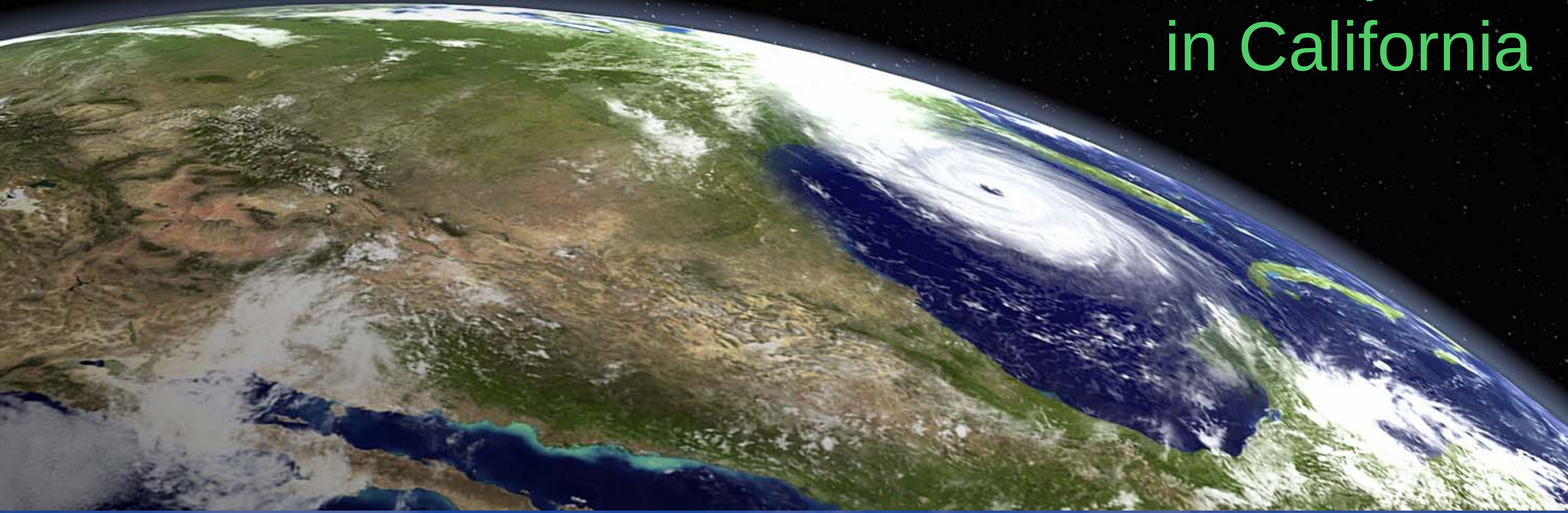
Toward Simultaneous Multi-station Data Pre-processing for Inversions of Greenhouse Gas Emissions and Uptake in California



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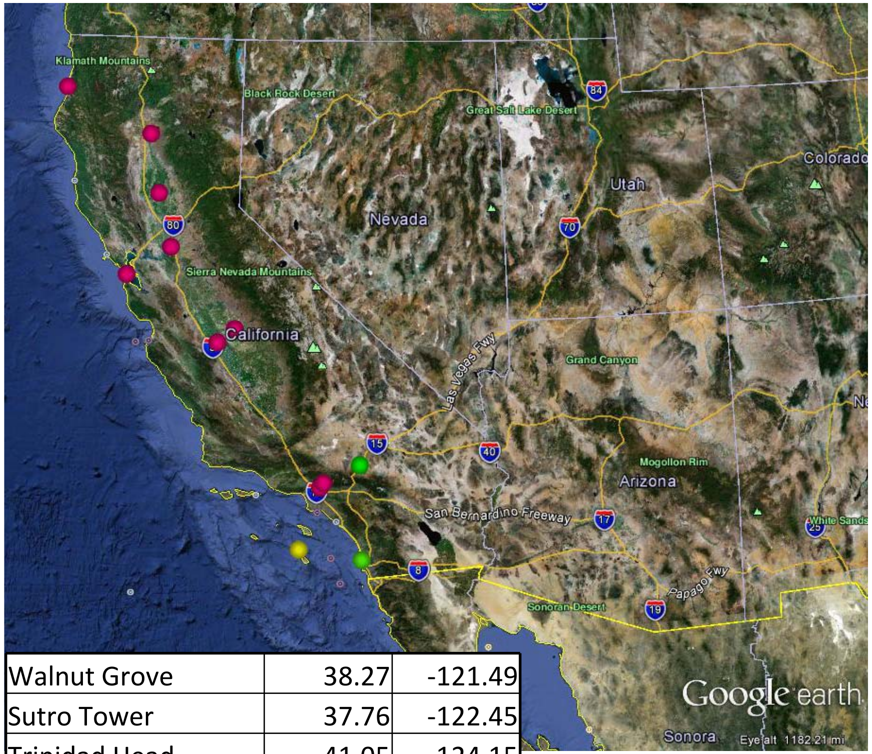
Top-Down Assessment of California's Greenhouse Gas Emissions

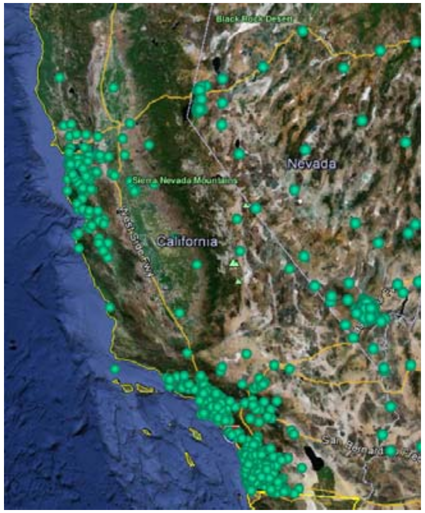
- With the passage of Assembly Bill-32 (AB-32), the State of California has taken a leading role in GHG regulation by committing to reduce the statewide GHG emissions to 1990 levels by year 2020, a 30% reduction relative to "business as usual."
- In the context of AB-32, GHG emissions are estimated based on a "bottom-up" approach, which involves quantification of industrial, agricultural and land-use activities multiplied by emissions factors (for example, used by the California Air Resources Board).
- Despite providing an essential metric for assessing progress and compliance, the resulting "inventories" are sometimes grossly inaccurate due to incomplete knowledge, compounded errors, and reporting biases.
- The bottom-up approach must be complemented by a "top-down" approach, which takes advantage of direct measurements of changes in GHG abundance downwind of sites of emissions, such as cities, industrial areas, etc.
- The top-down approach requires a **network** of **greenhouse gas measurements** and weather-related information to compute emissions **using inverse modeling**.
- 3-year project started in September 2011 by the team of collaborators: **Scripps Institution of Oceanography**, **Lawrence Berkeley National Laboratory**, **Earth Networks, Inc.**

GHG Sites in California



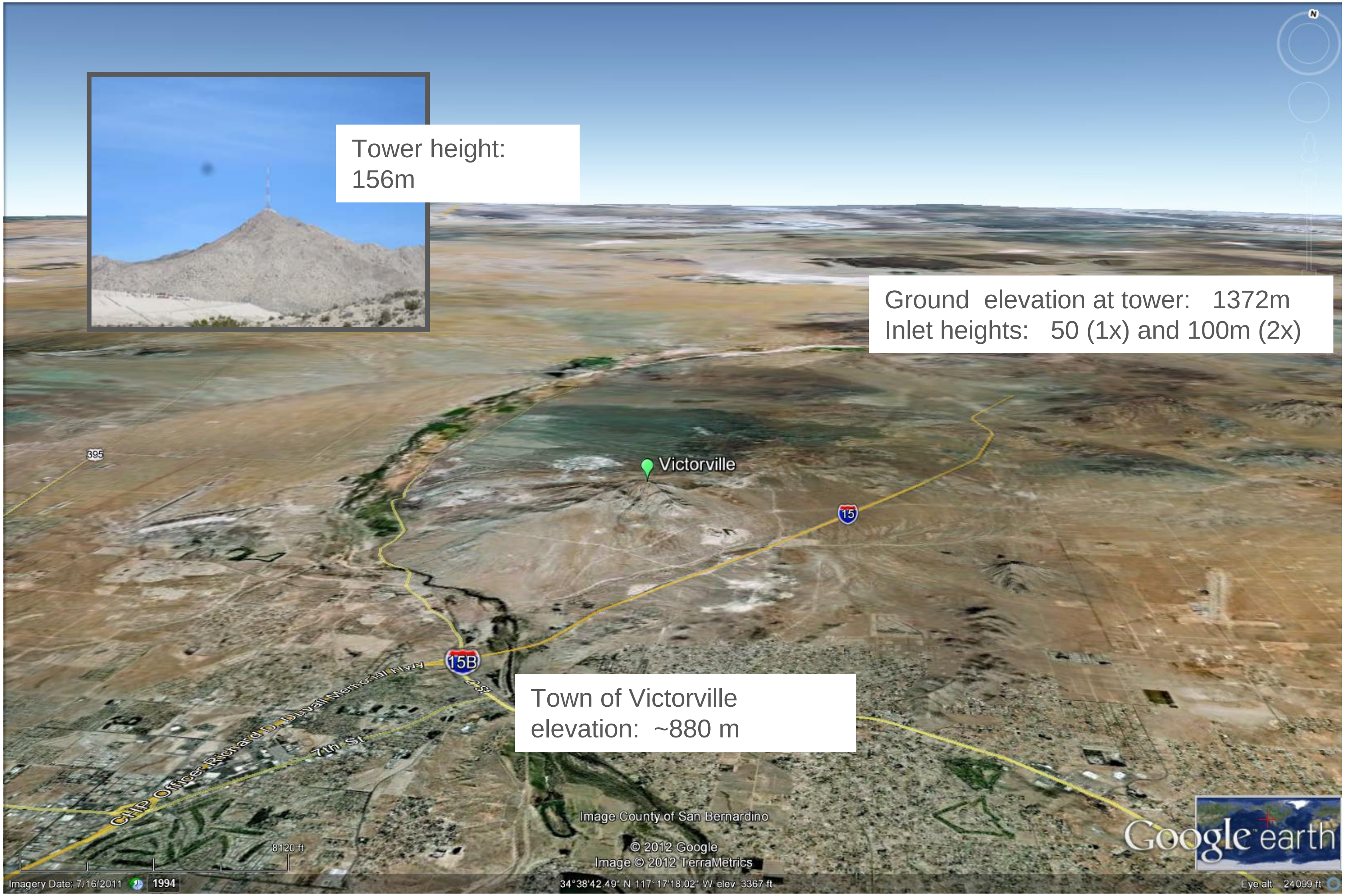
Walnut Grove	38.27	-121.49
Sutro Tower	37.76	-122.45
Trinidad Head	41.05	-124.15
Scripps Pier	32.87	-117.25
Victorville	34.54	-117.29
Madera	36.87	-120.01
Tranquility	36.63	-120.38
Sutter Buttes	39.21	-121.82
Tuscan Butte	40.26	-122.09
Mount Wilson	34.22	-118.06
Caltech	34.14	-118.13

- Number of GHG sites in California and along its border will be doubled to meet the needs for atmospheric GHG measurements for verification and top-down methodologies
- EN surface weather observations are also used for more accurate representation of local meteorology in the WRF-STILT modeling system



Earth Networks' surface weather sites

Victorville Tower



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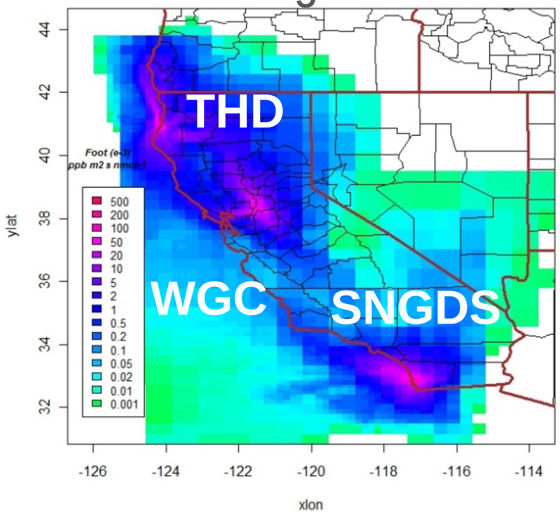
Selection of New Locations in California

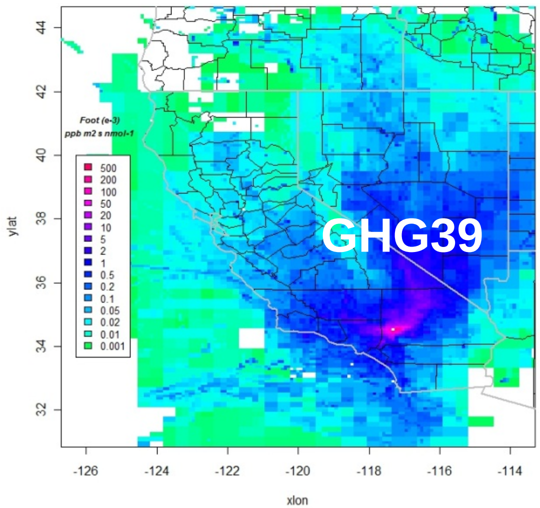
Looking for optimal locations:

1. Existing towers or/and very tall structures
2. Overlay with inventories to site away from strong sources (CO_2 and CH_4)
3. Understanding local weather patterns and footprint analysis based on WRF-STILT simulations

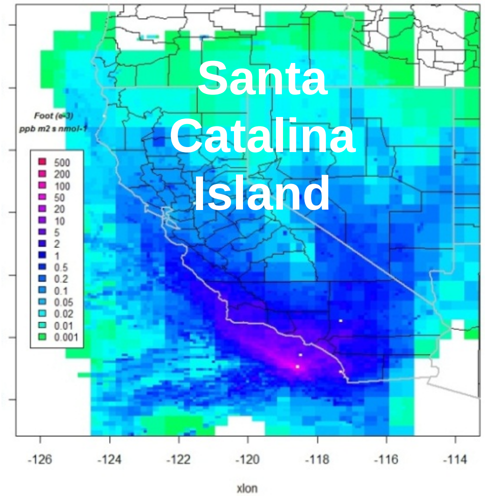
(Example: Jan. 2012 averages)

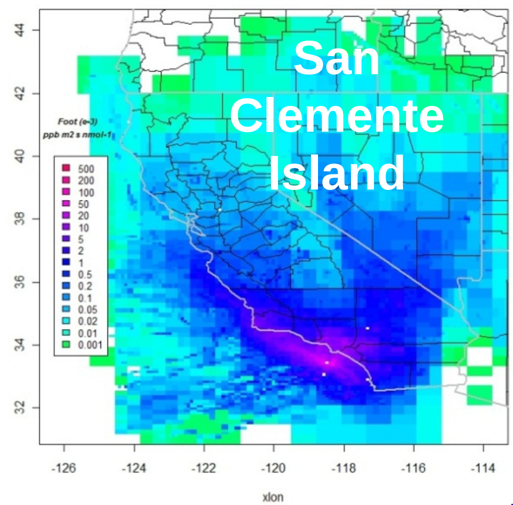
Existing Sites



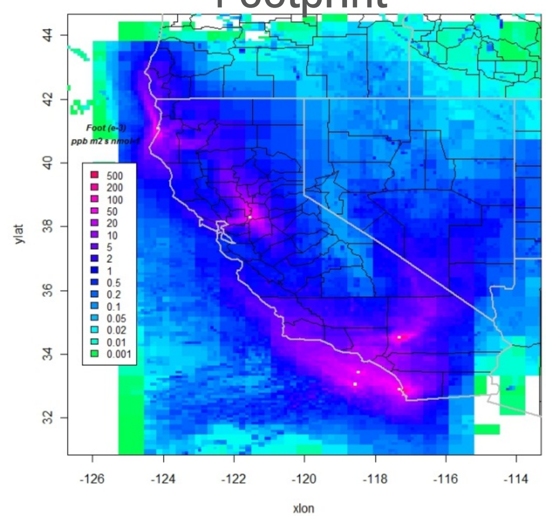


Potential New Sites





Combined Average Footprint



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Sampling towers

Three intakes:

1. Two intakes at high point (>80m)
2. One more at 50m

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Sampling System

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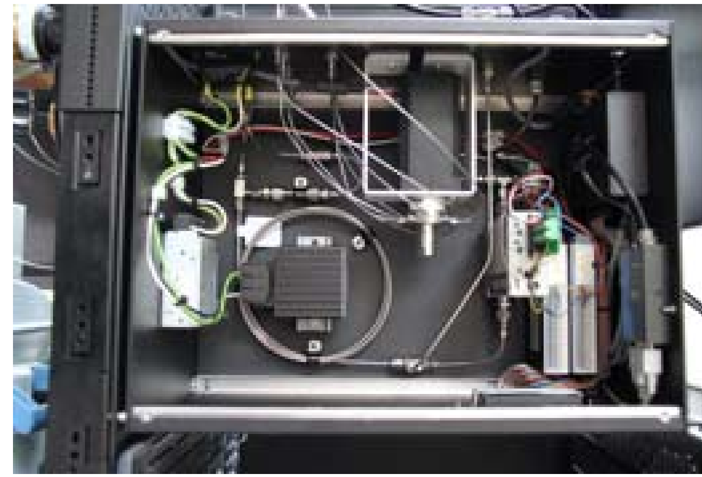
Front View

Side View

"Calibration Box"



- Level 0 – Raw Atmospheric, Operational and Metadata
- Level 1 – QC applied
- Level 2 – Calibrations applied
- Level 3 – Filters applied

Unified data streams for all sites within the network in real-time

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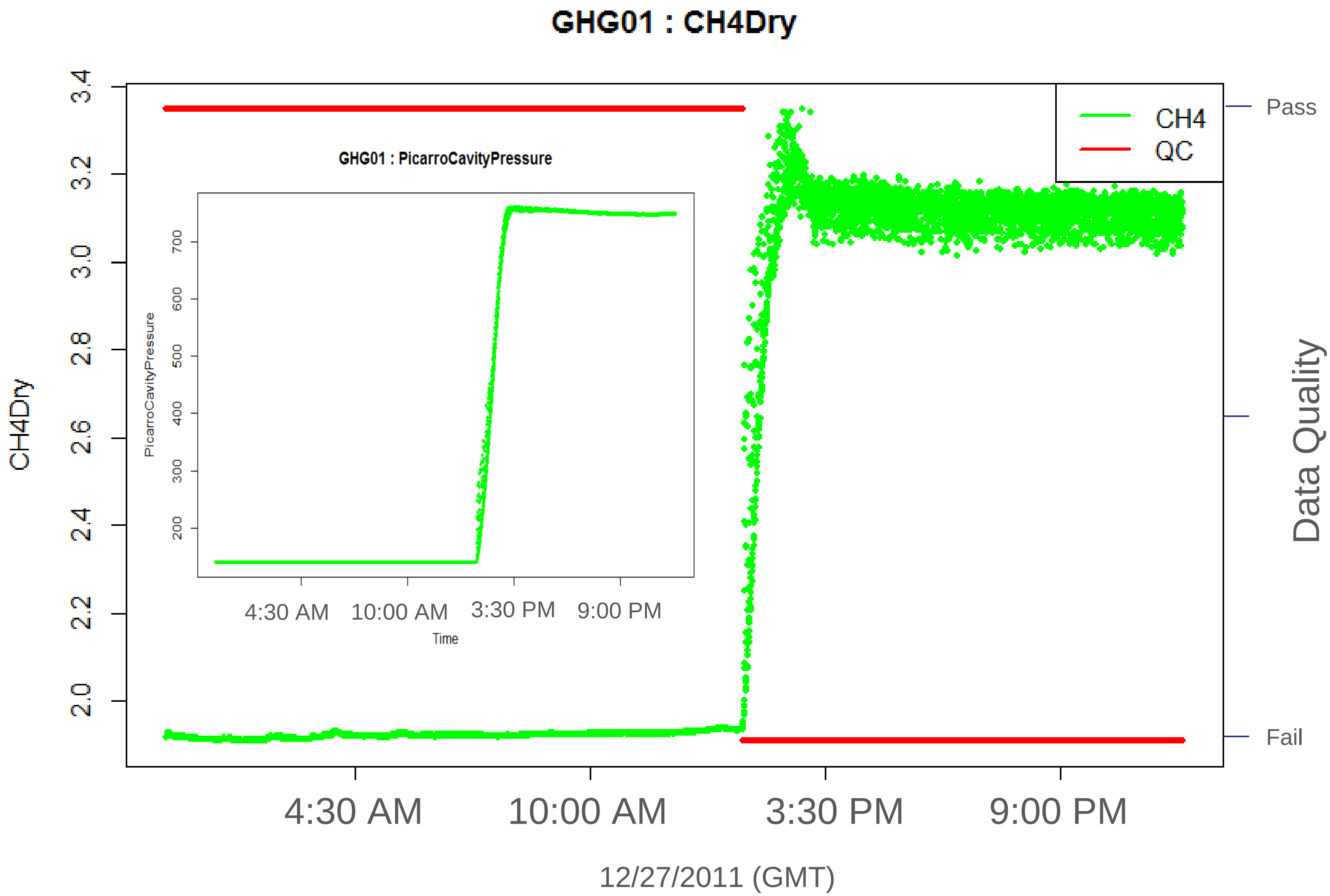
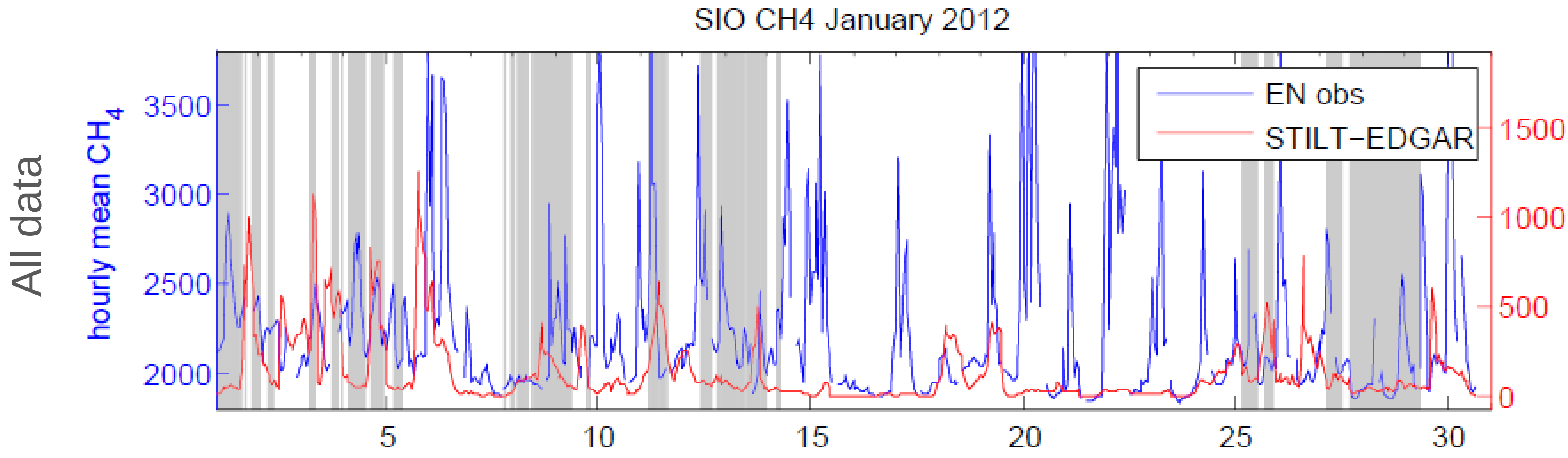
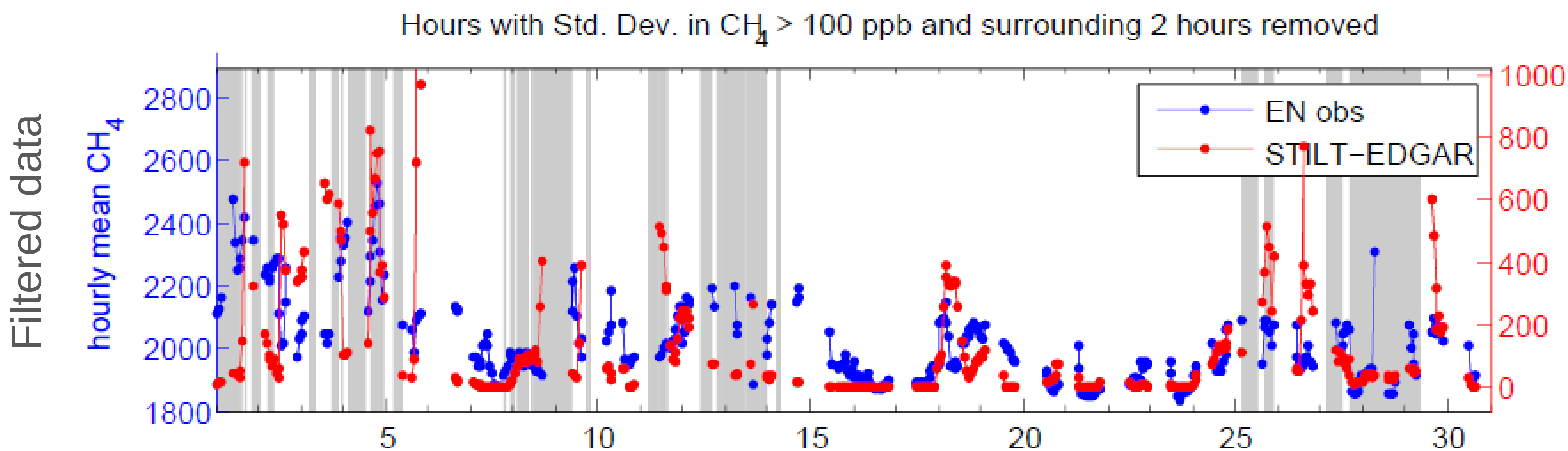
Data QC


GHG01 : CH4Dry
CH4Dry
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
CH4
QC
Pass
Fail
Data Quality
GHG01 : PicarroCavityPressure
PicarroCavityPressure
200
300
400
500
600
700
4:30 AM
10:00 AM
3:30 PM
9:00 PM
Time
4:30 AM
10:00 AM
3:30 PM
9:00 PM
12/27/2011 (GMT)

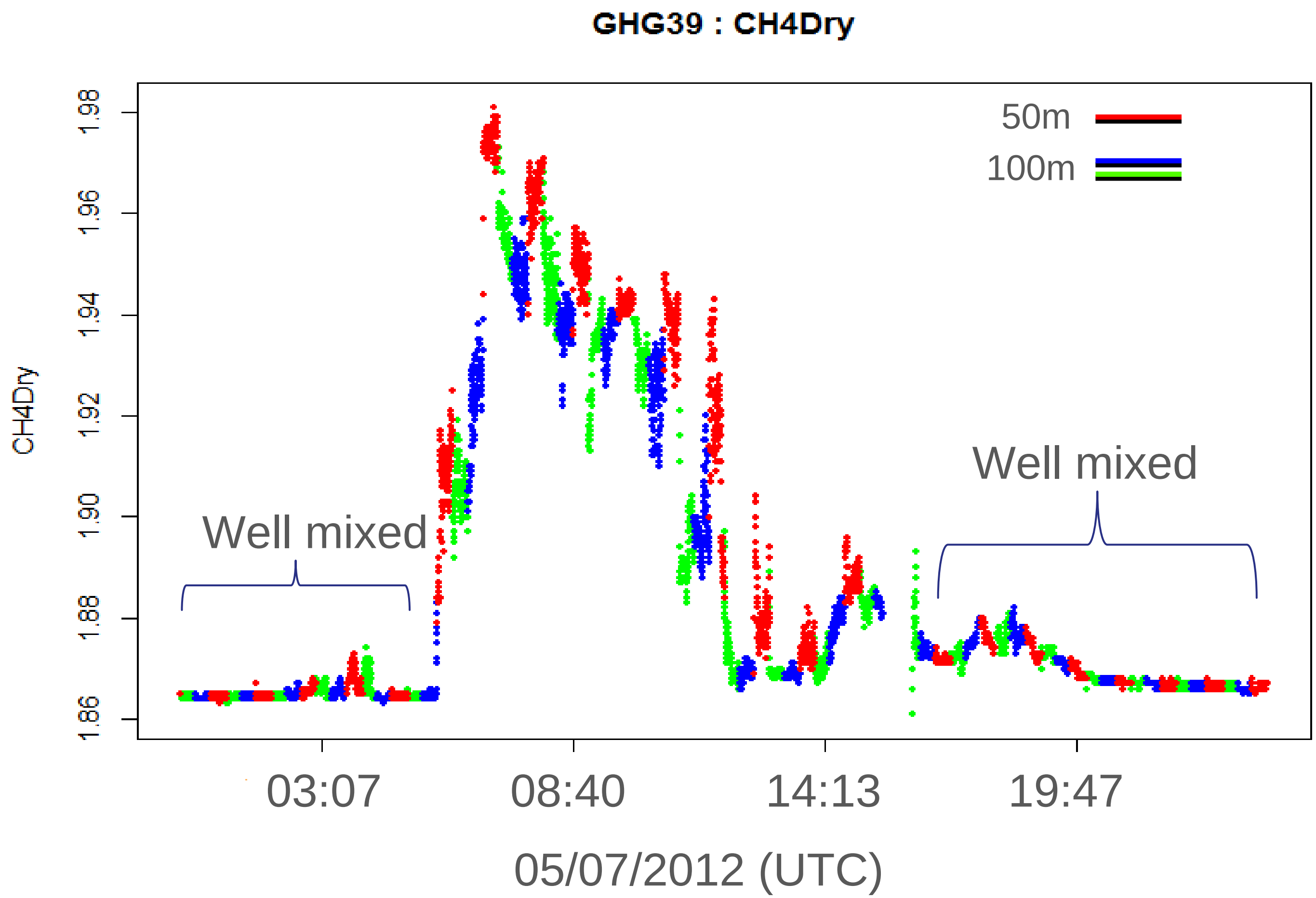
Variance Filter





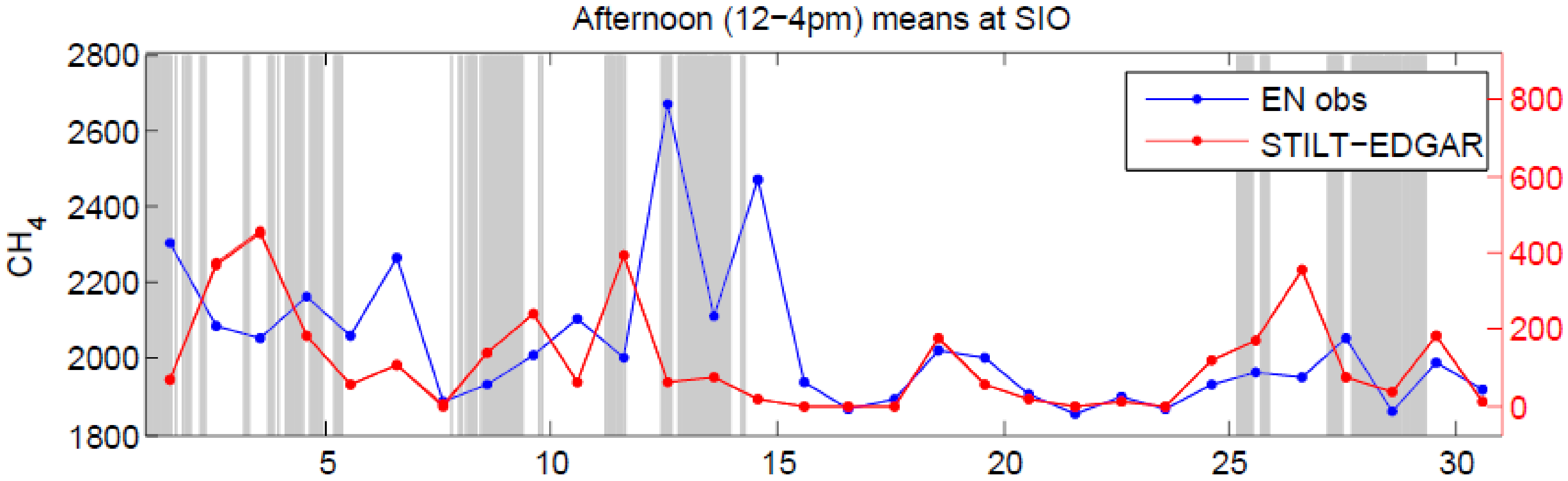
Model (STILT-EDGAR) at hourly intervals and at a given grid resolution has limited capabilities to represent short duration spikes from point sources, for example.

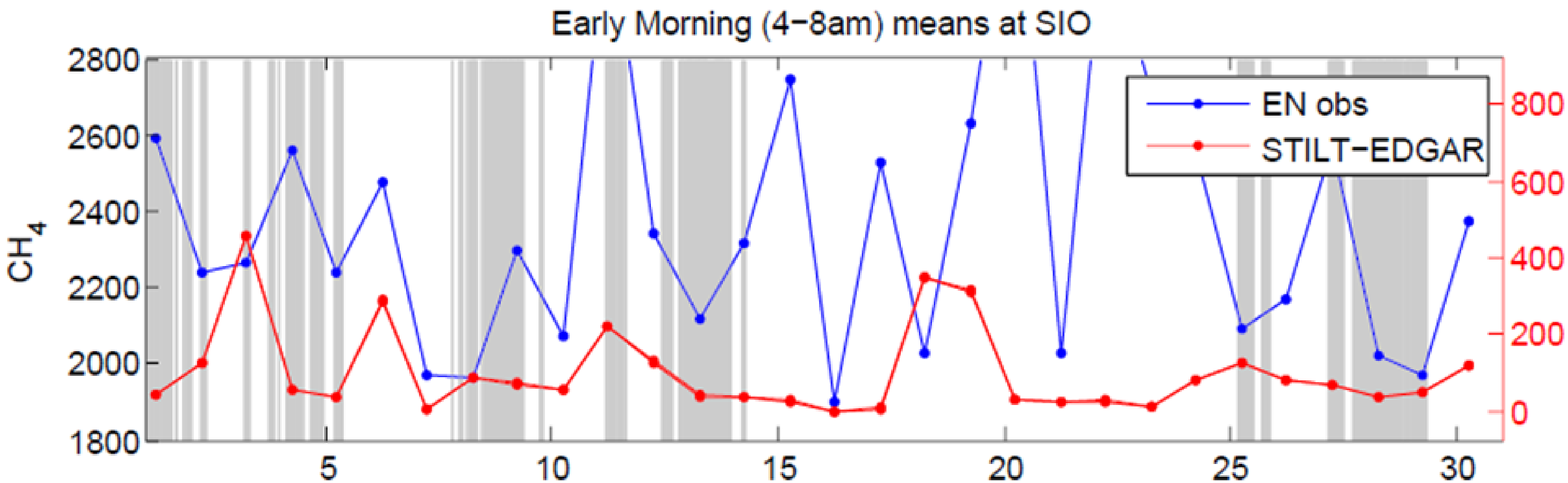
Most Recent Site - Victorville, CA



- Leveraging sampling strategy to take mixing ratio measurements at two heights, “well mixed” periods of the day can be identified.
- Night-time spikes at 50m CH_4 are seen at various sites within EN network and are related to local (point) sources based on analysis of correlations with wind direction/speed.

Time of Day Filter – Afternoon vs Early Morning





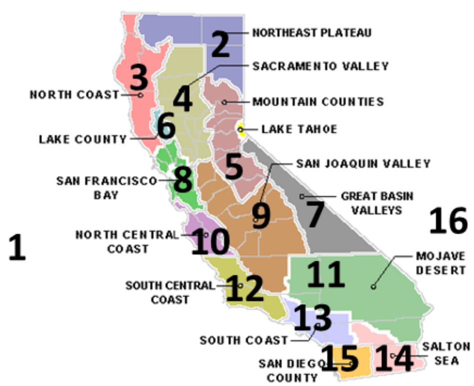
Models need to be improved to represent the night-time boundary layer.

Inversion Methodology: Region Analysis

Following LBNL's approach (Zhao et al., JGR, 2009):
A priori emission maps from different spatial regions in the domain are linearly scaled by factors λ, to provide *posterior* emissions that are optimally consistent with the tower measurements, *C*, and background air, C_{BG} , and predicted footprints, *f (x, y, z, t)*. λ_{prior} is the *a priori* scaling factor, typically assumed unity.

$$\underline{\hat{\lambda}} = (\underline{\underline{K}}^T \underline{\underline{S}}_{\varepsilon}^{-1} \underline{\underline{K}} + \underline{\underline{S}}_{prior}^{-1})^{-1} (\underline{\underline{K}}^T \underline{\underline{S}}_{\varepsilon}^{-1} \underline{y} + \underline{\underline{S}}_{prior}^{-1} \underline{\lambda}_{prior})$$

$$\underline{\underline{\hat{S}_{\lambda}}} = (\underline{\underline{K}}^T \underline{\underline{S}}_{\varepsilon}^{-1} \underline{\underline{K}} + \underline{\underline{S}}_{prior}^{-1})^{-1}$$



where:

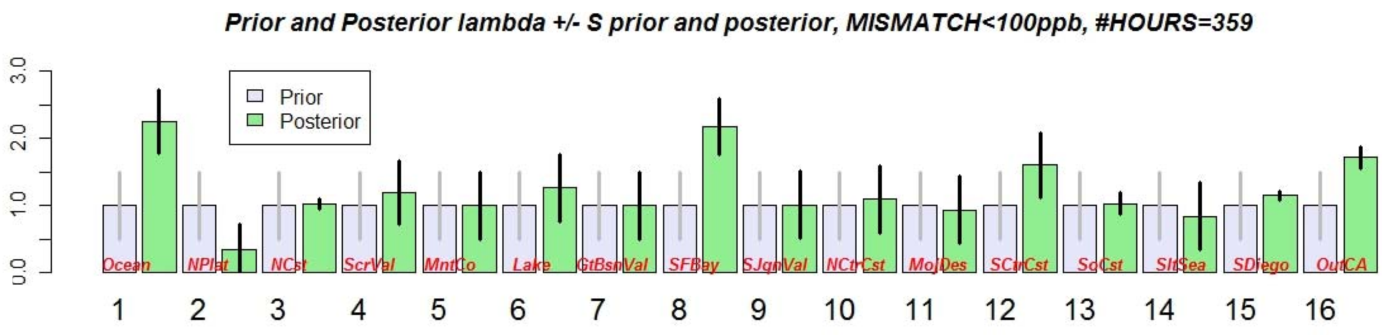
X_r - location of the sensor, t_r - Time of measurement *C*,

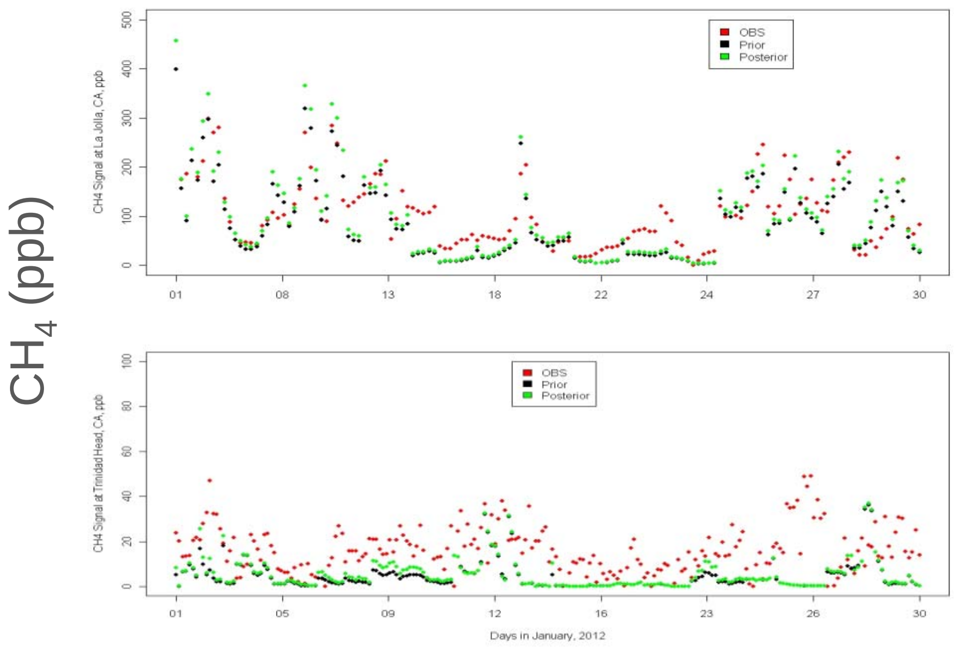
$y = \underline{C} - \underline{C_{BG}}$

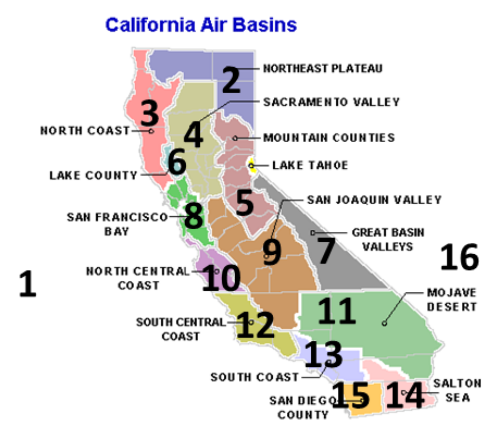
$\underline{\underline{K}}\ \underline{\lambda} = \sum_{i,j,m} f(X_r, t_r | x_i, y_j, t_m) \cdot F(x_i, y_j, t_m)$ - footprint-flux sums over space and time,

$\underline{\underline{S}}_{\varepsilon}$ - measurement error covariance matrix

Preliminary Inverse Modeling Results







Next Steps

- Refinement of background air estimates
- CH_4 emission trends for each region
- Deployment of additional towers
- Analysis of CO_2 sources and sinks (in situ observations, VPRM model and satellite data)
- Apply the same pre-processing, filtering and inverse modeling methodology to all EN sites (examples for the northeastern US, where dense network has already been deployed)