

Quantifying sources of methane using light alkanes in the Los Angeles basin, California

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Outline

1. Quantify emissions of CH₄ from the Los Angeles megacity
2. Compare to state CH₄ inventory
3. Source attribution using C₂–C₅ alkanes
4. Applicability to other cities



in press



1. Urban GHG emissions are significant but not well known

This issue is the focus of several new or nascent studies:

- *NASA Megacities Carbon Project*
- *NIST INFLUX study*
- *EDF Well-to-Wheels study*

Urban emissions are significant
1/4 of California methane comes from urbanized Los Angeles basin

Top-down assessments suggest substantial shortfalls in existing inventories of CH₄ in L.A.:

Top-down assessments of L.A. CH₄

Emissions of greenhouse gases from a North American megacity

D. Wunch,¹ P. O. Wennberg,¹ G. C. Toon,^{1,2} G. Keppel-Aleks,¹ and Y. G. Yavin^{1,3}

column CH₄, CO, and CO₂ at JPL (2008)

observed CH₄/CO = 0.66 ± 0.12

CARB CO and CO₂; EDGAR CO₂

**Inventory CH₄ shortfall of 35% (using CO)
to 57% (using CO₂)**

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Methane emissions inventory verification in southern California

Ying-Kuang Hsu^{a,*}, Tony VanCuren^a, Seong Park^a, Chris Jakober^a, Jorn Herner^a, Michael FitzGibbon^a, Donald R. Blake^b, David D. Parrish^c

in-situ CH₄ and CO from Mt. Wilson (2007-2008)

observed CH₄/CO = 0.52 ± 0.02

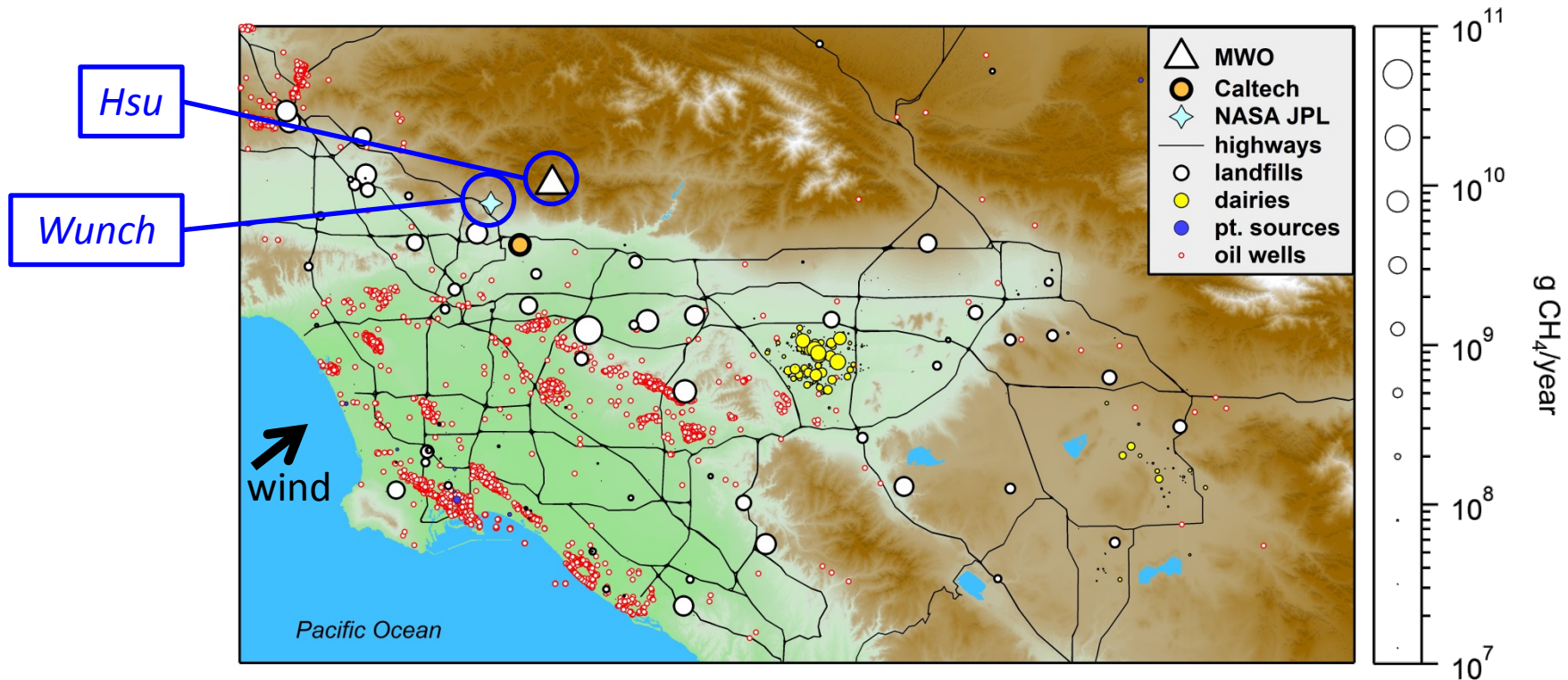
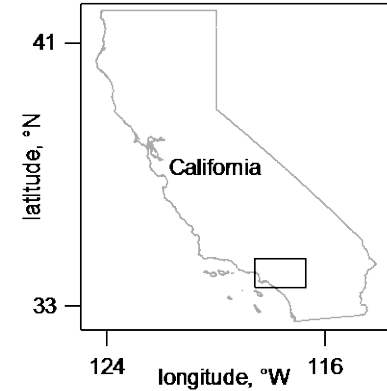
new bottom-up inventory for CH₄

Inventory CH₄ shortfall of 30%

Revisit this issue with updated inventories and CalNex 2010 data

1. Multiple sources complicate CH₄ quantification in L.A.

- sources: landfills, dairies, oil and gas production, traffic, natural gas pipelines, etc.

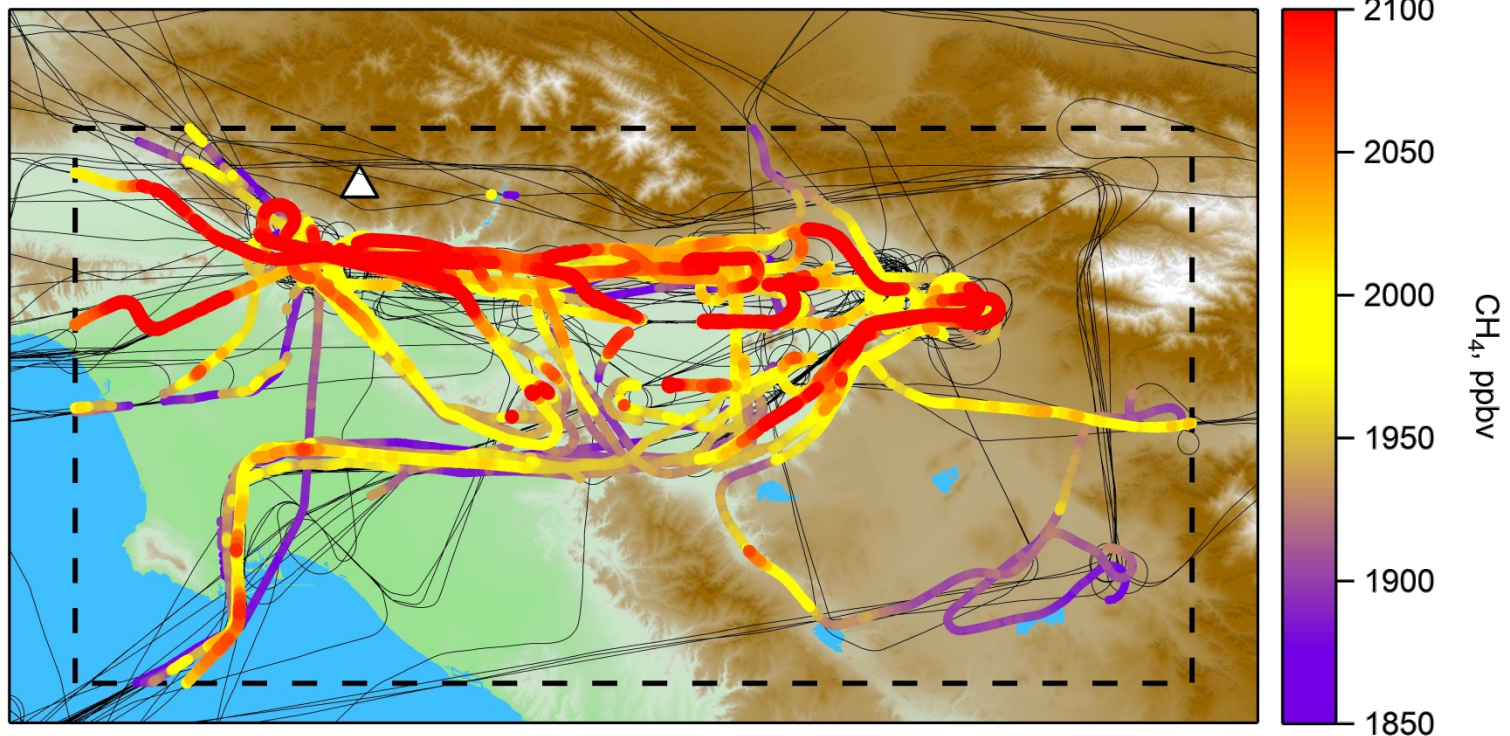
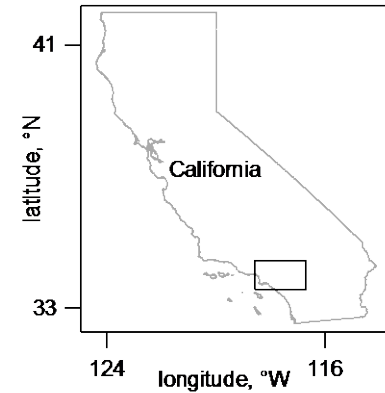


JPL and Mt. Wilson preferentially sample the western basin

e.g., another report in 2012 used Mt. Wilson data to conclude landfills are negligible

1. Information on L.A. source location and type

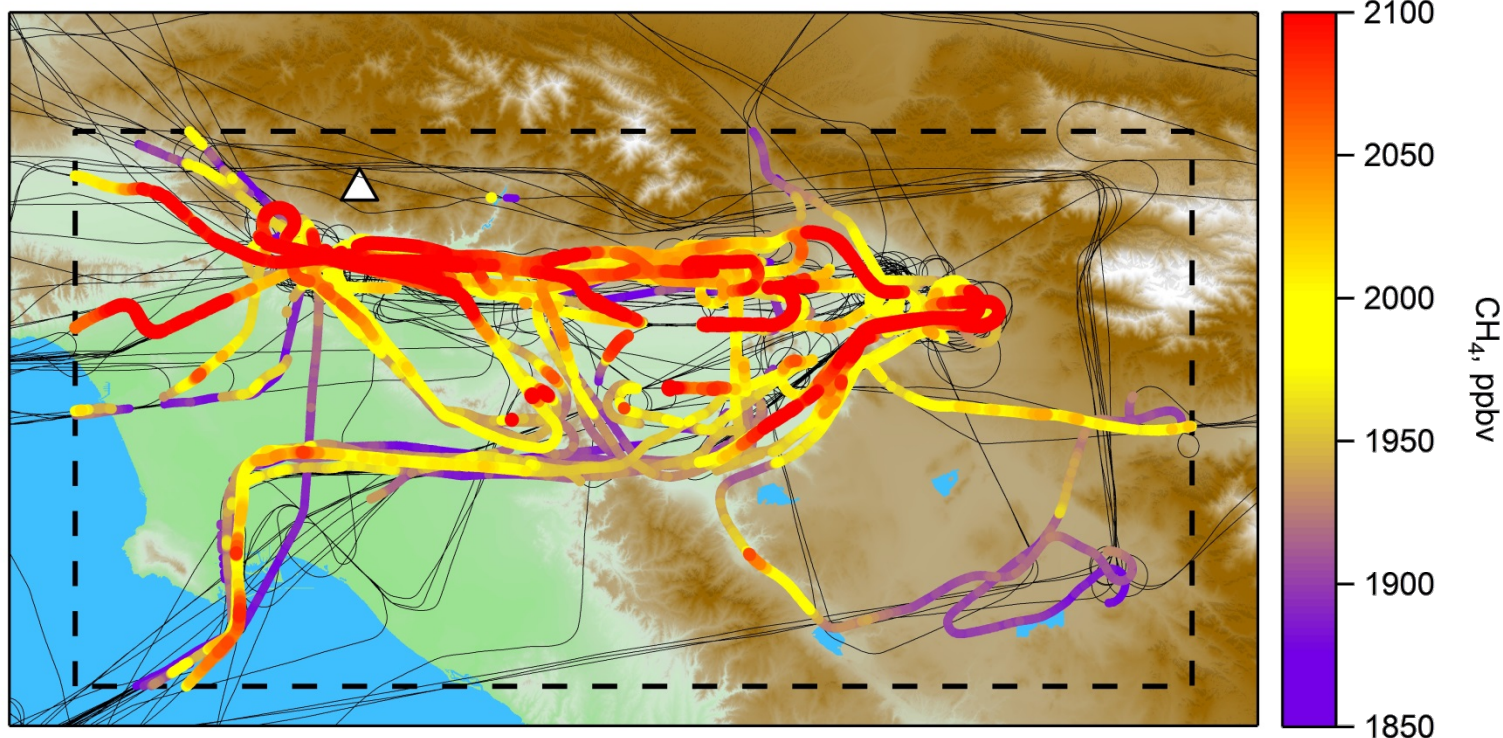
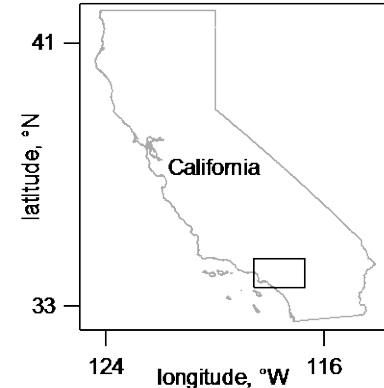
- basin-wide sampling and extensive measurements of CH₄ and co-emitted species from fourteen NOAA P-3 flights in the daytime boundary layer, May–June 2010



- scale obs. CH₄ ERs to CARB CO and CO₂ inventories ← derive total CH₄ for L.A. basin

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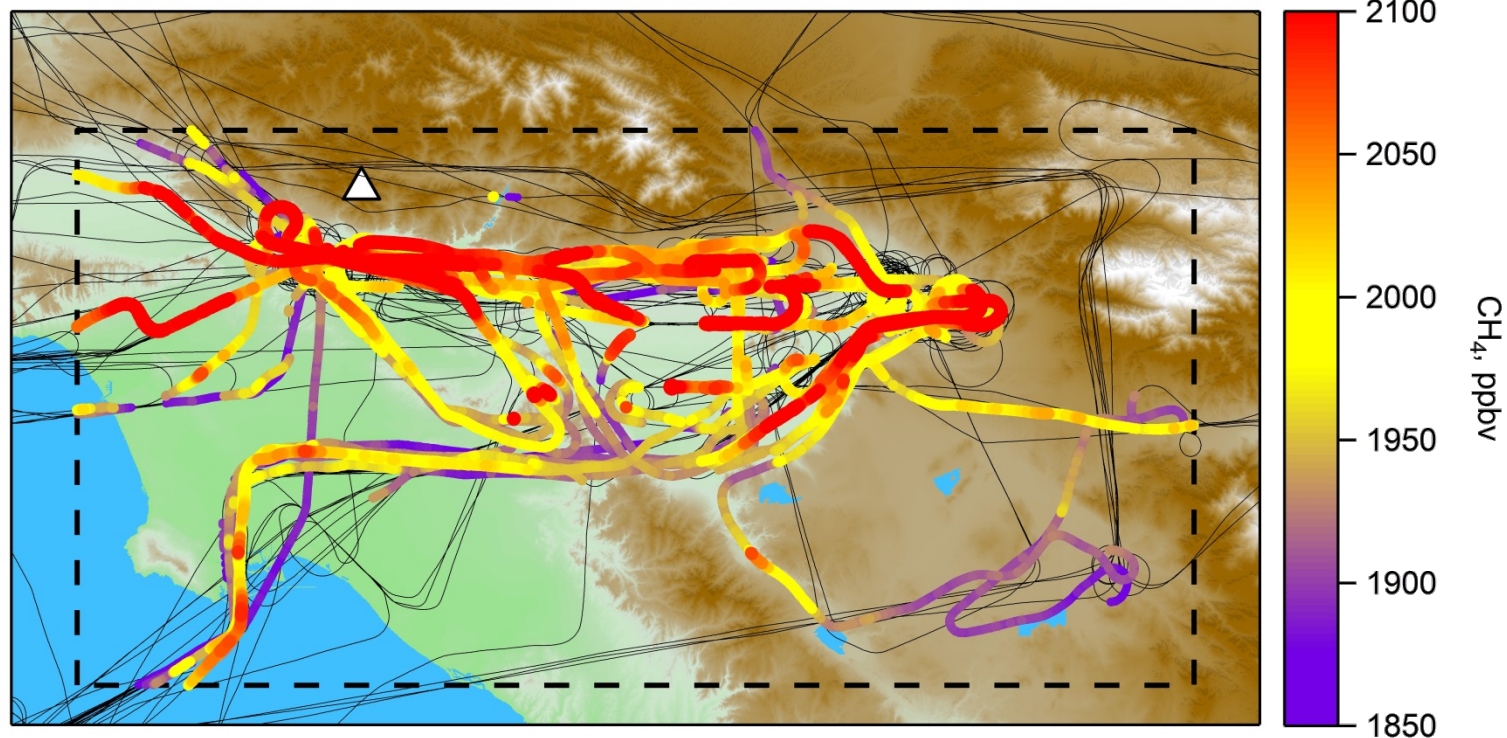
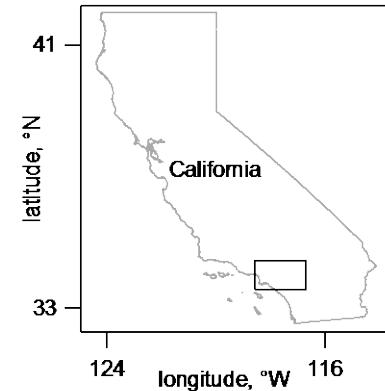


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← derive total CH₄ for L.A. basin
← spot-check inventory sectors

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- scale obs. CH₄ ERs to CARB CO and CO₂ inventories
- quantify emissions from landfills and dairies directly
- use light alkane data to attribute CH₄ to sources

- ← derive total CH₄ for L.A. basin
- ← spot-check inventory sectors
- ← quantify relative contributions

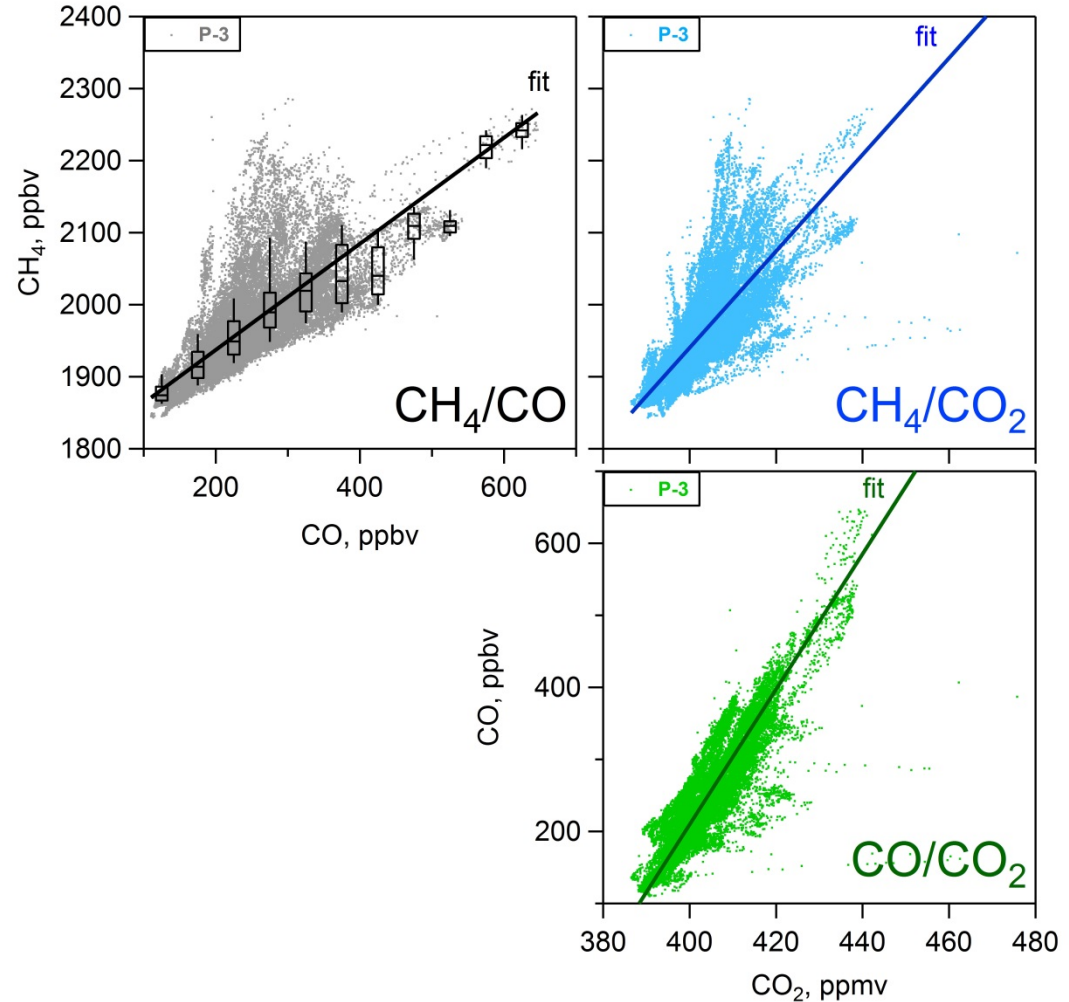
1. Methane emissions derived from observations are greater than expected from inventories

enhancement ratio (ER)



$$\text{CH}_{4(\text{total})} = (\text{CH}_4/\text{CO}) \cdot \text{CO}_{\text{CARB}}$$

ER accuracy is determined by extent of mixing between emissions from different sources within the basin



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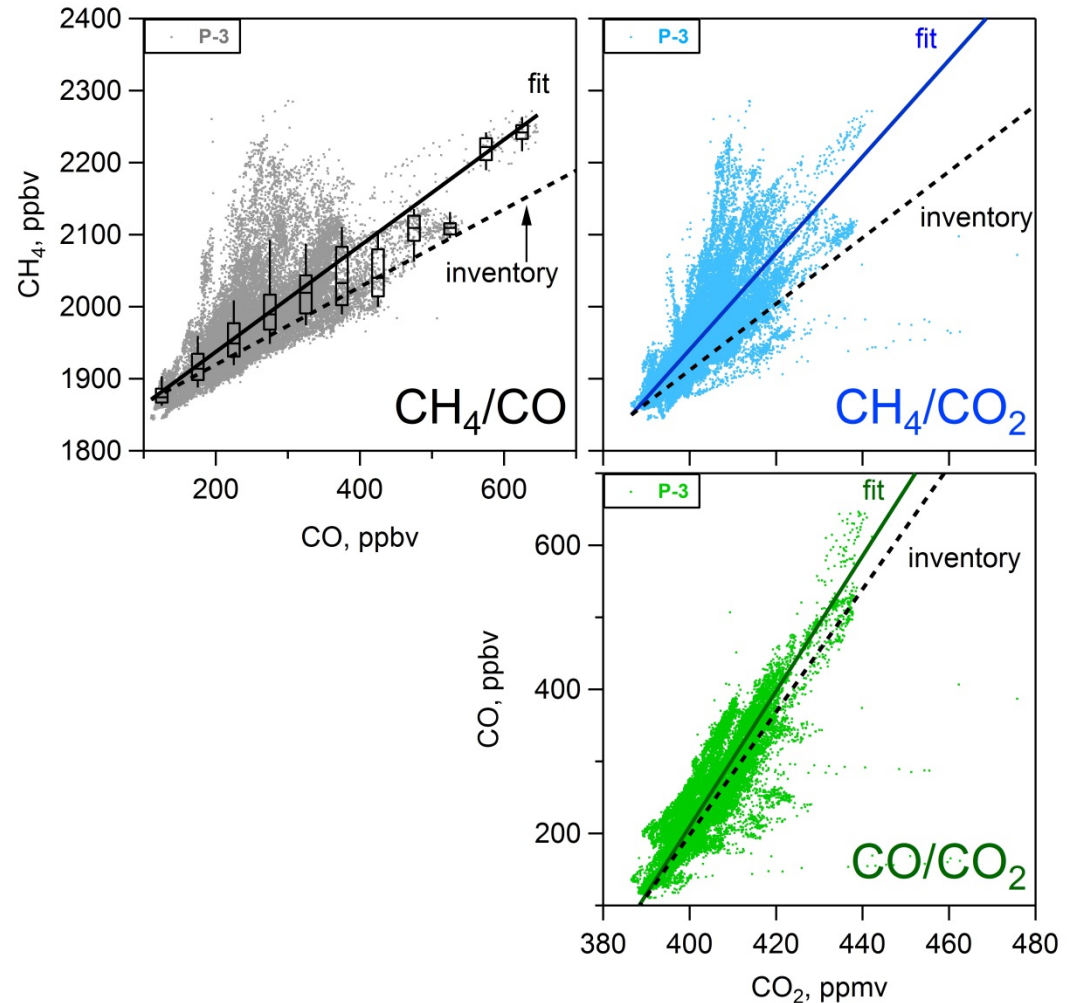
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Diagram showing the derivation of the equation: 'enhancement ratio (ER)' points to the first term in parentheses, and 'inventory' points to the second term.

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Accuracy is also determined by the uncertainties in the 2nd term - CARB **inventories** of CO and CO₂



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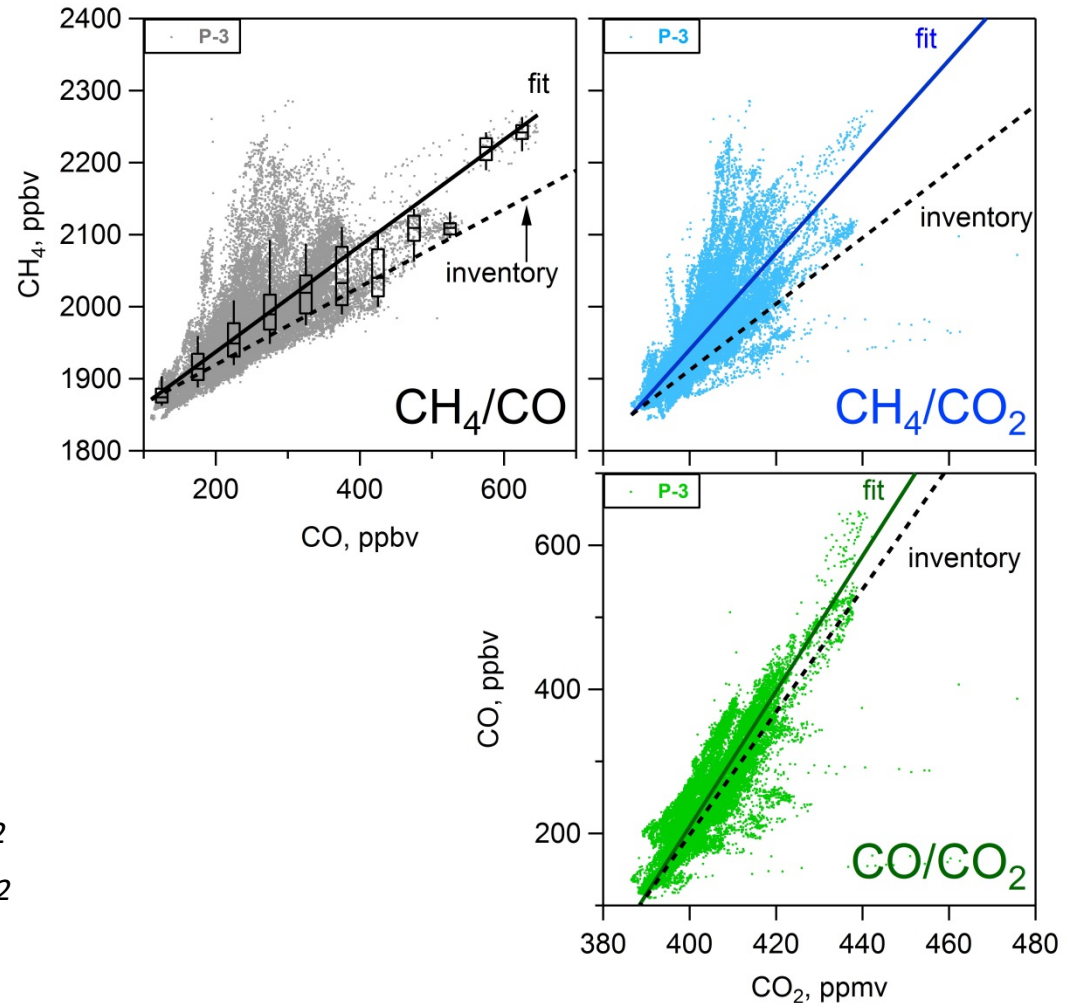
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Diagram showing the derivation of the equation: 'enhancement ratio (ER)' points to the fraction (CH_4/CO) , and 'inventory' points to CO_{CARB} .

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- *observed CO/CO₂ = inventory CO/CO₂*
- *inverse model supports inventory CO₂ (Brioude et al., ACP, 2013)*



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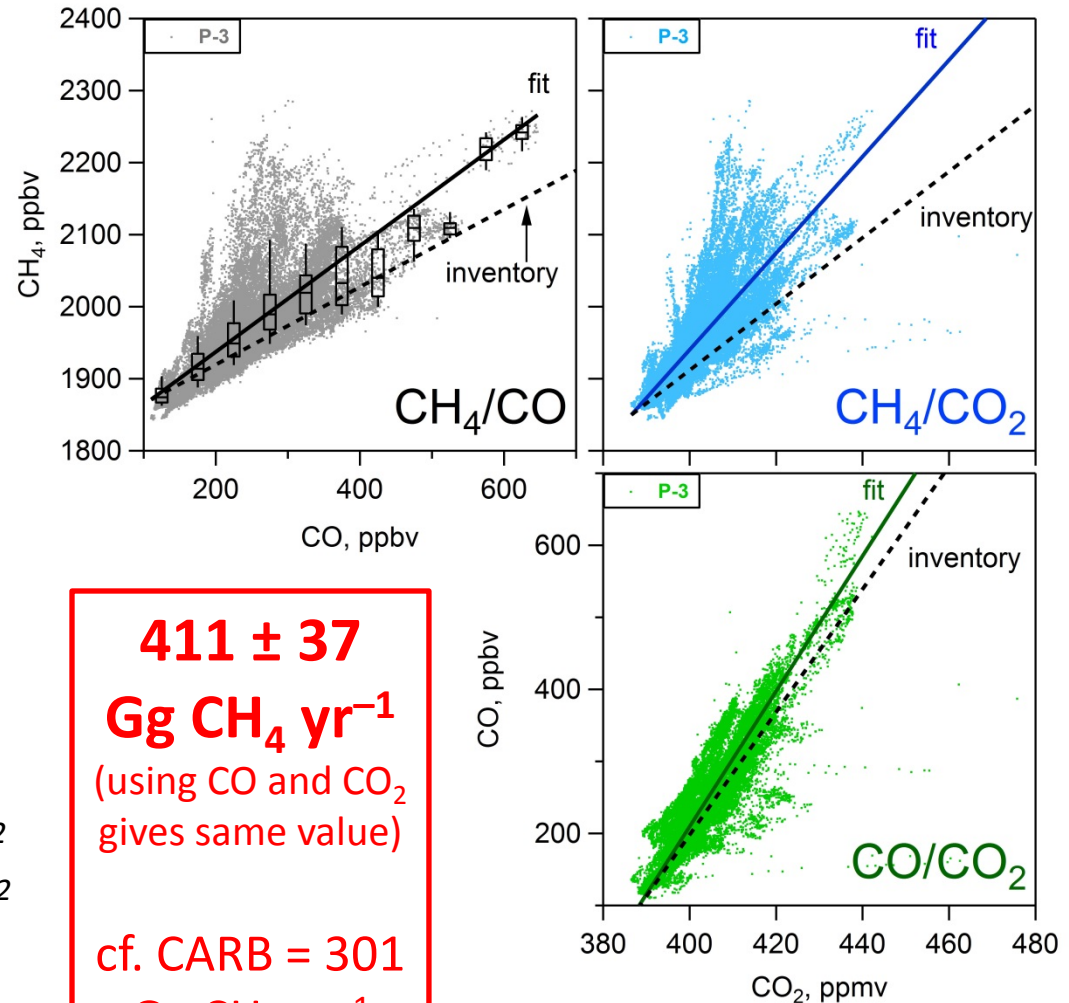
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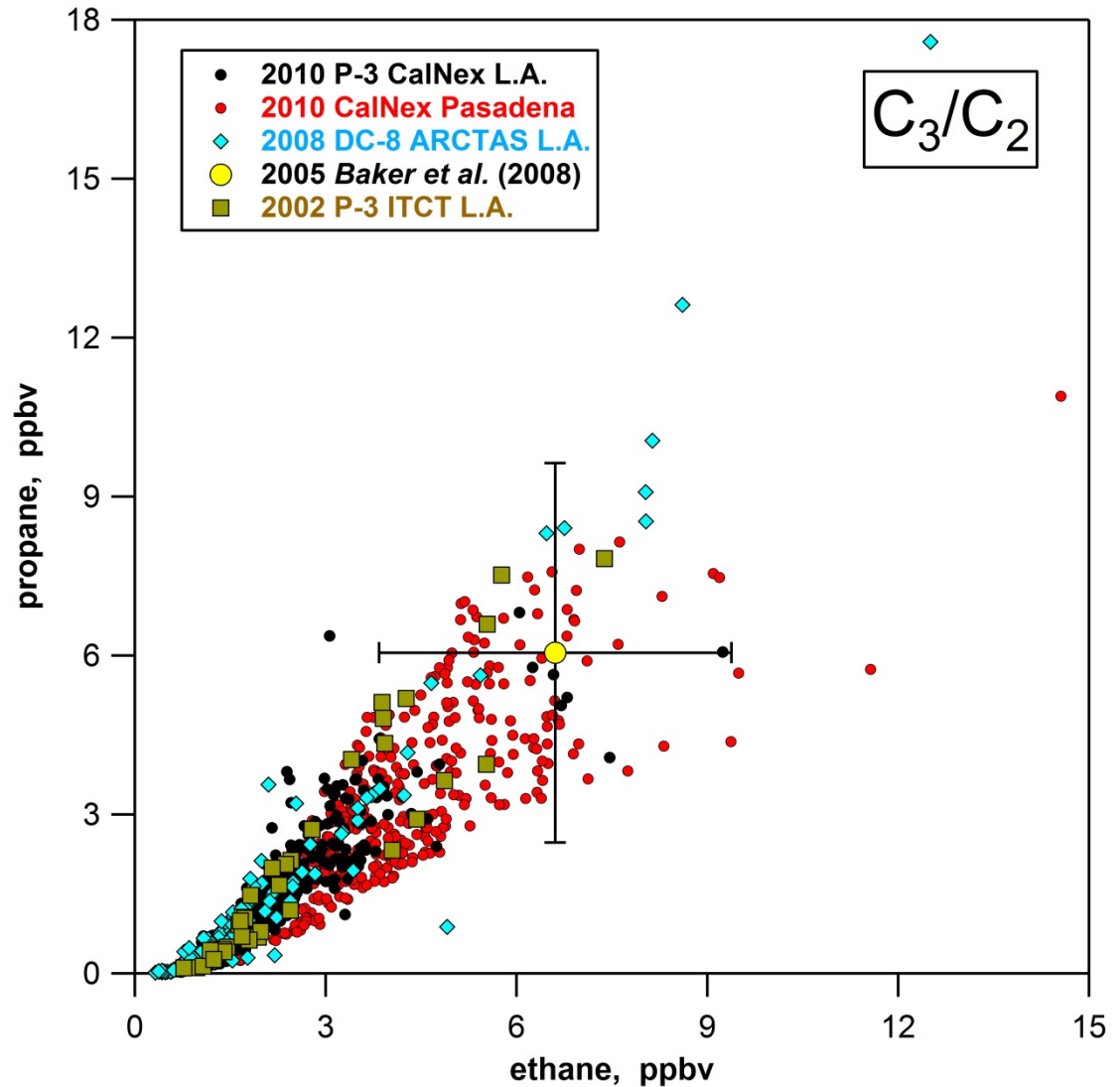


3. Use light alkane source fingerprints to determine sources of CH₄

one example:

Five field studies in eight years made atmospheric measurements of propane and ethane in L.A.

Compare with published source composition data



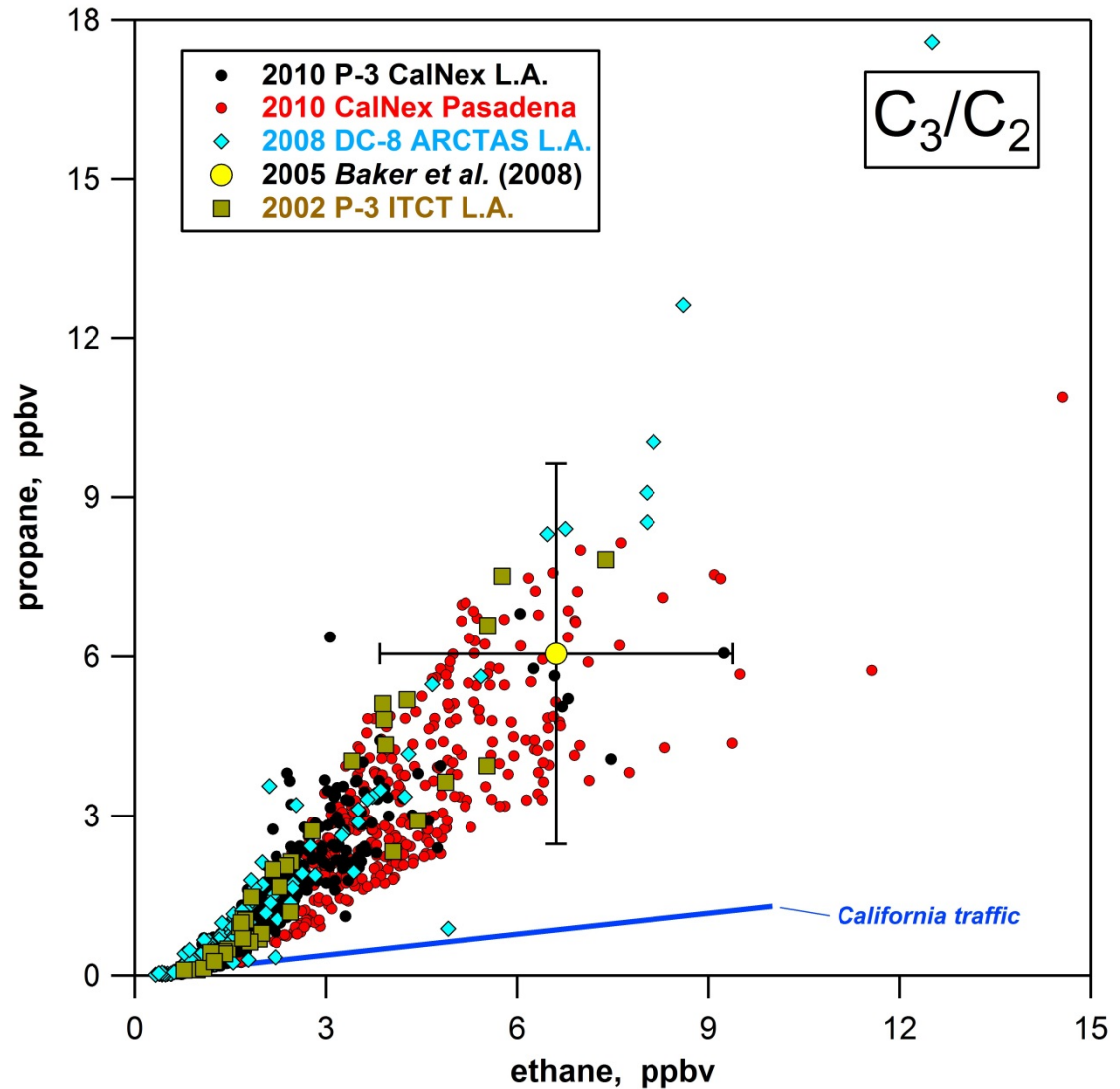
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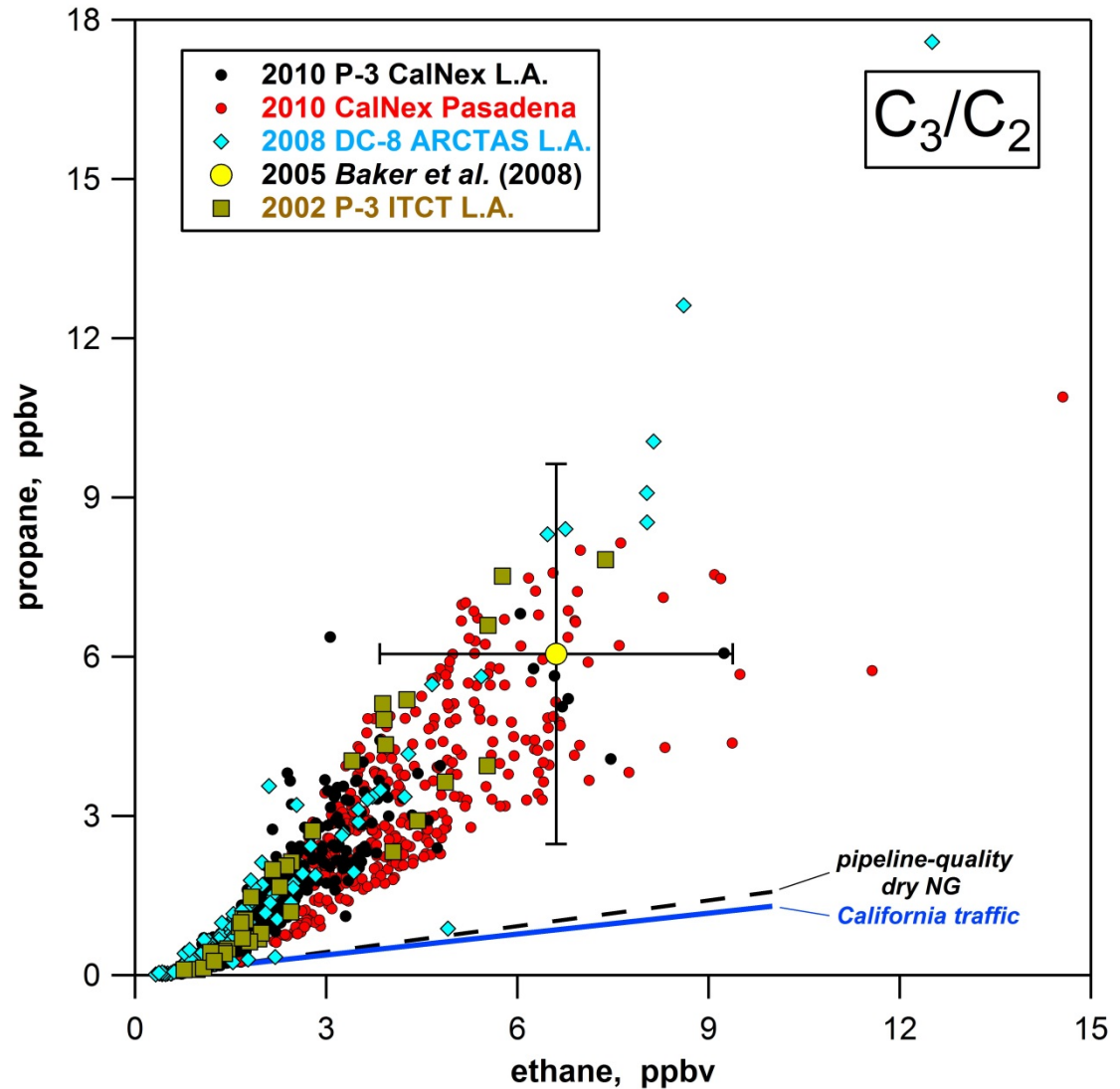
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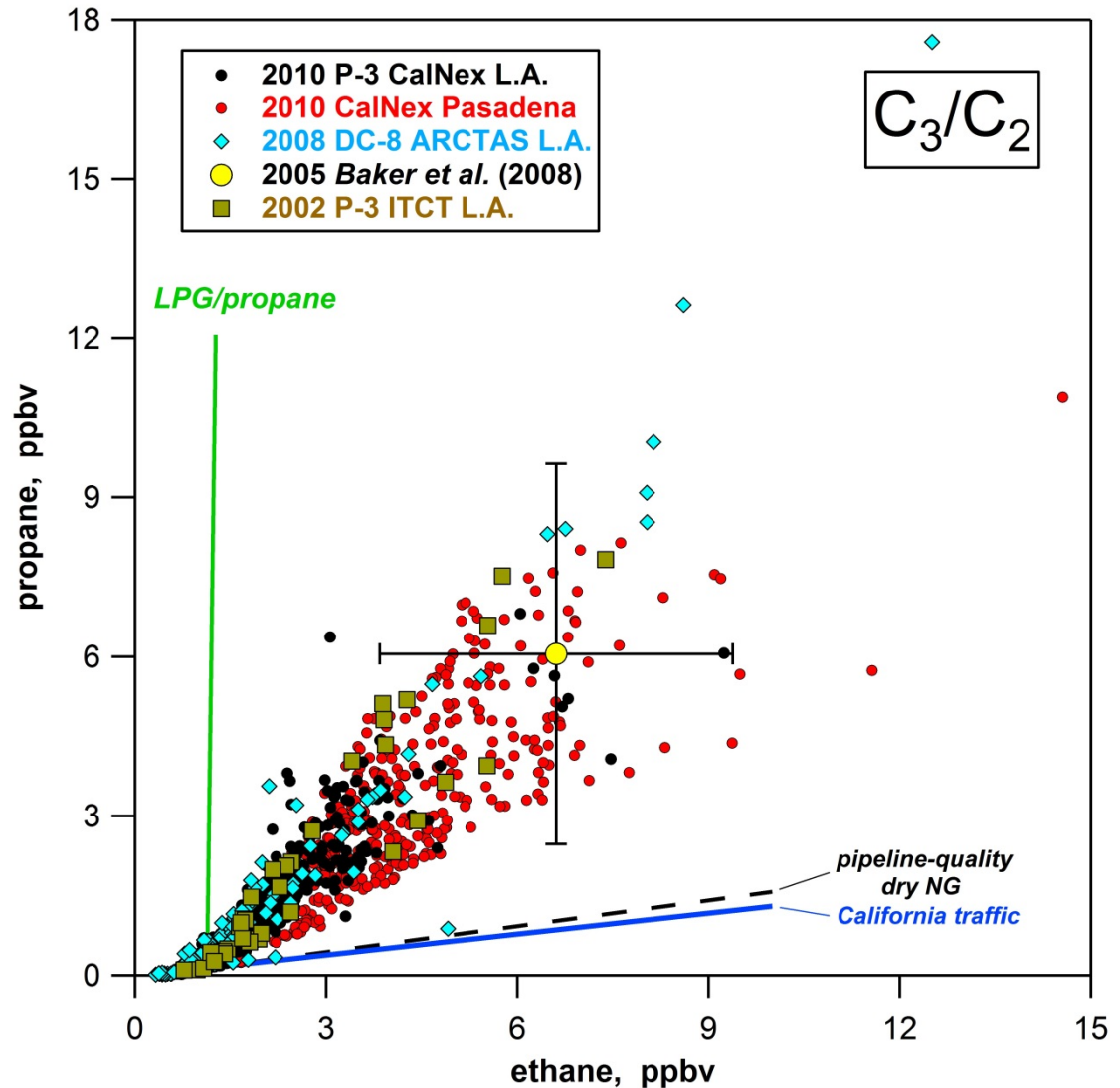
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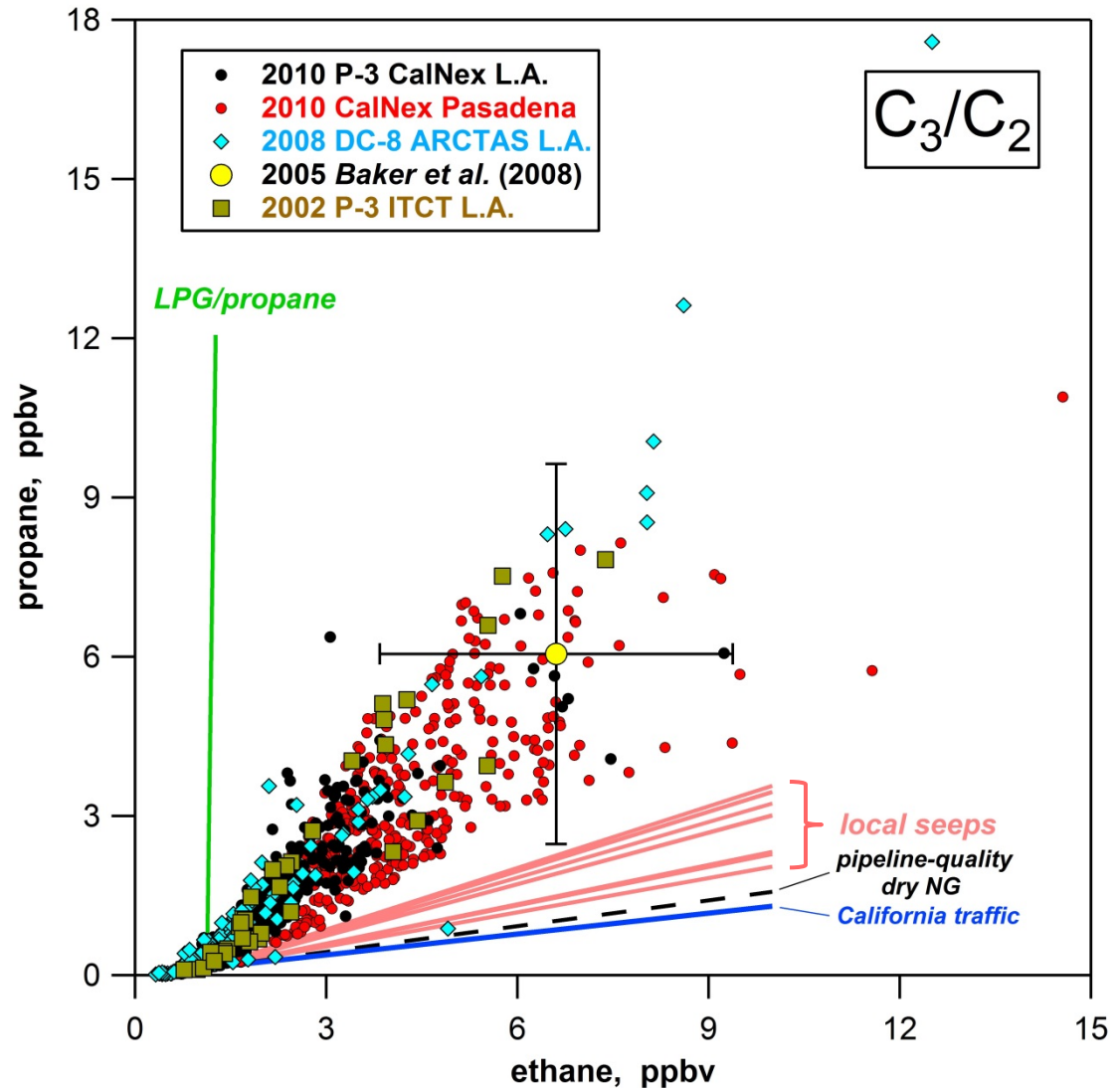
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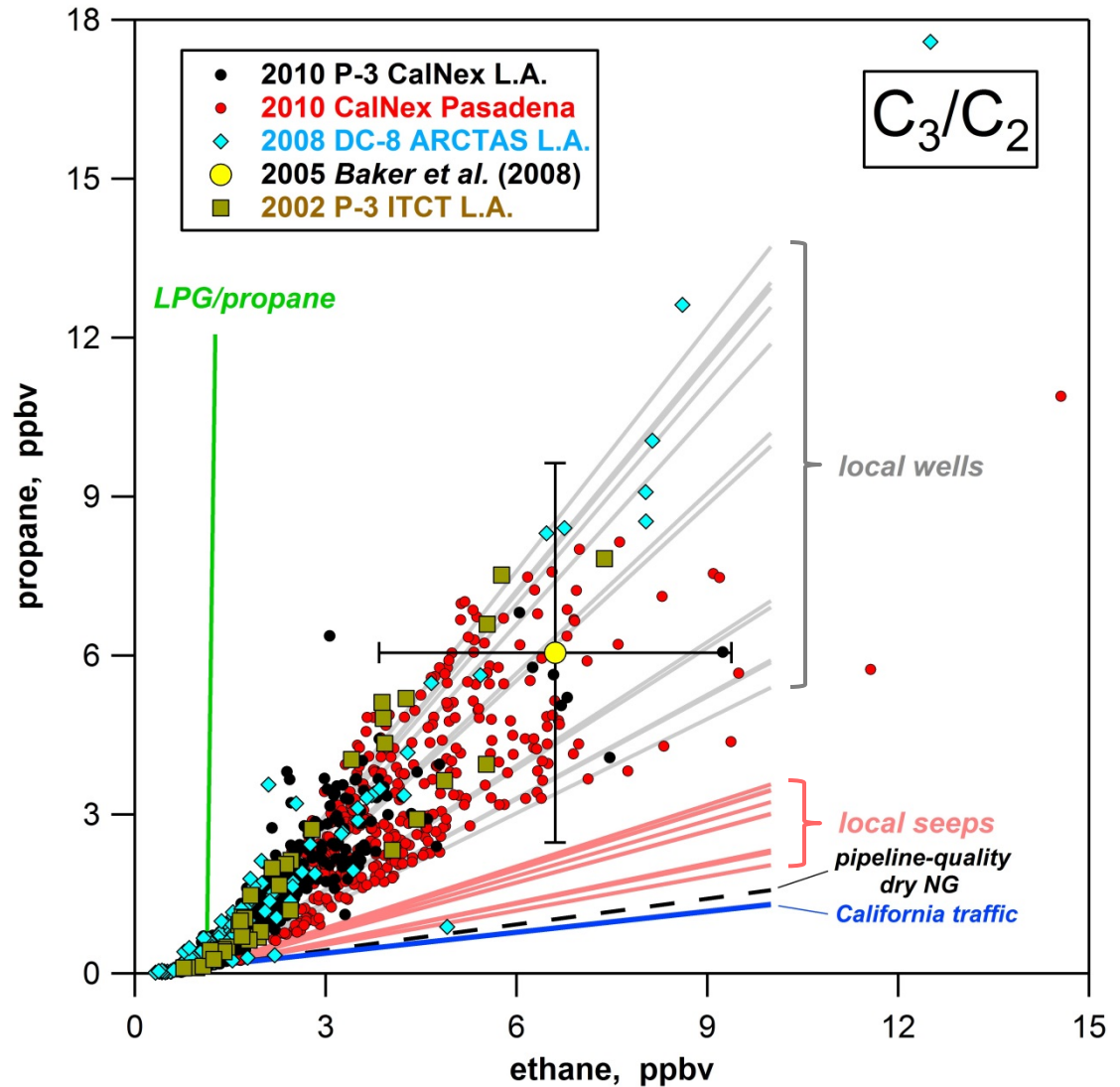
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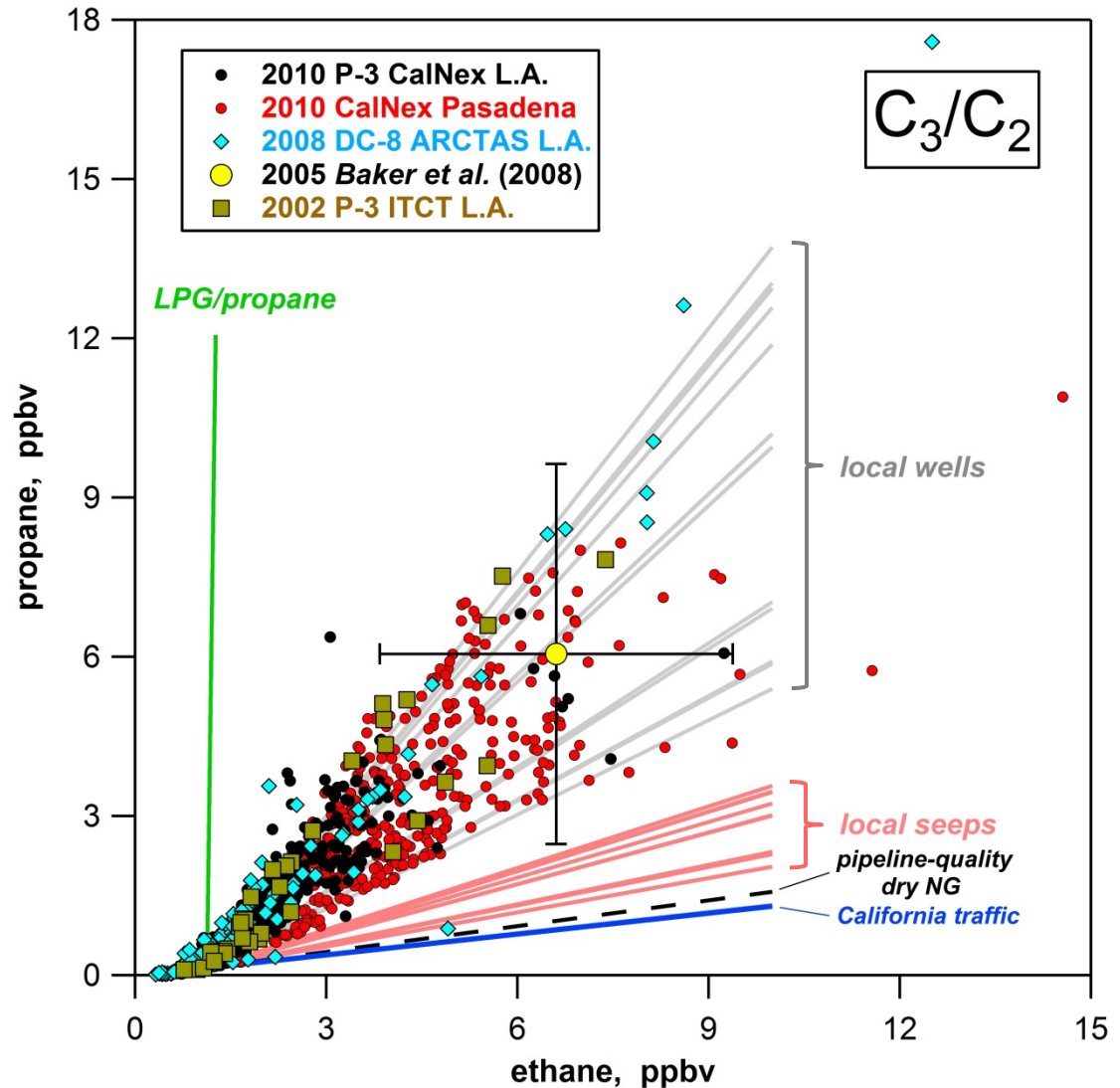
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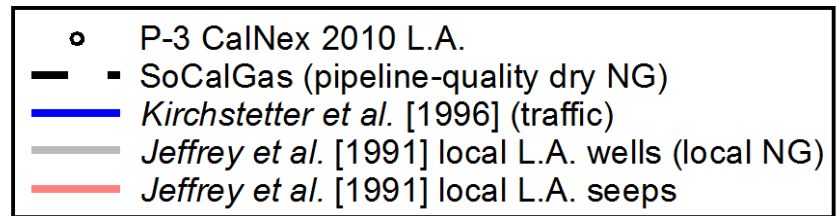
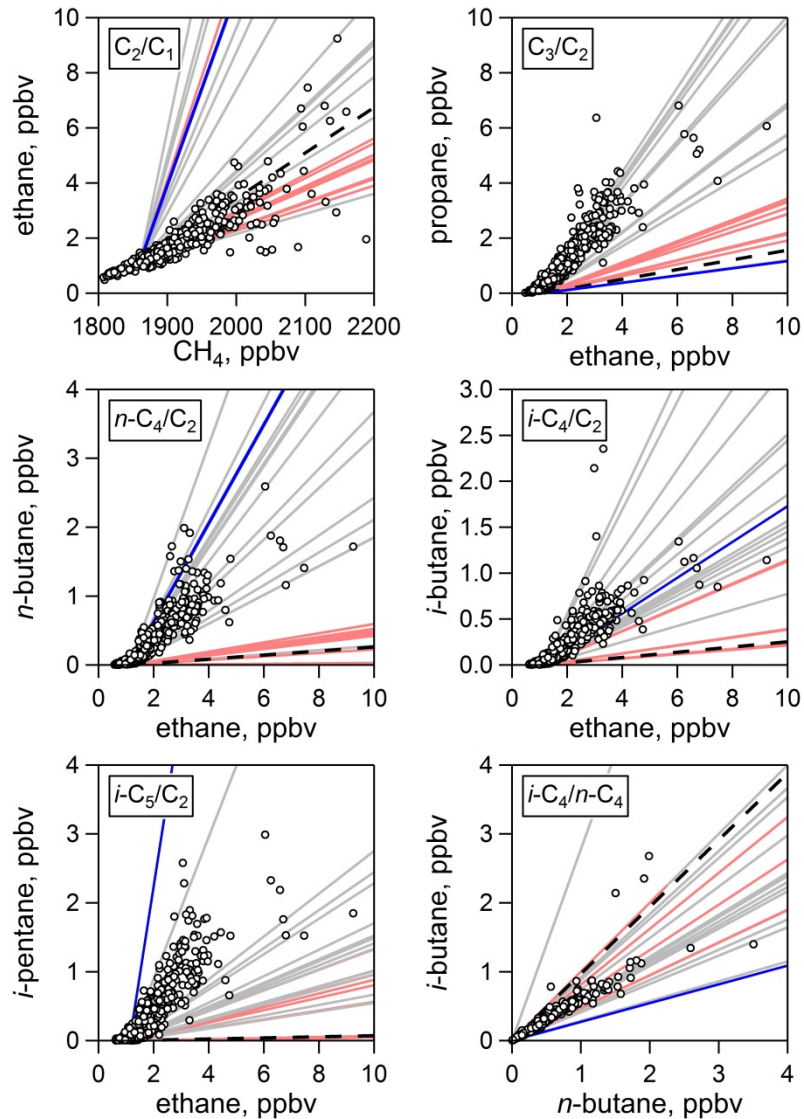
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- The suite of light alkanes provides essential information to attribute emissions to sources



3. Use light alkane source fingerprints to determine sources of CH₄

C₂ – C₅ alkane measurements
 (ethane through pentane isomers)
 permit robust attribution of CH₄ to
 specific source types



Use source composition data
 to solve for the linear combination of
 sources that can explain observed
 abundances in the L.A. atmosphere:
 $Ax = b$

model-independent quantification of
 relative contributions to CH₄ budget

3. Use light alkanes to apportion sources of CH₄ in L.A.

Results of a LLS solution using 7 hydrocarbons.

Black lines give derived annual totals for L.A.

$$\text{total emissions} = (X/CO) \cdot CO_{CARB}$$

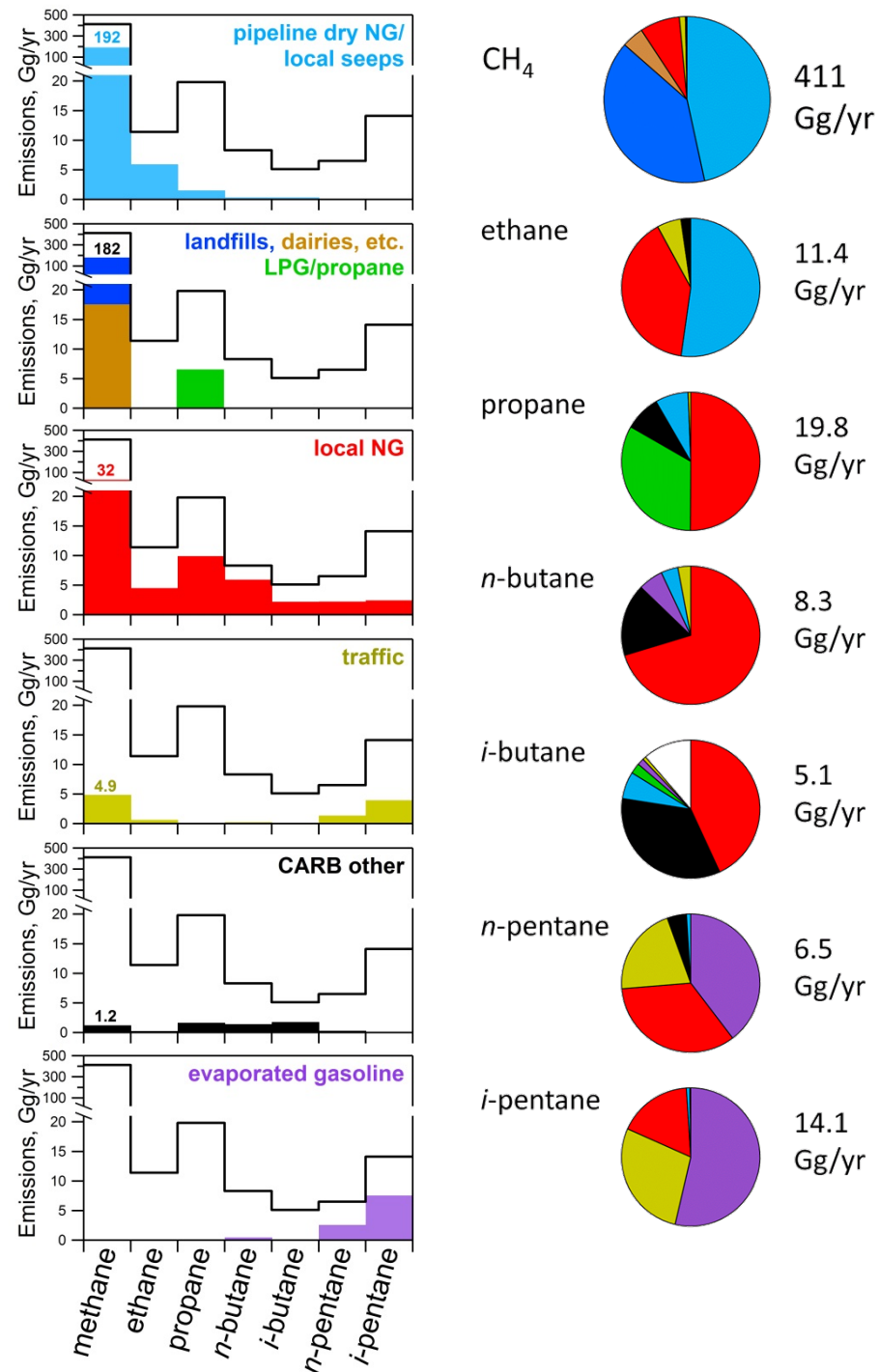
Colored bars:

fraction of the total from each of the 7 source sectors used in the linear analysis.

CH₄ emission attributed to each source type is written above the colored CH₄ bars.

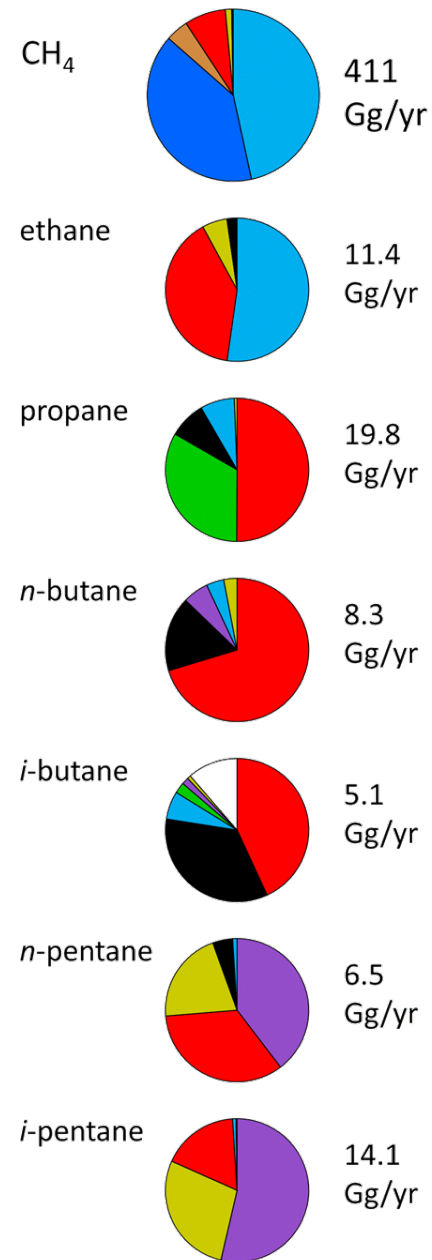
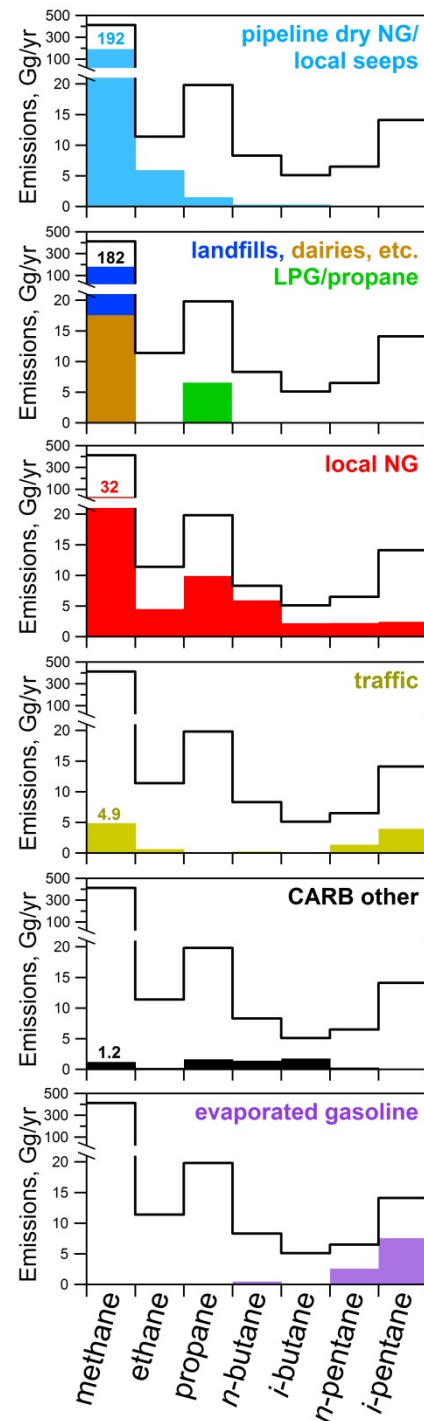
Pie charts:

relative contributions from each source for each of the 7 hydrocarbons



3. Conclusions from CH₄ source apportionment

- Inventories still significantly underpredict CH₄ in the Los Angeles atmosphere.
- Model-independent attribution of CH₄ to specific sources enabled by use of C₂–C₅ data.
- The majority of CH₄ is due to leaks from **pipeline dry NG/local seeps** and **landfills**.
- Leaks from **pipeline dry NG/local seeps** and **local NG** account for the consistent top-down vs. bottom-up discrepancies in CH₄.
- Loss of **local NG** contributes 8% of CH₄ in L.A. (loss = 17% of local production).
 - later confirmed by CARB industry survey
 - cf. 4% for gas production basins in Colorado (Petron et al., 2012)



4. Applicability to other cities

Required measurements:

CH_4
 $\text{C}_2\text{--C}_5$ alkanes } relative attribution;
which sources to focus on first

CO
 CO_2 } + inventory = total emission;
provides global context

Required platforms:

