A21A-0035

Quantifying Molecular Hydrogen Emissions and an Industrial Leakage Rate for the South Coast Air Basin of California

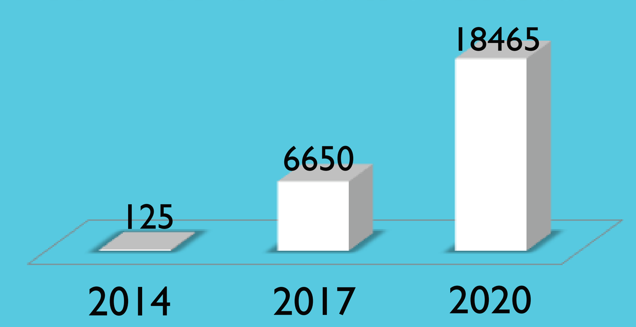
Matt Irish[1], Jason Schroeder[2], Andreas Beyersdorf[3], & Donald Blake[2]

[1](mairish@umich.edu) Univ. of Michigan; [2]Univ. of California, Irvine; [3]NASA Langley Research Center

INTRODUCTION & BACKGROUND

The poorly understood atmospheric budget and distribution of molecular hydrogen (H_2) have invited further research since the discovery that emissions from a hydrogen-based economy could have negative impacts on the global climate system and stratospheric ozone (see below). The burgeoning fuel cell electric vehicle industry in the South Coast Air Basin of California (SoCAB) presents an opportunity to observe and constrain urban anthropogenic H_2 emissions.

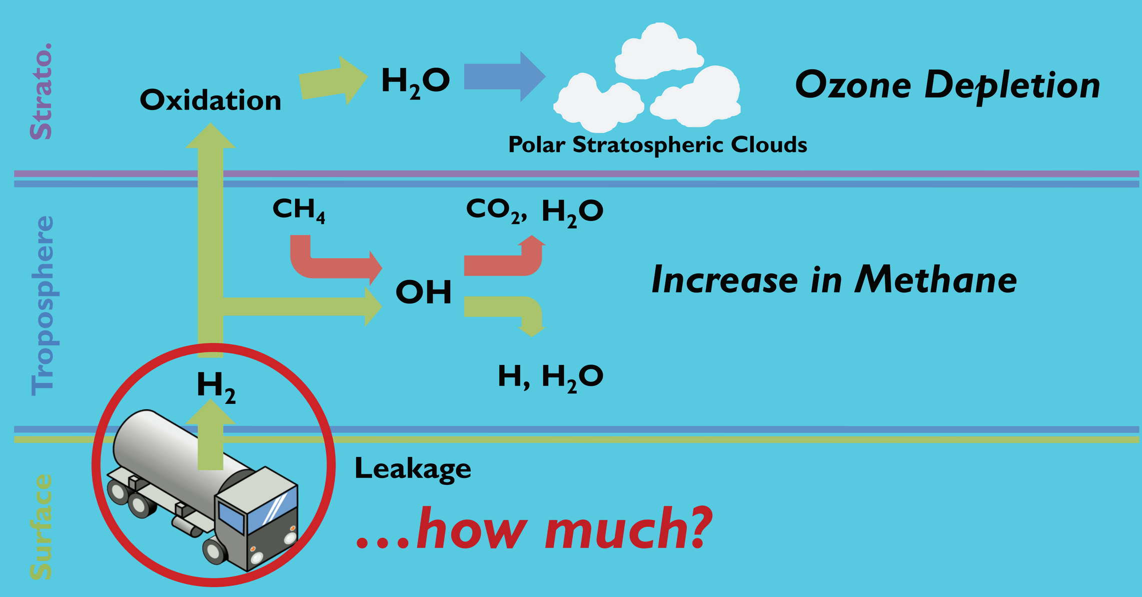
No. of Fuel Cell Vehicles



Projected growth of number of fuel cell electric vehicles in CA.[1]

Objectives:

- Quantify H_2 emissions totals for SoCAB through a top-down approach
- Separate contributions from direct industrial leakage and combustion engine sources for the first time
- Calculate an upper limit leakage rate for H_2 infrastructure

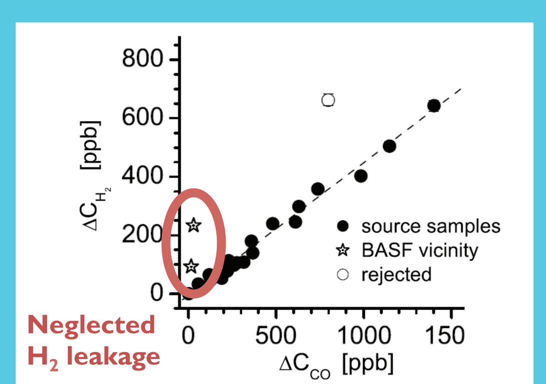


METHODS

- H_2 shares its main anthropogenic source, vehicular combustion, with carbon monoxide (CO)
- The CO emissions inventory is well constrained
- We can use experimentally established molar ratio to calculate combustion-based H_2 emissions from CO emissions:

$$\frac{j_{H_2}^{emi,combust}}{j_{CO}^{emi}} \cong \frac{\Delta C_{H_2,combust}}{\Delta C_{CO}} = 0.48 \pm 0.07$$

Past work assumes that combustion alone comprises total anthropogenic H_2 emissions[2]



Non-combustion source emissions (this project):

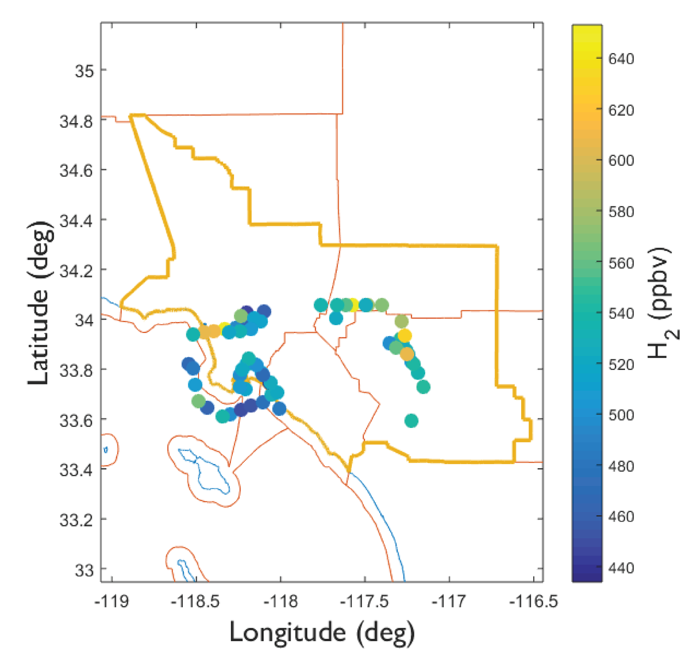
$$\frac{j_{H_2}^{emi,combust} + j_{H_2}^{emi,non-combust}}{j_{CO}^{emi}} \cong \frac{\Delta C_{H_2,combust} + \Delta C_{H_2,non-combust}}{\Delta C_{CO}}$$

$$= 0.48 \pm 0.07 + \Delta C_{H_2,non-combust}$$

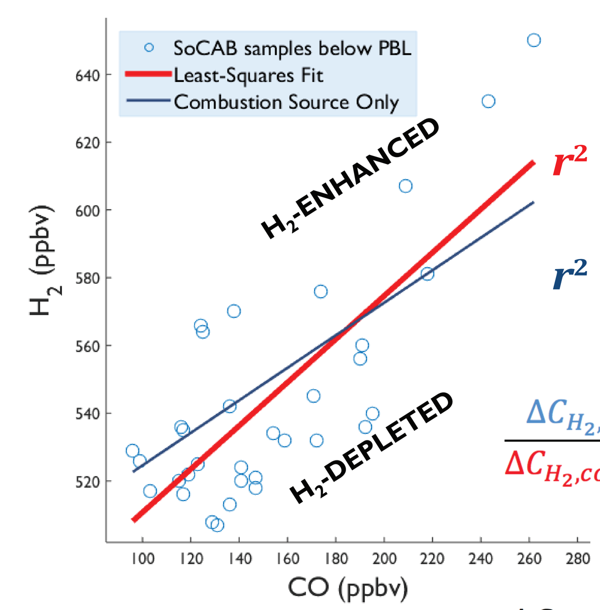
H_2 EMISSIONS ESTIMATION

Data:

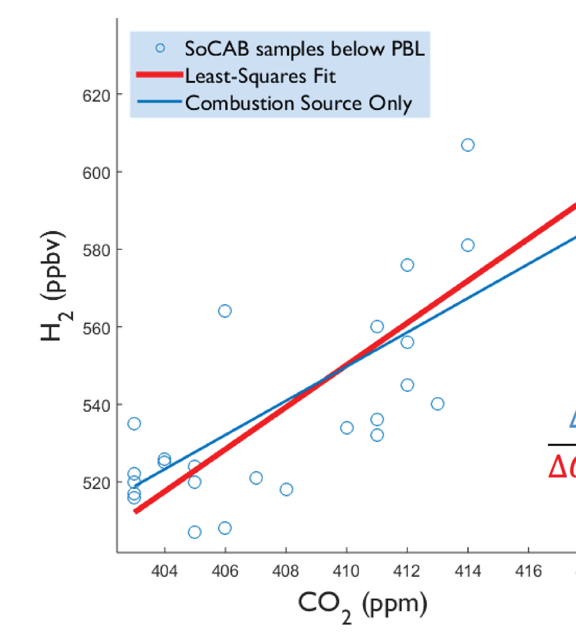
- Two flights and eight missed approaches conducted in NASA's DC-8 aircraft
- 66 ambient air samples within 1000 m of the planetary boundary layer
- 10th percentile selected for background H_2 & CO mixing ratios
- Only compared samples one standard deviation above background levels



Comparing tracer ratios H_2/CO and H_2/CO_2:



$$\frac{\Delta C_{H_2,total}}{\Delta C_{H_2,combust}} = 1.33$$



$$\frac{\Delta C_{H_2,total}}{\Delta C_{H_2,combust}} = 1.23$$

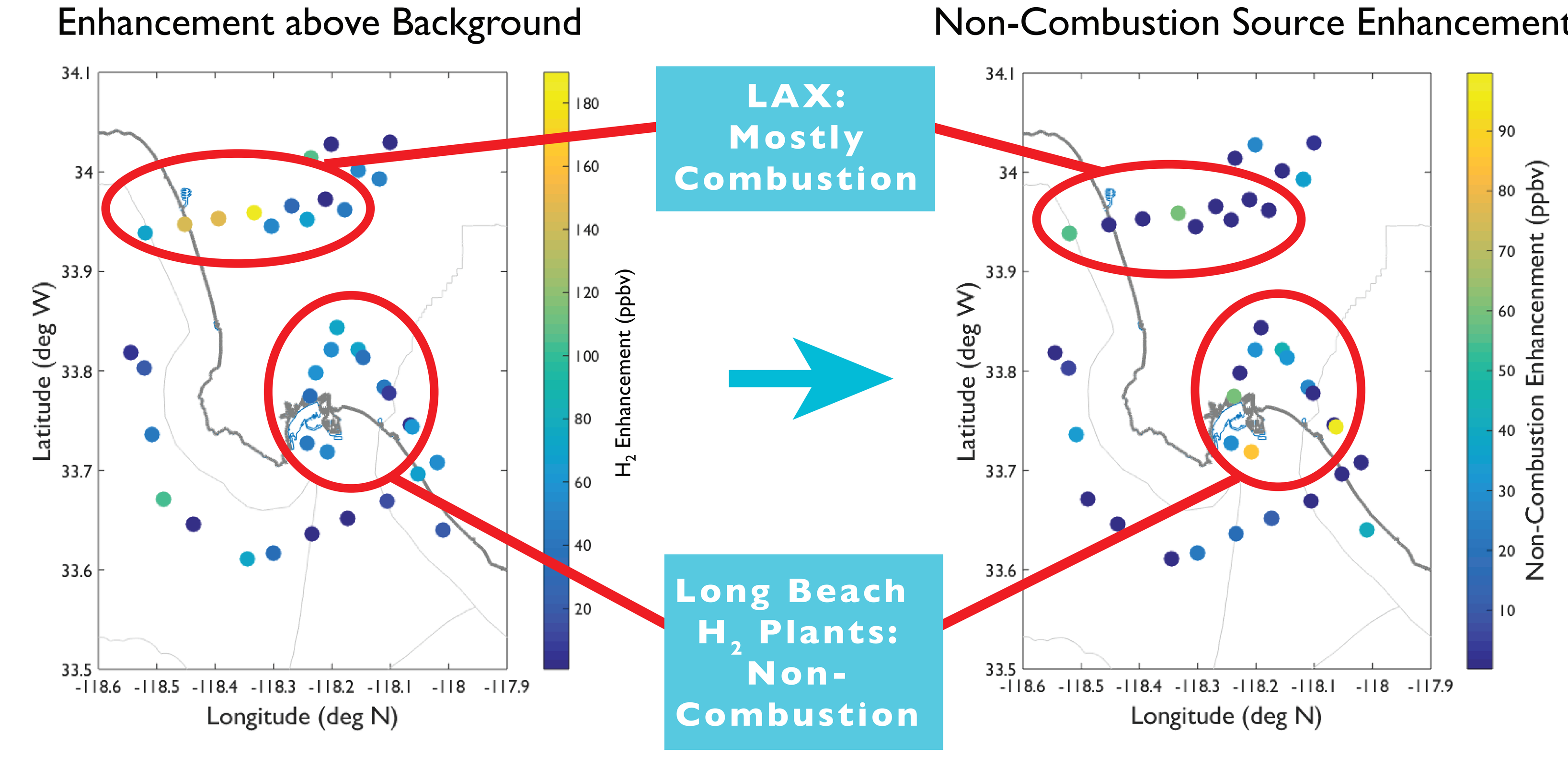
$\frac{\Delta C_{H_2,total}}{\Delta C_{H_2,combust}}$ are within 8% of one another.

Scaling with CO inventory:

$j_{H_2}^{emi,combust} =$ **24.9 ± 3.6 Gg yr^{-1} or 68.1 ± 9.9 tons day^{-1}**

$j_{H_2}^{emi,non-combust} =$ **8.2 ± 4.7 Gg yr^{-1} or 22.6 ± 13.0 tons day^{-1}**

LOCATING LEAKAGE



H_2 enhancement above the background mixing ratio (left) compared with the calculated non-combustion enhancement (ascribed here to direct leakage of H_2 to the atmosphere (right). Note that color scales differ between plots.

INDUSTRIAL LEAKAGE RATE

Source	Daily Output (tons H_2/day)
Carson Air Products Hydrogen Plant	227
Wilmington Air Products Hydrogen Plant	196
Hydrolytic production at H_2 fueling stations	2
DAILY OUTPUT:	**425**

Total daily industrial production of H_2 (left)[3] is focused mainly in the Torrance and Long Beach area (right). Production facilities are shown as yellow triangles and the pipeline connecting them is shown in red.[4]

Total daily production of H_2 in the SoCAB was compared with the top-down results to estimate an upper limit leakage rate of 5%, where all emissions not accounted for by incomplete combustion in engines were assumed to be emitted from H_2 infrastructure.

CONCLUSIONS

- H_2 emissions from non-combustion sources in the SoCAB are likely significant, but more in-depth analysis is required to better understand the atmospheric implications of a hydrogen economy.
- An upper limit leakage rate of 5% was calculated for H_2 infrastructure, to be compared with a range of 0.1-10% given by previous non-experimental estimates
- H_2 industry is nascent: this will serve as a baseline for future studies

  Much more work needed: D/H isotope studies, direct source observations at production plants, fuel pumps, etc.

ACKNOWLEDGEMENTS

Matt would like to thank the NASA Student Airborne Research Program, its administrators at the Univ. of North Dakota, and its supporters in the NASA administration. Extra special thanks go to the Rowland-Blake Lab at UC Irvine and the DC-8 flight crew/staff at Armstrong Flight Center.

REFERENCES

[1]Air Resources Board (California). Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development. June 2014.

[2]Hammer, S., Vogel, F., Kaul, M. and Levin, I. (2009), The H2/CO ratio of emissions from combustion sources: comparison of top-down with bottom-up measurements in southwest Germany. Tellus B, 61: 547–555. doi: 10.1111/j.1600-0889.2009.00418.x

[3]Air Products and Chemicals, Inc. Air Products and Ultramar Sign Hydrogen Agreement. Prnewswire.com. N.p., 16 Jan. 2002.

[4]Abele, Andris R. (TechCompass). 2014. Status of Existing Hydrogen Refueling Stations. California Energy Commission. Publication Number: CEC-600-–2015-004.