

# Methane Emissions from Point and Area Sources in California

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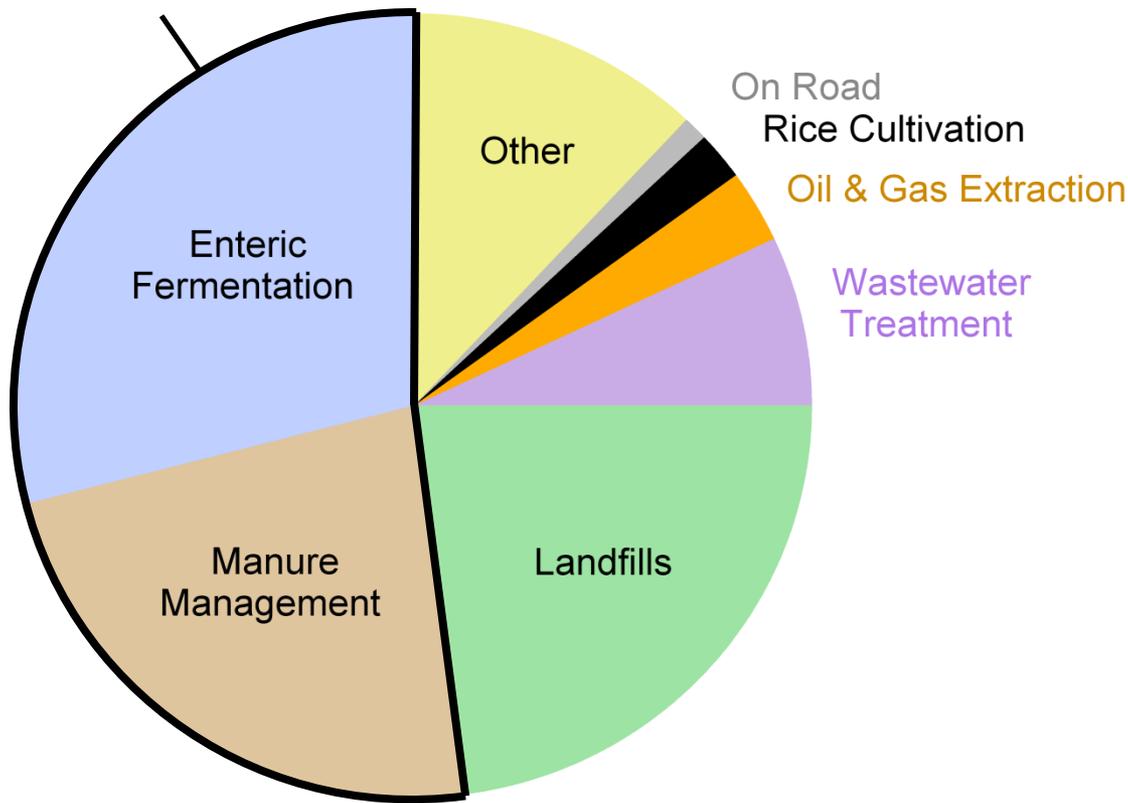
## Outline:

- CH<sub>4</sub> emissions inventories for California
- Observations from P-3 during CalNex
  - a) L.A. Basin (dairies, landfills, wastewater treatment, ...)
  - b) Sacramento Valley (rice, dairies, gas wells, wetlands)
- Summary

# Known sources of CH<sub>4</sub> in California

Air Resources Board (ARB) emissions inventories (EI)

cattle – see Nowak  
et al. 10:10 am



We can evaluate many of these sectors with P-3 data:

- dairies in Central Valley and L.A. Basin
- rice in Sacramento Valley
- L.A. Basin – combination of all but rice

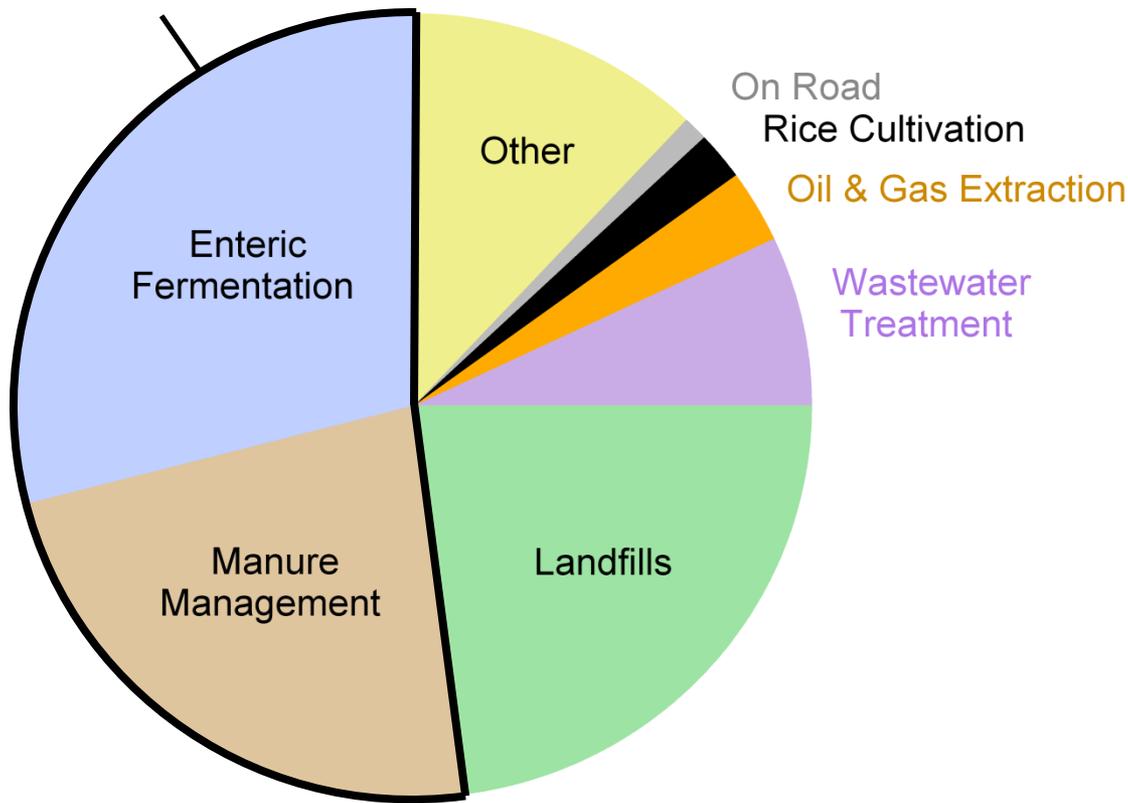
ARB CH<sub>4</sub> EI: <http://www.arb.ca.gov/cc/inventory/inventory.htm>

ARB criteria pollutants EI: <http://www.arb.ca.gov/ei/maps/basins/abscmap.htm>

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L.A. Basin CH<sub>4</sub> to CO  
inventory emission ratios

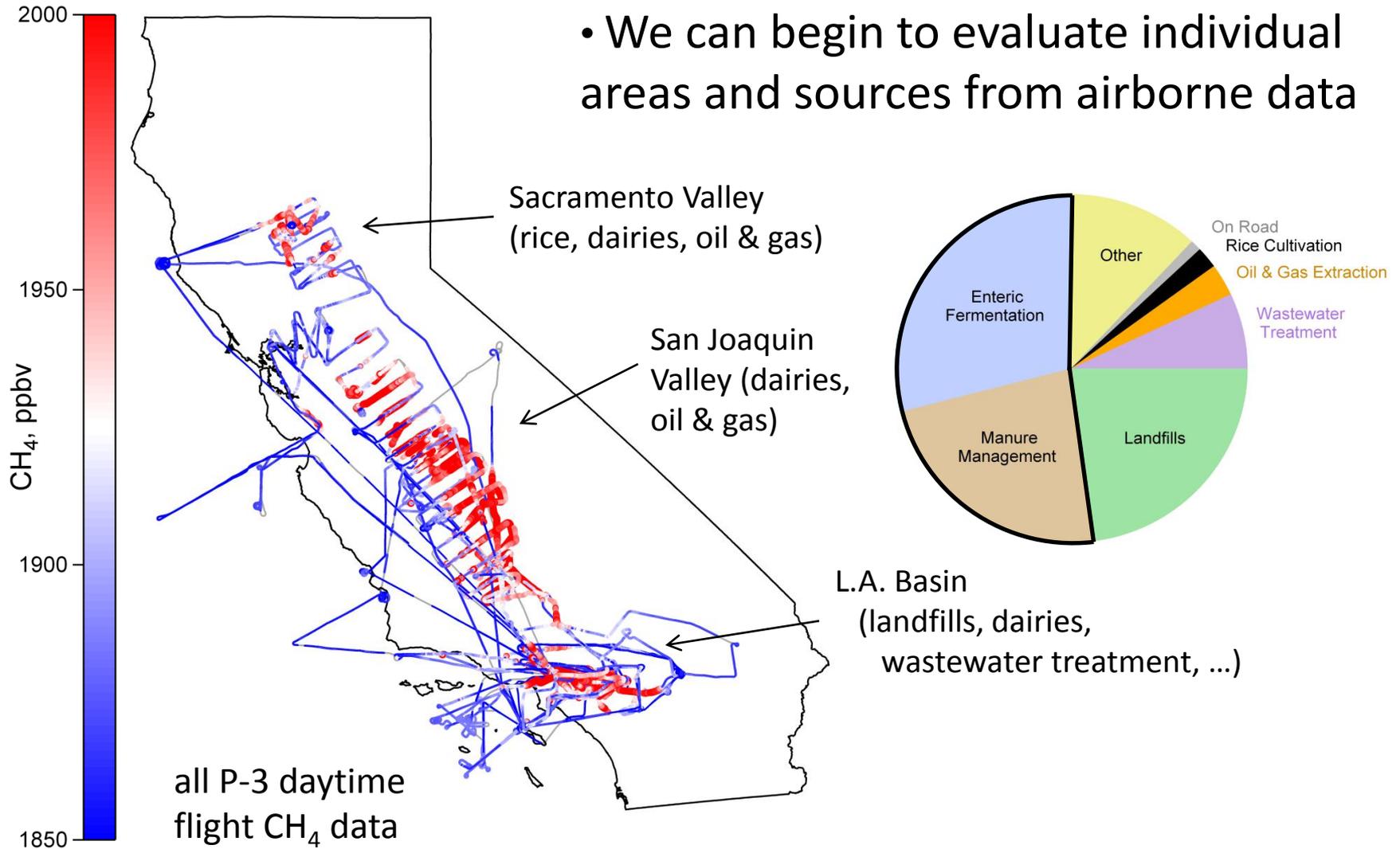
- total  $\approx 0.12$
- cars  $\approx 0.017$

ARB CH<sub>4</sub> EI: <http://www.arb.ca.gov/cc/inventory/inventory.htm>

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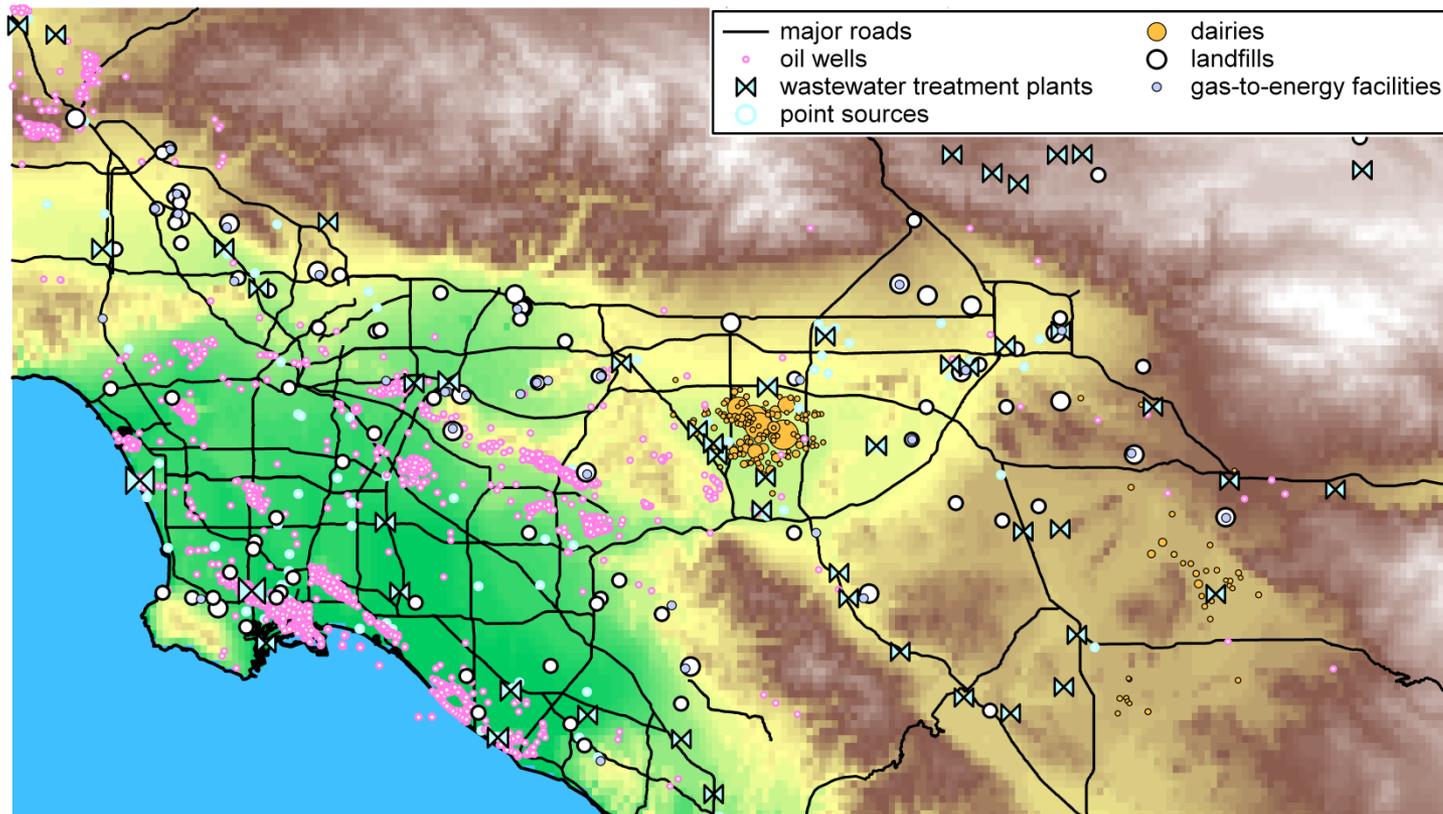
# P-3 data show areas with high CH<sub>4</sub> emissions

- We can begin to evaluate individual areas and sources from airborne data



## a) CH<sub>4</sub> in L.A. Basin has multiple sources

- sources: dairies, landfills, water treatment, traffic, etc.

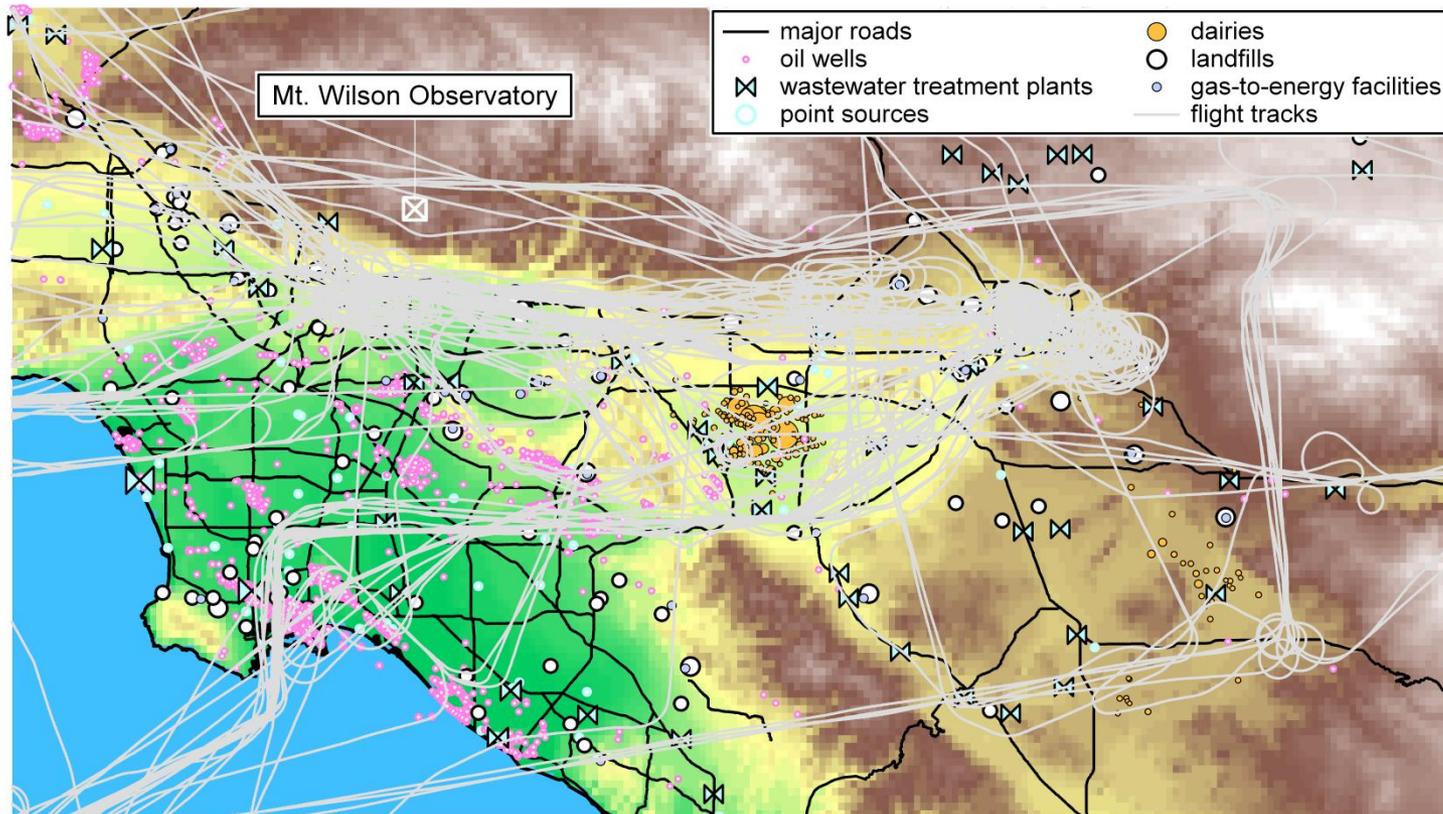


dairy location and size from William Salas et al.

landfill location from ARB: <http://www.calrecycle.ca.gov/SWFacilities/Directory/>

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- sources: dairies, landfills, water treatment, traffic, etc.
- interpret data from:
  - i.) fourteen daytime NOAA P-3 flights
  - ii.) NOAA flasks at Mt. Wilson observatory

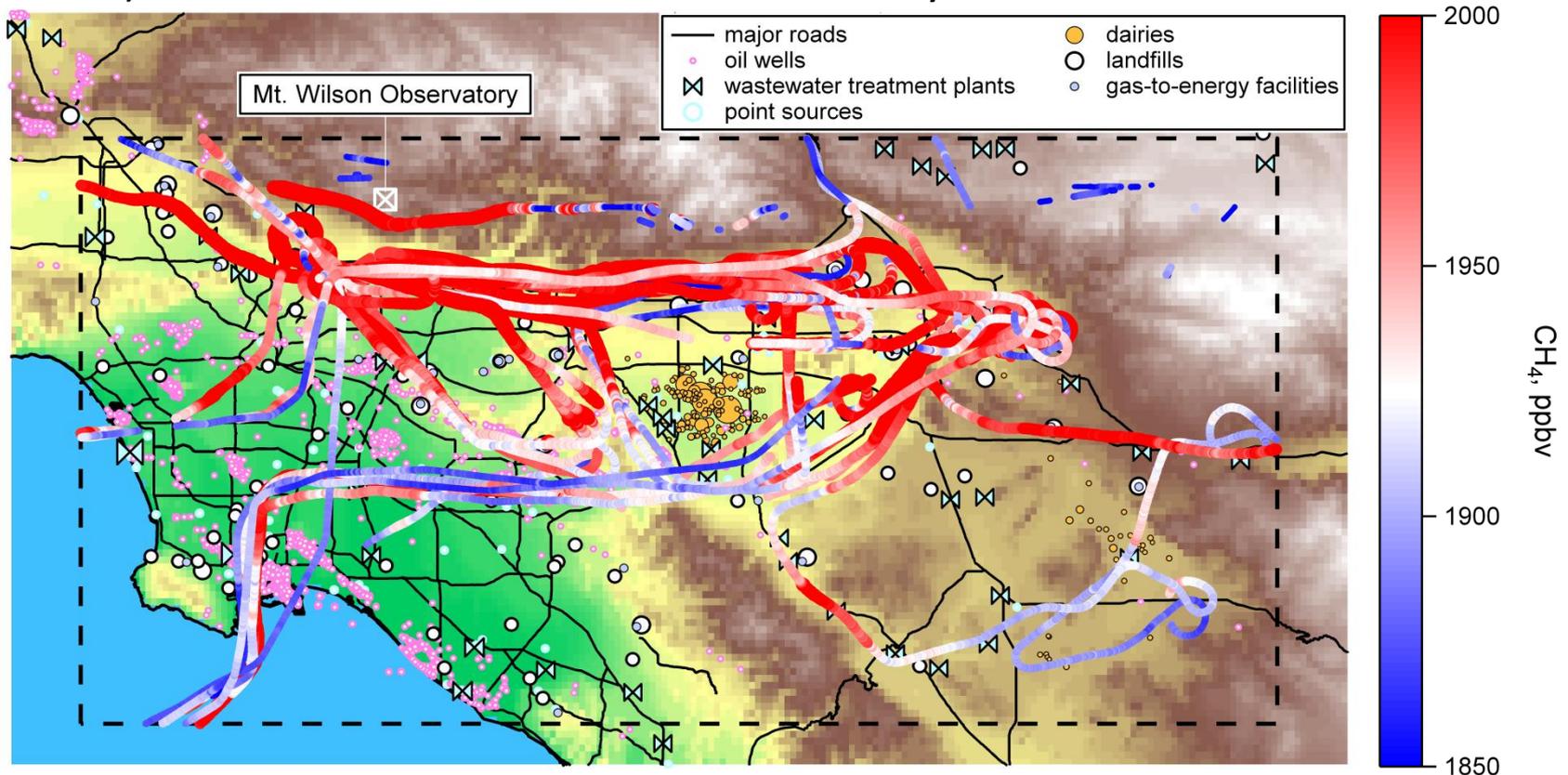


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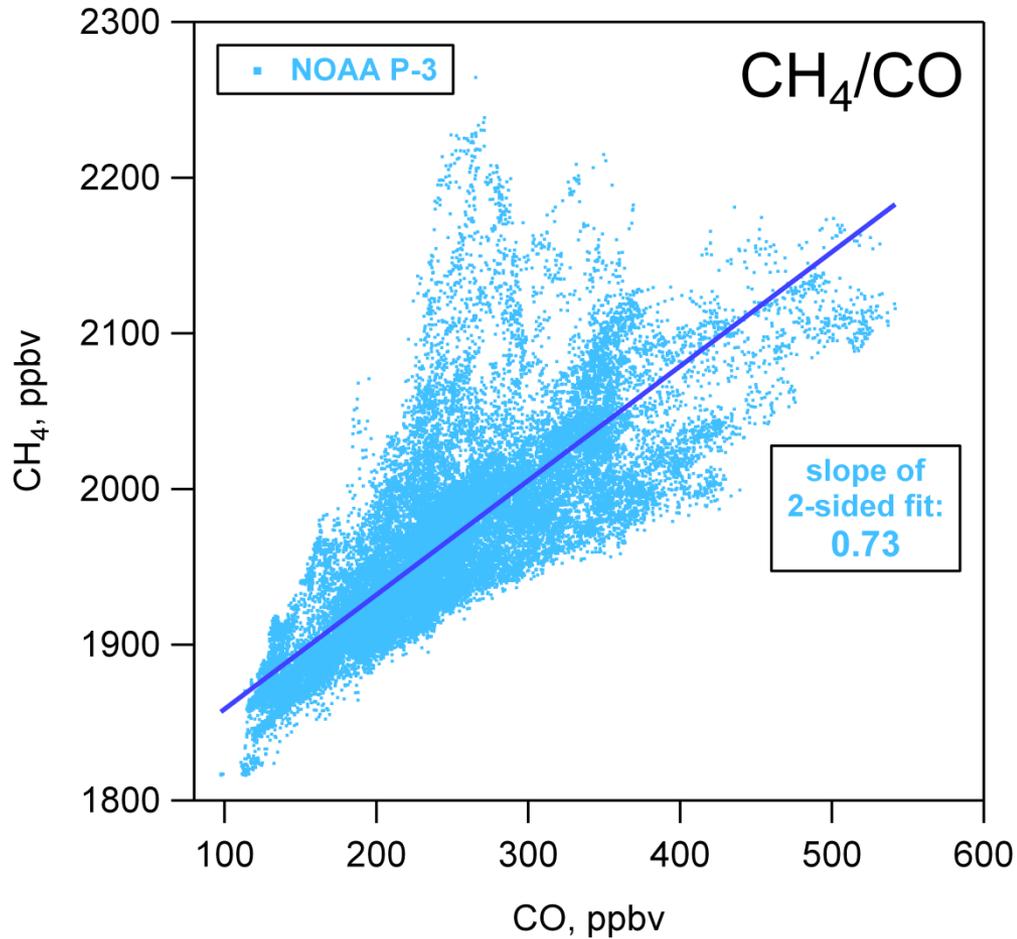
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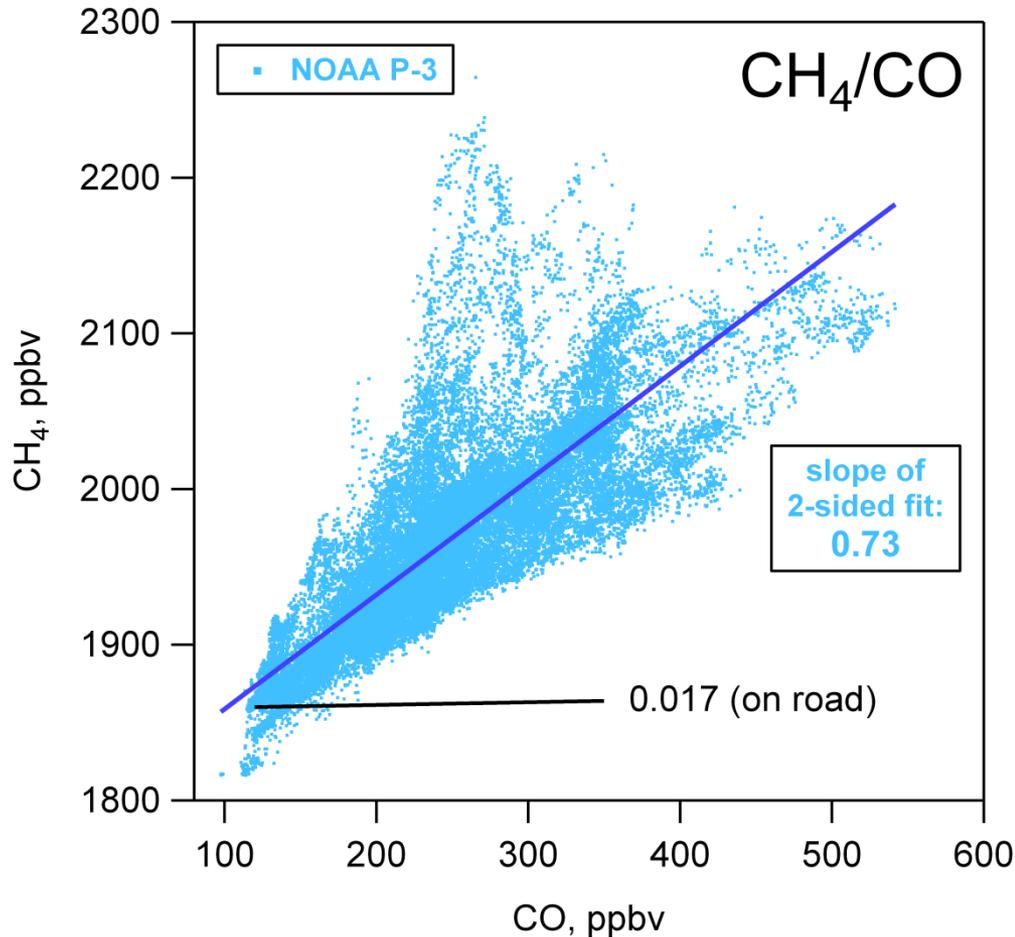
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# Observed CH<sub>4</sub>/CO in L.A. Basin



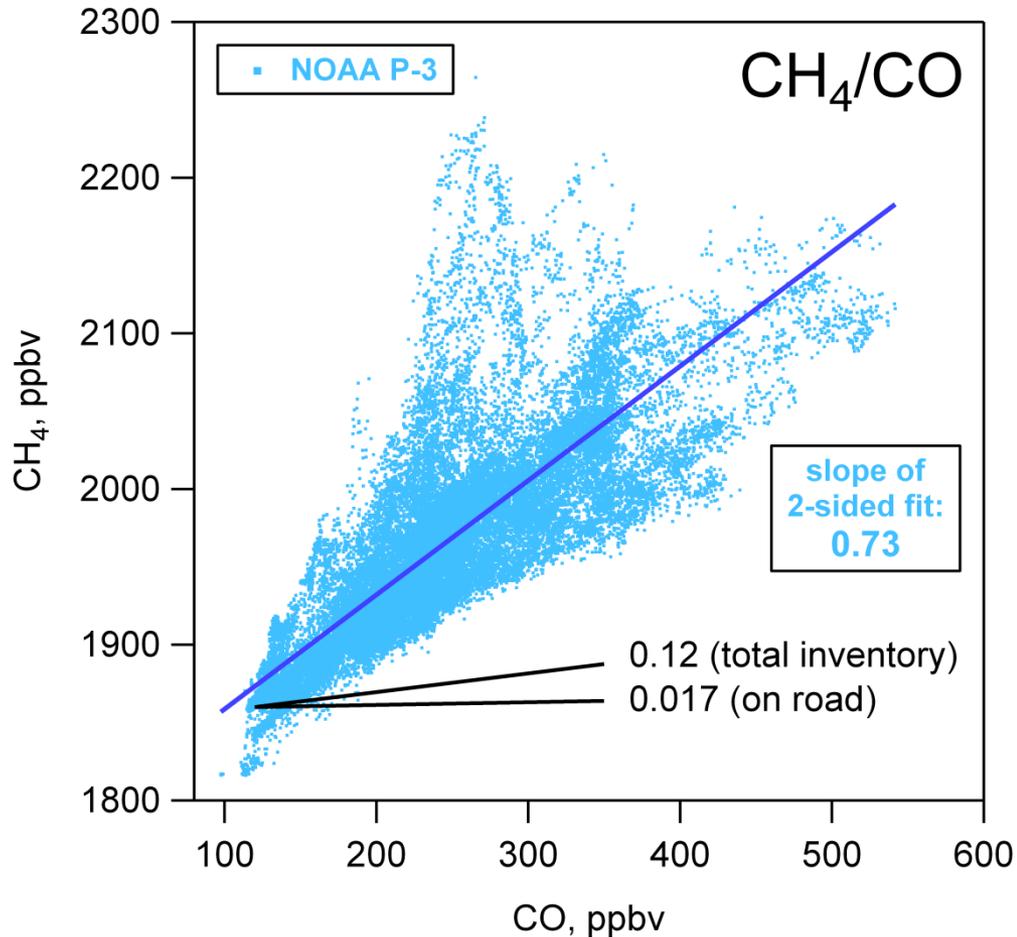
- linear regression of P-3 data influenced by CH<sub>4</sub> sources not correlated with CO emissions

# Observed CH<sub>4</sub>/CO is higher than expected from ARB criteria pollutants inventory (2008 preliminary EI – latest available)



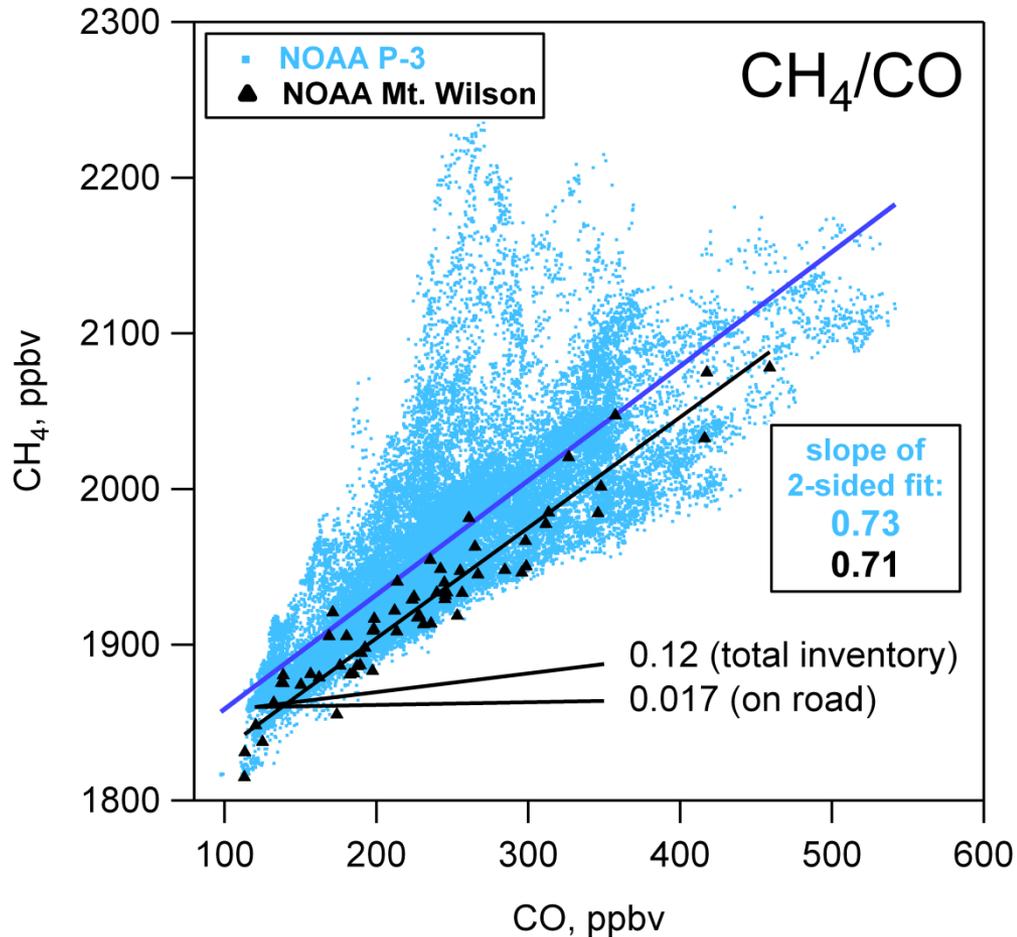
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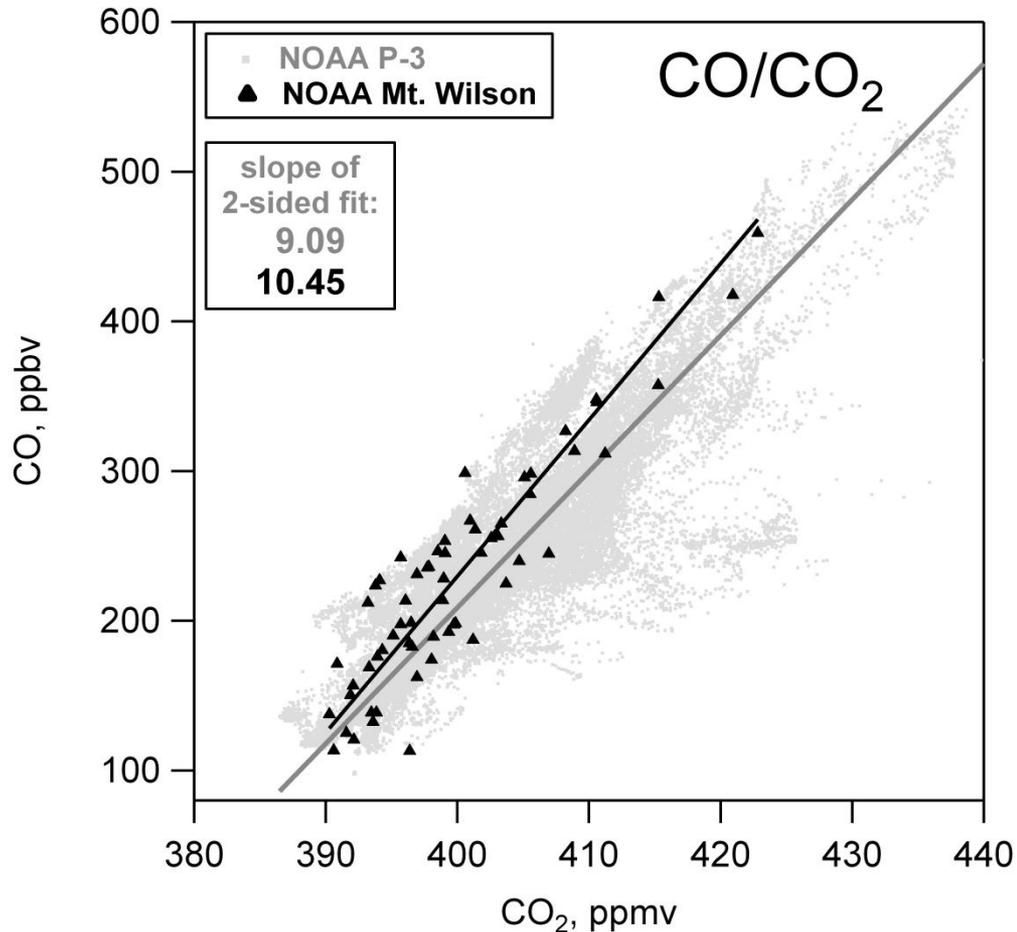
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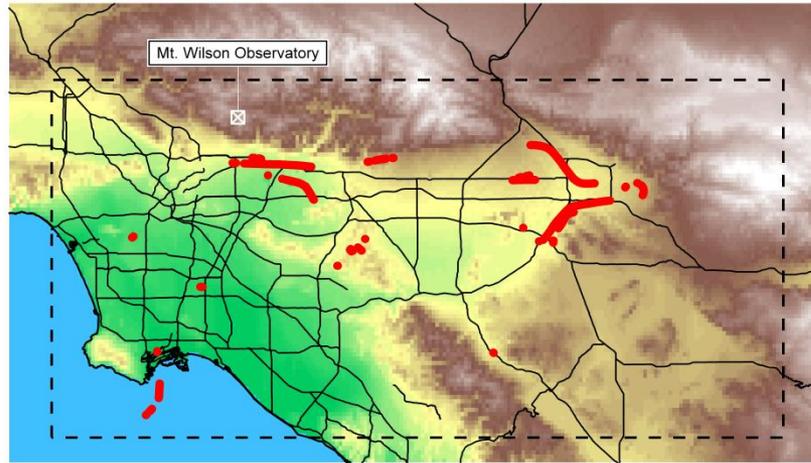
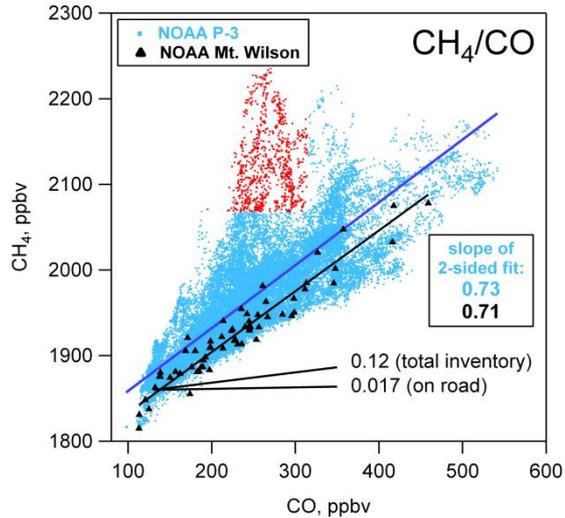
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- traffic very minor contributor to total  $\text{CH}_4$  in L.A. Basin
- significant difference between observed and inventory  $\text{CH}_4$  ratios to  $\text{CO}$
- NOAA Mt. Wilson data consistent with a subset of P-3 data

# Observed CO/CO<sub>2</sub> is higher for Mt. Wilson data than for P-3 data



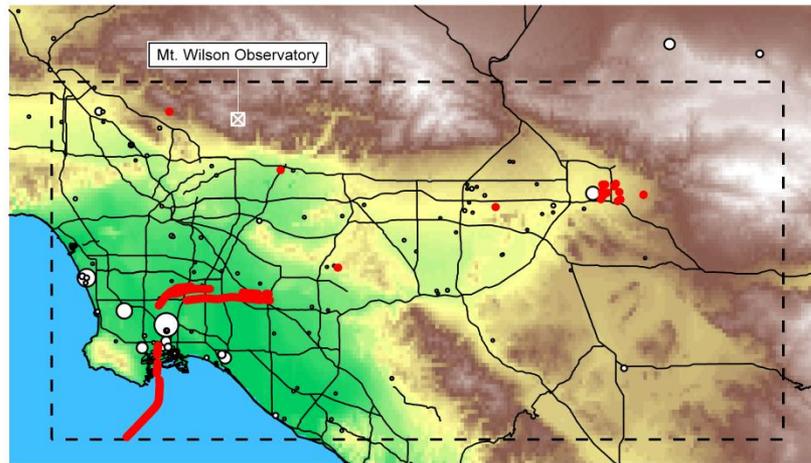
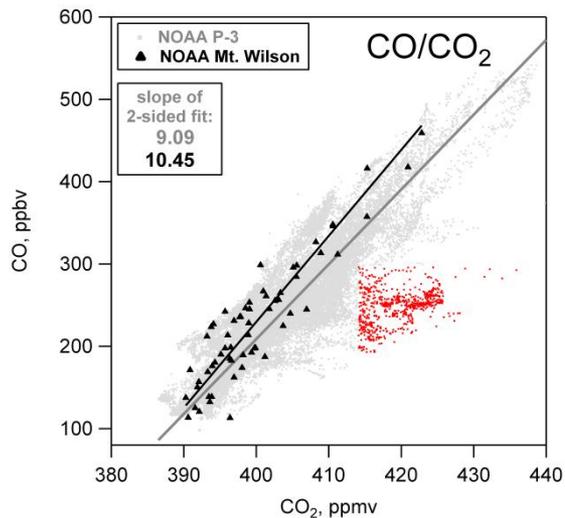
- linear regression of P-3 data influenced by CO<sub>2</sub> sources not correlated with CO emissions
- NOAA Mt. Wilson data consistent with a subset of P-3 data
- NOAA Mt. Wilson data show same variability in CO as NOAA P-3, but not for CH<sub>4</sub> and CO<sub>2</sub>

# Mt. Wilson data may not sample entire L.A. Basin

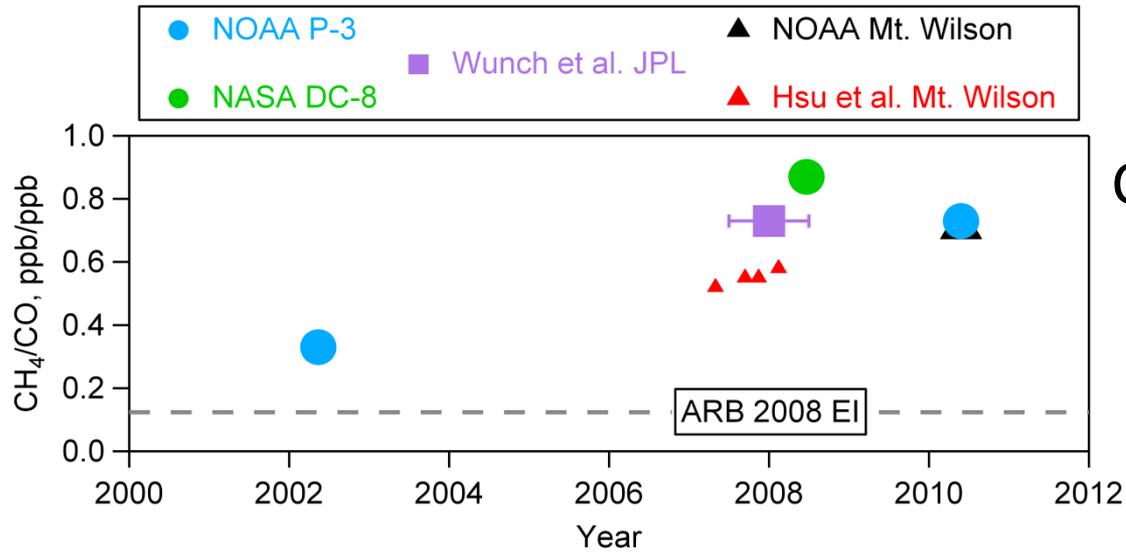


Mt. Wilson data not influenced by:

- CH<sub>4</sub> emissions from East L.A. Basin, or
- CO<sub>2</sub> emissions from Long Beach



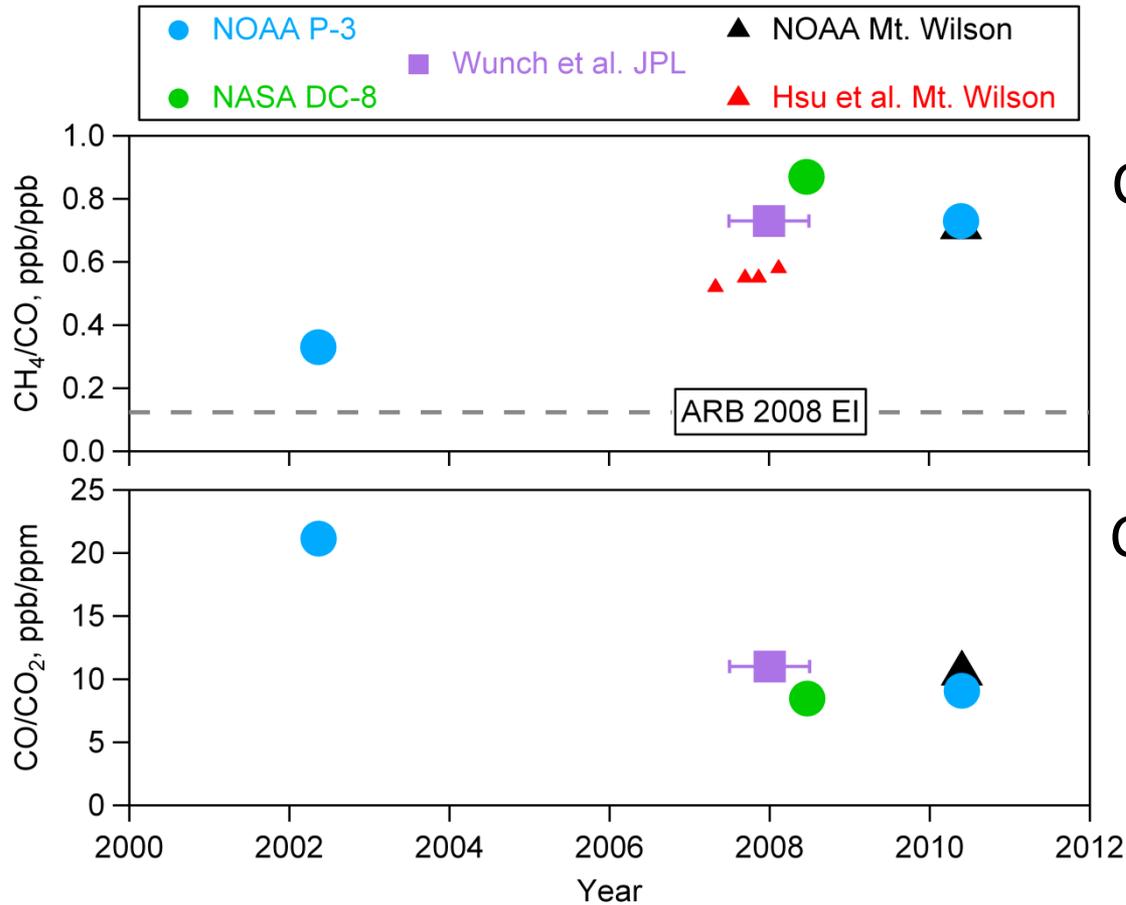
# L.A. Basin CH<sub>4</sub>/CO emission ratios over time



CH<sub>4</sub>/CO

- 50-200% change in CH<sub>4</sub>/CO over eight years

# L.A. Basin CH<sub>4</sub>/CO emission ratios over time



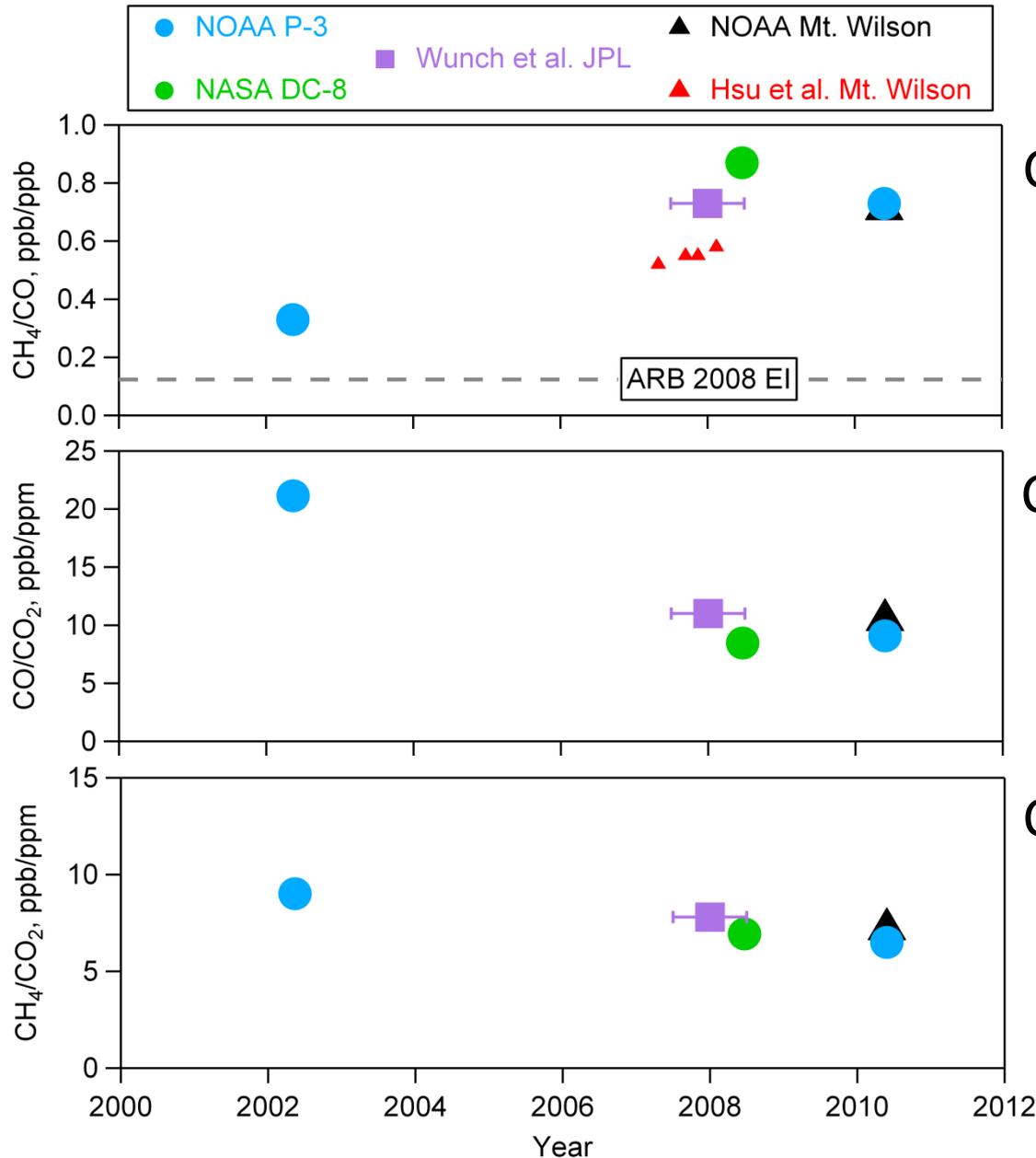
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- see Warneke et al. and Pollack et al.

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CH<sub>4</sub>/CO<sub>2</sub>

- we need to account for either decreasing CO or changing CO<sub>2</sub> emissions before evaluating absolute changes to CH<sub>4</sub> emissions

b) Agricultural emissions in the Sacramento Valley  
(rice + dairies, gas wells, wetlands)



# a lot already known about rice CH<sub>4</sub>

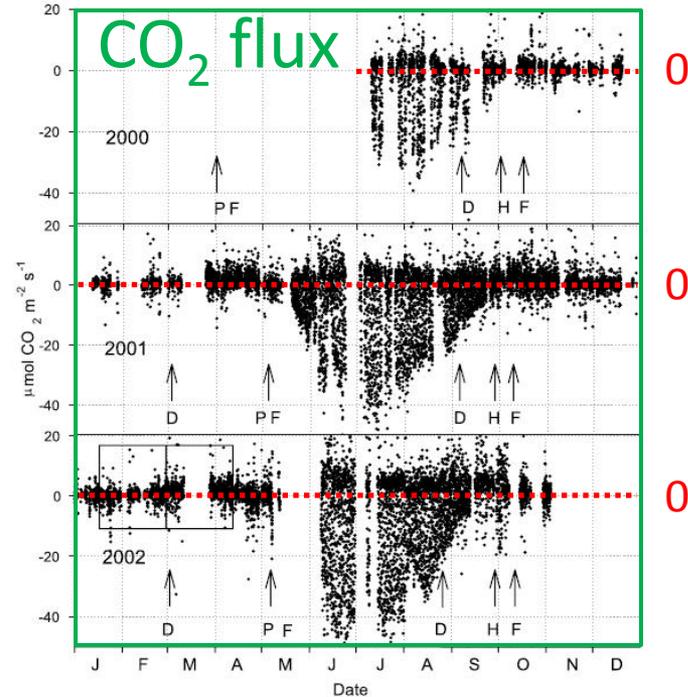
JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 112, G01008, doi:10.1029/2006JG000198, 2007

## Stoichiometry of CH<sub>4</sub> and CO<sub>2</sub> flux in a California rice paddy

Andrew M. S. McMillan,<sup>1</sup> Michael L. Goulden,<sup>1</sup> and Stanley C. Tyler<sup>1</sup>

Received 12 March 2006; revised 27 September 2006; accepted 19 October 2006; published 3 February 2007.

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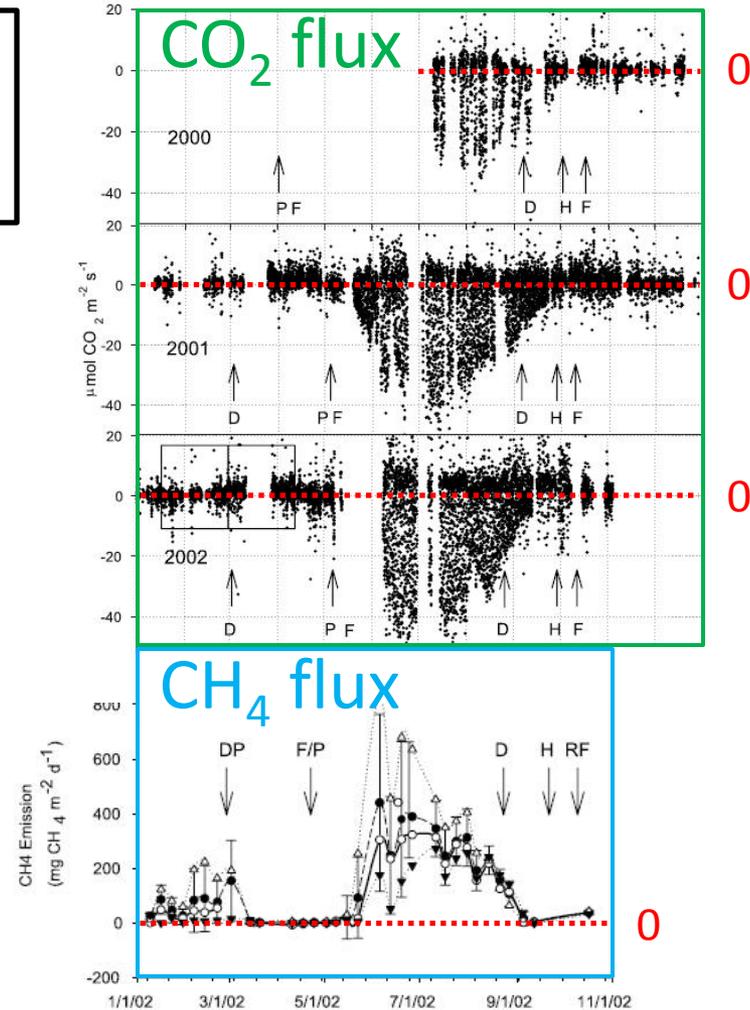
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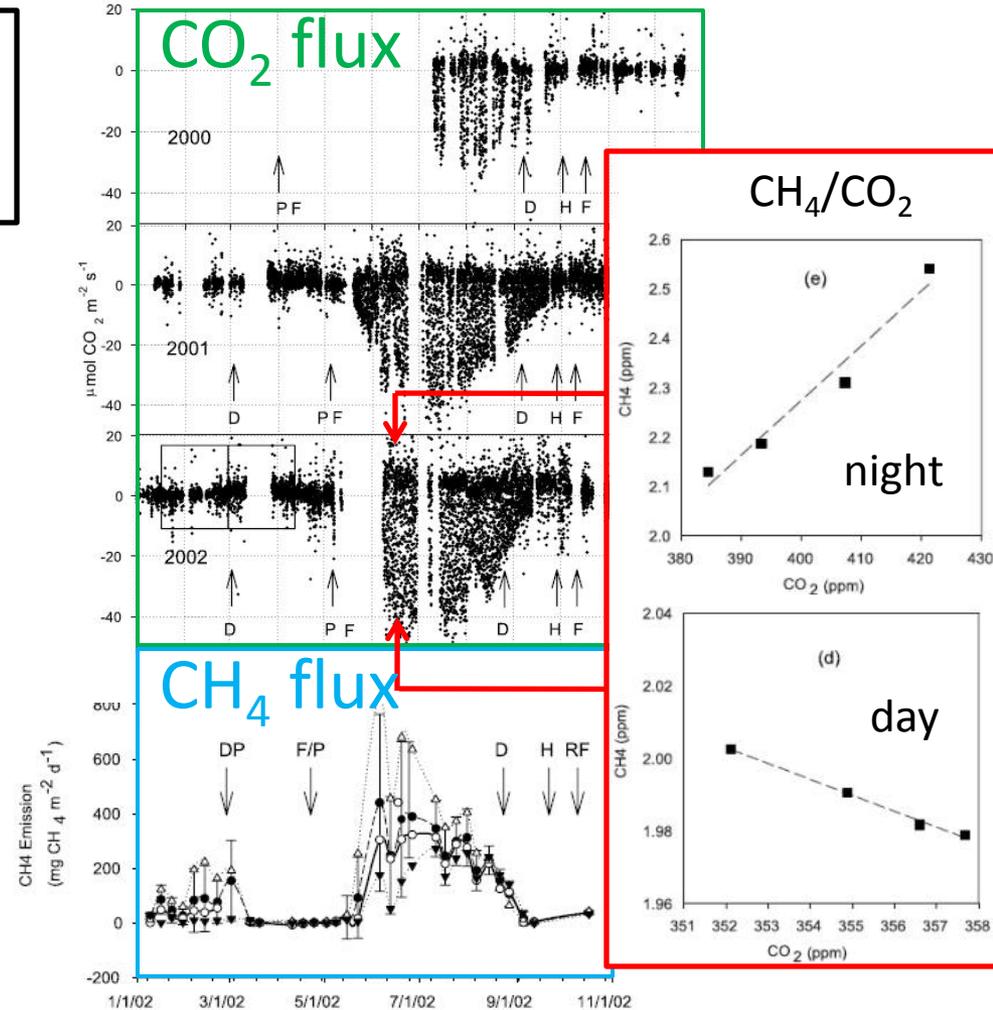
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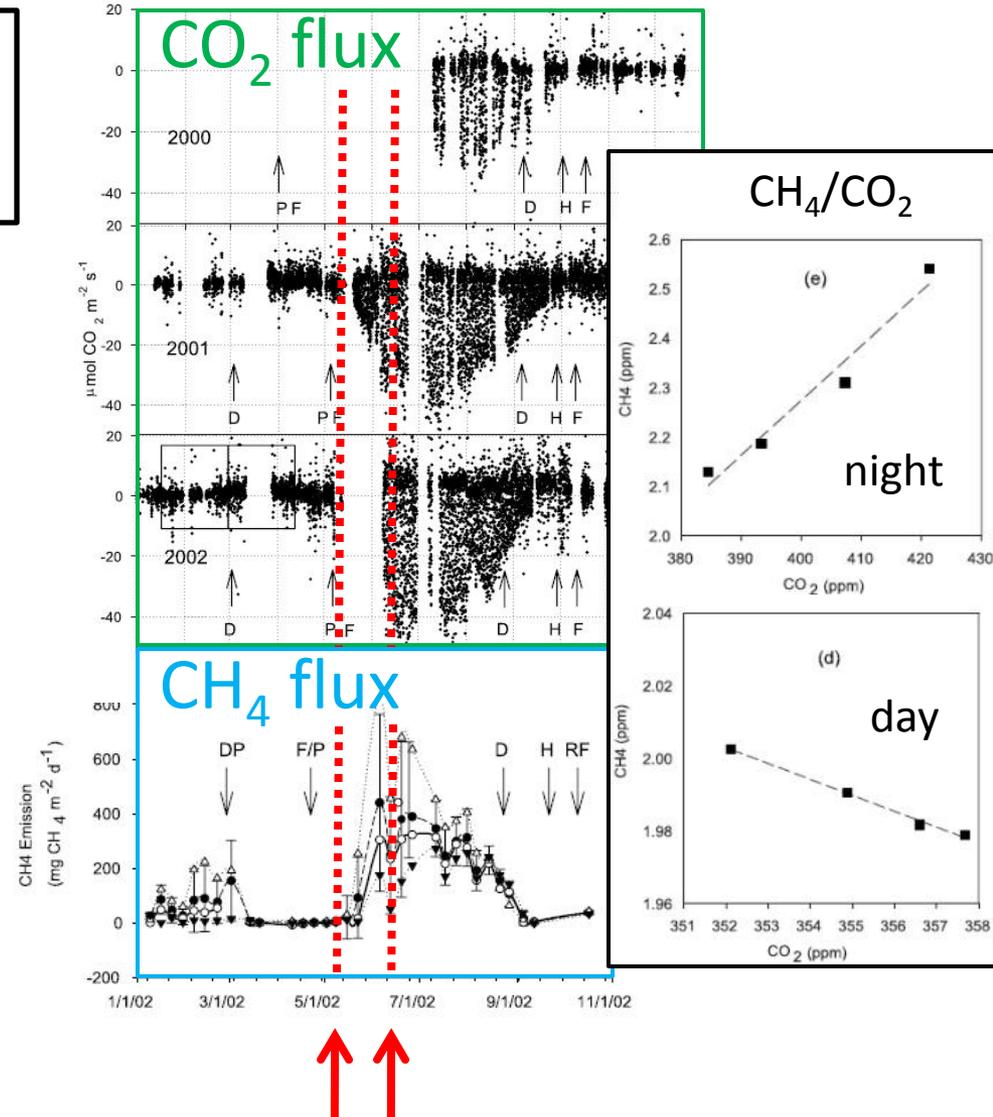
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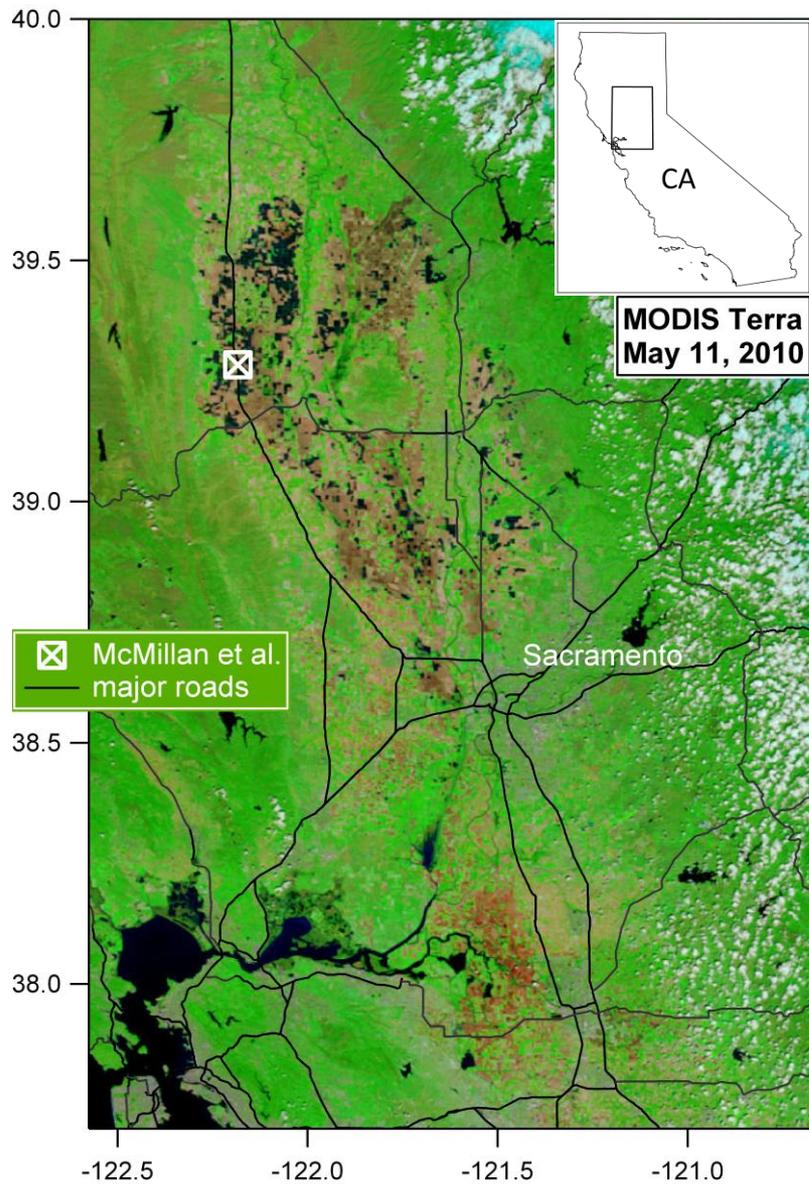
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P-3 adds spatial information – data for model constraints

show data from two flights: before and during growing phase



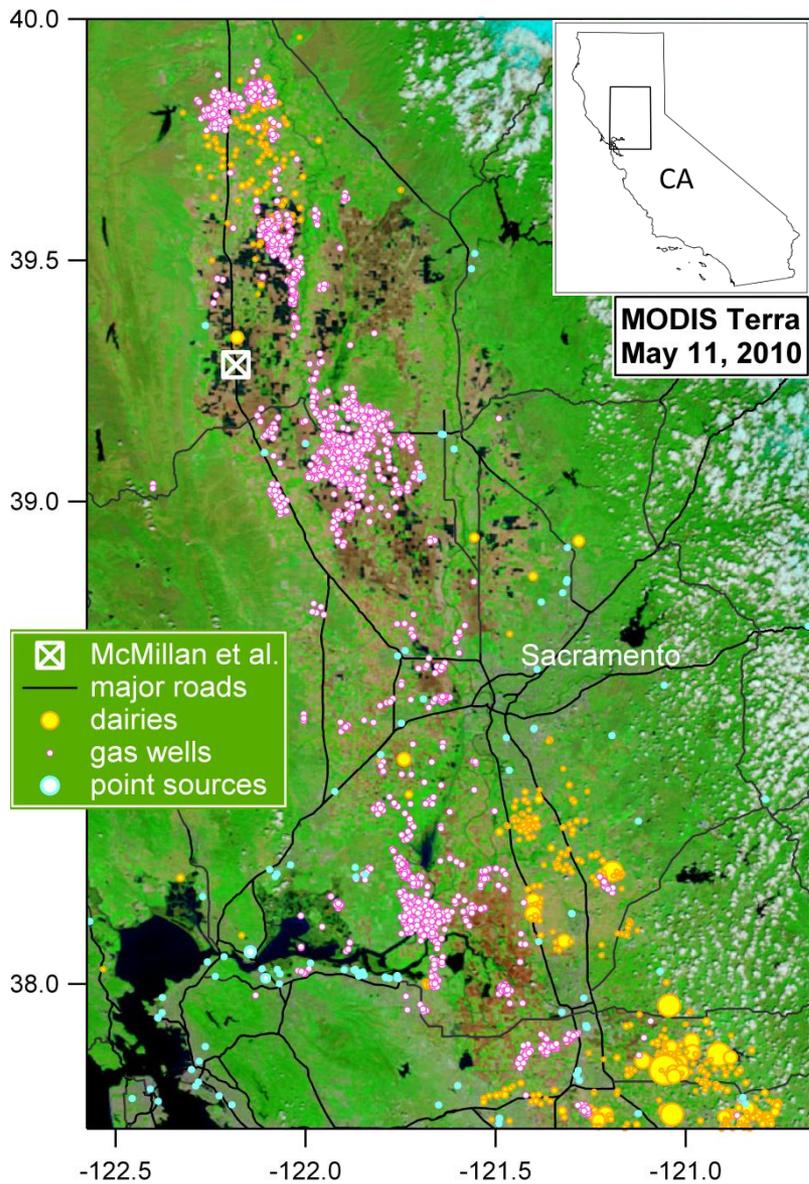
# CH<sub>4</sub> emission from Sacramento Valley rice crops



flooded rice fields show up well on MODIS Terra images

- some fields have already been flooded
- watch as rice grows over one month in 2010

# CH<sub>4</sub> emission from Sacramento Valley rice crops

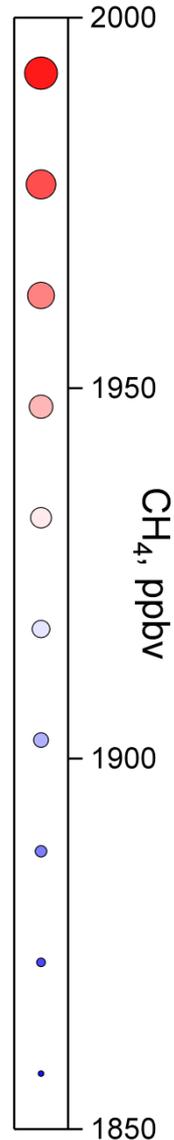
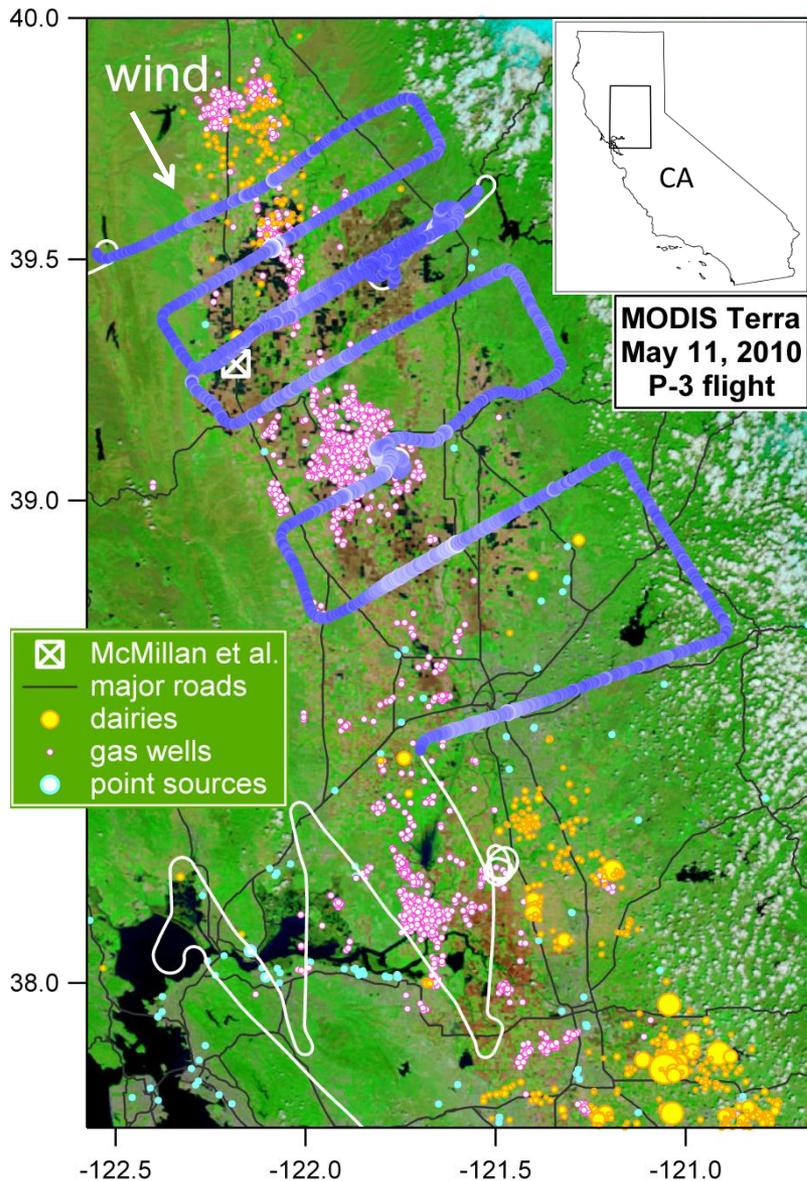


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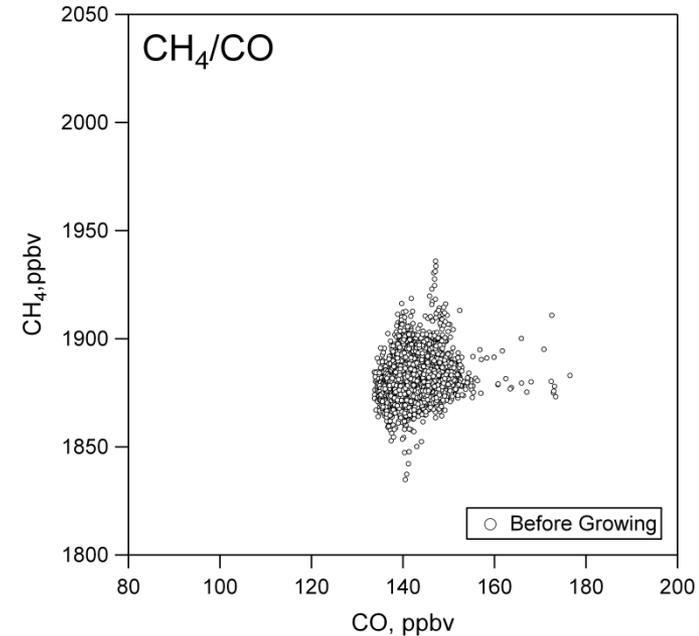
- some fields have already been flooded
- watch as rice grows over one month in 2010
- other sources of CH<sub>4</sub> in the area

# CH<sub>4</sub> emission from Sacramento Valley rice crops

## Minimal flooding – before growing phase



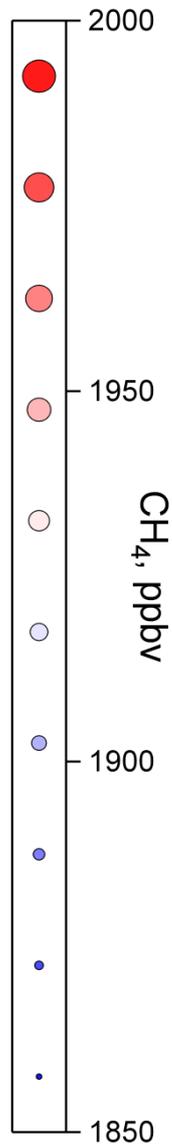
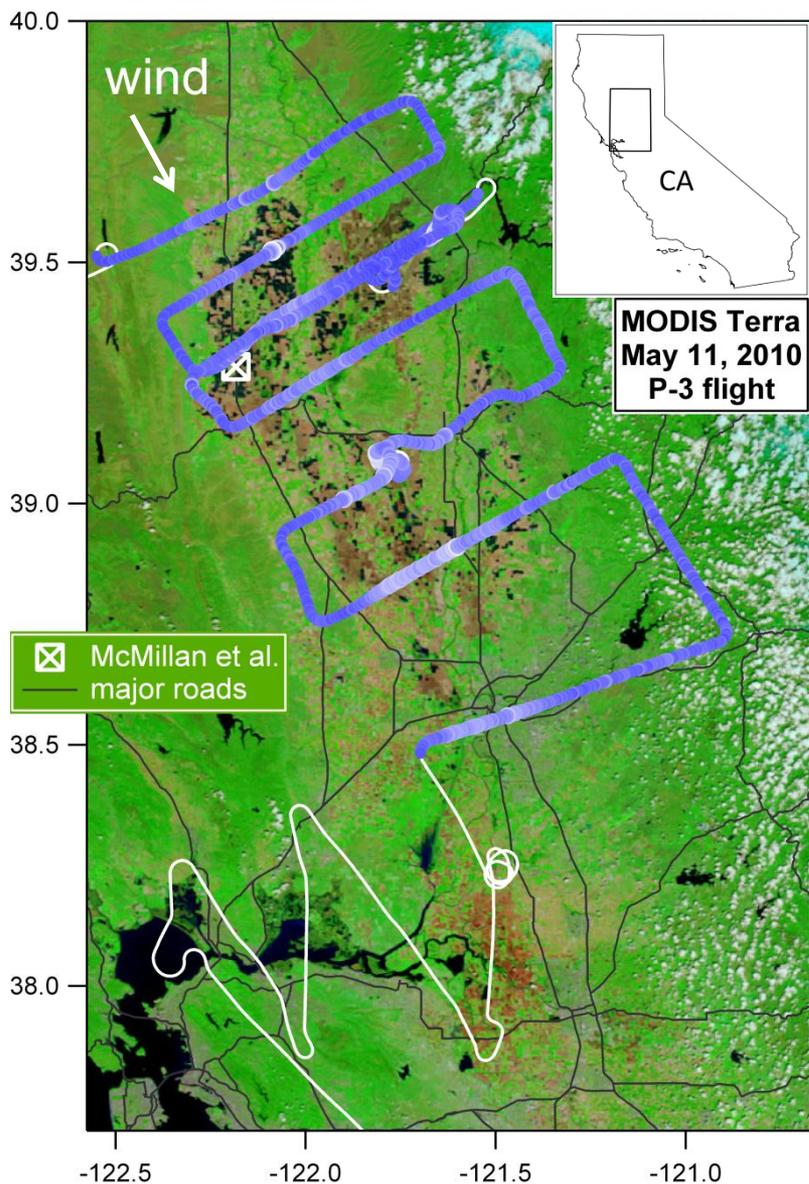
- P-3 track with CH<sub>4</sub> in boundary layer
- data from 12:30 to 3 pm PDT



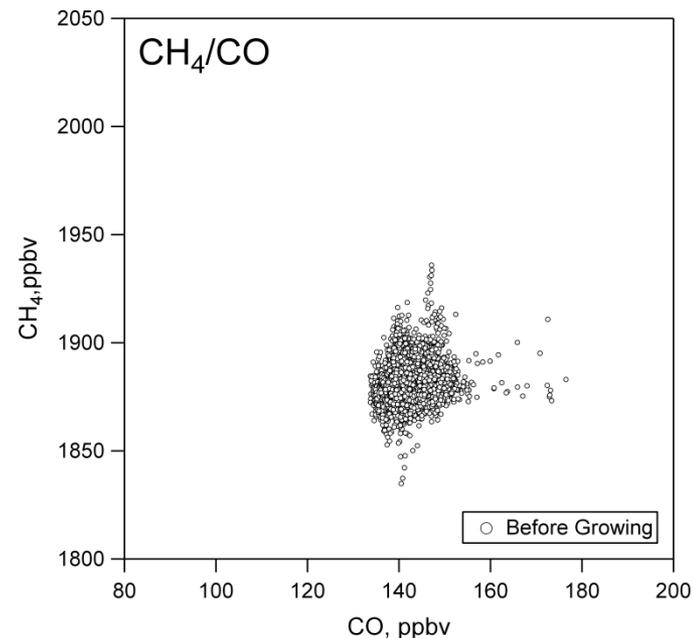
- no CH<sub>4</sub> before growing phase
- no correlation with CO – no urban signature
- no significant enhancement from dairies, gas wells, or point sources

# CH<sub>4</sub> emission from Sacramento Valley rice crops

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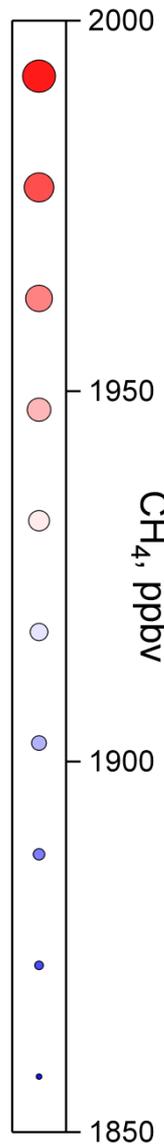
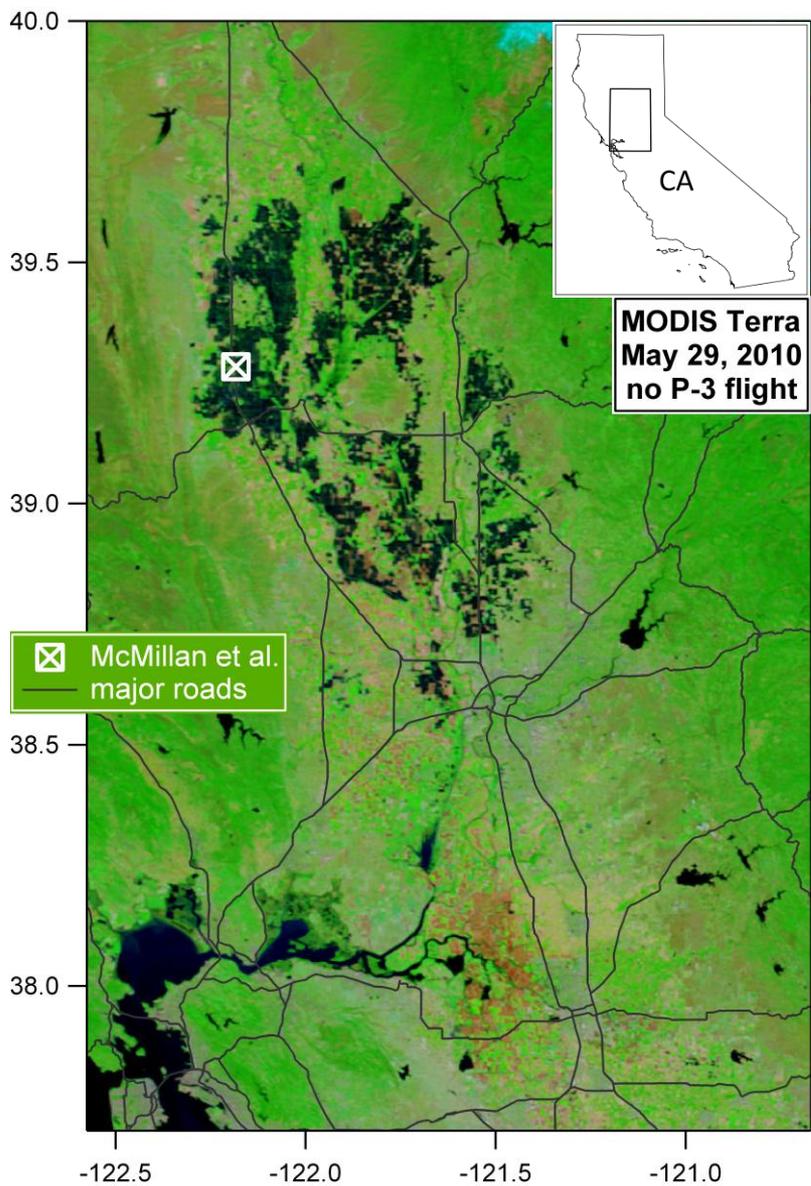
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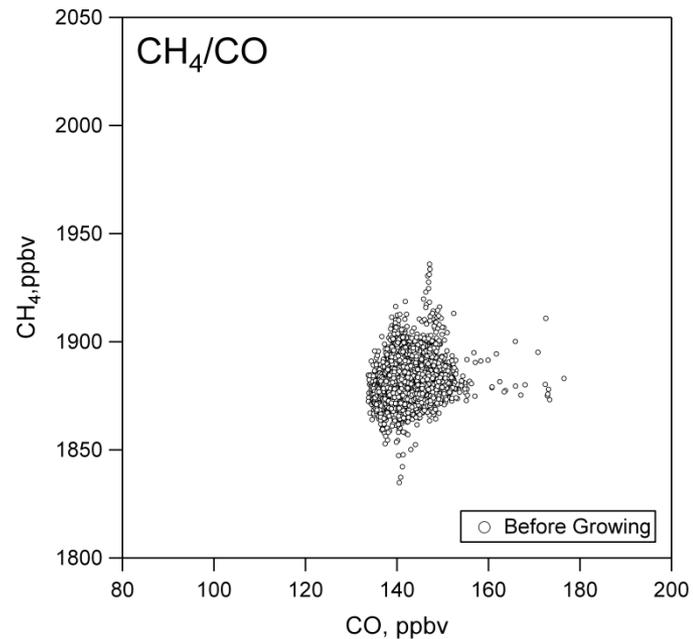
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# CH<sub>4</sub> emission from Sacramento Valley rice crops

Two weeks later – fields all flooded

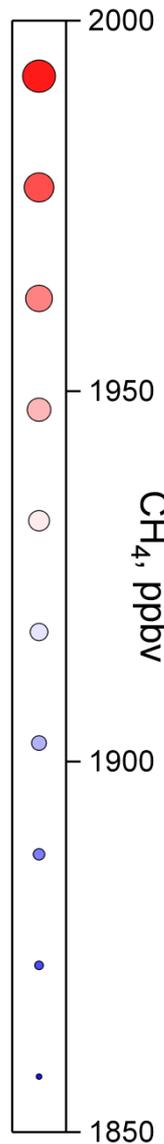
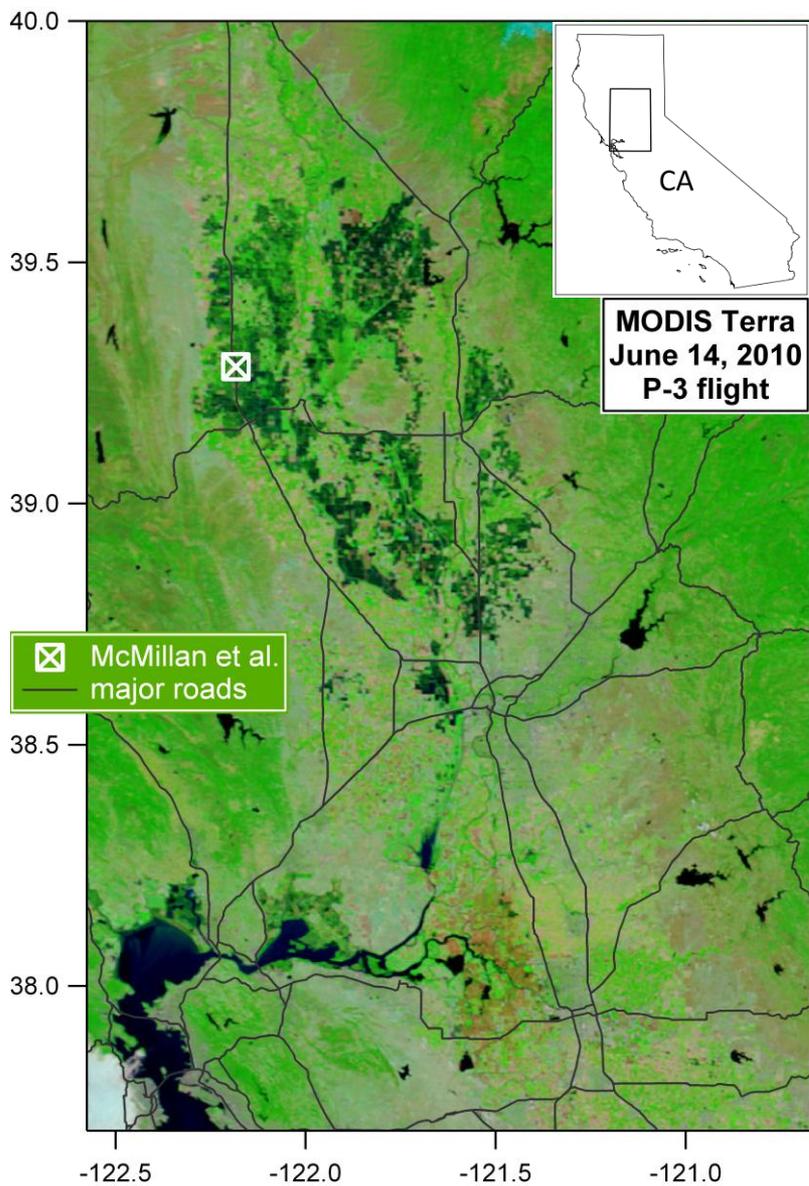


• no P-3 flight

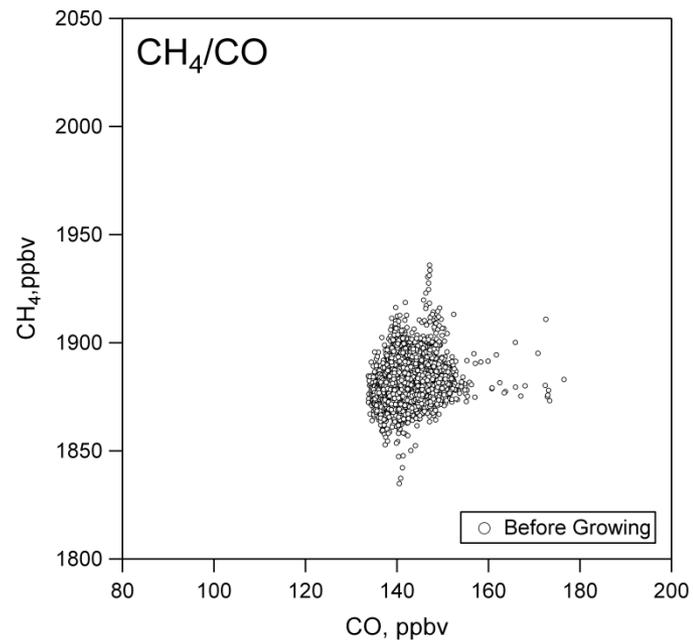


# CH<sub>4</sub> emission from Sacramento Valley rice crops

## One month later – rice growing phase

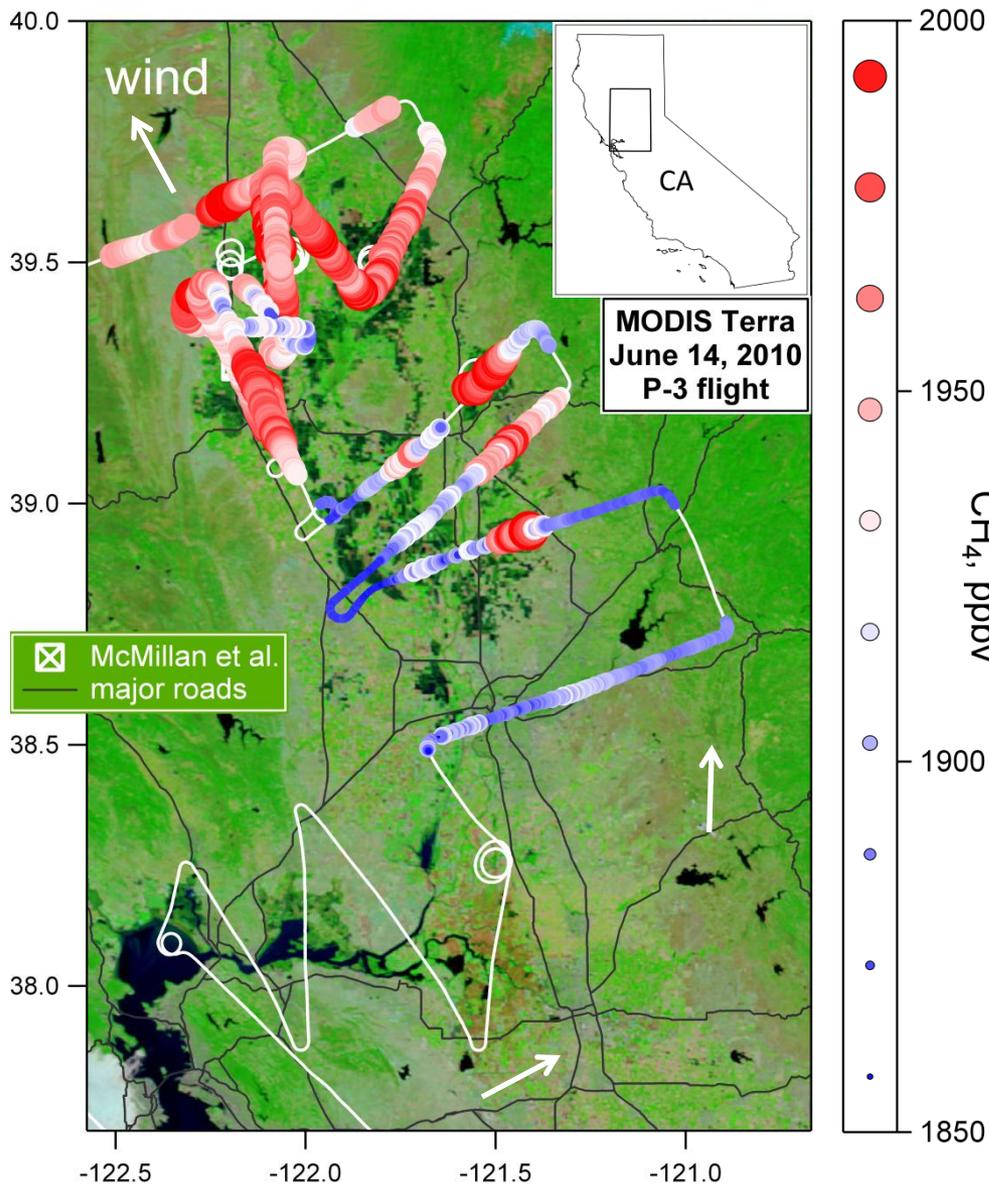


- satellite shows rice actually growing

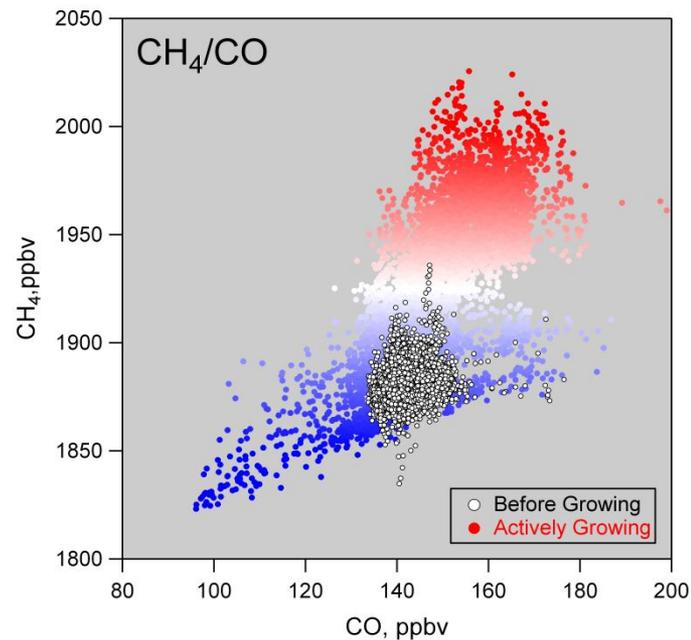


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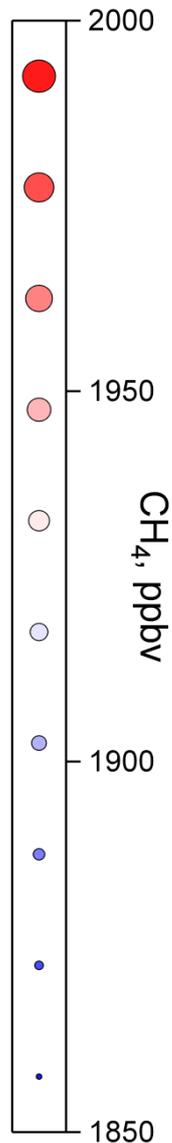
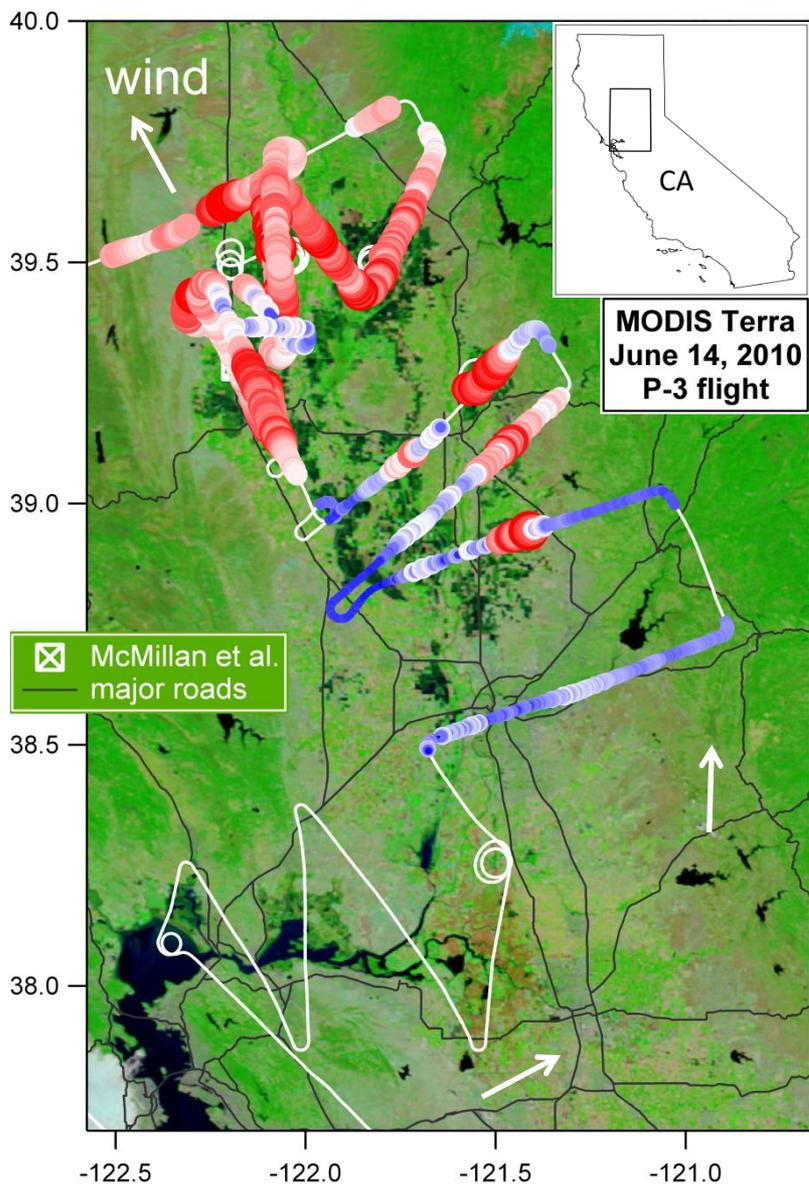


- same scale as before growing phase
- data from 1:30 to 4 pm PDT

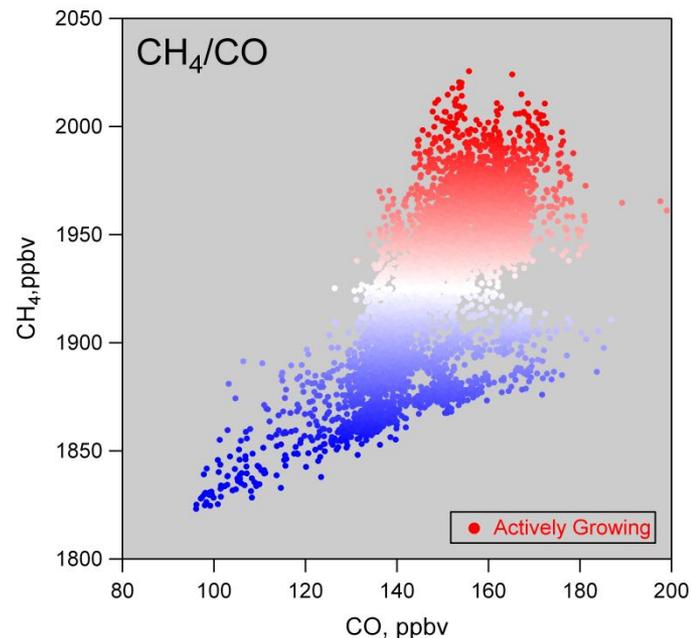


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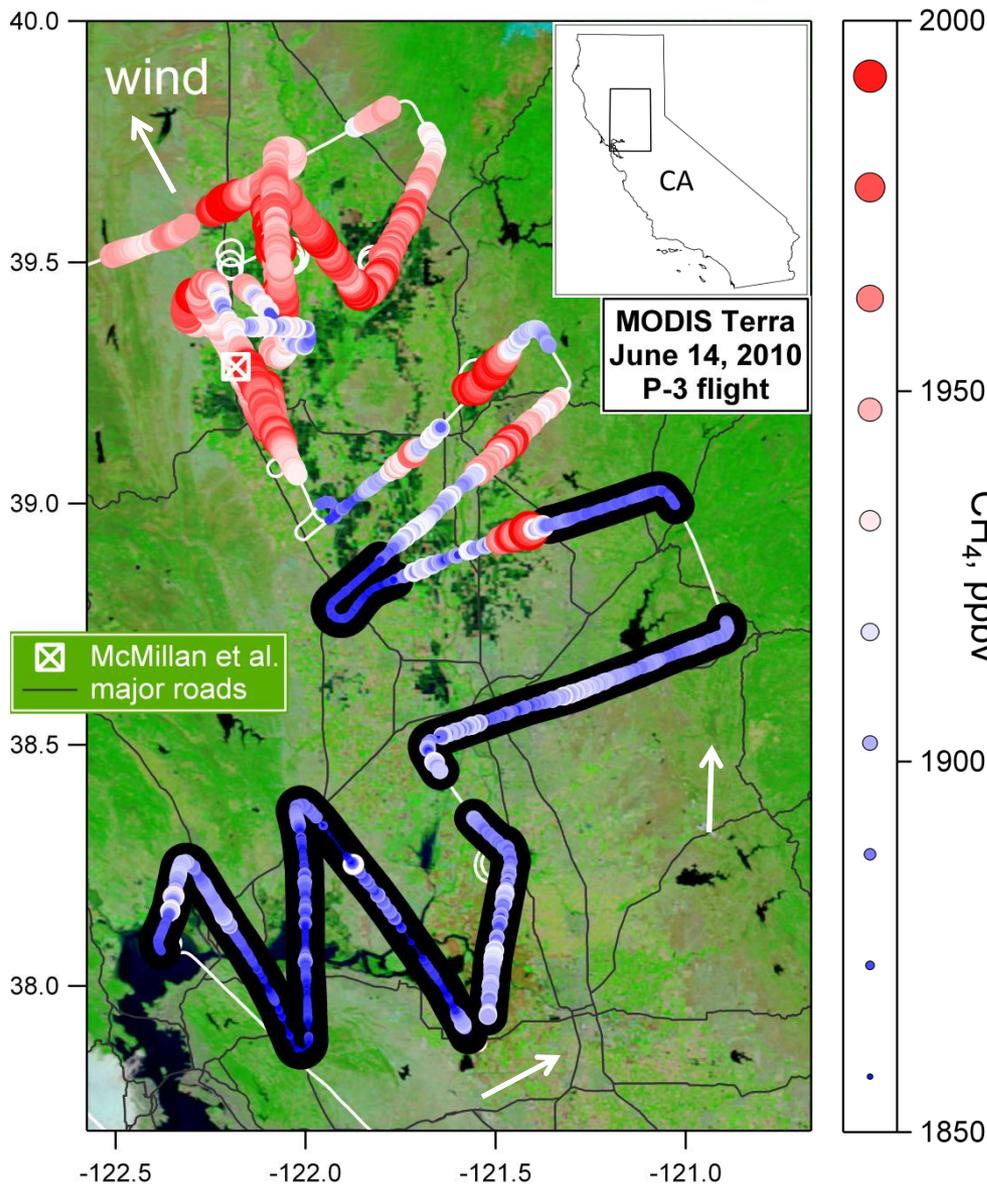


using June 14<sup>th</sup> data only:

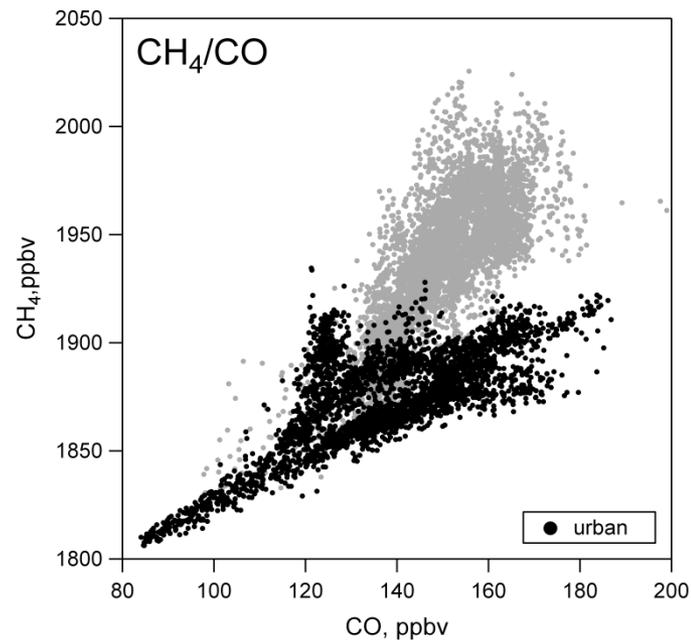
- use correlation with CO to remove urban CH<sub>4</sub> contribution
- compare CH<sub>4</sub> emissions to McMillan

# CH<sub>4</sub> emission from Sacramento Valley rice crops

## Upwind of rice fields

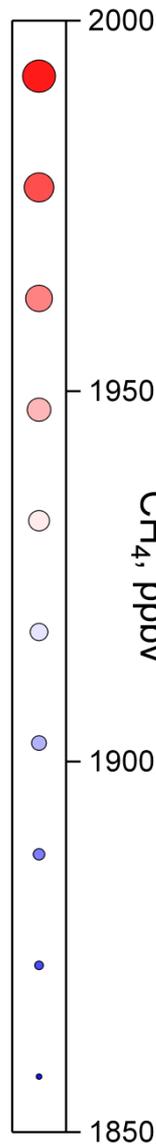
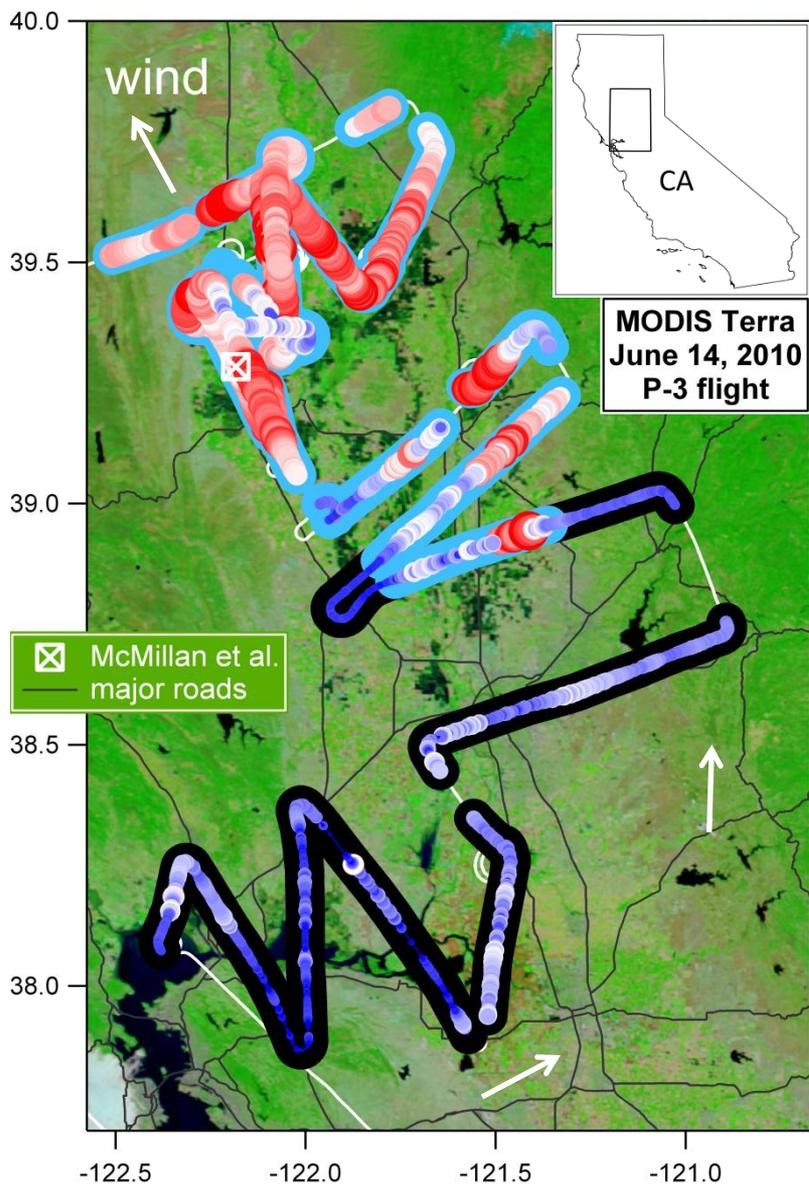


1. urban & other non-rice
- 2.

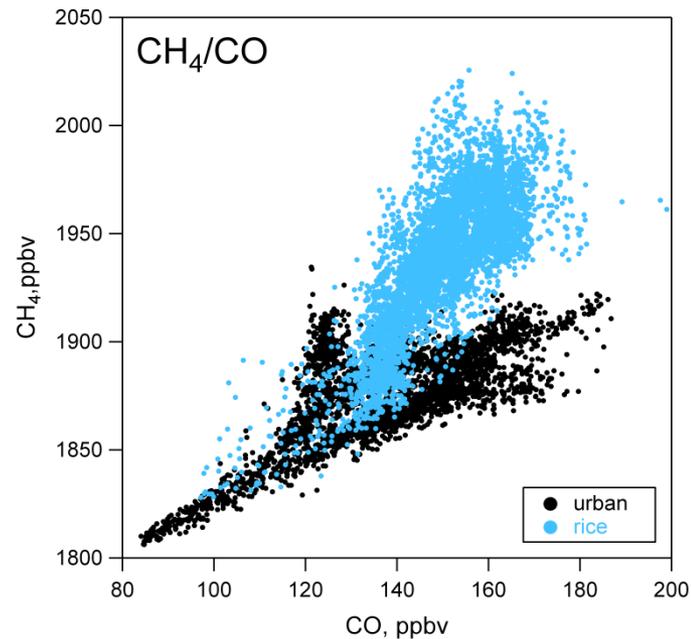


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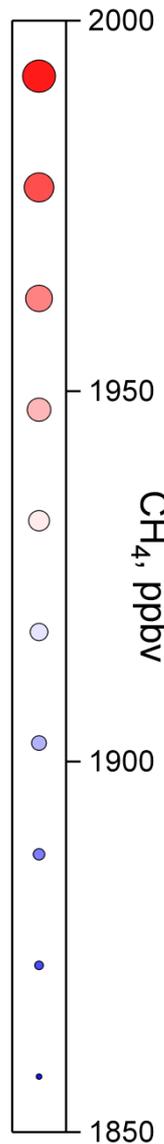
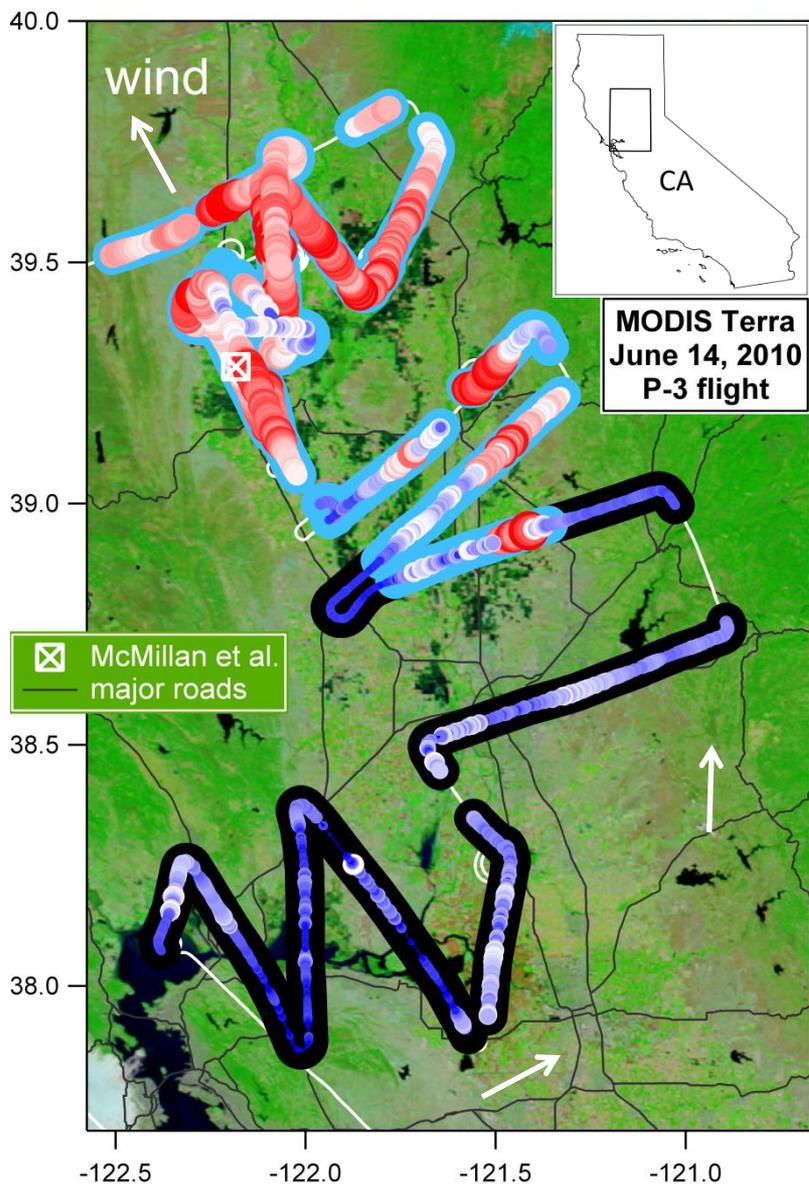


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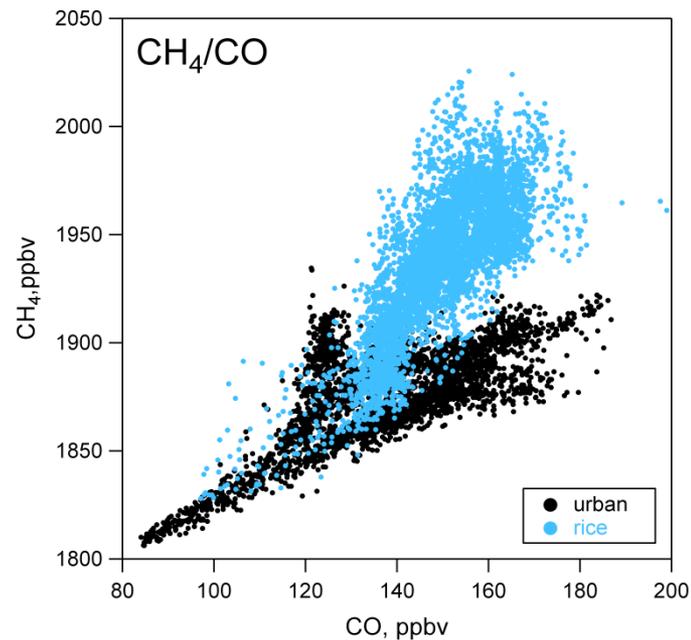


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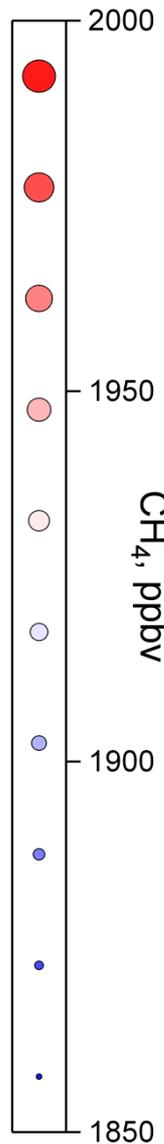
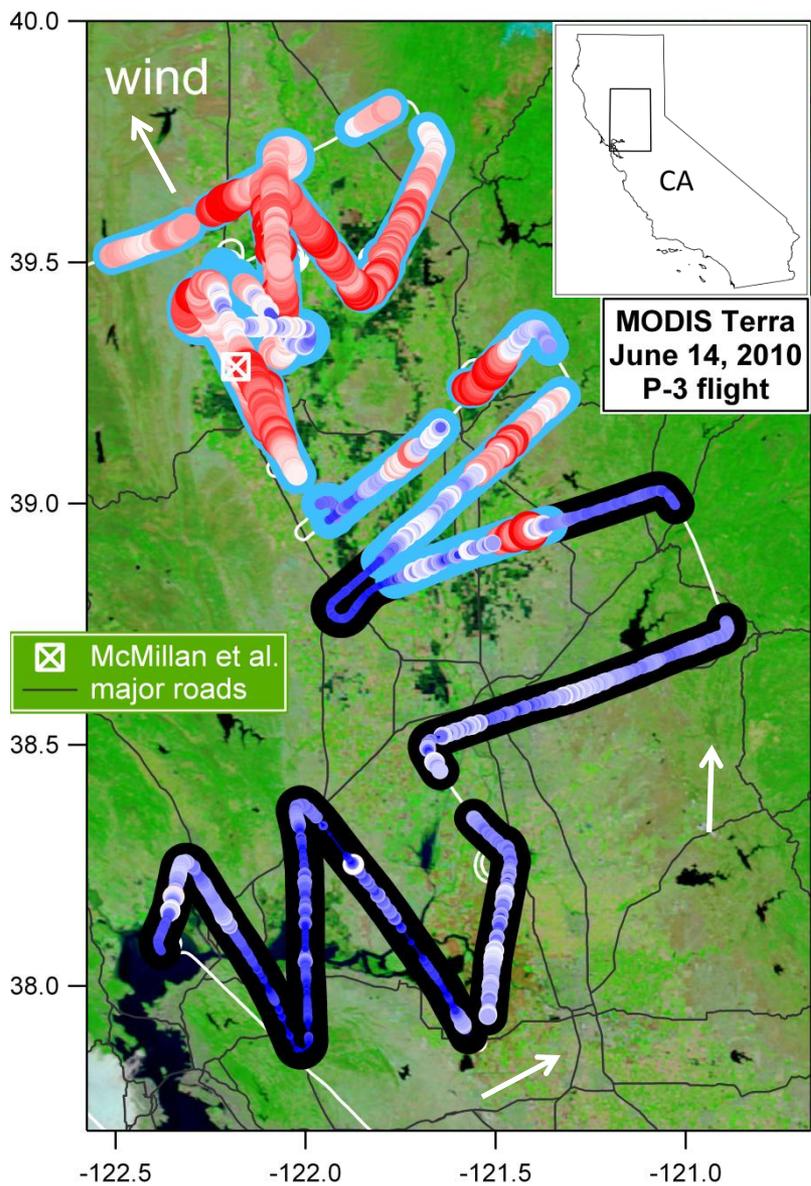
1. urban & other non-rice
2. rice



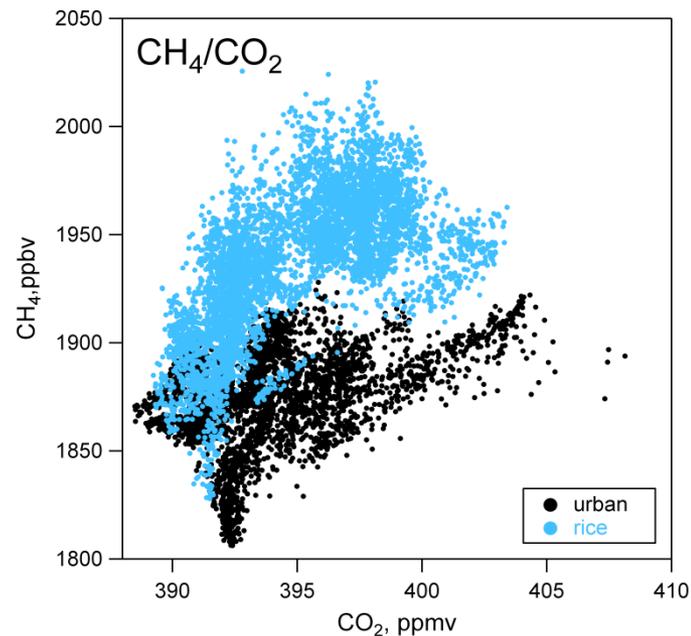
Compare to McMillan: CH<sub>4</sub> and CO<sub>2</sub>

# CH<sub>4</sub> emission from Sacramento Valley rice crops

## CH<sub>4</sub> from rice



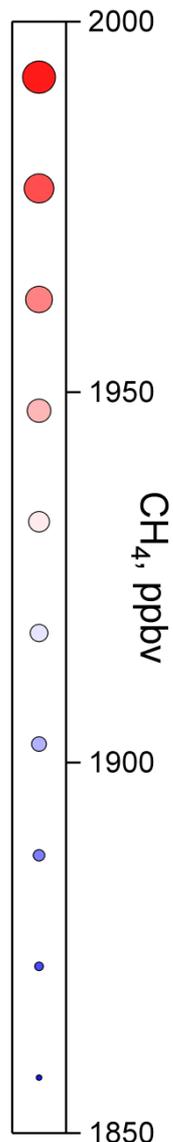
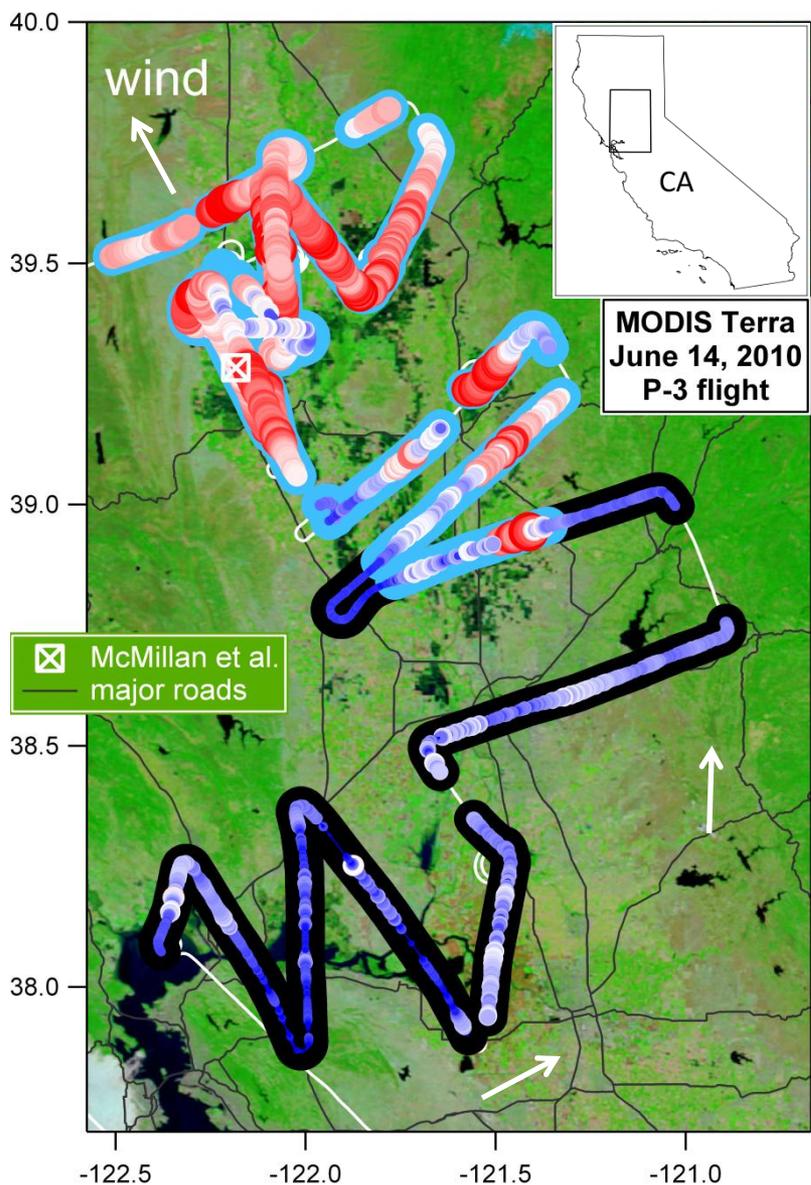
1. urban & other non-rice
2. rice



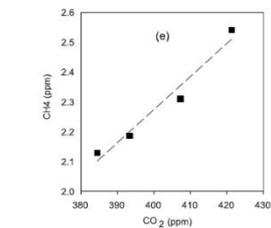
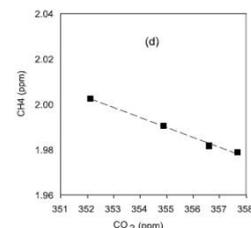
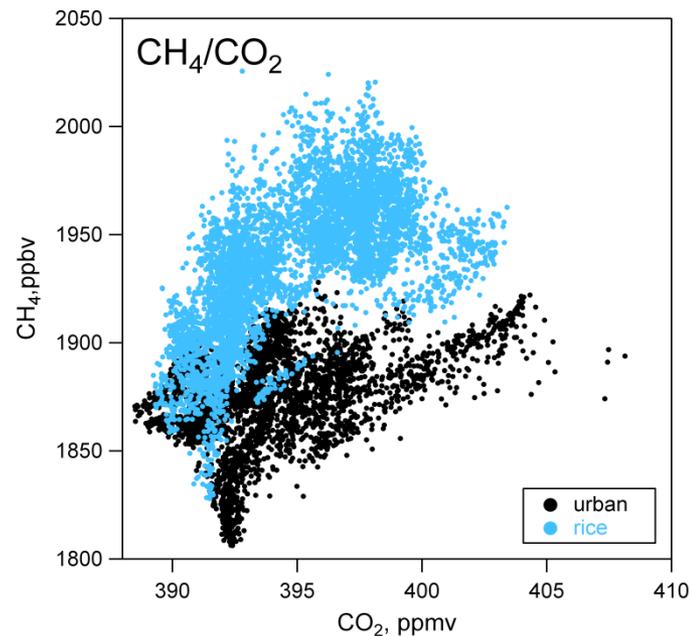
Compare to McMillan: CH<sub>4</sub> and CO<sub>2</sub>

# CH<sub>4</sub> emission from Sacramento Valley rice crops

## CH<sub>4</sub> from rice



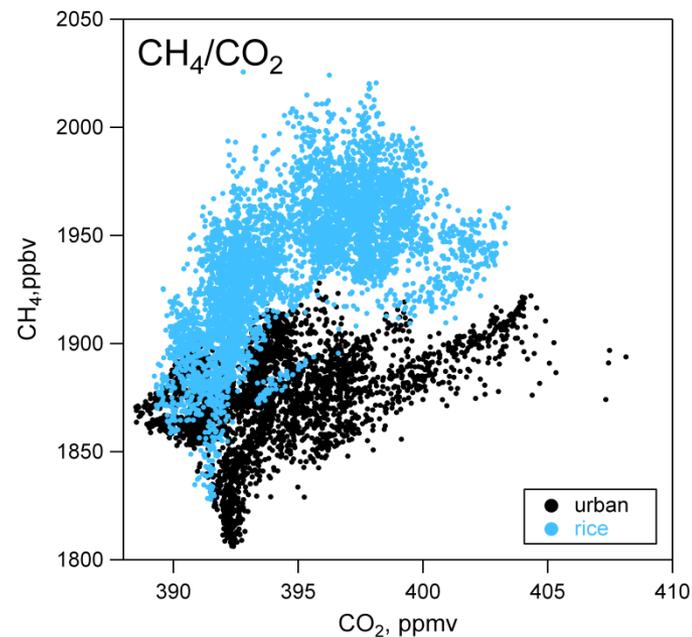
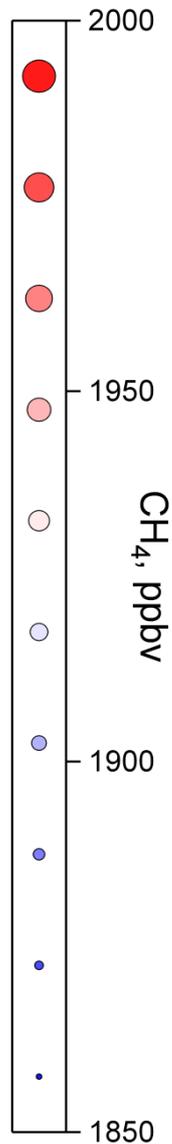
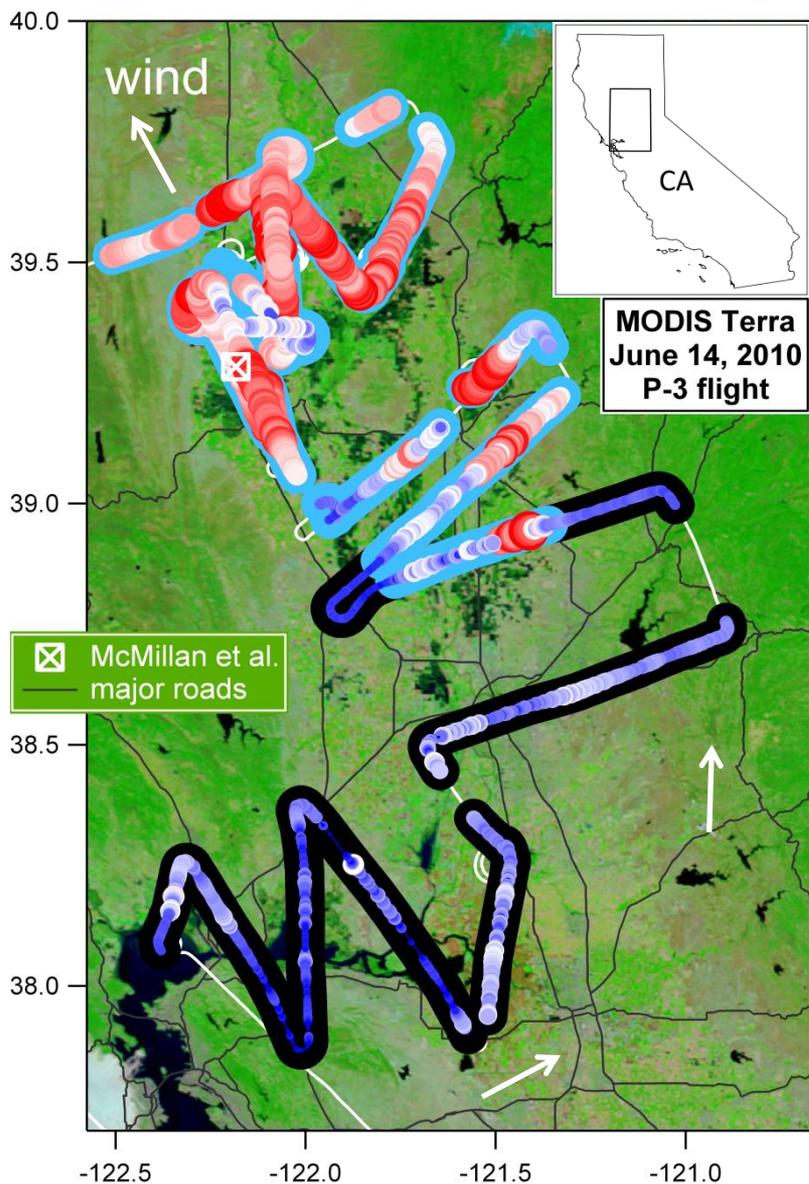
1. urban & other non-rice
2. rice



Compare to McMillan: CH<sub>4</sub> and CO<sub>2</sub>

# CH<sub>4</sub> emission from Sacramento Valley rice crops

## CH<sub>4</sub> from rice

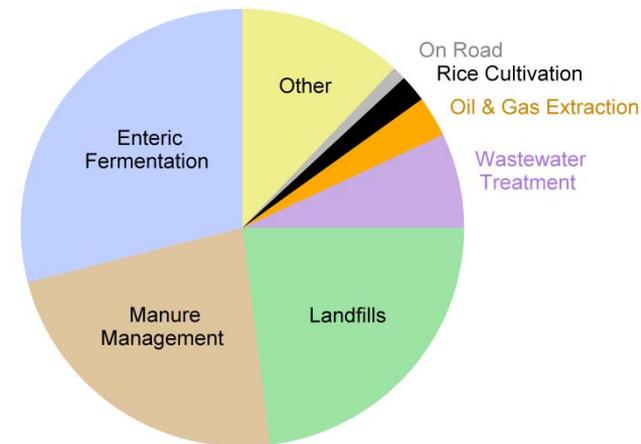
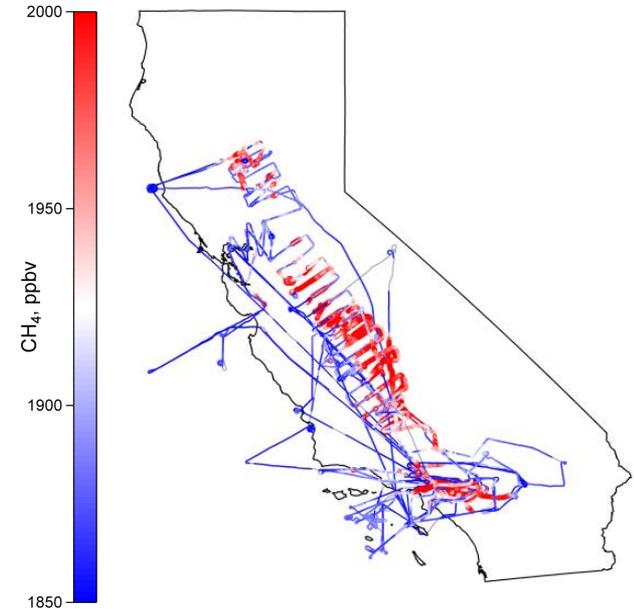


Further analysis of CO<sub>2</sub> and CH<sub>4</sub> from photosynthesis, respiration, and other sources and sinks:

- Inverse modeling – NOAA
- Transport modeling – Wofsy group, e.g. see Santoni et al. (next)

# Summary

- We can clearly see CH<sub>4</sub> point and area sources in P-3 data: rice, dairies, and the mix of sources in the L.A. Basin. Future analysis will try to quantify CH<sub>4</sub> contribution from these sources.
- ARB criteria pollutants emissions inventory ratio of CH<sub>4</sub>/CO in the L.A. Basin significantly lower than observations
- Data over rice fields provides spatial data, along with other data sets:
  - QCLS data from CalNex (Wofsy group)
  - NOAA ESRL GMD/LBNL light aircraft (C. Sweeney, A. Karion, M. Fischer)
  - NASA ARCTAS-CARB (G. Diskin, G. Sachse, S. Vay)to constrain inverse (NOAA) and STILT (Wofsy) models



# CH<sub>4</sub>/CO<sub>2</sub>

