Some Stories from CalNex 2010 Field Study

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7 August 2014

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University of Colorado

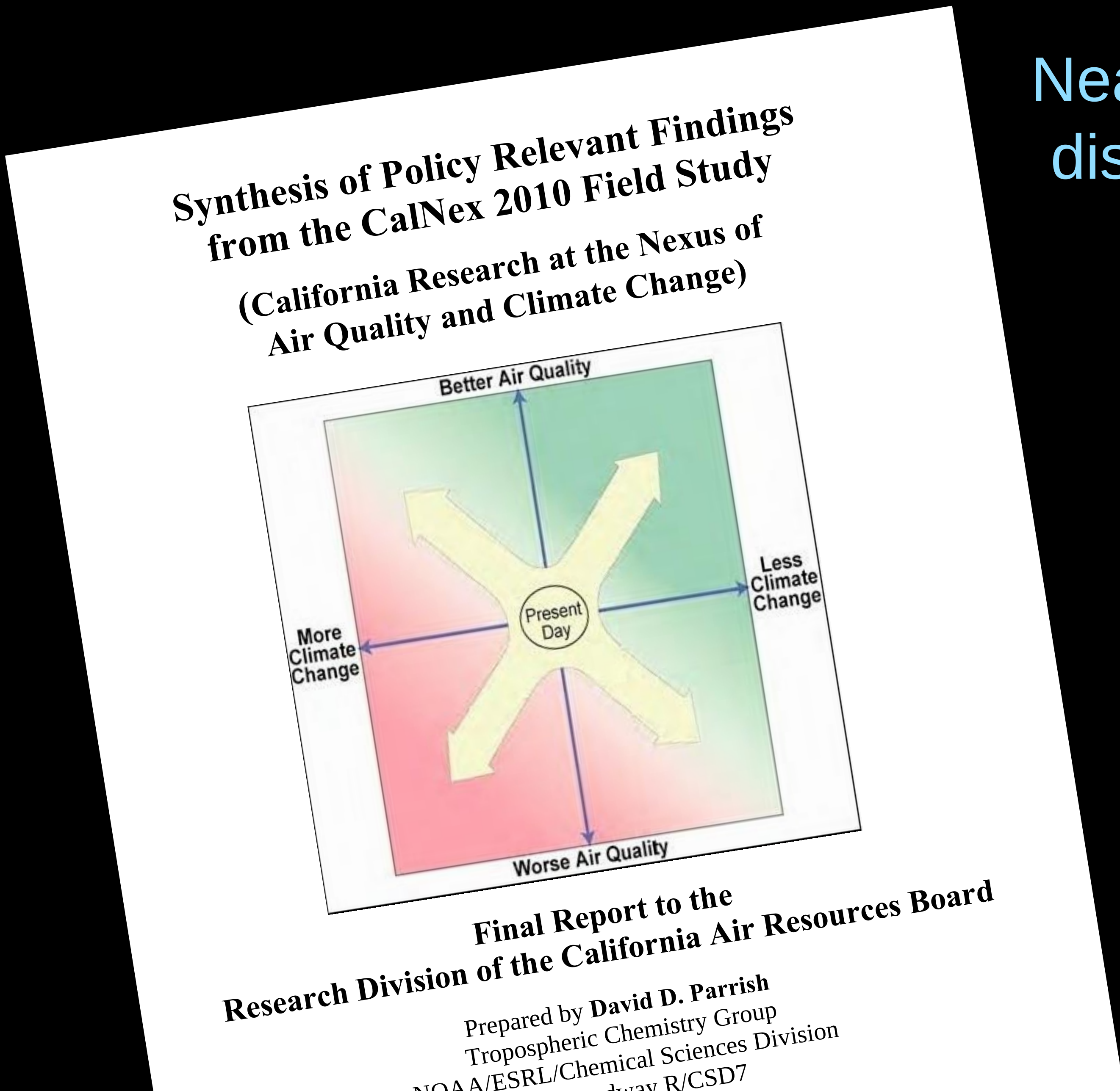
CalNex 2010 Field Study:
May - June, 2010

Some Stories from CalNex 2010 Field Study

1. Sources of methane (CH_4) emissions in California
2. Role of long-range pollutant transport in California
3. SJVAB vs. SoCAB Response to emission controls

Warning!!! Don't expect complete, final stories

CalNex Synthesis Completed



Synthesis of Policy Relevant Findings from the CalNex 2010 Field Study

(California Research at the Nexus of Air Quality and Climate Change)

Better Air Quality

More Climate Change

Present Day

Less Climate Change

Worse Air Quality

Final Report to the Research Division of the California Air Resources Board

Prepared by **David D. Parrish**
Tropospheric Chemistry Group
NOAA/ESRL/Chemical Sciences Division

Nearly everything discussed today is in here!

Available at:
http://esrl.noaa.gov/csd/projects/calnex/synthesisreport.pdf

CalNex Synthesis Completed

Synthesizes scientific results and implications of CalNex 2010 Field Study into clear language that policy-makers can use effectively

A substantial body of scientific publications have resulted from the study http://tinyurl.com/CalNex-papers

- 93 papers originally "promised"
- 106 papers published & in press (14 different journals)
- 6 other papers submitted

Special Section organized in *J. Geophys. Res. – Atmospheres*

Synthesis organized around CalNex Science Questions

1. Sources of methane (CH_4) emissions in California

SoCAB – Landfills, dairies and natural gas

(Peischl, J., et al. (2013), Quantifying sources of methane using light alkanes in the Los Angeles basin, California, *J. Geophys. Res. Atmos., 118*, 4974–4990, doi:10.1002/jgrd.50413.)

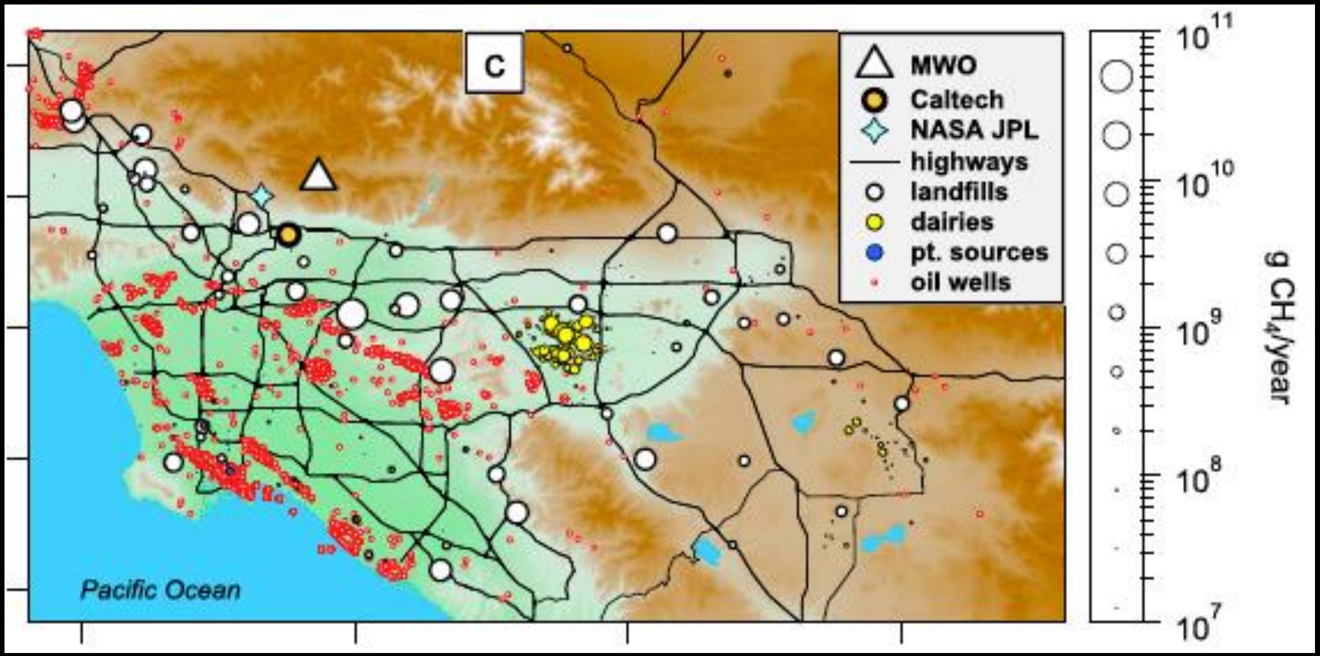
Sacramento Valley - Rice agriculture

(Peischl, J., et al. (2012), Airborne observations of methane emissions from rice cultivation in the Sacramento Valley of California, *J. Geophys. Res., 117*, D00V25, doi:10.1029/2012JD017994.)

SJVAB – Petroleum operations and dairies

(Gentner, D.R., et al. (2014), Emissions of organic carbon and methane from petroleum and dairy operations in California's San Joaquin Valley, *Atmos. Chem. Phys., 14*, 4955–4978, doi:10.5194/acp-14-4955-2014.)

1. Sources of methane (CH_4) emissions in California - SoCAB



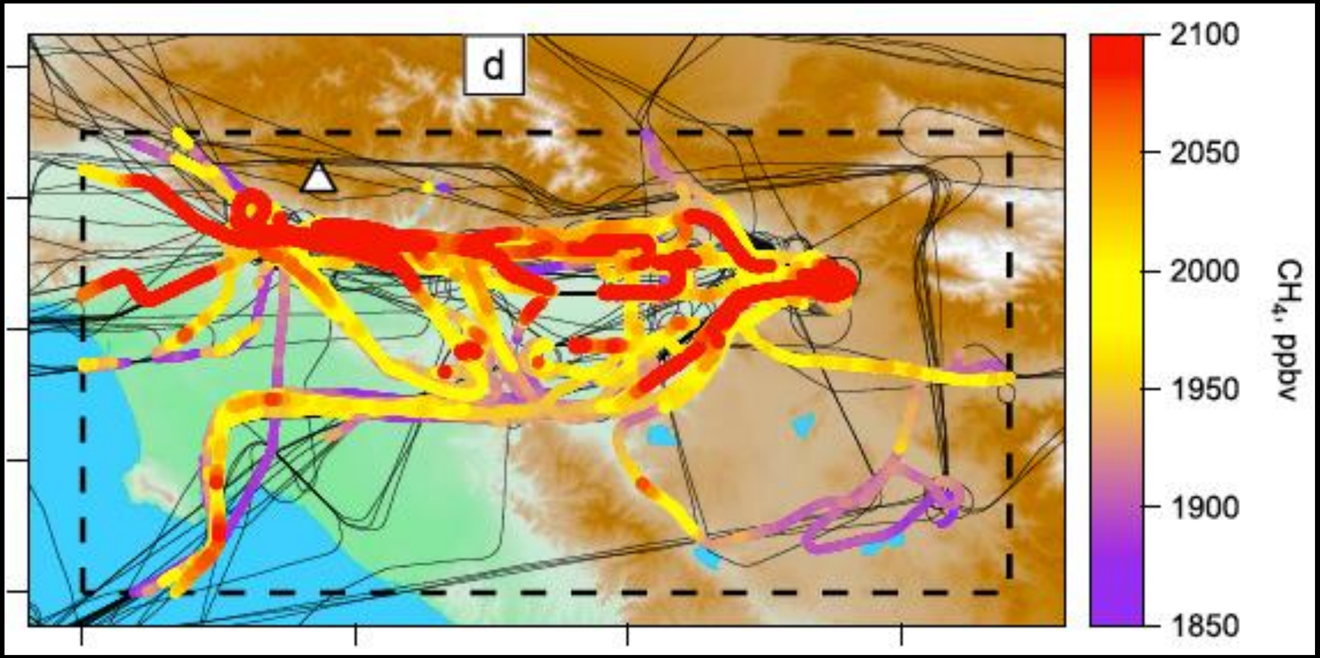
WMO = Mount Wilson Observatory (white triangle)

Complicated – many potential sources

- Natural gas – distribution system, local production, natural seeps.
- Landfills, dairies, mobile sources, waste water treatment.

Peischl et al., *J. Geophys. Res.*, 2013

1. Sources of methane (CH_4) emissions in California - SoCAB



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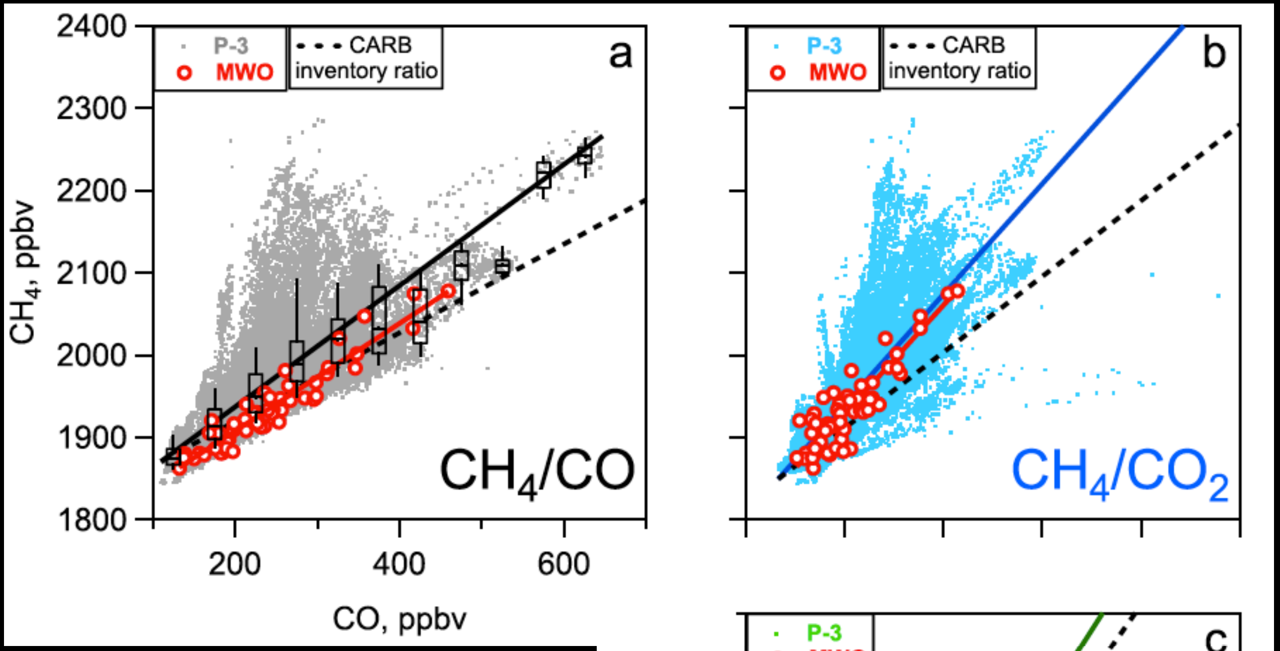
Data from 16 daytime NOAA P-3 aircraft flights plus canisters collected at WMO

Peischl et al., *J. Geophys. Res.*, 2013

1. Sources of methane (CH_4) emissions in California - SoCAB

Correlation of CH_4 with CO and CO_2, plus CO and CO_2 emission inventories allow total CH_4 emission estimate:

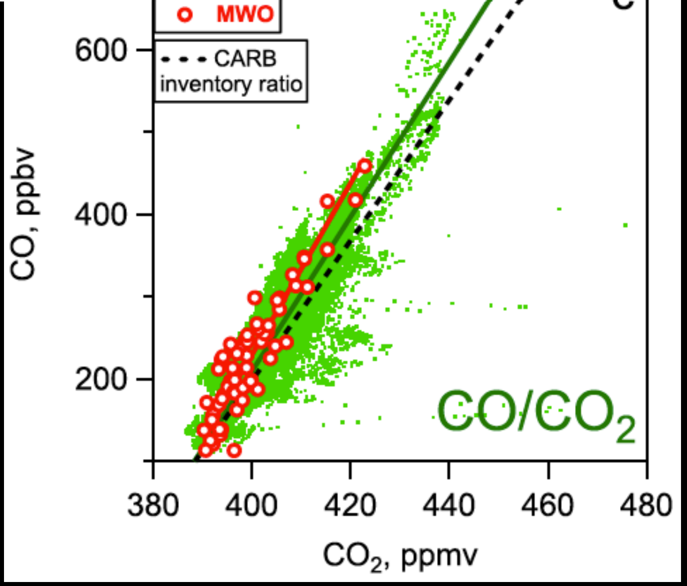
410 ± 40 Gg CH_4/yr from SoCAB



Significantly larger than 301 Gg CH_4/yr in CARB 2009 GHG emission inventory

Consistent with *Wunch et al.*, 2009; *Hsu et al.*, 2010 and *Wennberg et al.*, 2012

What source is responsible for discrepancy?



Peischl et al., *J. Geophys. Res.*, 2013

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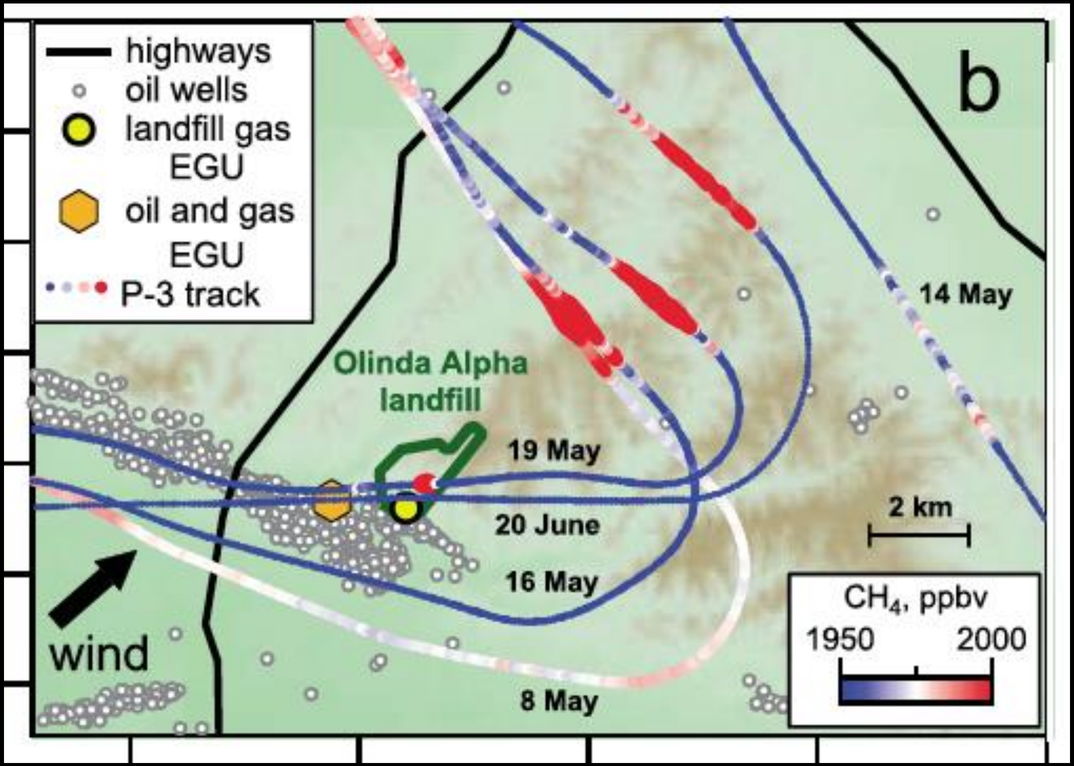

Fly through plumes downwind of landfills

CH_4 data plus boundary layer height and wind speed and direction allows absolute flux to be calculated.

Peischl et al., *J. Geophys. Res.*, 2013

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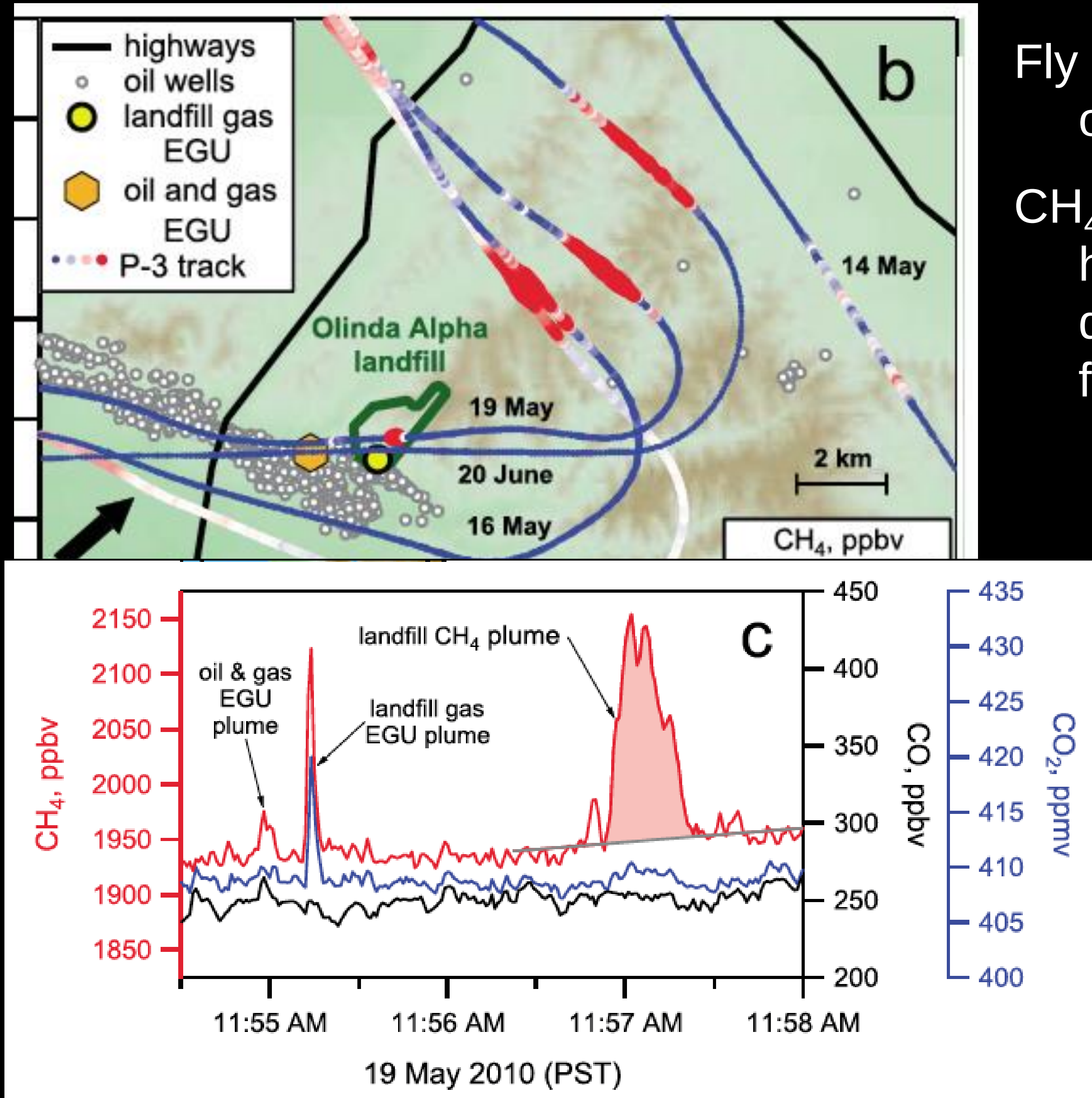

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Co-measurement of CO_2 allows plume from landfill to be isolated from other sources.

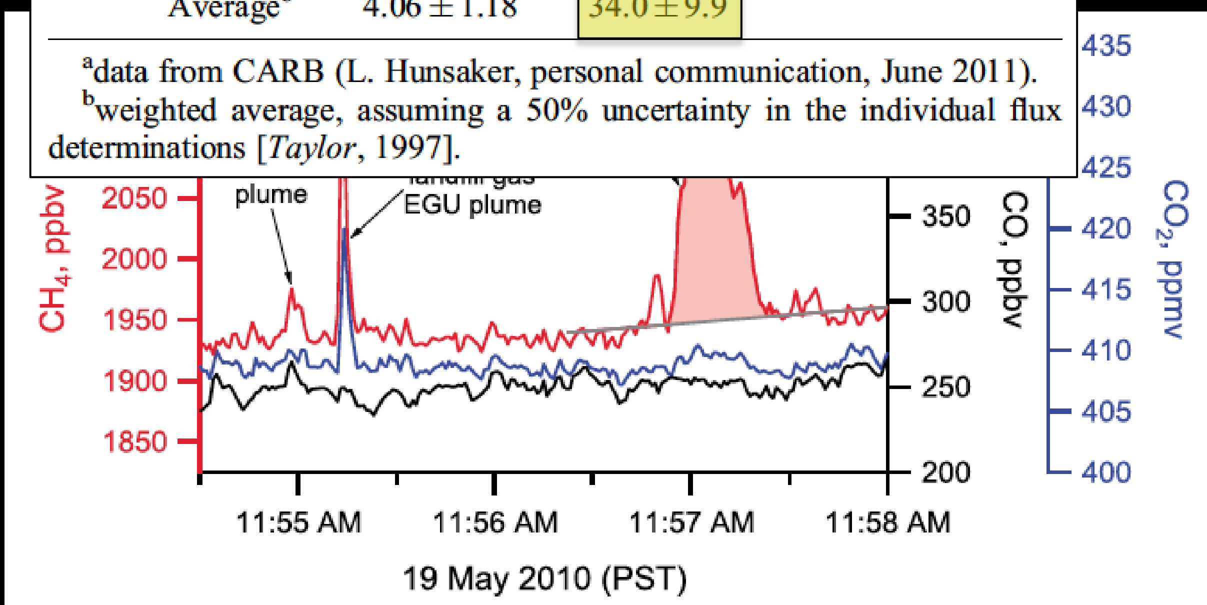
Peischl et al., *J. Geophys. Res.*, 2013

1. Sources of methane (CH_4) emissions in California - SoCAB

Table 3. Landfill Emission Fluxes Determined Aboard the NOAA P-3 in 2010 From Downwind Plume Transects

Landfill	Transect Date	Flux (10^{25} molecules/s)	Flux (Gg/yr)	2008 CARB GHG Inventory[a] (Gg/yr)
Olinda	8 May	1.13	9.5	11.0
Alpha	14 May	1.45	12.2	
	16 May	1.74	14.6	
	19 May	1.61	13.5	
	20 June	2.90	24.3	
	Average[b]	1.49 ± 0.35	12.5 ± 2.9	
Puente	8 May	4.29	36.0	38.8
Hills	19 May	3.62	30.4	
	20 June	4.48	37.6	
	Average[b]	4.06 ± 1.18	34.0 ± 9.9	

[a]data from CARB (L. Hunsaker, personal communication, June 2011).
[b]weighted average, assuming a 50% uncertainty in the individual flux determinations [*Taylor*, 1997].



Fly through plumes downwind of landfills

CH_4 data plus boundary layer height and wind speed and direction allows absolute flux to be calculated.

Co-measurement of CO_2 allows plume from landfill to be isolated from other sources.

Excellent agreement with CARB 2008 GHG emission inventory!

Peischl et al., *J. Geophys. Res.*, 2013

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Fly through plumes downwind of landfills

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Co-measurement of CO_2 allows plume from landfill to be isolated from other sources.

Dairies: Emissions/cow x population of cows, plus manure management considerations.

Landfills plus dairies = 182 ± 54 Gg CH_4/yr

Total from SoCAB = 410 ± 40 Gg CH_4/yr

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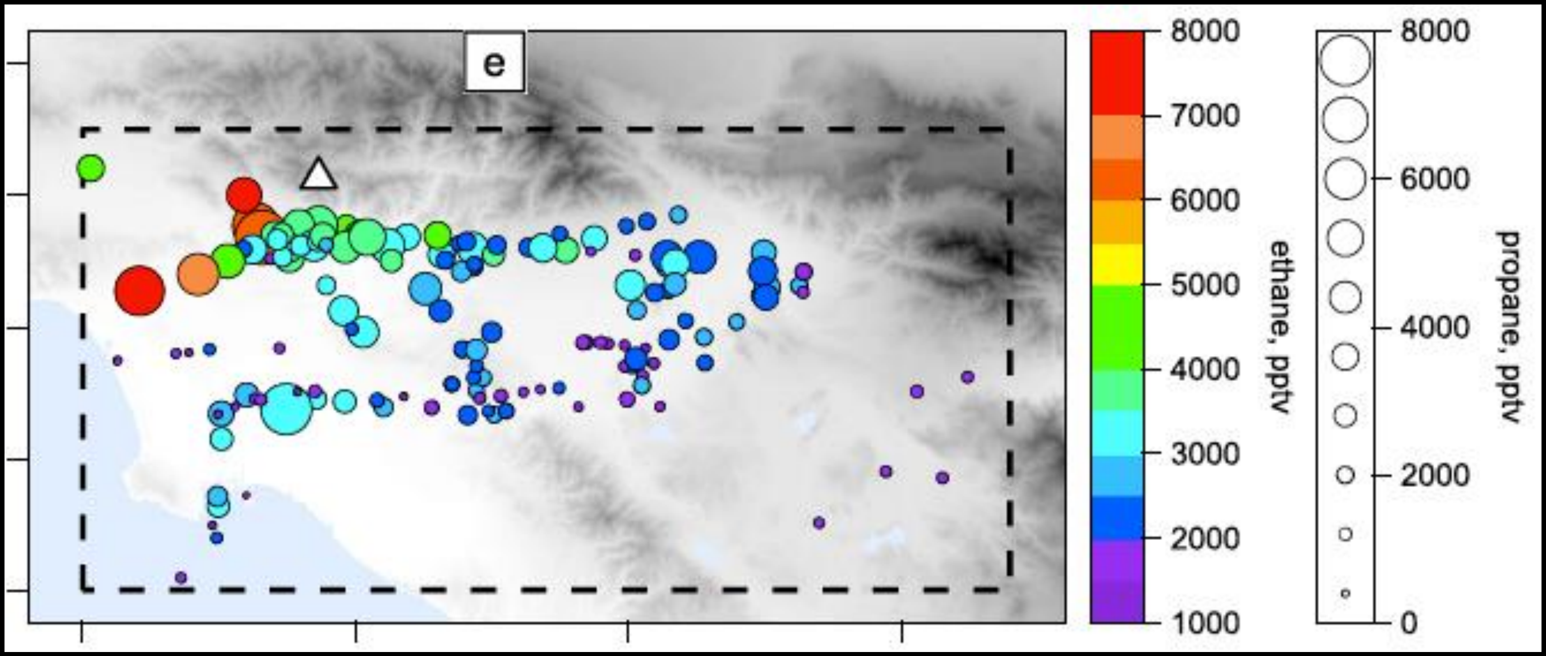

Source apportionment based on light alkane measurements

Peischl et al., *J. Geophys. Res.*, 2013

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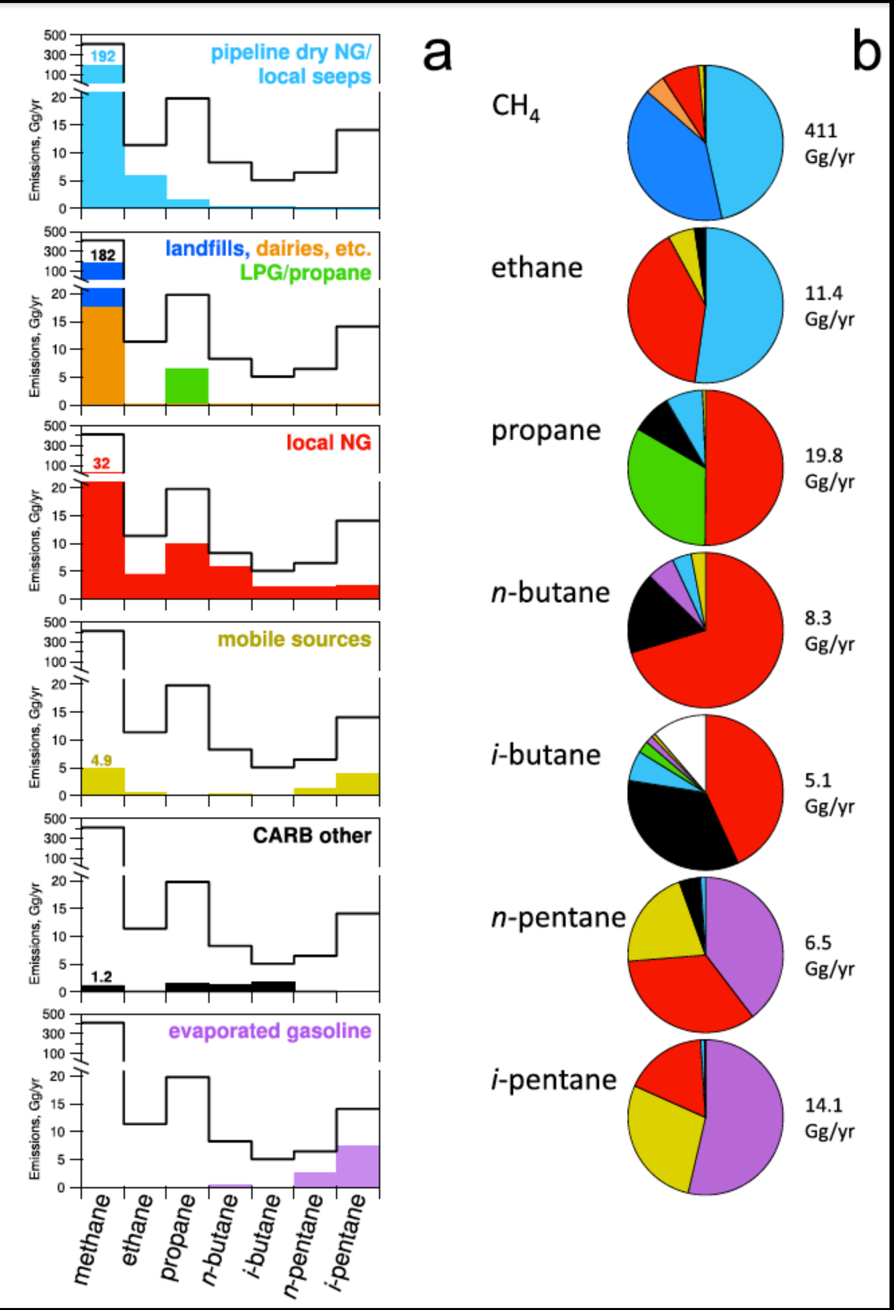
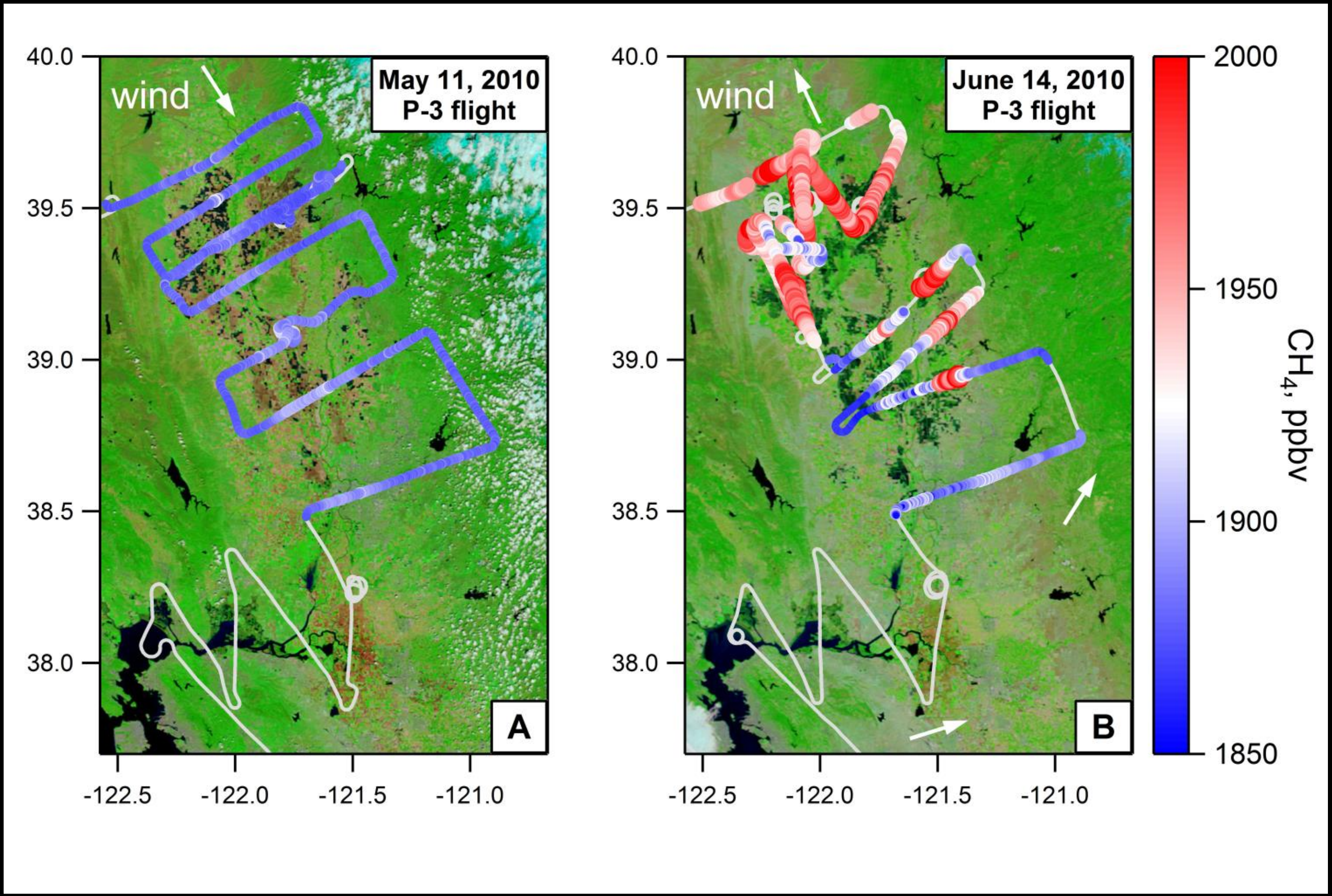


Source	Gg/yr in 2010
Natural gas distribution, Local seeps	192 ± 54
Landfills, Dairies, Wastewater	182 ± 54
Natural gas production	32 ± 7
Mobile sources	4.9 ± 1.3
CARB other	1.2 ± 0.3
Total	411 ± 77

Source apportionment based on light alkane measurements

Peischl et al., *J. Geophys. Res.*, 2013

1. Sources of methane (CH_4) emissions in California – Rice agriculture in Sacramento Valley



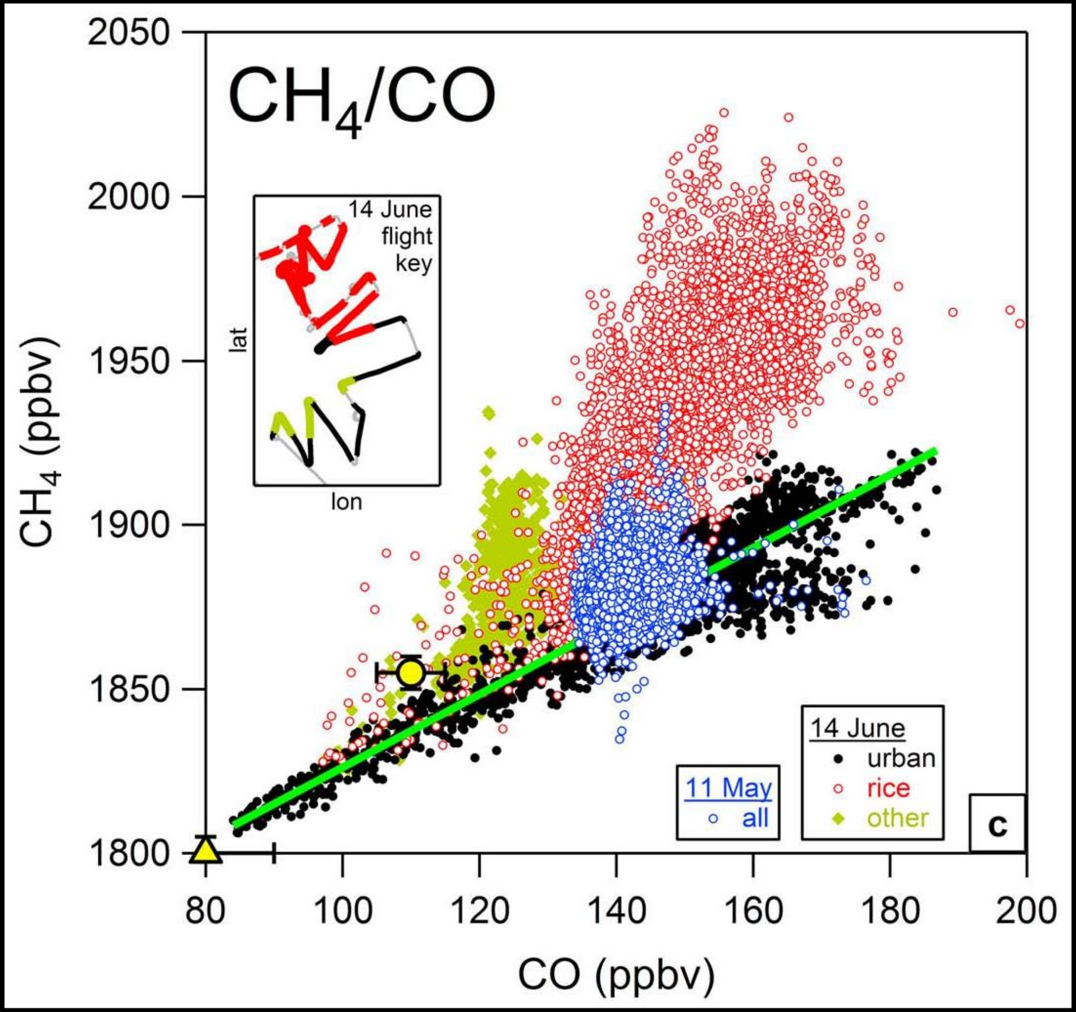
Two flights in Sacramento Valley:

- May 11 before rice fields flooded,
- June 14 after rice was growing

Peischl et al., *J. Geophys. Res.*, 2012

1. Sources of methane (CH_4) emissions in California – Rice agriculture in Sacramento Valley

Complex relationship between urban, biomass burning and agricultural emissions of CO, CO_2 and CH_4.



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Peischl et al., *J. Geophys. Res.*, 2012

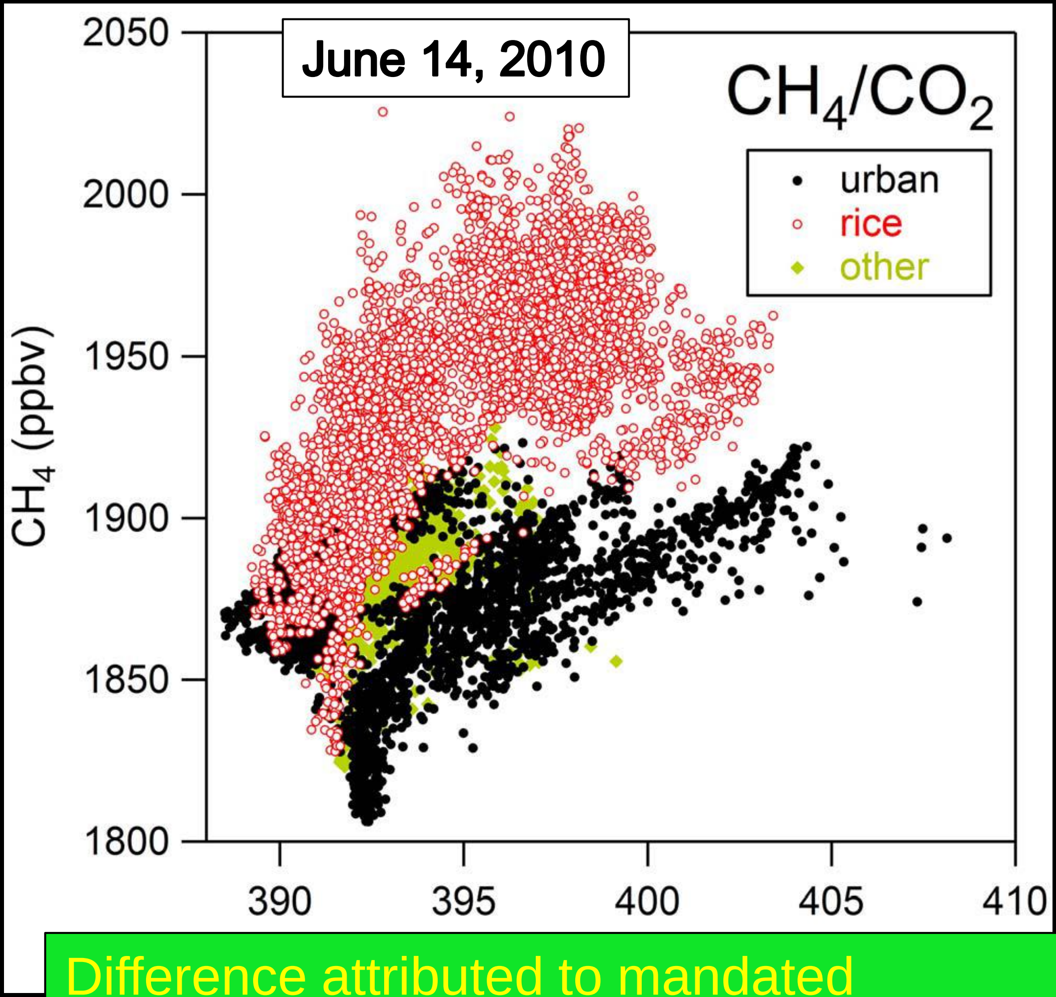
1. Sources of methane (CH_4) emissions in California – Rice agriculture in Sacramento Valley

Complex relationship between urban, biomass burning and agricultural emissions of CO, CO_2 and CH_4.

~ 0.6% of CO_2 uptake by photosynthesis was released as CH_4.

Findings of *McMillan et al.* [2007] are representative of the Sacramento Valley rice growing region.

Emissions approximately 3 times the CARB GHG inventory rate of 122 kg/ha.



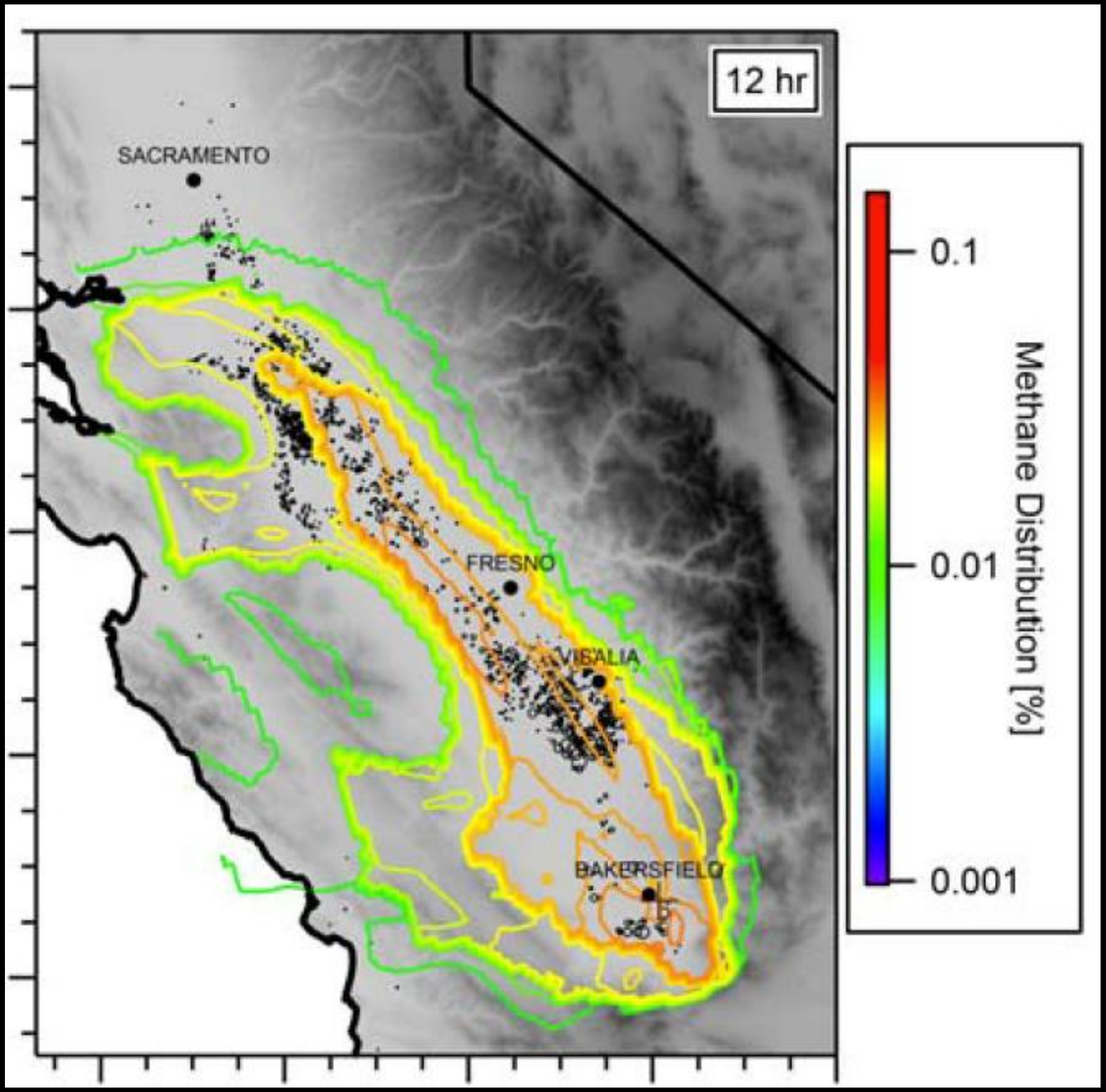
Difference attributed to mandated decrease of crop residue burning – Win for air quality - Lose for climate change.

Peischl et al., *J. Geophys. Res.*, 2012

1. Sources of methane (CH_4) emissions in California - SJVAB

- Back trajectory tracer model derives "foot print" of methane emissions – points to dairies rather than oil and gas activities as major methane source

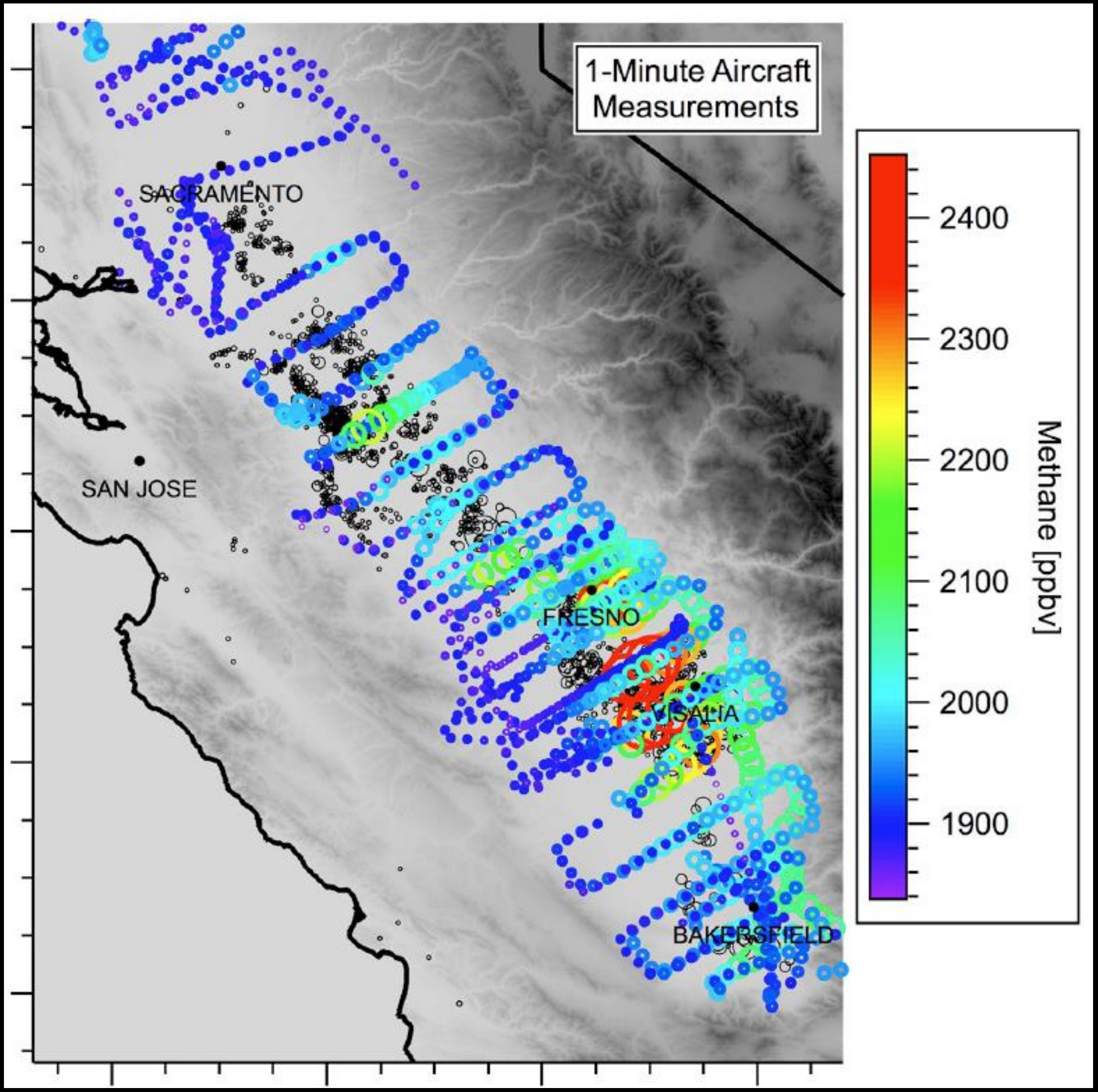
- Large sources of paraffinic hydrocarbons from petroleum, but CH_4 not included. Fugitive emissions of condensate (residual natural gas after methane and ethane removed).



Gentner et al., *Atmos. Chem. Phys*, 2014

1. Sources of methane (CH_4) emissions in California - SJVAB

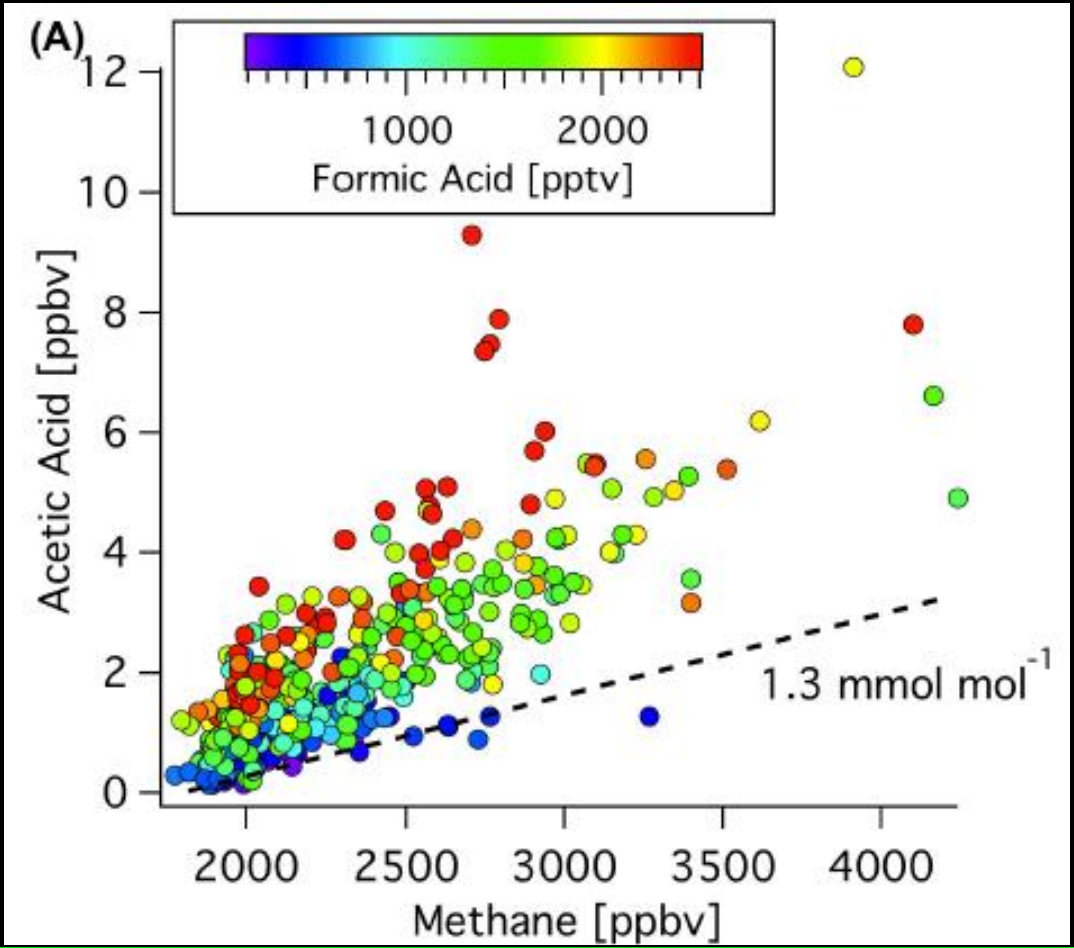
Aircraft measurements also find elevated CH_4 concentrations primarily over dairies.



Gentner et al., *Atmos. Chem. Phys*, 2014

1. Sources of methane (CH_4) emissions in California - SJVAB

Bakersfield measurements:
Elevated CH_4 correlates with oxygenated VOCs (species emitted from dairies) rather than alkanes from oil and gas production.



Dairy operations are responsible for the vast majority of CH_4 emissions in the SJVAB.

Gentner et al., *Atmos. Chem. Phys*, 2014

2. Role of long-range pollutant transport in California

Layers of enhanced O_3 aloft are common

(Neuman, J. A., et al. (2012), Observations of ozone transport from the free troposphere to the Los Angeles basin, *J. Geophys. Res., 117*, D00V09, doi:10.1029/2011JD016919.)

Mixing of stratospheric O_3 to surface has significant impact

(Langford, A. O., et al. (2012), Stratospheric influence on surface ozone in the Los Angeles area during late spring and early summer of 2010, *J. Geophys. Res., 117*, D00V06, doi:10.1029/2011JD016766.)

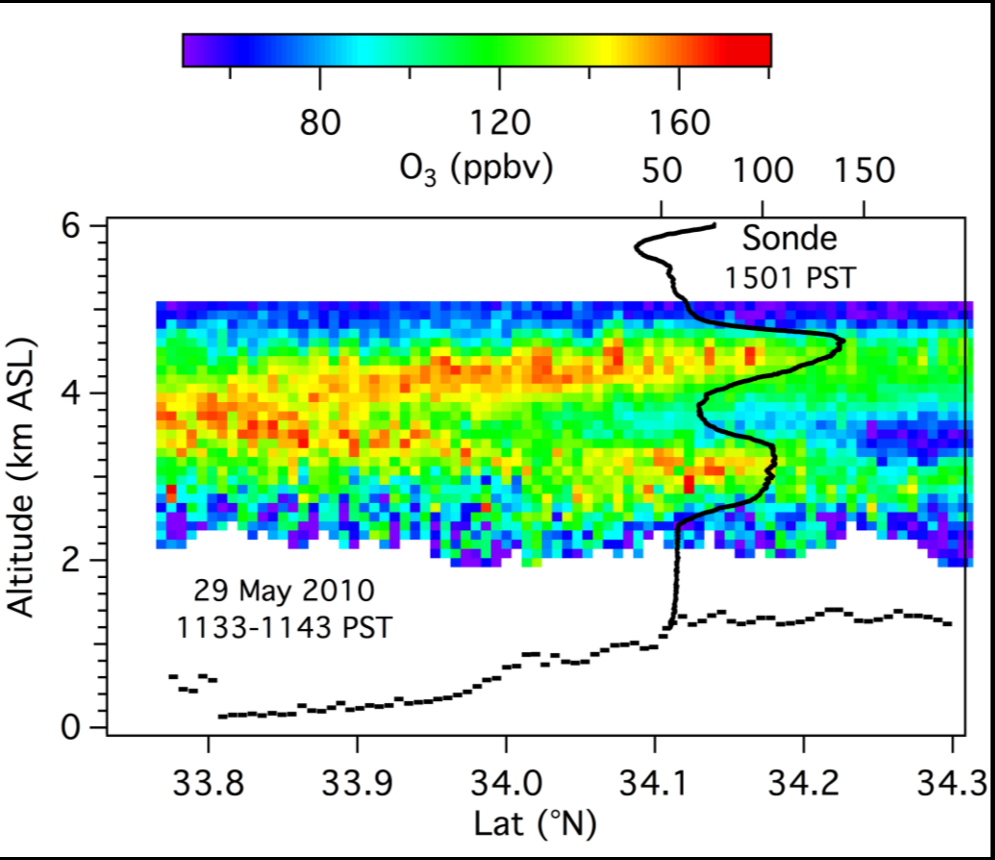
(Lin, M., et al. (2012), Springtime high surface ozone events over the western United States: Quantifying the role of stratospheric intrusions, *J. Geophys. Res., 117*, D00V22, doi:10.1029/2012JD018151.)

California is also a source of transport to downwind areas.

(Langford, A. O., et al. (2010), Long-range transport of ozone from the Los Angeles Basin: A case study, *Geophys. Res. Lett., 37*, L06807, doi:10.1029/2010GL042507)

2. Role of long-range pollutant transport in California – Layers of enhanced O_3 aloft are common

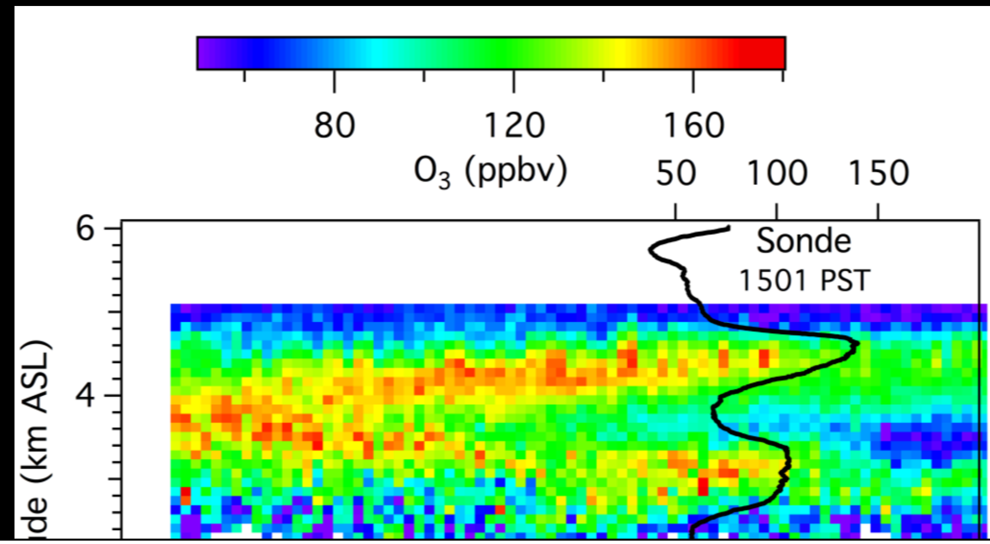
Layers from stratospheric O_3 descent, long-range transport of anthropogenic emissions (e.g., from Asia), and lofted aged regional pollution (e.g., from California urban areas).

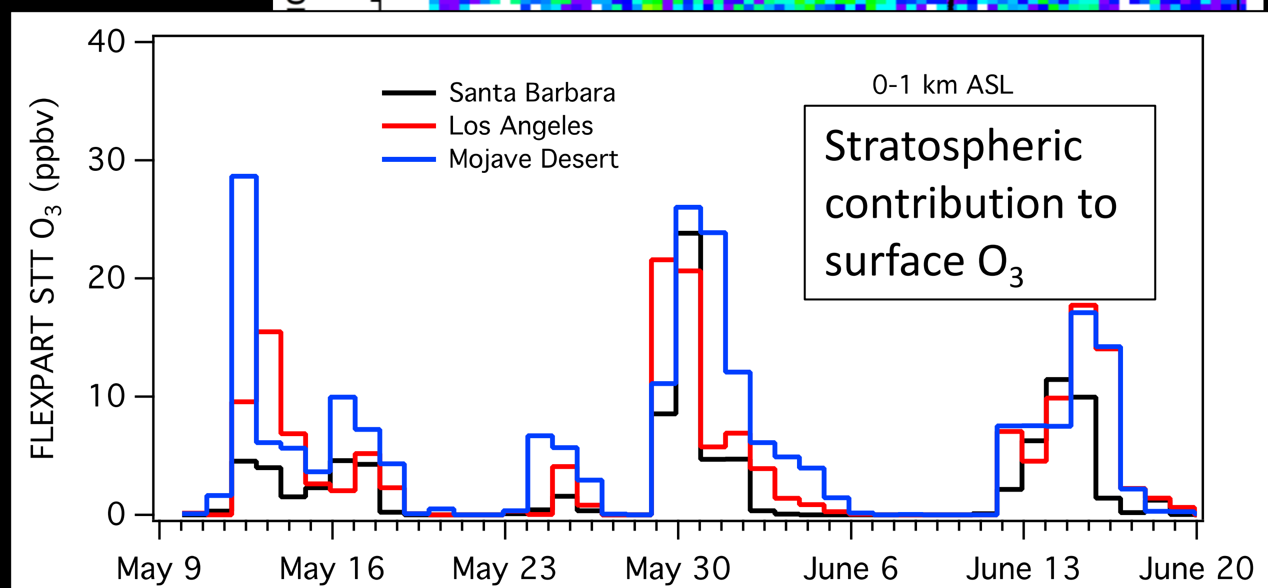


Langford et al., *J. Geophys. Res.*, 2012

2. Role of long-range pollutant transport in California – Mixing of stratospheric O_3 to surface has significant impact

These layers are entrained into the convective boundary layer throughout California, thereby enhancing surface level ozone concentrations.





FLEXPART results (a Lagrangian particle dispersion model)

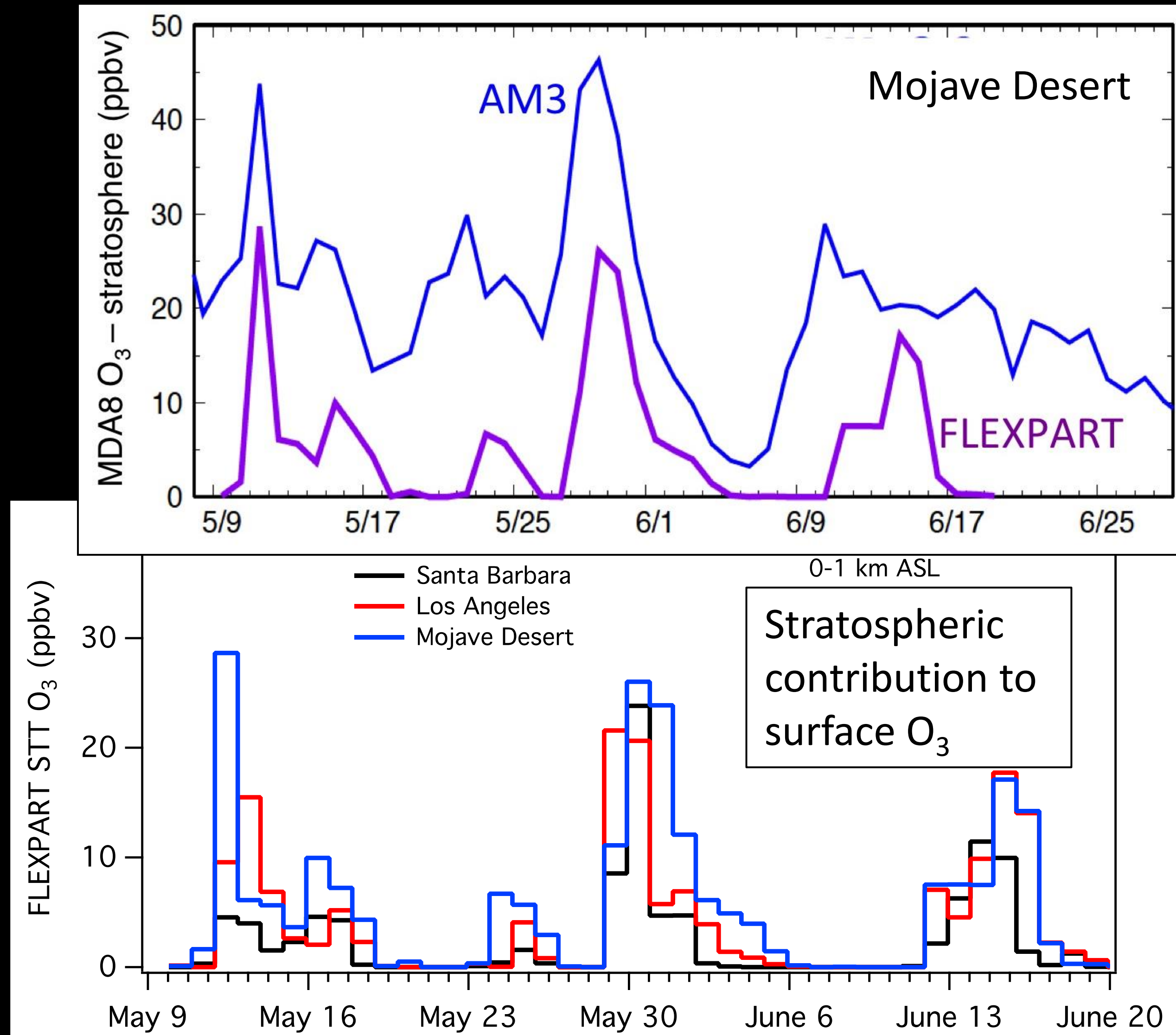
Langford et al., *J. Geophys. Res.*, 2012

2. Role of long-range pollutant transport in California – Mixing of stratospheric O_3 to surface has significant impact

Chemistry-transport model suggests that FLEXPART underestimates total stratospheric contribution.

Stratospheric O_3 is a major fraction of "background" O_3 coming into any urban or rural area

FLEXPART results (a Lagrangian particle dispersion model)



Lin et al., *J. Geophys. Res.*, 2012

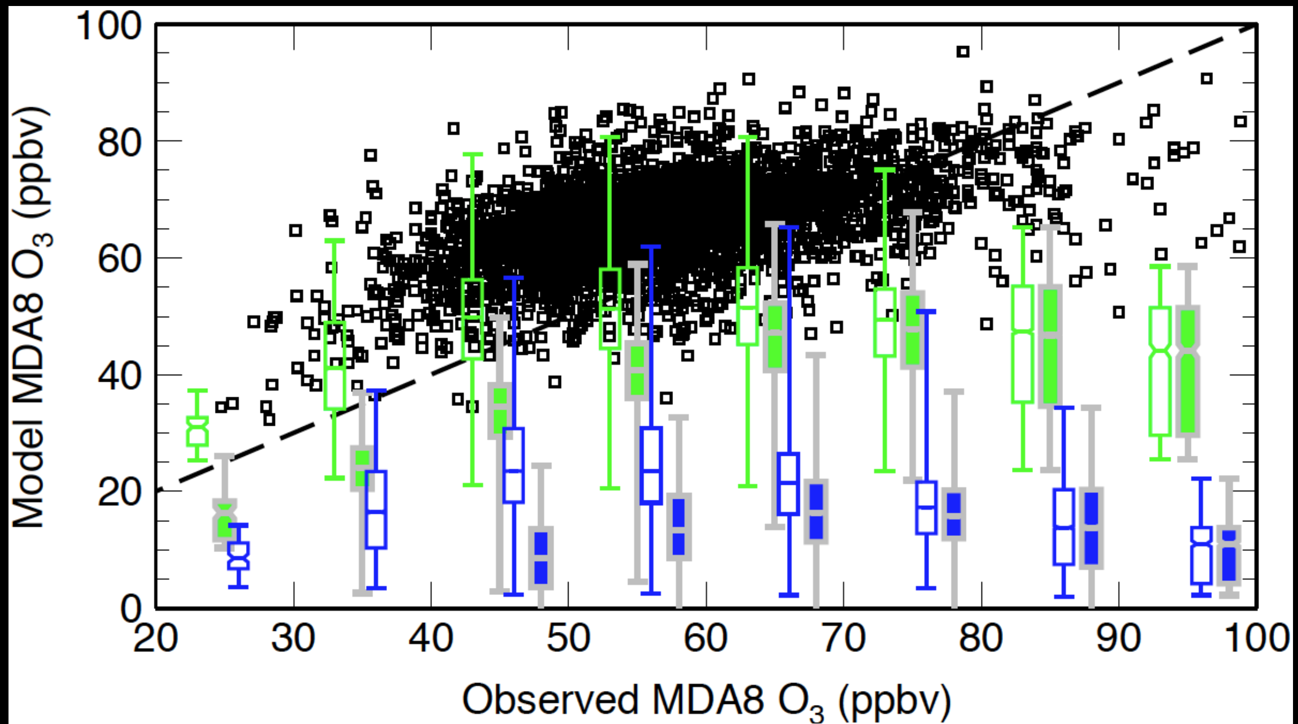
2. Role of long-range pollutant transport in California – Transport of baseline O_3 accounts for a majority of surface O_3 concentrations in California at urban as well as rural locations, both on average and during many exceedance events.

Chemistry-transport model results. (Filled boxes are bias corrected.)

PRB O_3 is green.

Stratospheric O_3 contribution is blue

During CalNex, contribution from Asian transport was small.



MDA8 surface O_3 for April–June 2010 at polluted sites in the densely populated regions of the Central Valley, Southern California, and Las Vegas, Nevada. The box-and-whisker plots give minimum, 25th, 50th, 75th percentiles, and maximum.

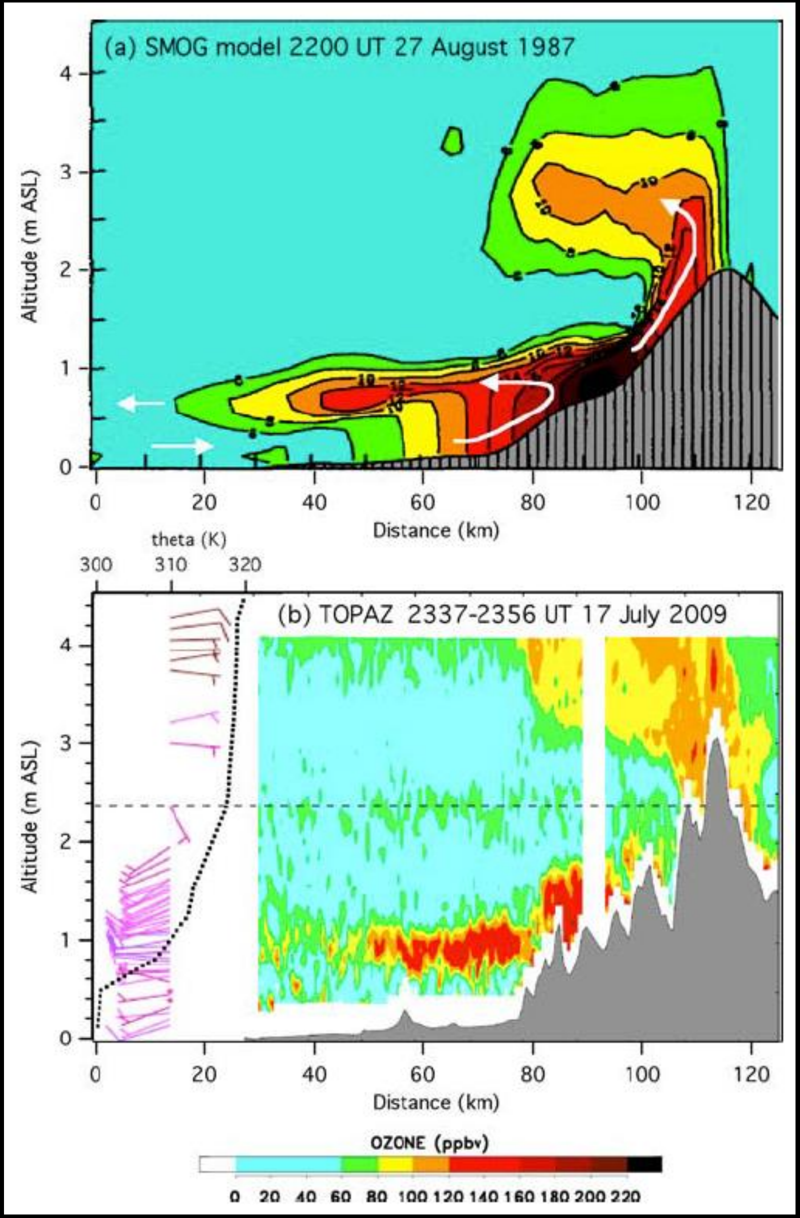
Lin et al., *J. Geophys. Res.*, 2012

2. Role of long-range pollutant transport in California – California is also a source of transport to downwind areas

Orographic lifting of O_3 from the surface to the free troposphere by the San Gabriel Mountains.

Lidar observations from 17 July 2009 (bottom) very similar to model calculations [*Lu and Turco,* 1996] for 27 August 1987 (top).

Subject to efficient transport in free troposphere.

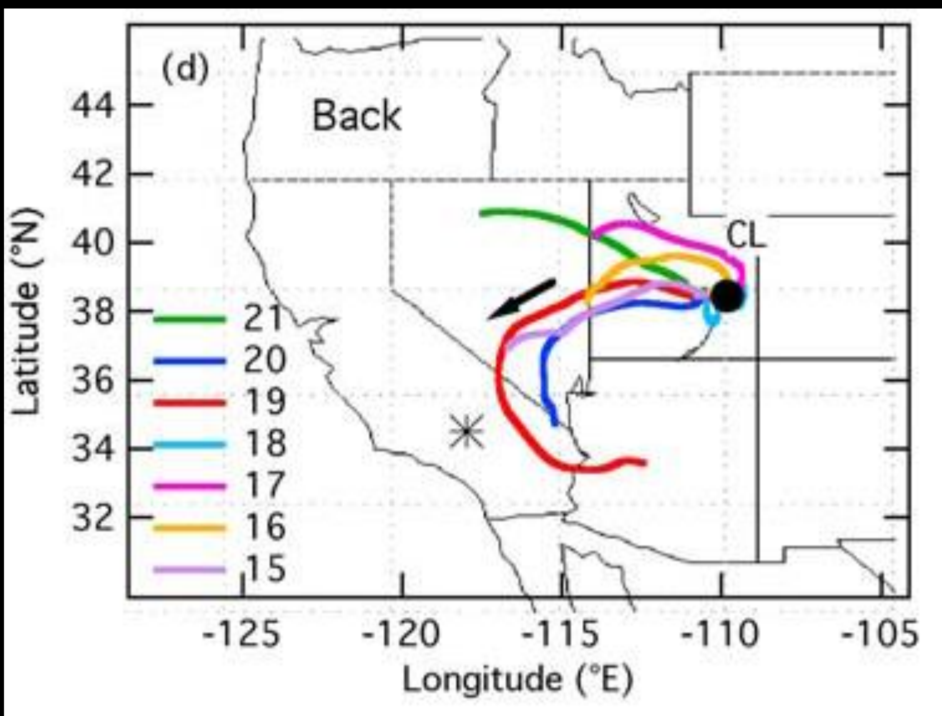


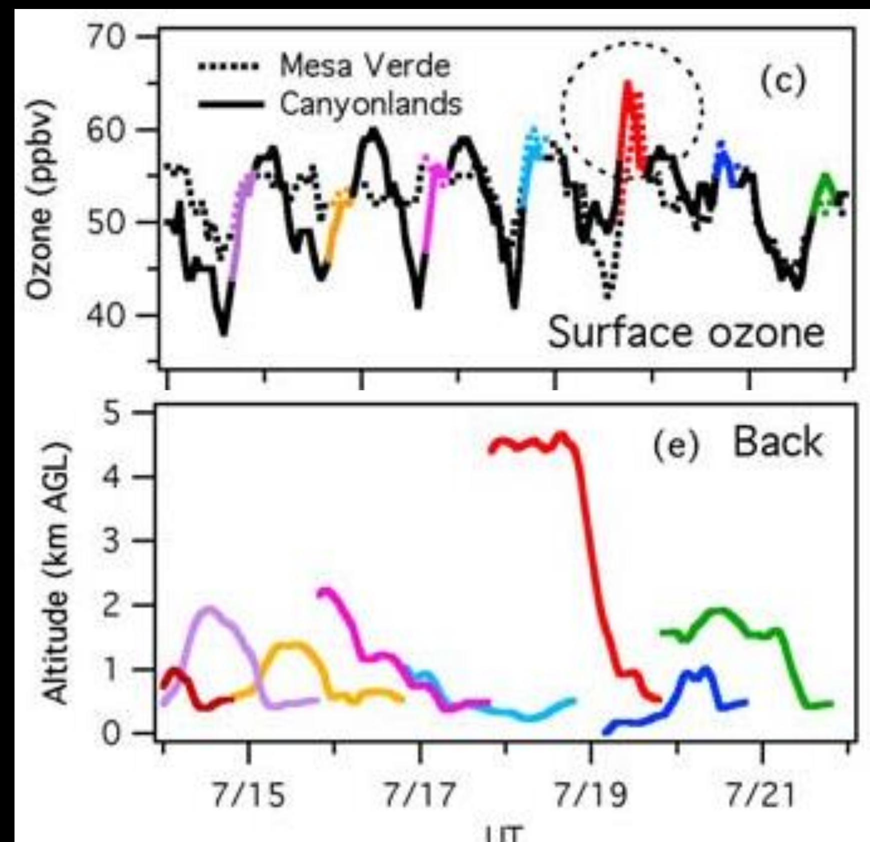
Langford et al., *Geophys. Res. Lett.*, 2010

2. Role of long-range pollutant transport in California – California is also a source of transport to downwind areas

Generally lofted O_3 would contribute to northern mid-latitude baseline O_3 that circulates zonally – layer of enhanced O_3 over downwind neighbor.

Trajectory calculations can plausibly argue that O_3 lofted from Los Angeles on 17 July 2009 affected Mesa Verde and Canyonlands NPs 2 days later.





Langford et al., *Geophys. Res. Lett.*, 2010

3. SJVAB vs. SoCAB Response to emission controls

Different gasoline and diesel mix give different VOC/NOx ratio evolution between basins

(McDonald, B.C., et al., (2012), Long-term trends in nitrogen oxide emissions from motor vehicles at national, state, and air basin scales, *J. Geophys. Res., 117*, D00V18, doi:10.1029/2012JD018304.)

Unknown VOC source in SJVAB

(Pusede, S.E., et al., (2014), On the temperature dependence of organic reactivity, nitrogen oxides, ozone production, and the impact of emission controls in San Joaquin Valley, California, *Atmos. Chem. Phys., 14, 3373–3395, 2014*, doi:10.5194/acp-14-3373-2014.)

Long-range transport may affect air basins differently

(Parrish, D.D., et al., (2014), work in preparation.)

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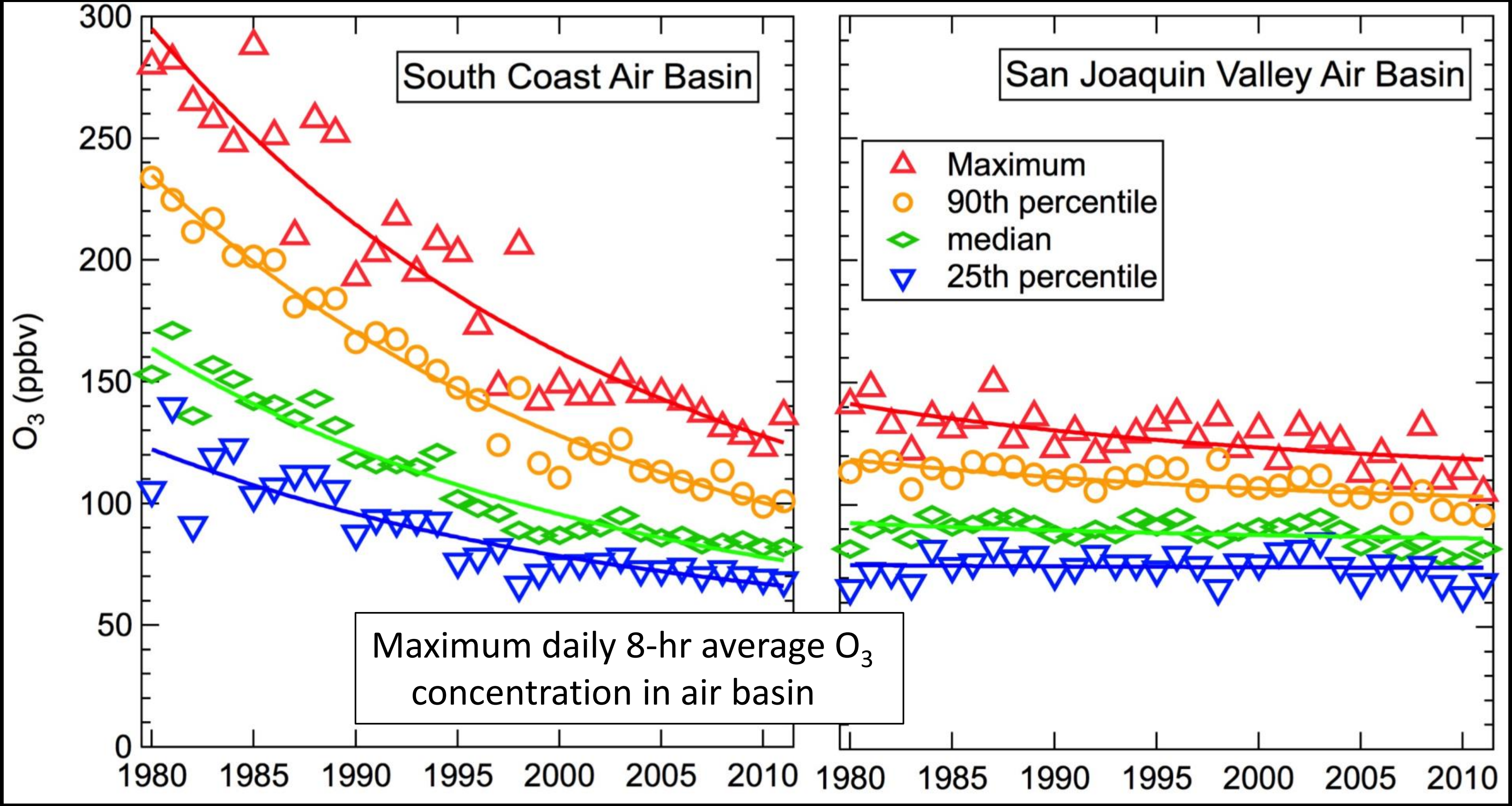


Very large differences !

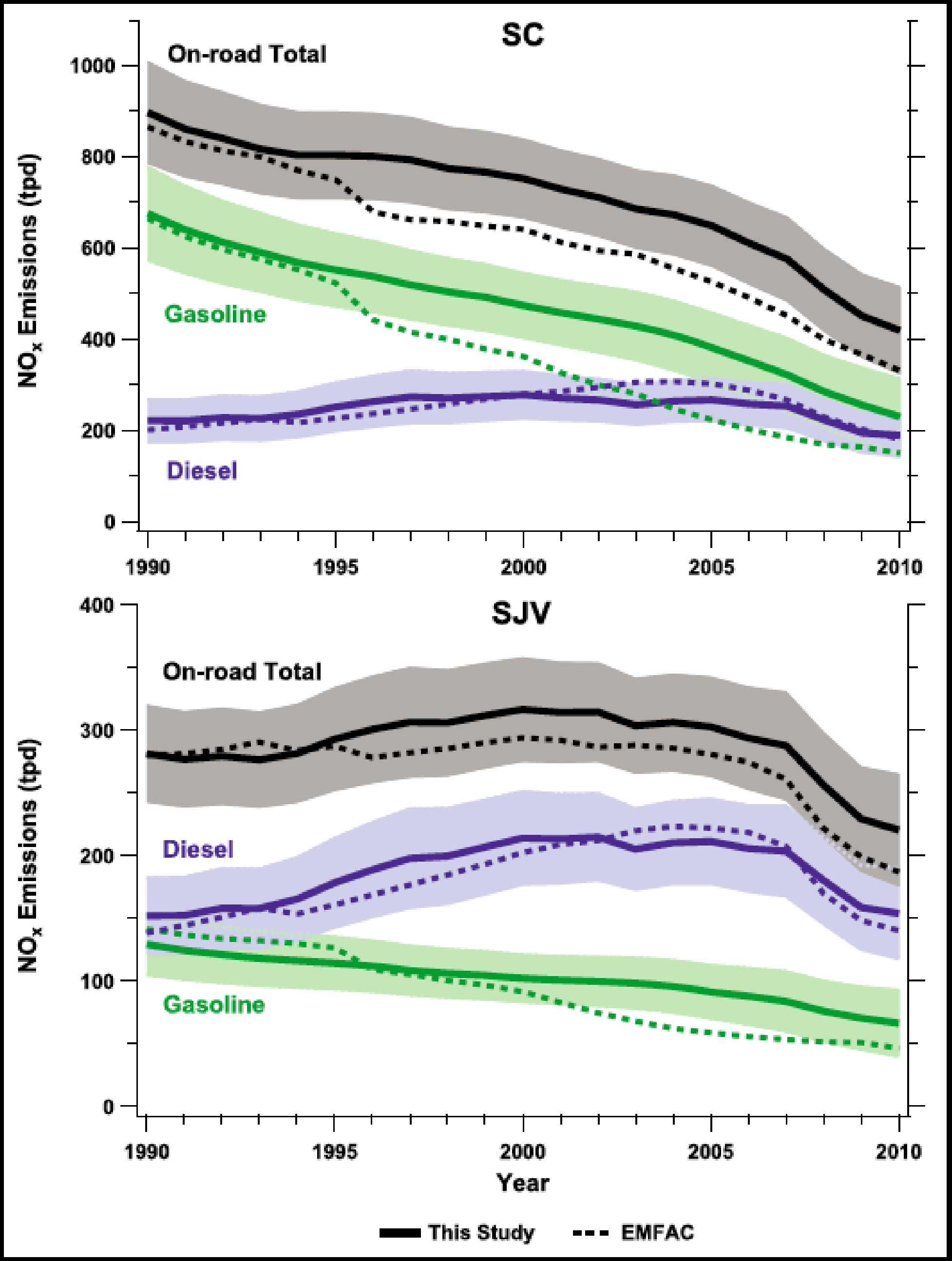
3. SJVAB vs. SoCAB Response to emission controls - Different gasoline and diesel mix

Fuel-based approach to estimating vehicle NOx emissions; some differences from EMFAC.

Very different gasoline and Diesel mix between the two air basins. Diesel dominates in SJVAB, gasoline in SoCAB.

From 1990-2000 vehicle NOx emissions increased in SJVAB, but decreased in SoCAB. Therefore very different VOC/NOx ratio evolution.

Is this relevant to discussion of efficacy of NOx vs. VOC emission controls?



McDonald et al., *J. Geophys. Res.*, 2012

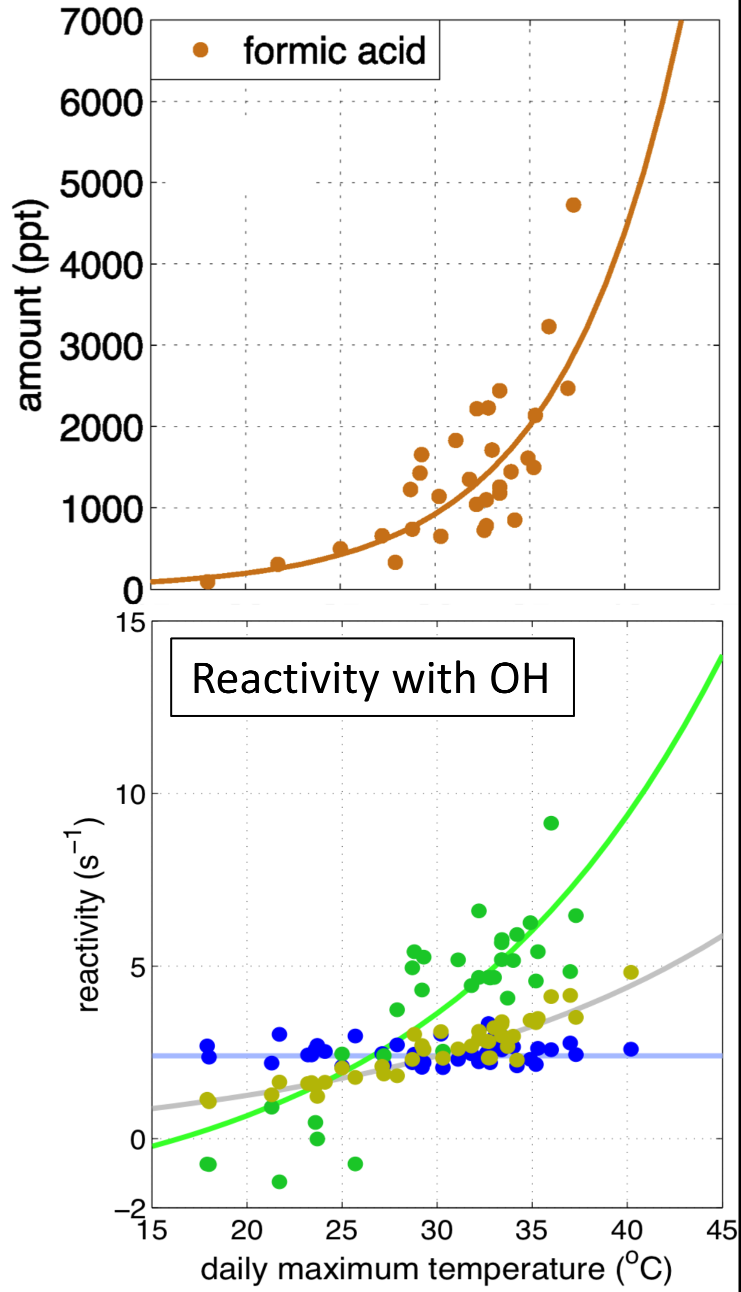
3. SJVAB vs. SoCAB Response to emission controls - Unknown VOC source in SJVAB

Temperature-independent reactivity associated with motor vehicles dominates on cool days (blue data).

At high temperatures, characteristic of days with high ozone, the largest portion of the total organic reactivity increases exponentially with temperature.

Temperature dependent reactivity (green data) is dominated by small, oxygenated organics (yellow data) and unidentified species.

NOx reductions are the most effective control option for reducing the frequency of O_3 violations in the southern SJV.



Pusede et al., *Atmos. Chem. Phys.*, 2014

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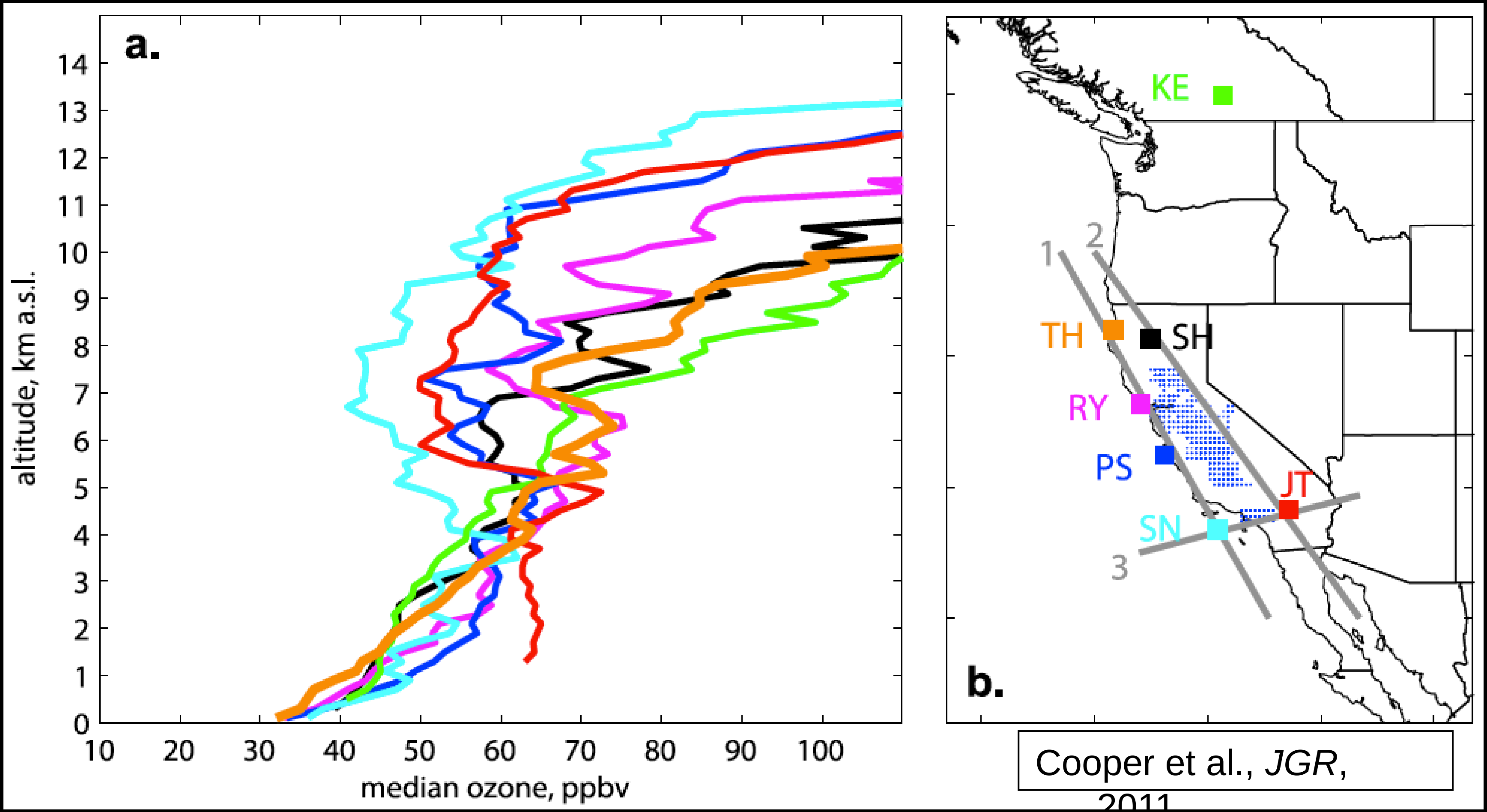


Cooper et al., *JGR*, 2011

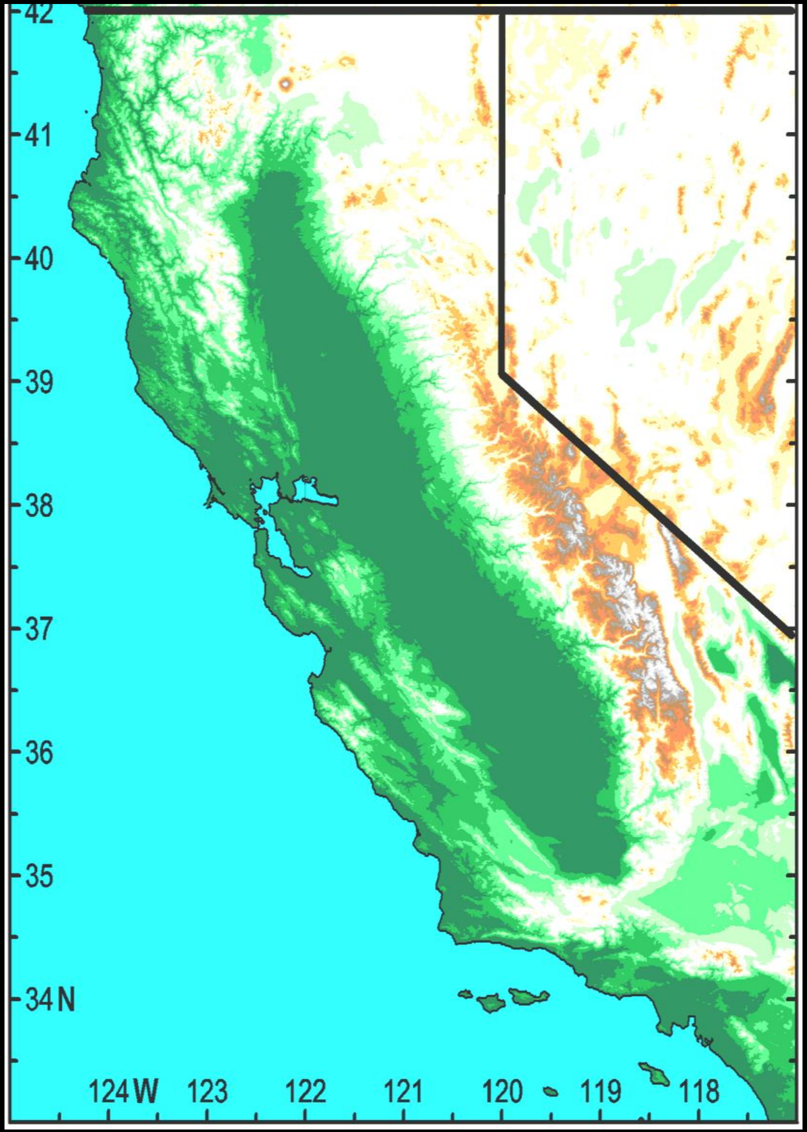
O_3 concentrations coming ashore to California increase with altitude in lower few kilometers.

Parrish et al., *in preparation*, 2014

3. SJVAB vs. SoCAB Response to emission controls - Long-range transport may affect air basins differently

Coastal air basins receive inflow from the Pacific marine boundary layer: ~ 30 ppbv in summer.

Central Valley air basins are partially isolated from the Pacific marine boundary layer – may receive higher O_3 concentrations from aloft.



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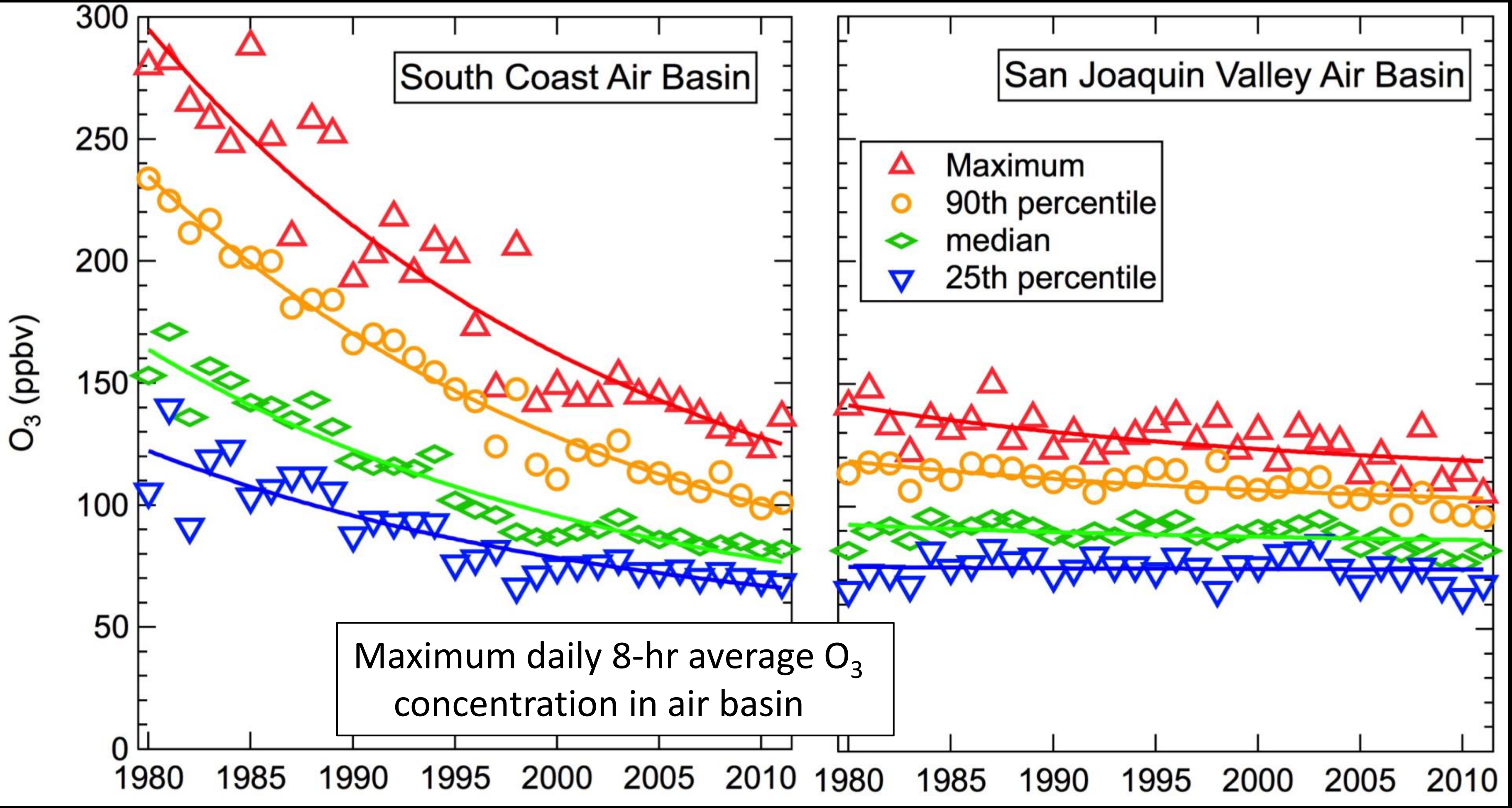

Very large differences !

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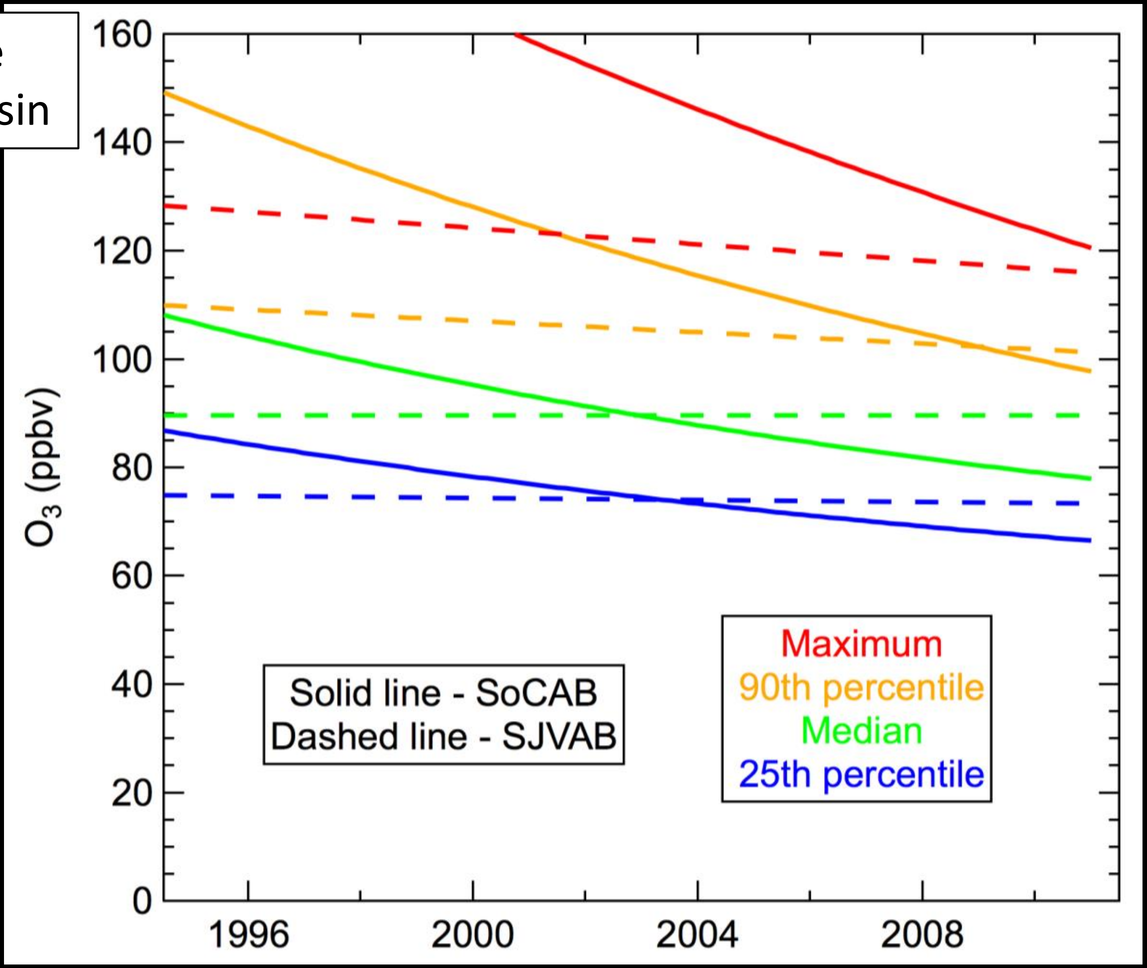
Maximum daily 8-hr average O_3 concentration in air basin

By 2011, 25th, 50th, and 90th percentiles of MDA8 are lower in SoCAB than SJVAB!

MDA8 in SoCAB and SJVAB seem to be converging to different lower limits. Higher background O_3, due to inflow from higher altitude on average?



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These plus other differences may all contribute!

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Thank you for your attention!

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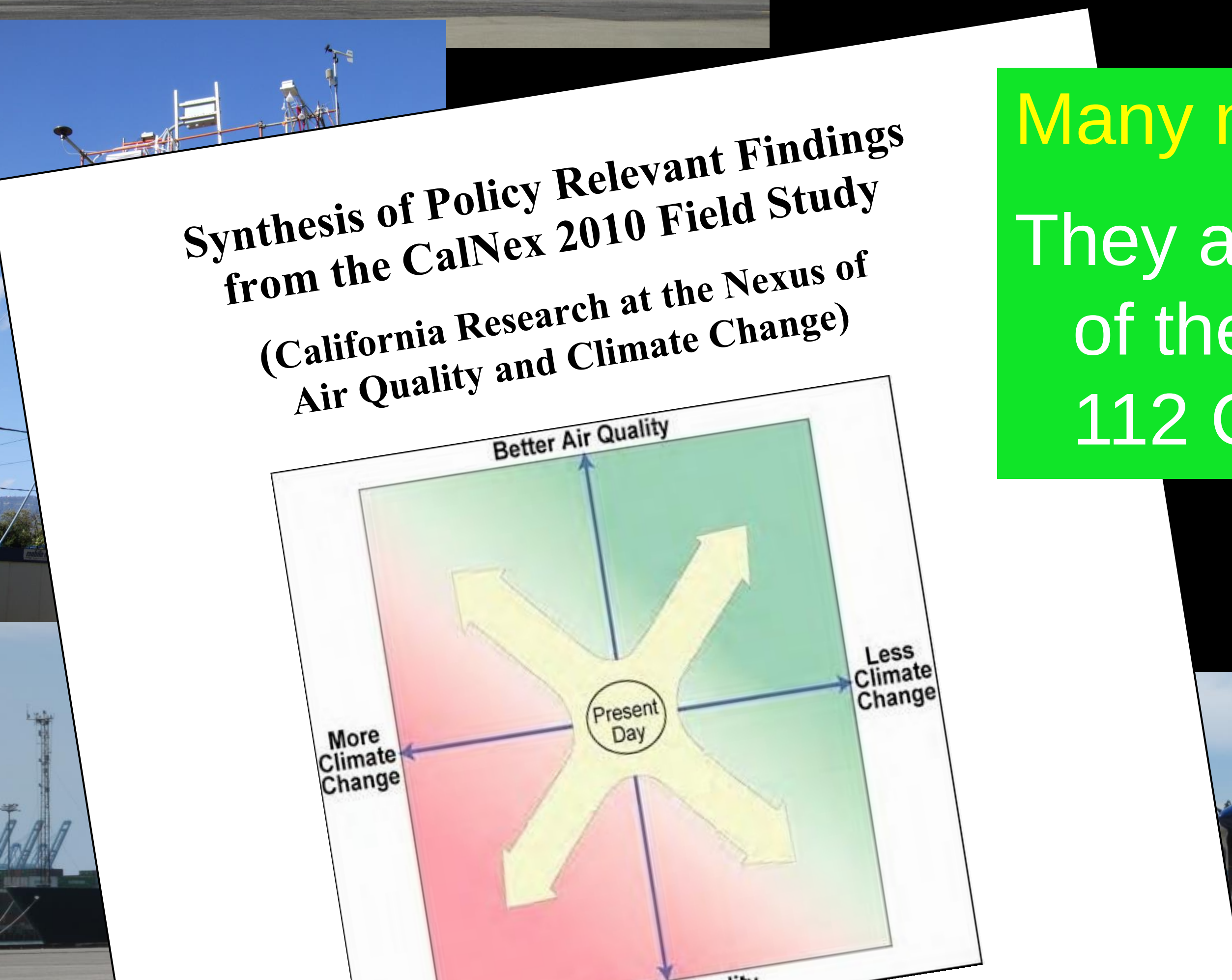
David Parrish

7 August 2014



Synthesis of Policy Relevant Findings from the CalNex 2010 Field Study

(California Research at the Nexus of Air Quality and Climate Change)

Many more stories!

They all rely on the work of the authors of the 112 CalNex papers!