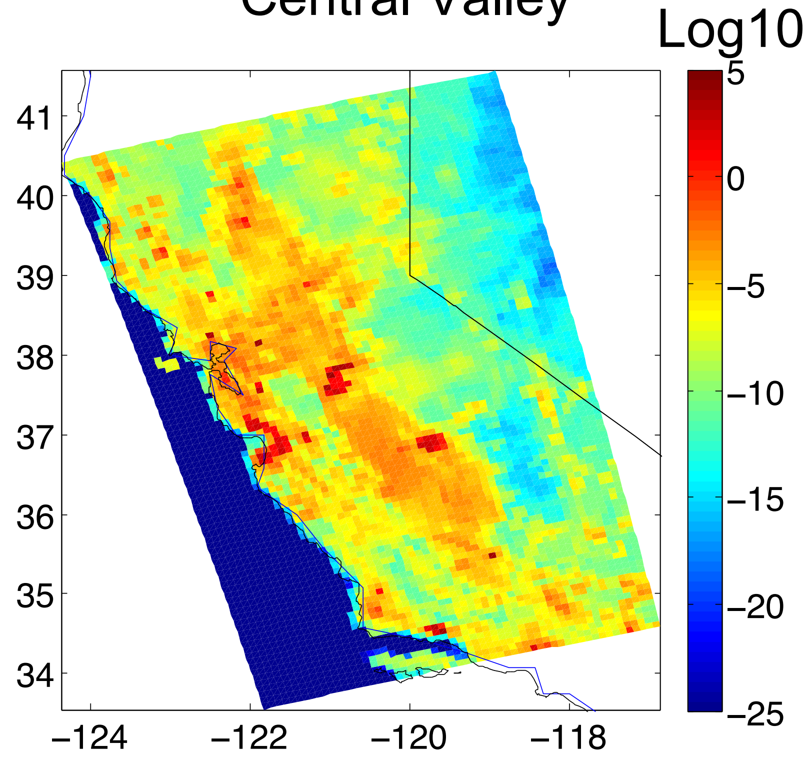
Based on Fisher information matrix, a criterion map is used to present the significance of each grid cell in constraining the CH_4 emissions.

$$J = Tr\,(BW^T R^{-1} W)$$

The SoCAB

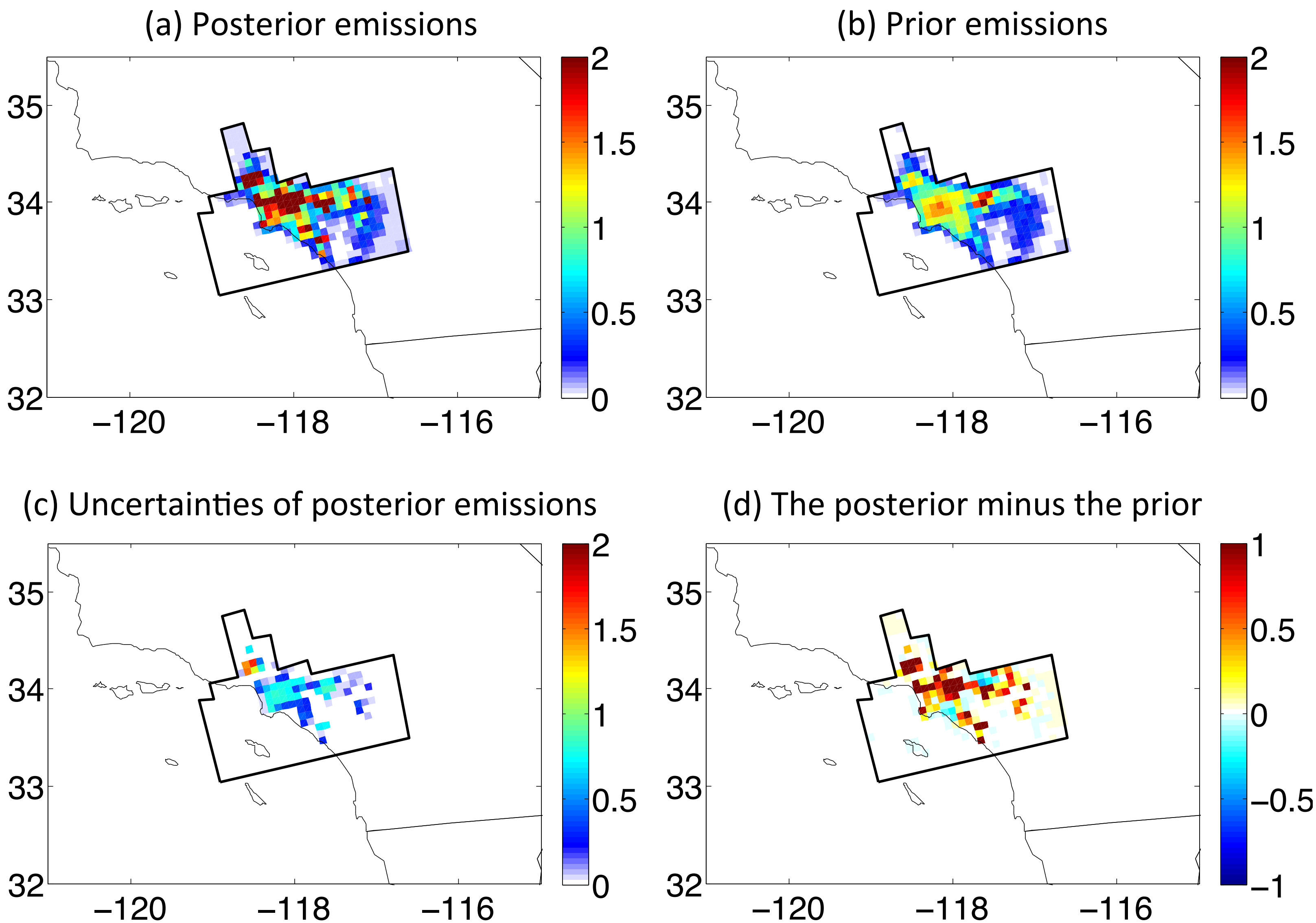


Central Valley



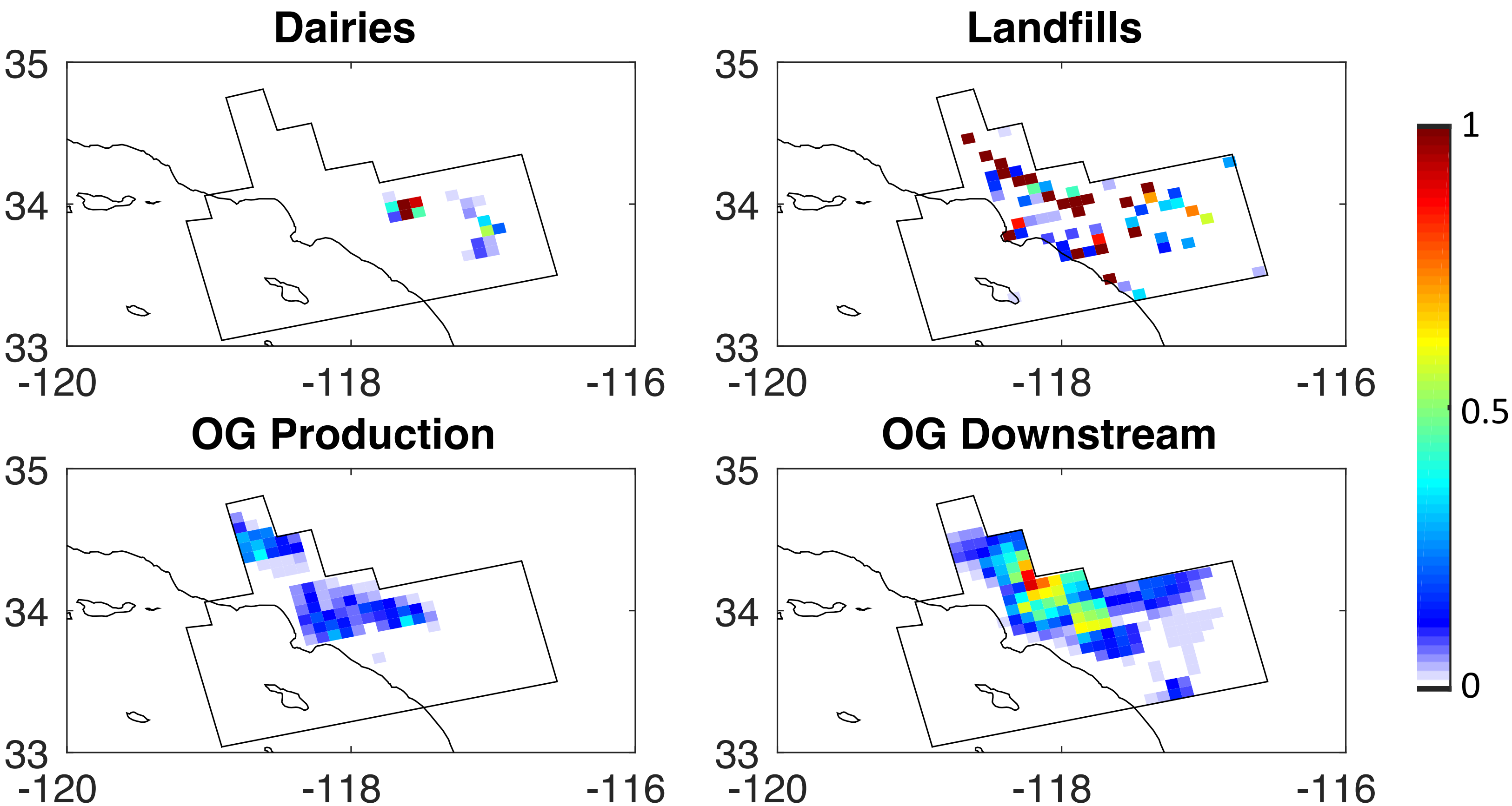
Bocquet el al. (2011)

SoCAB Results



Cui, YY et al. submitted, 2014

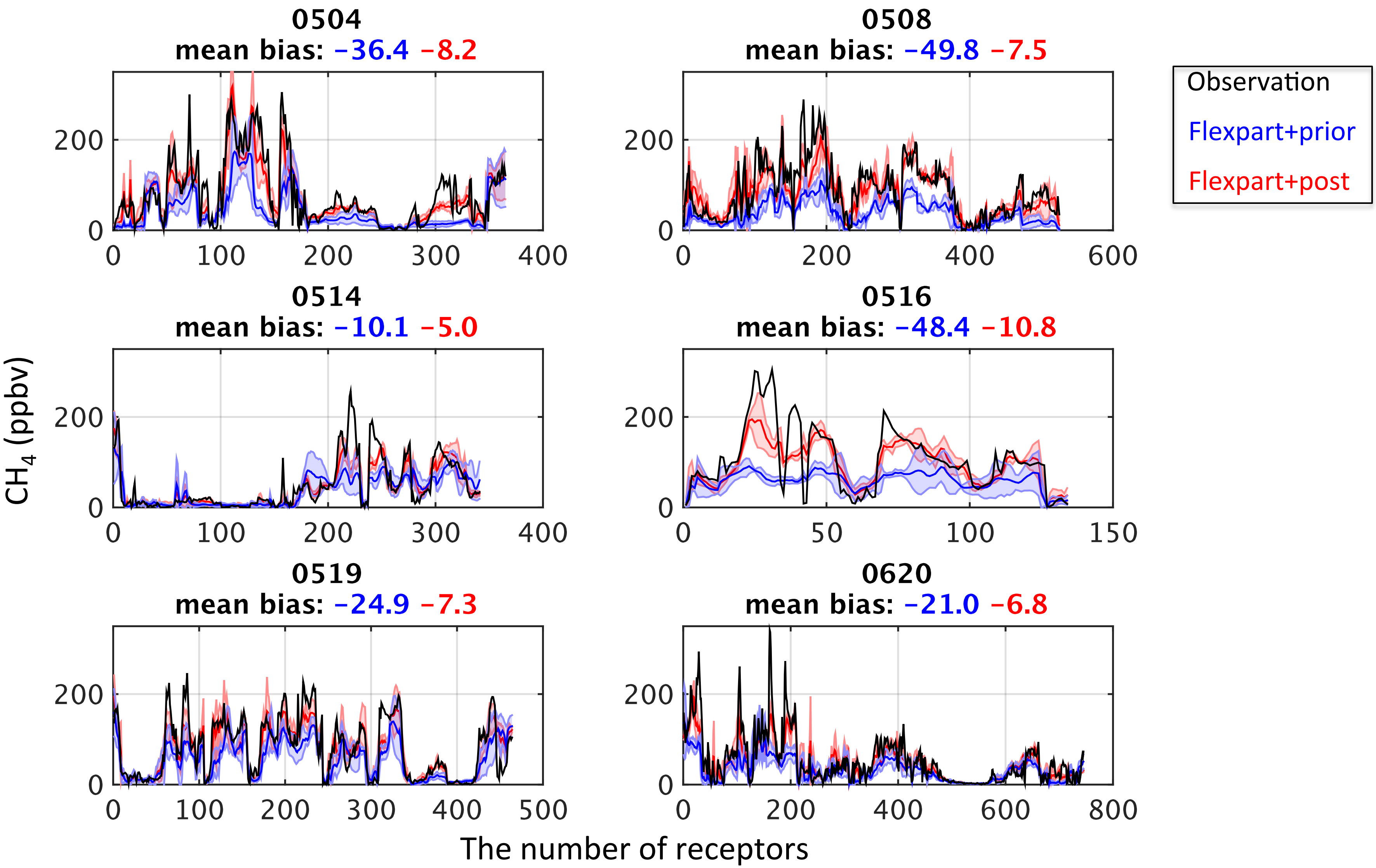
SoCAB Results (cont.)



We estimate that dairies contributed 52 ± 15 Gg CH_4/yr and the two sectors of oil and gas industry (production and downstream) and landfills together contributed 347 ± 71 Gg CH_4/yr in the SoCAB.

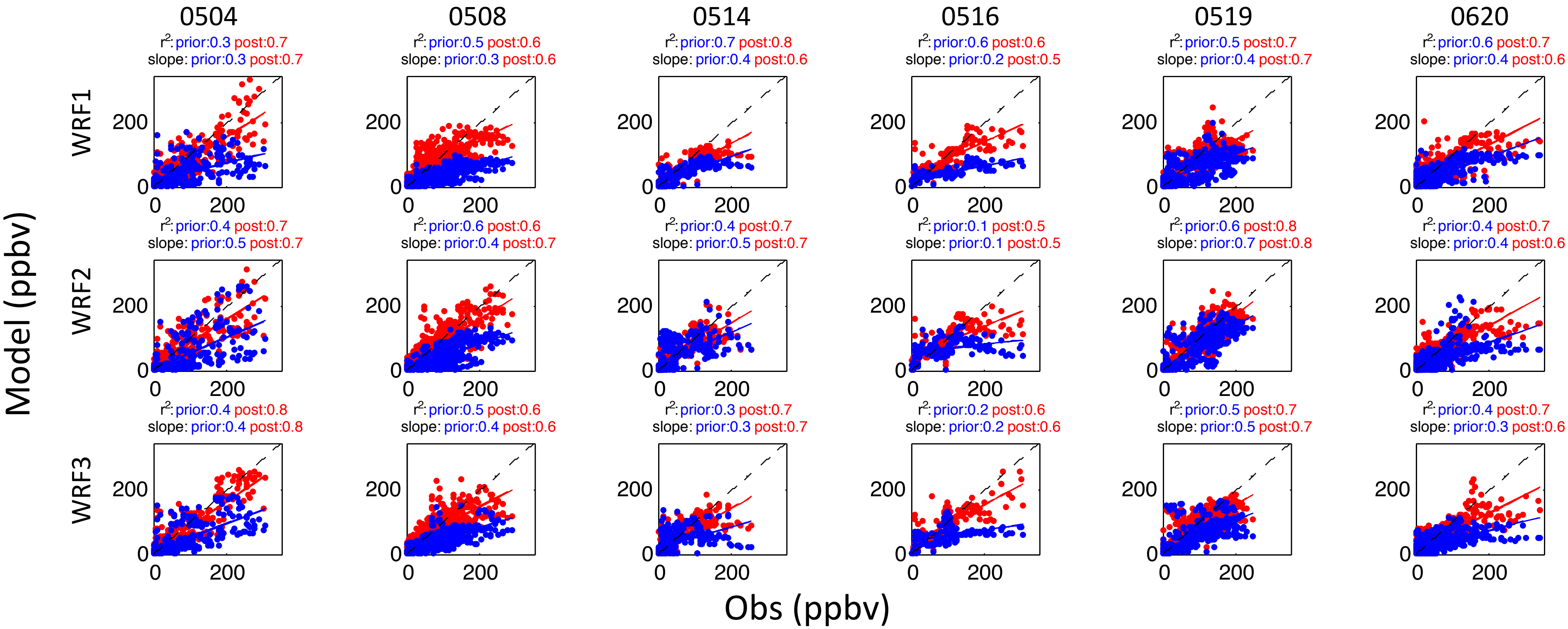
Cui, YY et al. submitted, 2014

SoCAB Results (cont.)



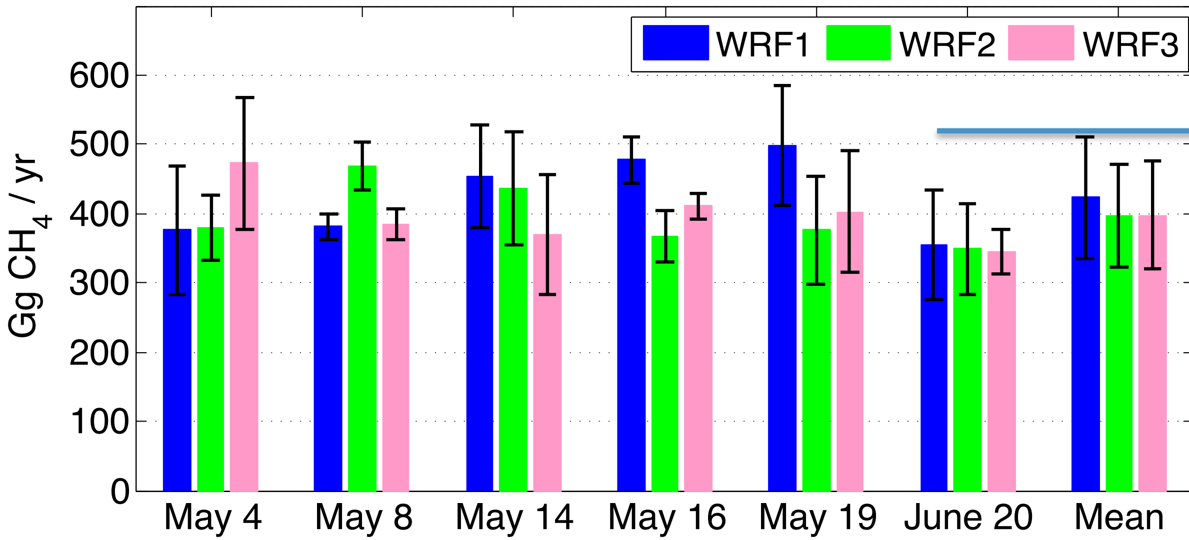
Cui, YY et al. submitted, 2014

SoCAB Results (cont.)



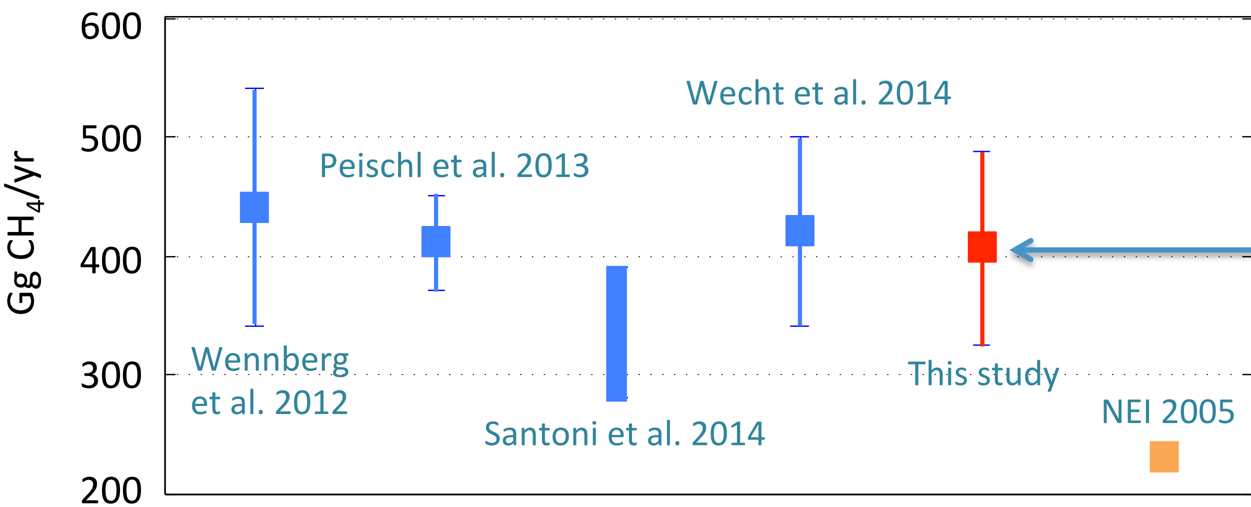
Cui, YY et al. submitted, 2014

SoCAB Results (cont.)



- The posterior values range from 396 to 423 Gg CH_4/yr.
- Vary by ~ 20% from a single flight's data with current meteorological modeling of this summer period.

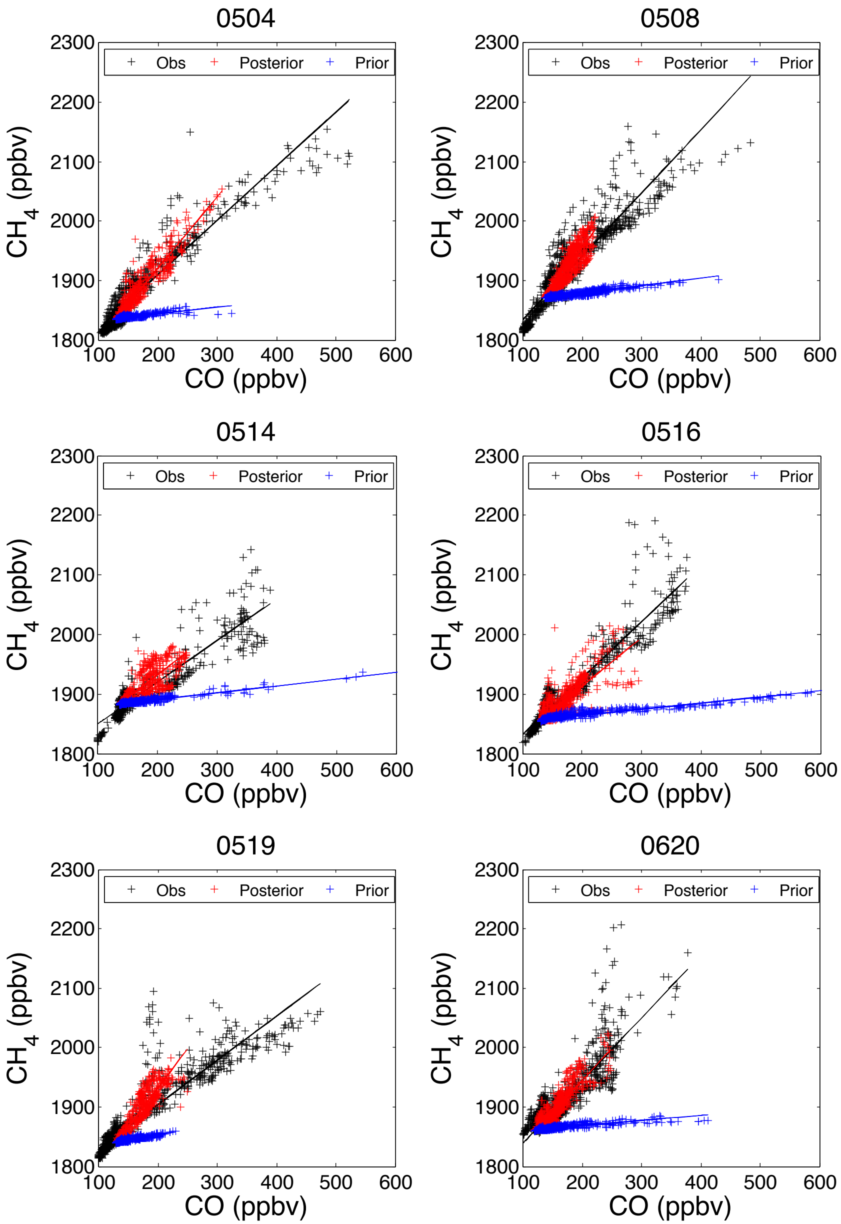
The SoCAB area

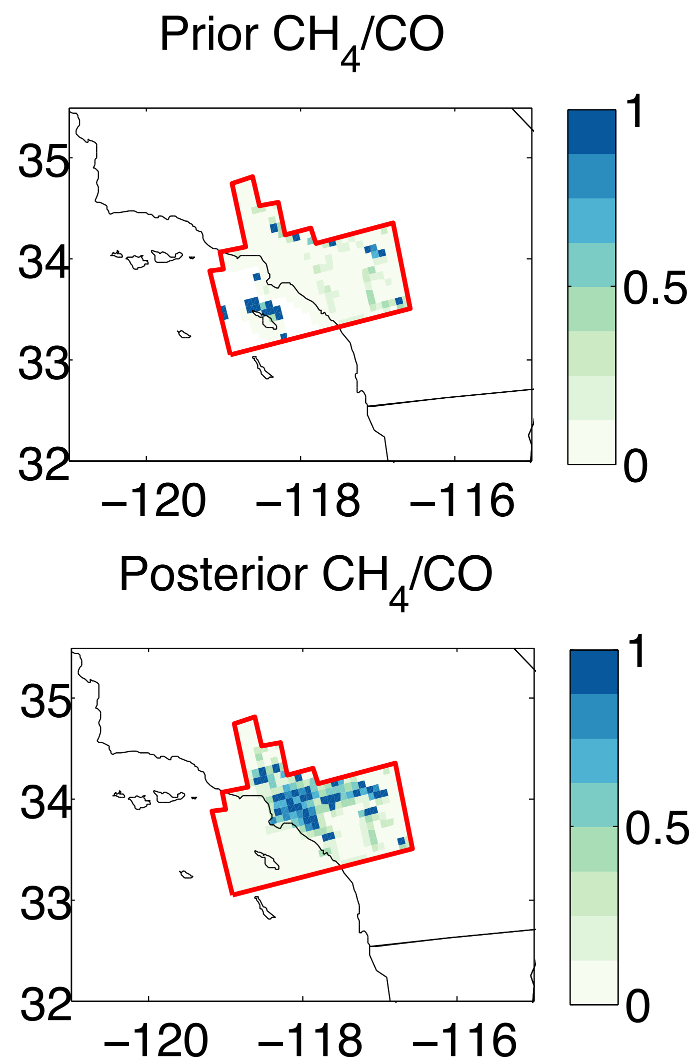


406± 81 Gg CH_4/yr

Cui, YY et al. submitted, 2014

SoCAB Results (cont.)

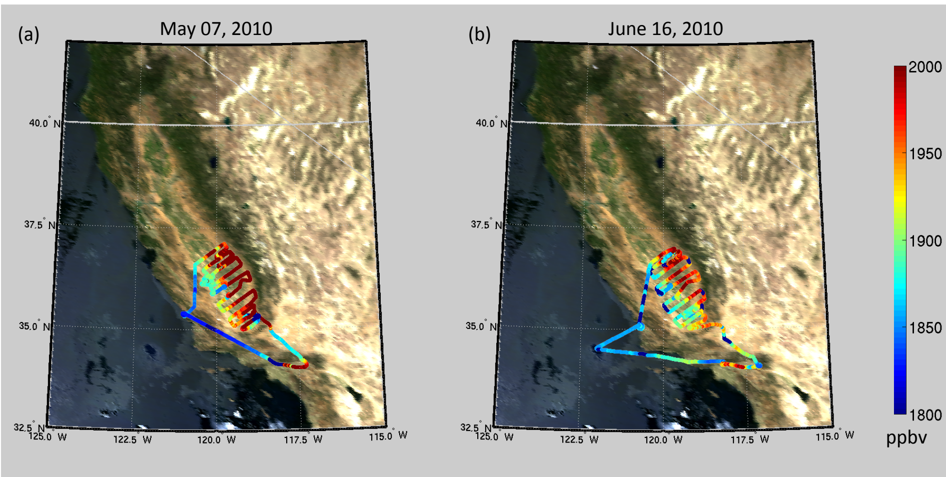


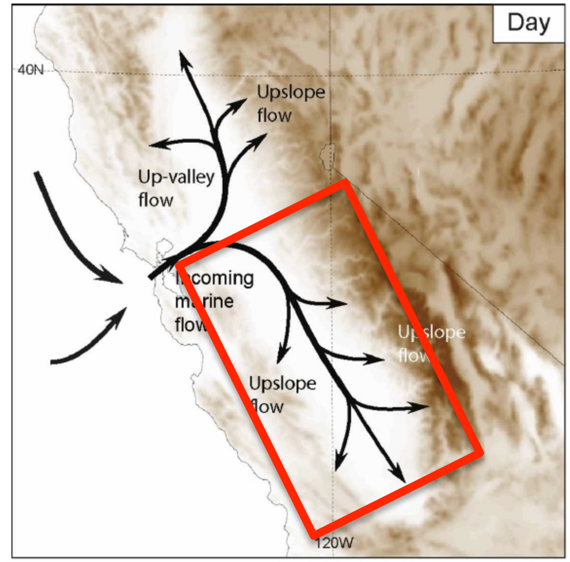


Cui, YY et al. submitted, 2014

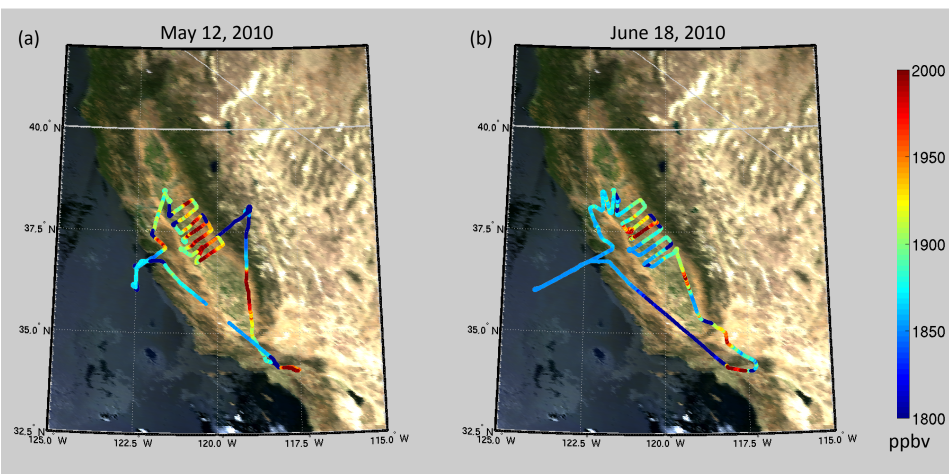
Central Valley Results

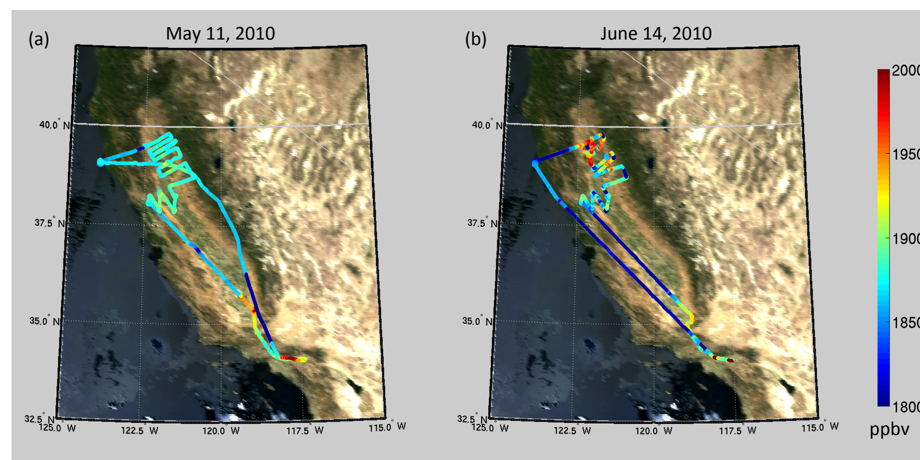
San Joaquin Valley





Sacramento Valley





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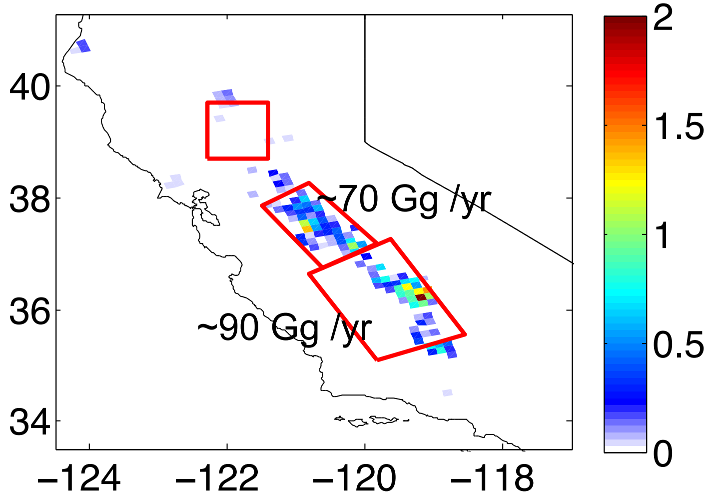
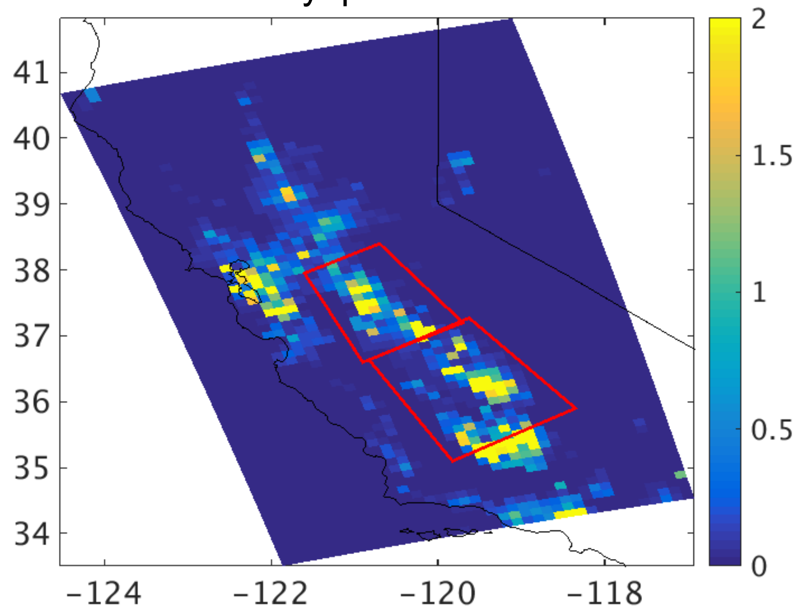
Central Valley Results (cont.)

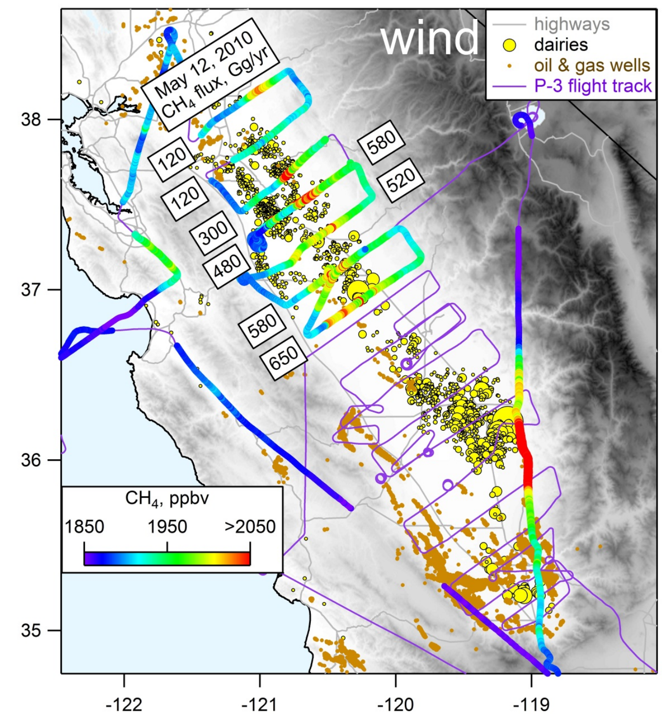
Dairies



In this study: posterior emissions



Mass Balance method (0512)



- Consistent with mass balance approach (530 Gg CH4/yr).
- Higher by factor of ~7.5 in the posterior inventory in the Dairy sector

Cui, YY et al. in prep, 2015

Conclusions

- A mesoscale inversion ensemble is used first to estimate CH4 emissions in CA.

- The mesoscale inverse method improve simulations of CH_4 mixing ratios and the slopes of correlations between CH_4 and CO. And our uncertainty estimates include the uncertainty of the inversion method and also the uncertainty from the transport models.

- Emission estimates are consistent with previous observation-based estimates.

- Oil and gas industry emissions mostly explain differences between posterior and prior inventories in SoCAB. The CH_4 emissions of the dairy sector are highly underestimated by factor of ~7.5 in the Central Valley by the bottom-up inventory.