Methane emissions from dairies in the Los Angeles Basin

Camille Viatte, Hedelius J., Chen J., Parker H., Jones T., Franklin J., Lauvaux T., Deng A.J., Gaudet B., Wunch D., Roehl C., Duren R., Verhulst K., Dubey M. K., Wofsy S., and Wennberg P. O.

TCCON/IRWG meeting Toronto, June 8th-12th 2015

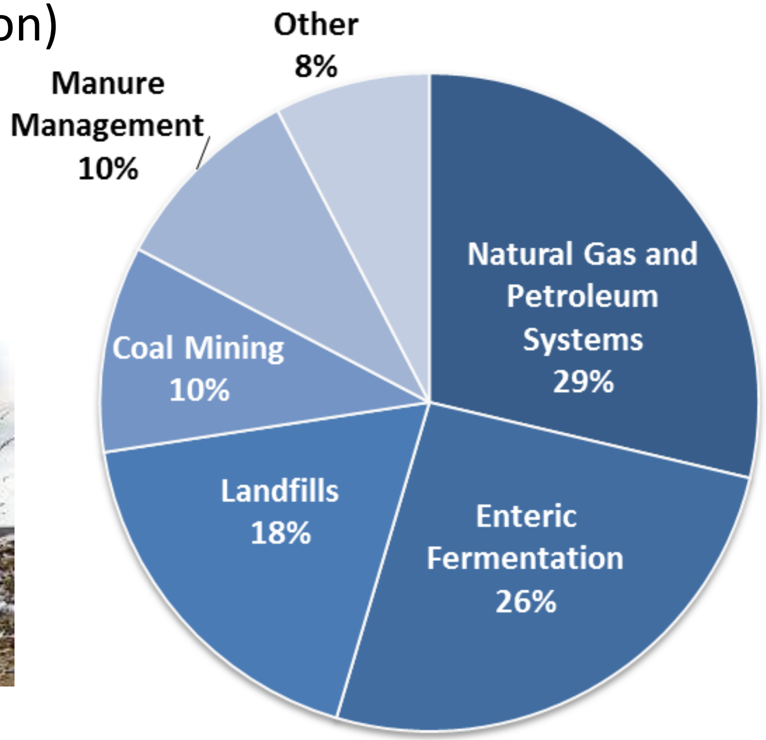
Methane emissions

In the US

- White House requires to reduce methane emissions by at least 17% by 2020 [Climate action plan, March 2014].

Sources include:

- ❑ Agriculture (enteric fermentation + manure management + rice cultivation)
- ❑ Energy sector (natural gas and oil operations and coal mining)
- ❑ Waste management (landfills and waste treatment)
- ❑ Biomass burning



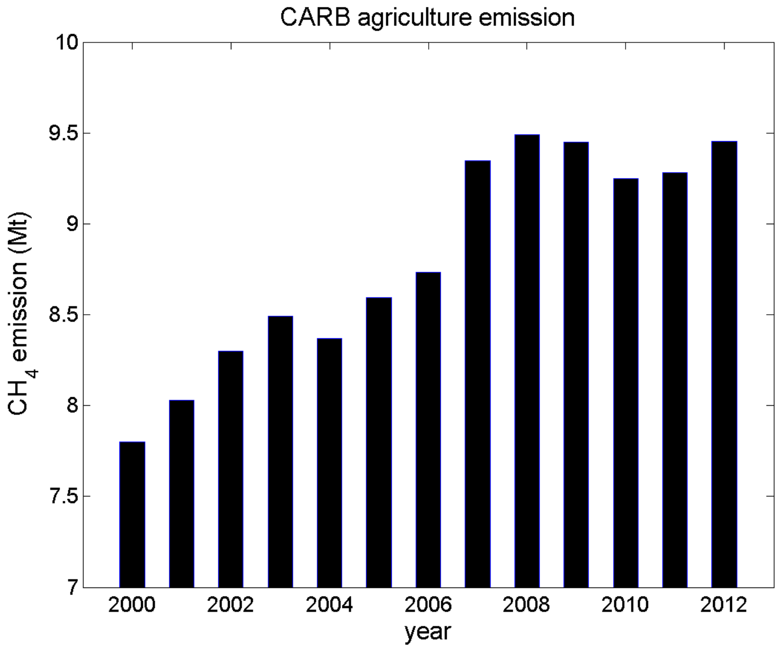
[U.S. Environmental Protection Agency (EPA), inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2013 (April 2015)]

- Between 1990 and 2013, CH_4 emissions from agricultural activities increased by 11.3% [EPA, US-GHG-Inventory-2015-Chapter-5-Agriculture.pdf]

Methane emissions

In California

- The California Air Resources Board (CARB) estimate CH_4 emissions from agriculture:

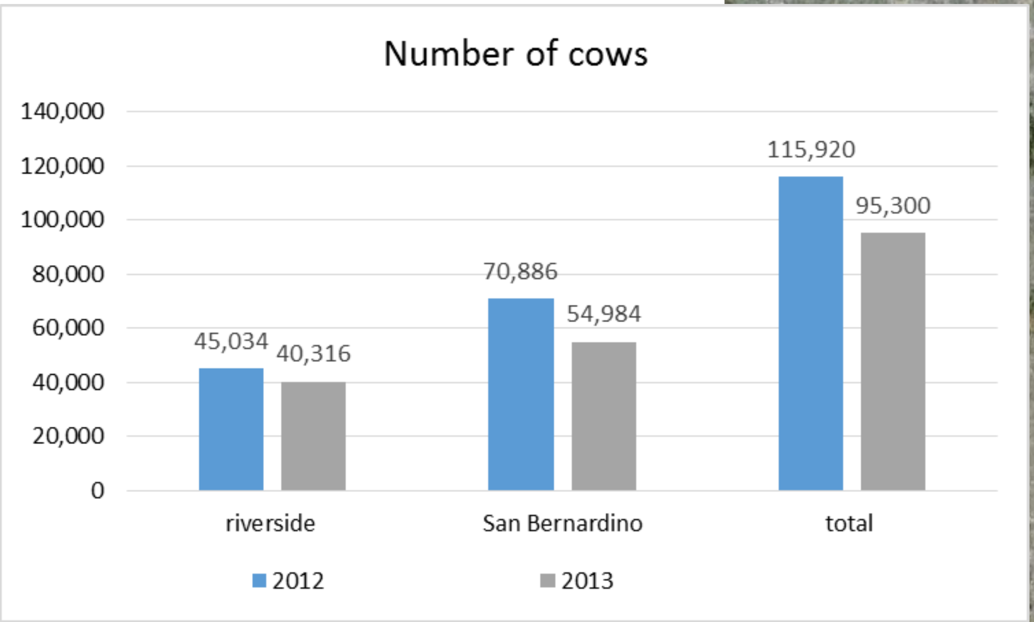


- GHG from agriculture are projected to increase by 80% by 2050 [Tilman and Clark, 2014].
- Livestock (mainly dairy cows) account for 63% of the total agricultural emissions.

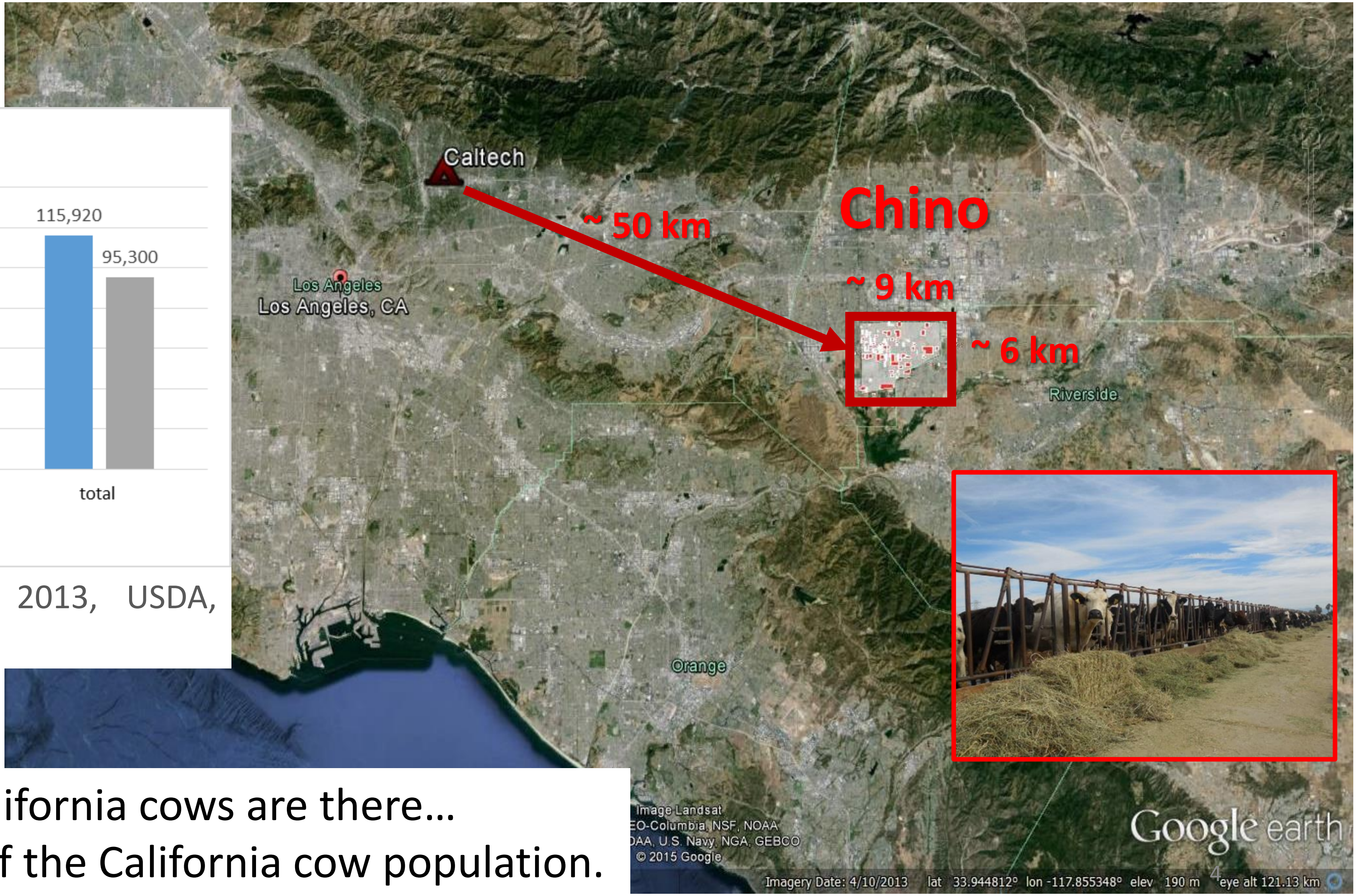
- Actions are already underway to reduce methane emissions from oil and gas drilling and storage sites. Now, efforts are made to reduce emissions from dairies [ARB concept paper, May, 7th, 2015].
- Total CH_4 emission is well-known, however the individual contributions from its diverse sources remain uncertain [Wunch et al., 2009; Wennberg et al., 2012; Hsu et al. 2010; Peischl et al., 2013; Miller et al., 2013; Guha et al., 2015; Wong et al., 2015].

Methane emissions

In Los Angeles



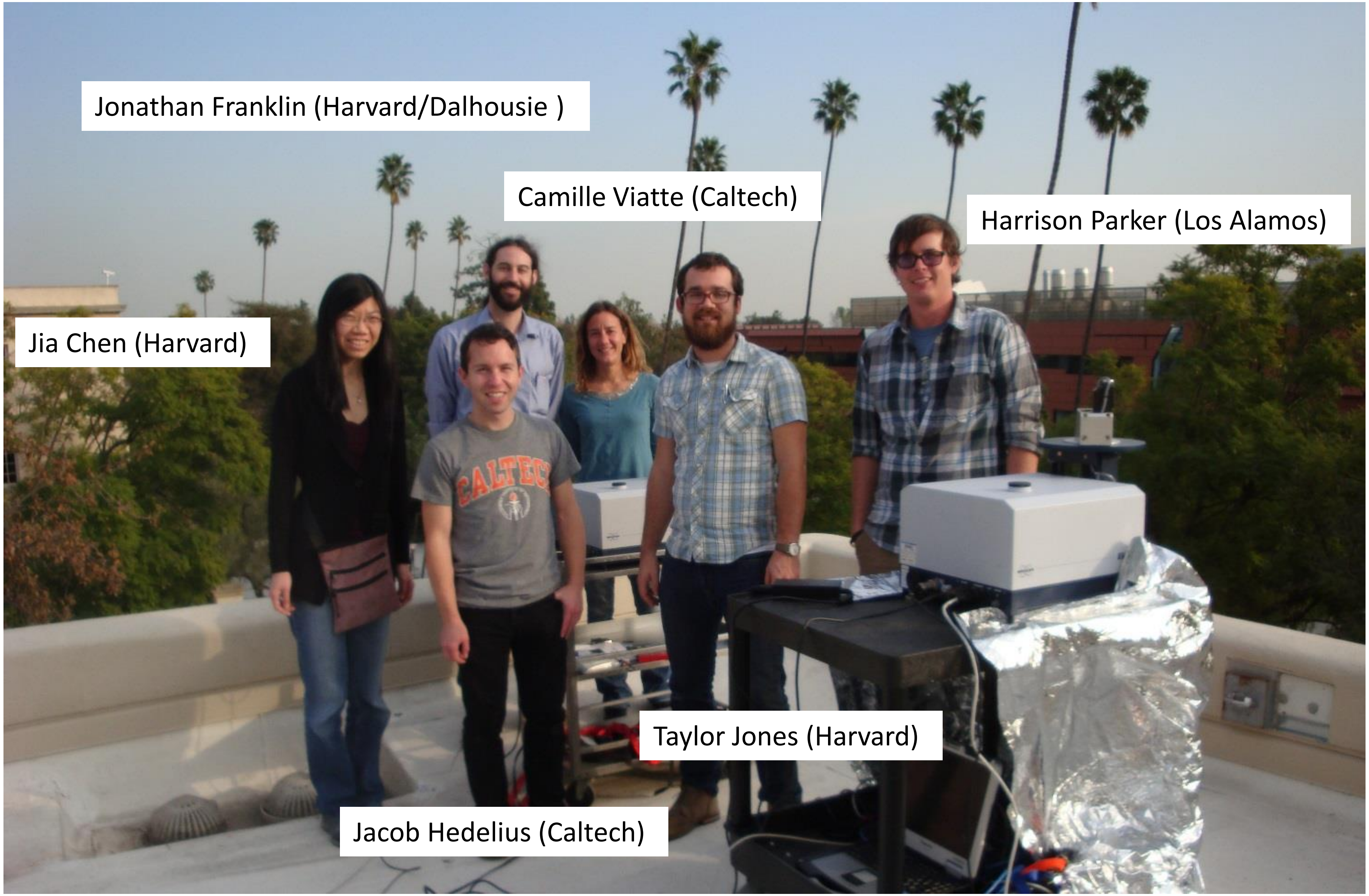
[California Agricultural Statistics, 2013, USDA, NASS, Pacific Region]



- ~90% of all Southern California cows are there…

But it only represents 5% of the California cow population.

Campaign EM27 (January 05th to 31th, 2015)



Two-phases EM27 campaign

1) Inter-comparisons – calibrations (10-12 days)

- Calibrate each EM27 with the existing TCCON station.
- Assess the capacity of the EM27's.

2) Field campaign (4 days)

- Develop a methodology to estimate GHG (mainly methane) emissions from local source with mobile FTS (EM27).

Calibration TCCON – EM27s

Note: results are quantitative (smoothed by AKs), 10 min averaged, and within 10 to 12 days of comparison

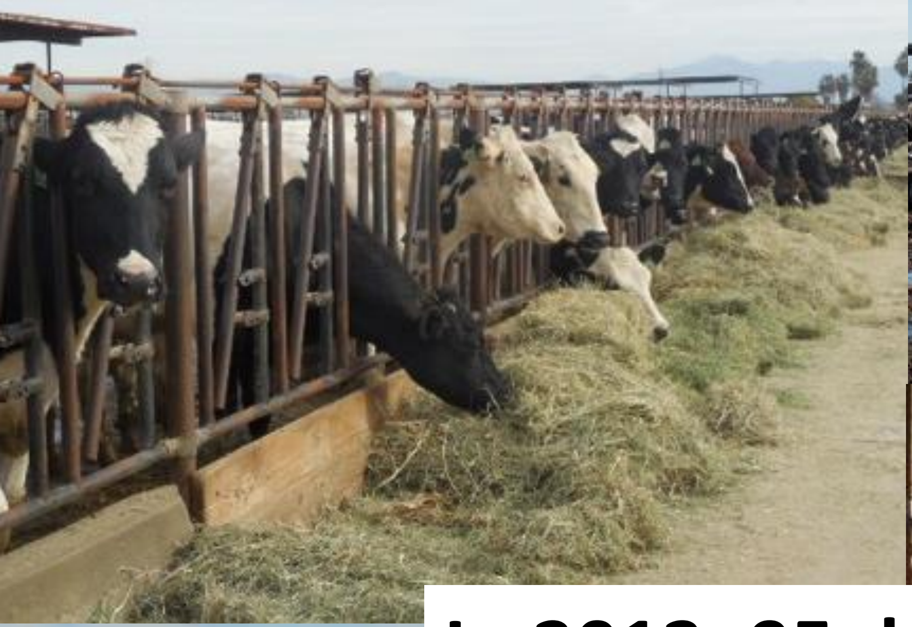
XCO_2 (ppm)	EM27 vs. TCCON			
	N	slope	slope_err	r^2
Caltech (cn)	264	0.99795	0.00012	0.899
LANL (pl)	225	0.99827	0.00009	0.930
Harvard1 (ha)	146	0.99863	0.00109	0.922
Harvard2 (hb)	143	0.99798	0.00014	0.921

XCH_4 (ppm)	EM27 vs. TCCON			
	N	slope	slope_err	r^2
Caltech (cn)	264	1.00820	0.00016	0.956
LANL (pl)	225	1.00730	0.00017	0.955
Harvard1 (ha)	146	1.01210	0.00021	0.944
Harvard2 (hb)	143	1.00790	0.00022	0.951

- Good agreement between EM27s and TCCON

[Hedelius J. et al.: *Intercomparison of XGas measurements from multiple Low and High-Resolution Near IR Solar Viewing Spectrometers*, to be submitted in AMT]

Chino - California



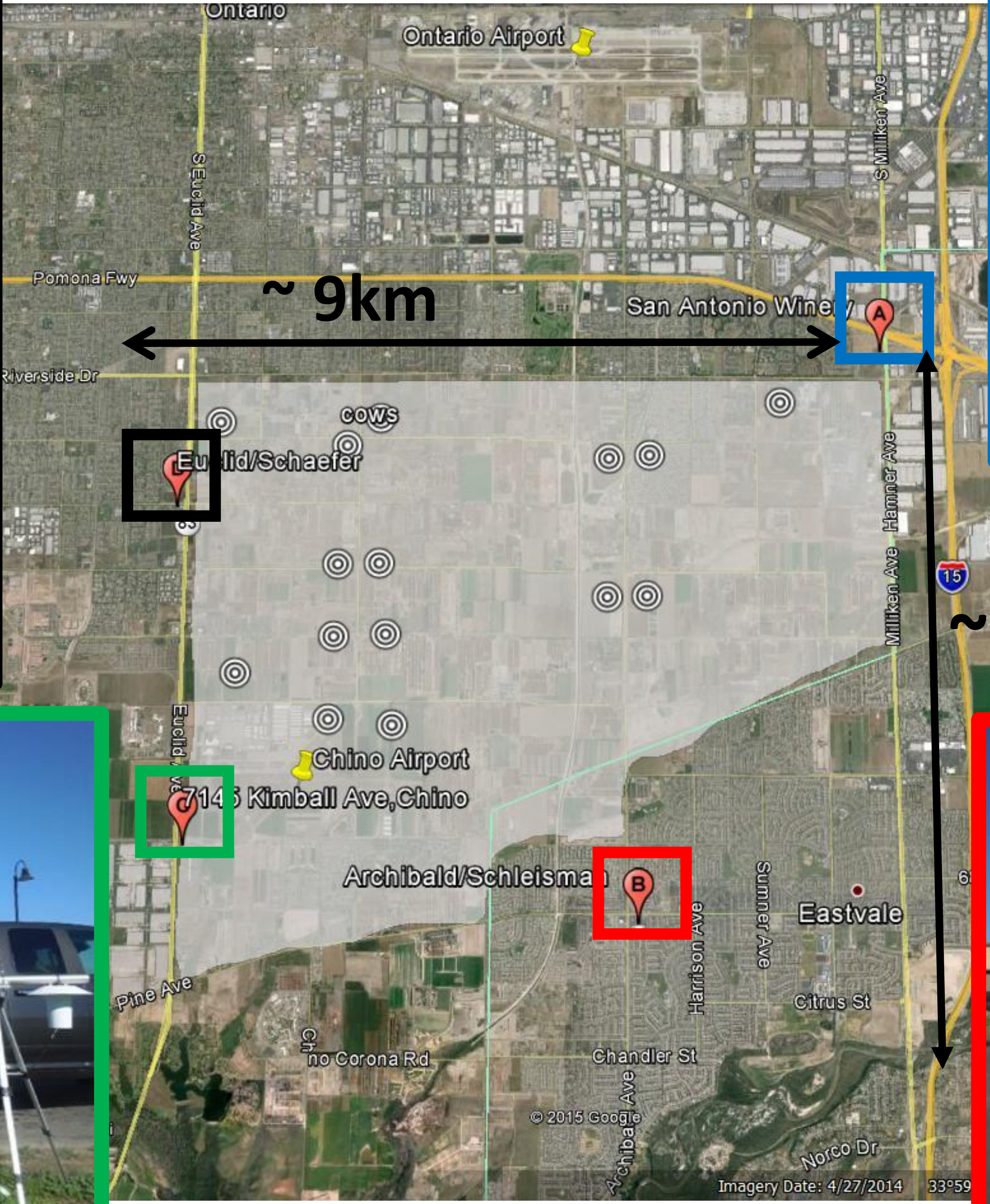


In 2013: 95 dairies with 95 300 dairy cows

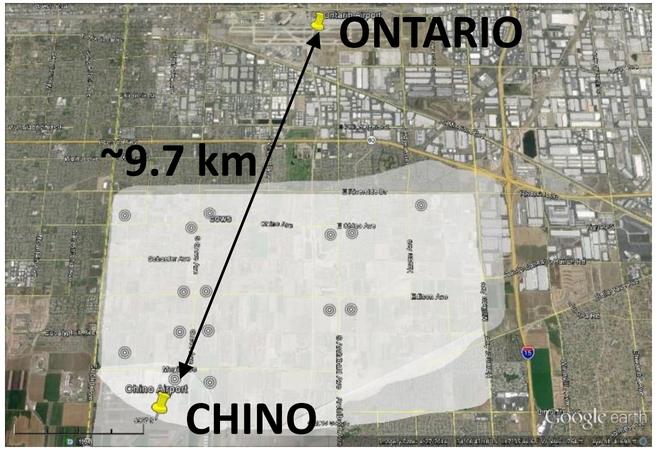


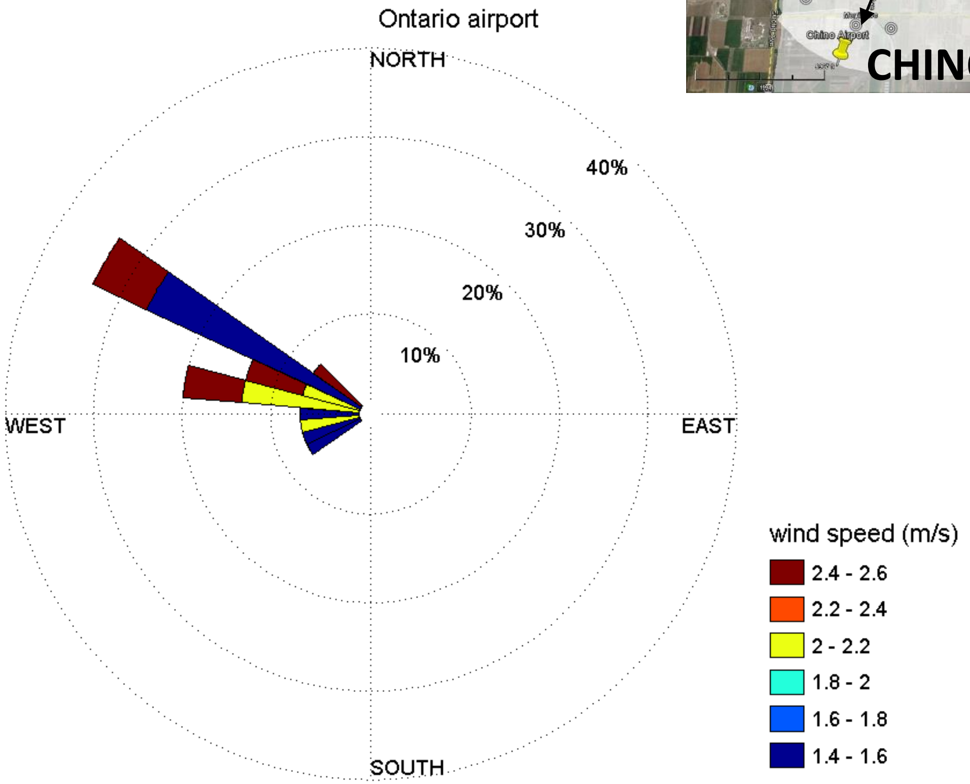


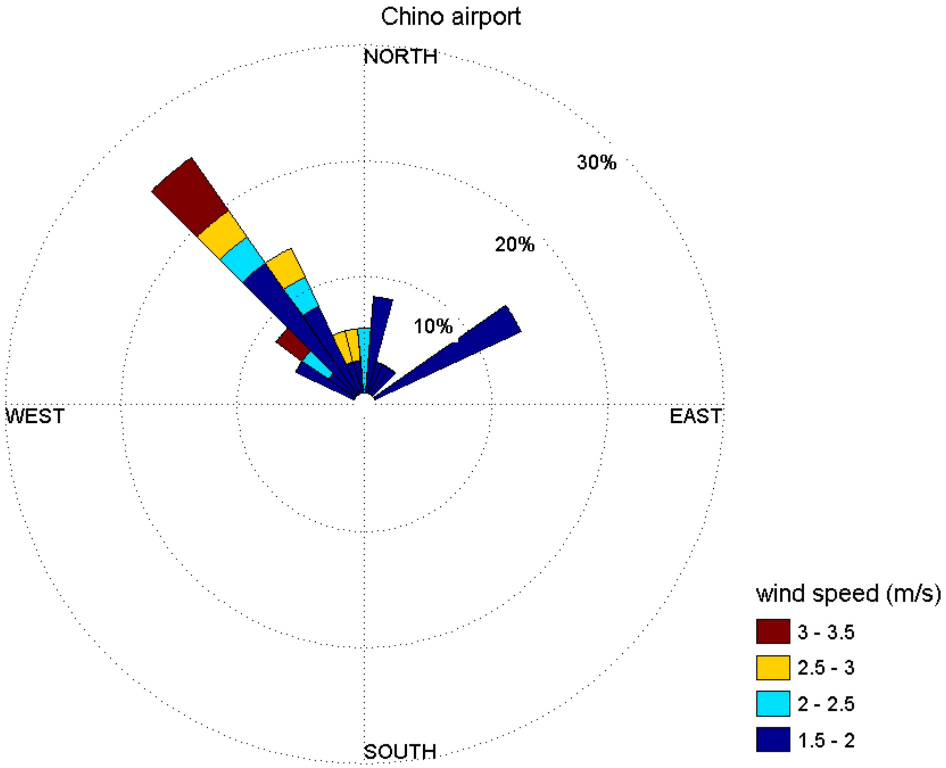
January 15th locations



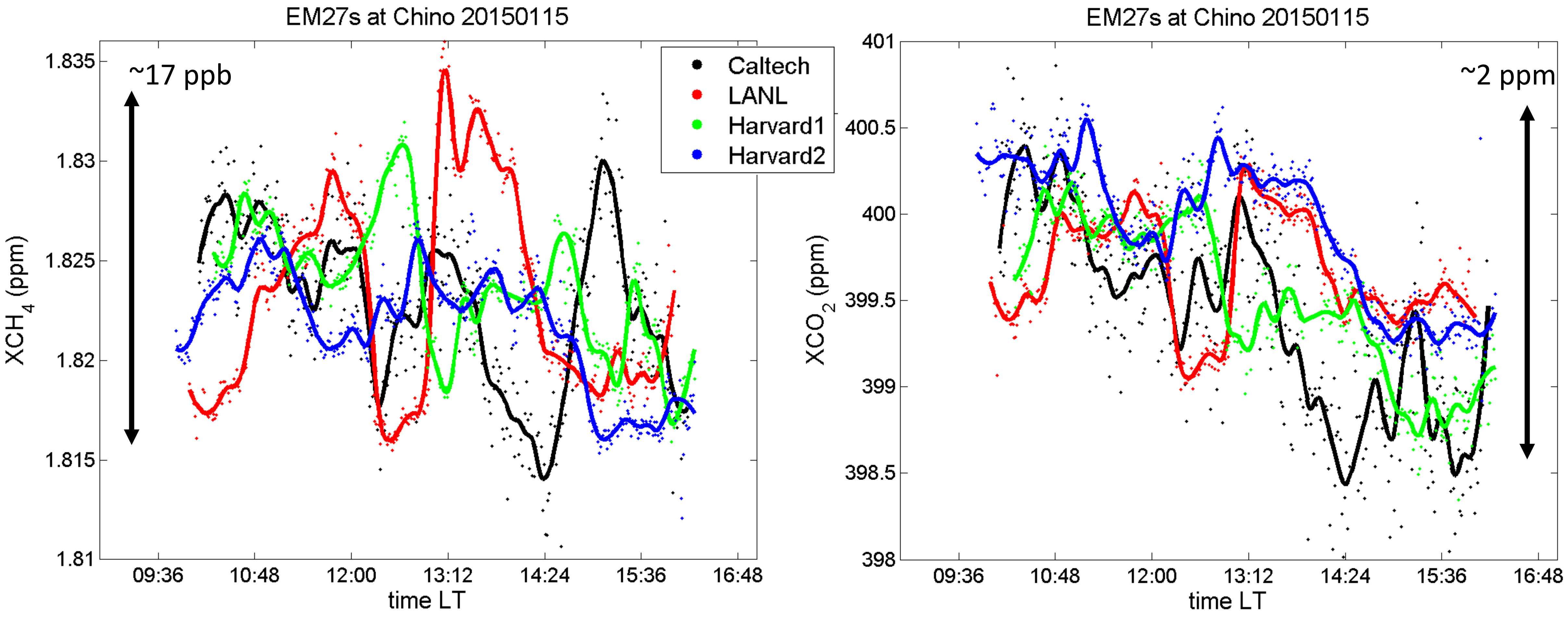
January 15th wind measurements





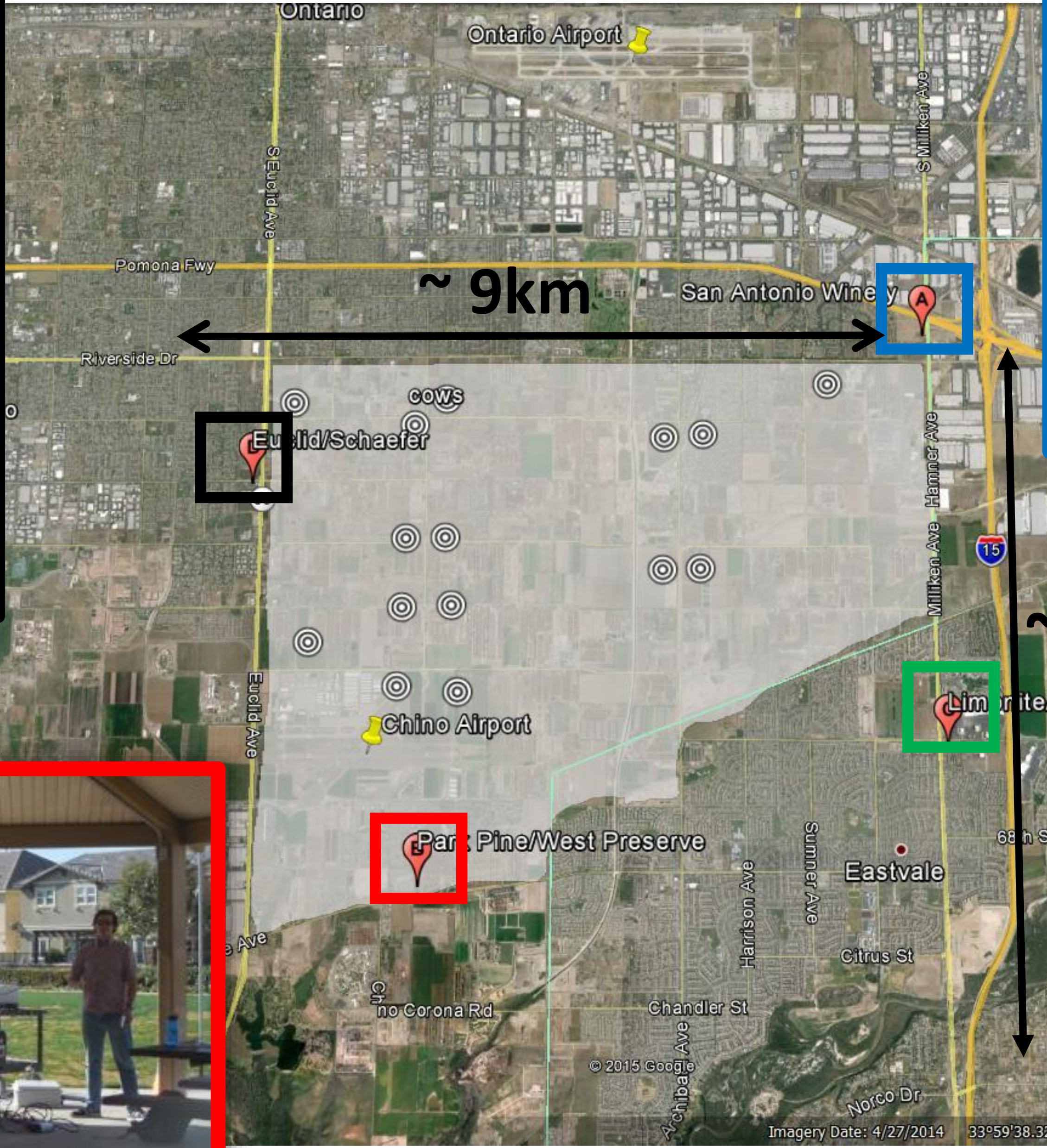


January 15th GHG gradients

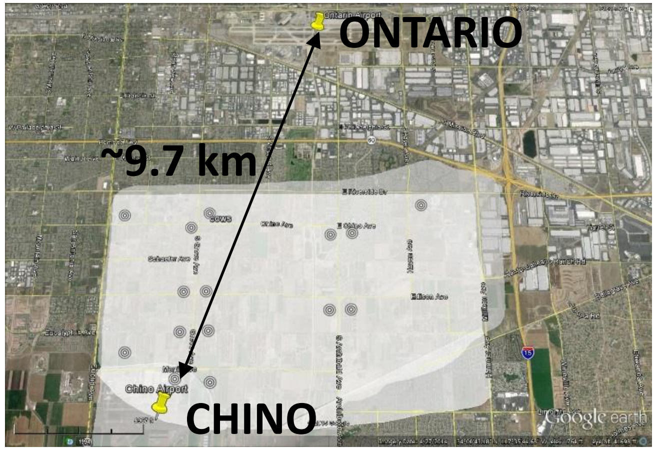


Wind speed is low (<3 $m.s^{-1}$) and direction changed all day

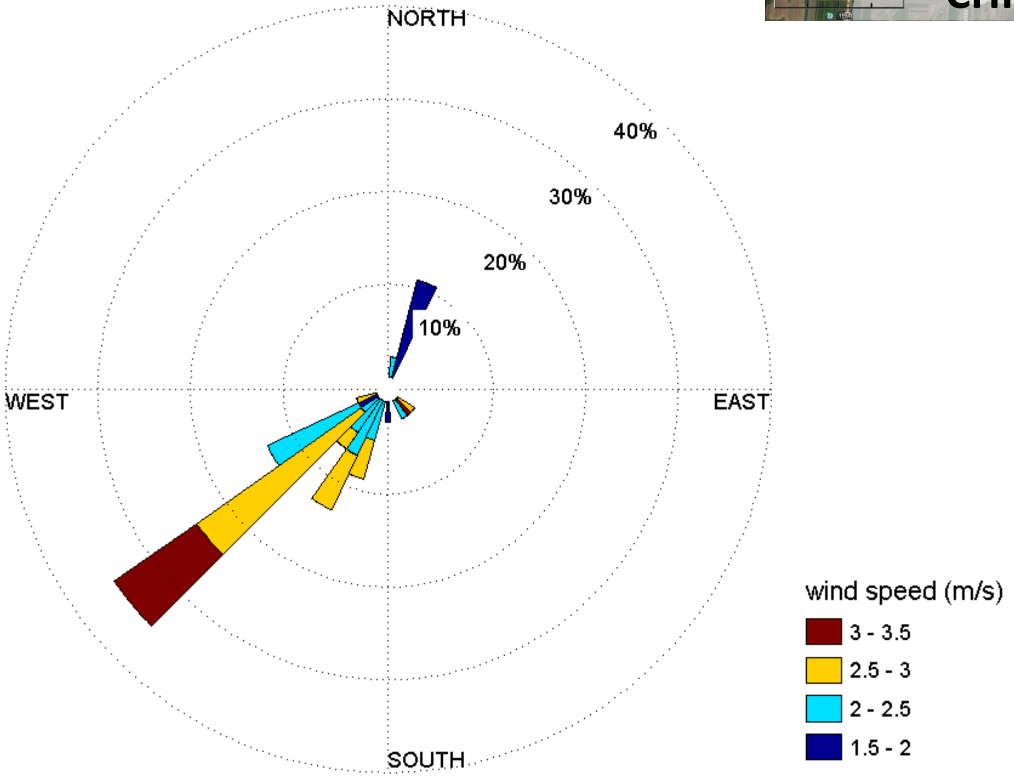
January 16th locations



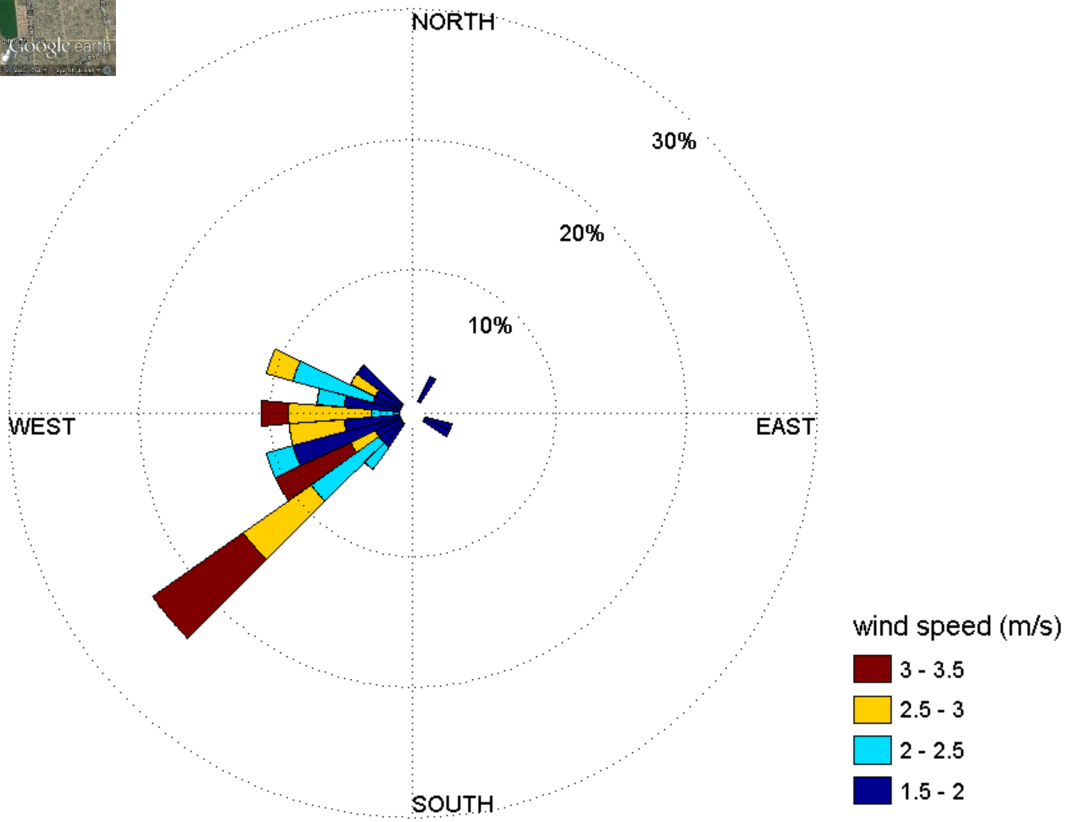
January 16th wind measurements



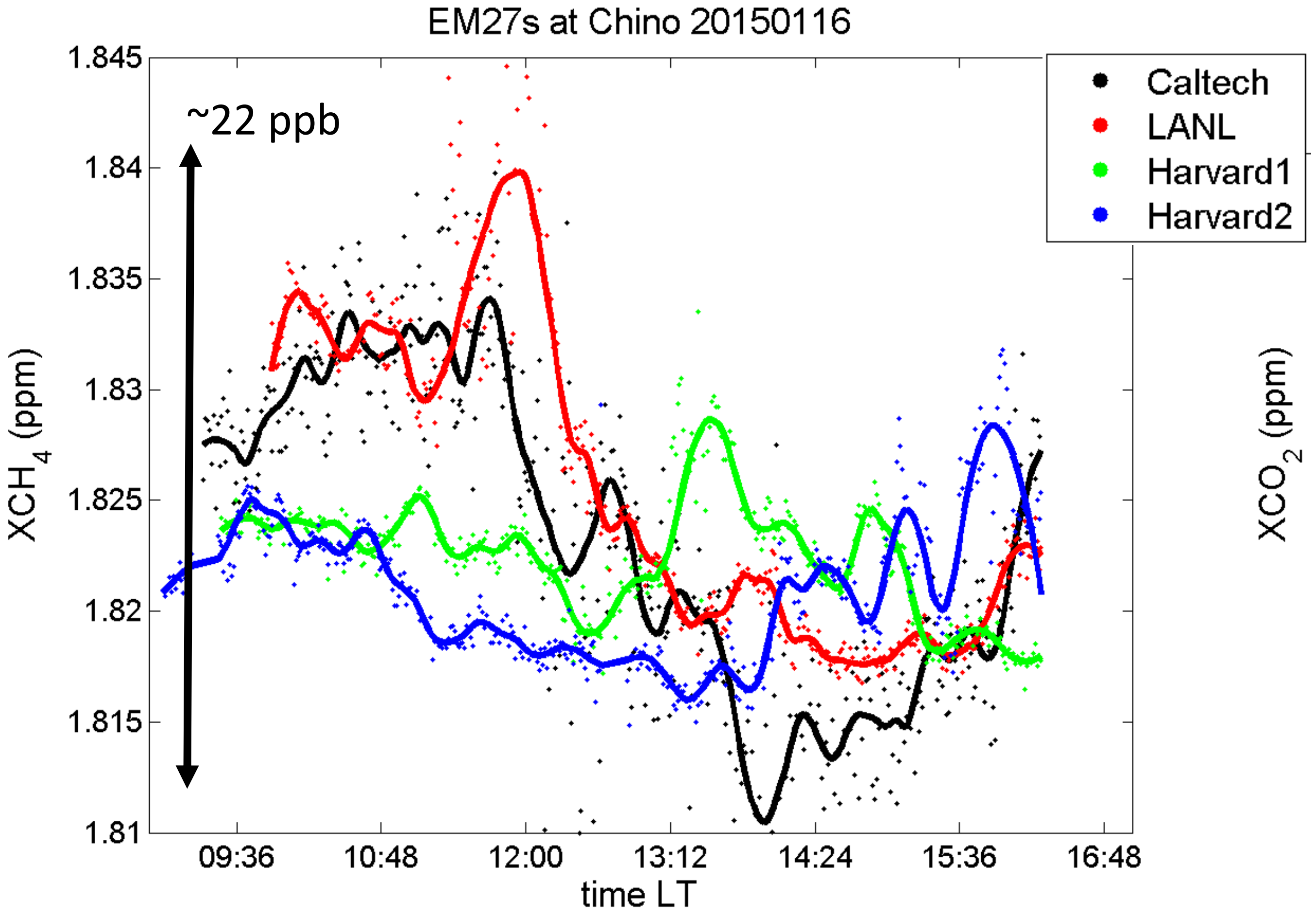
Ontario airport

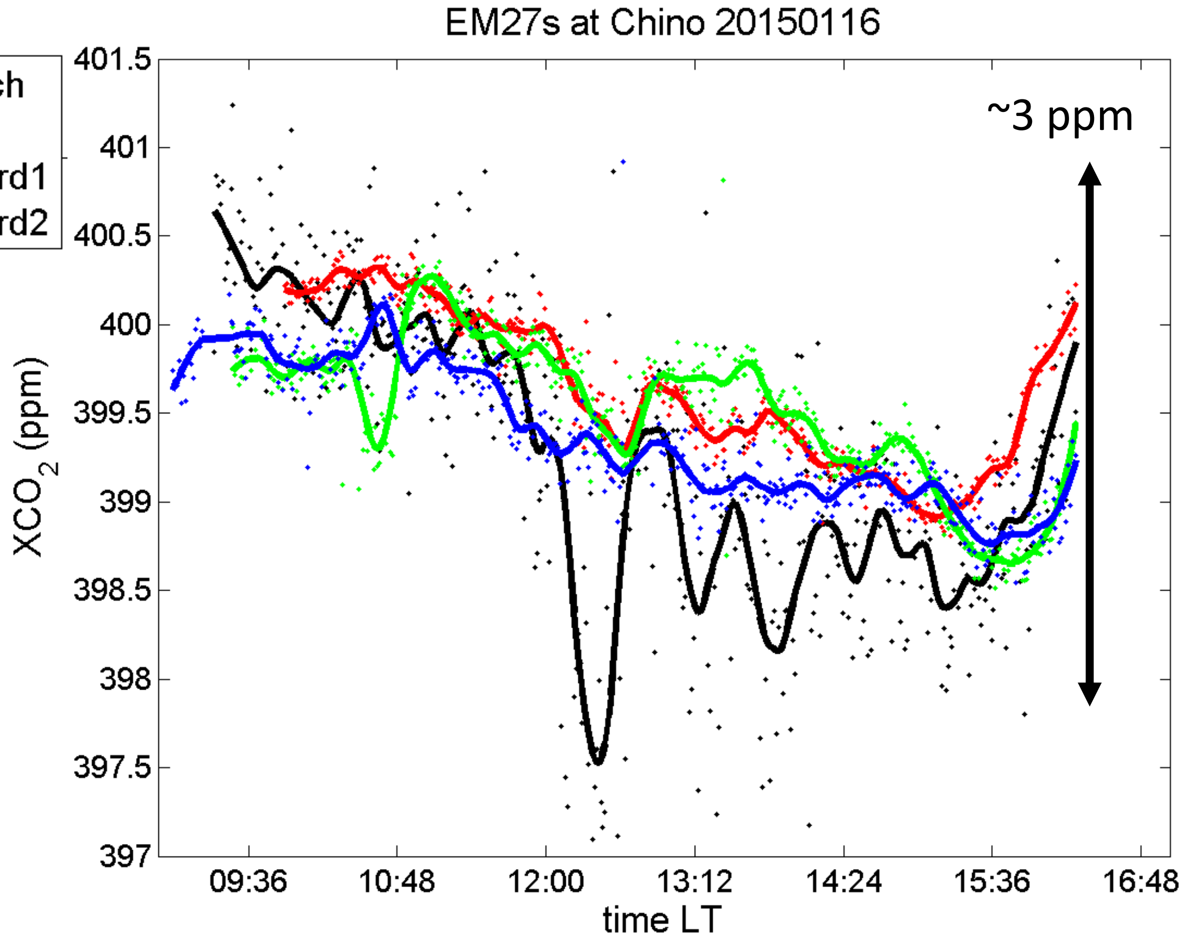


Chino airport



January 16th GHG gradients



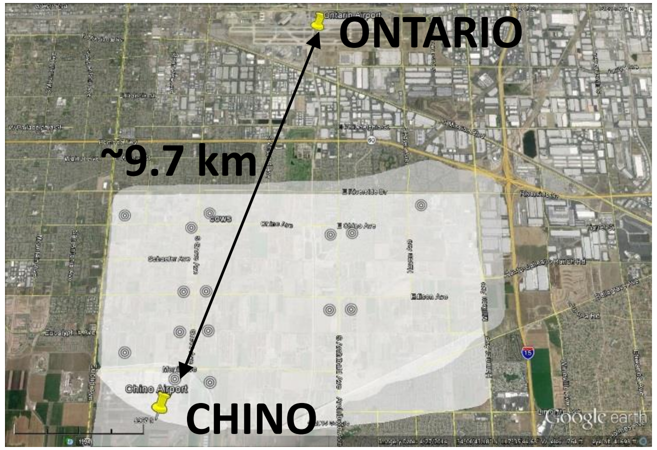


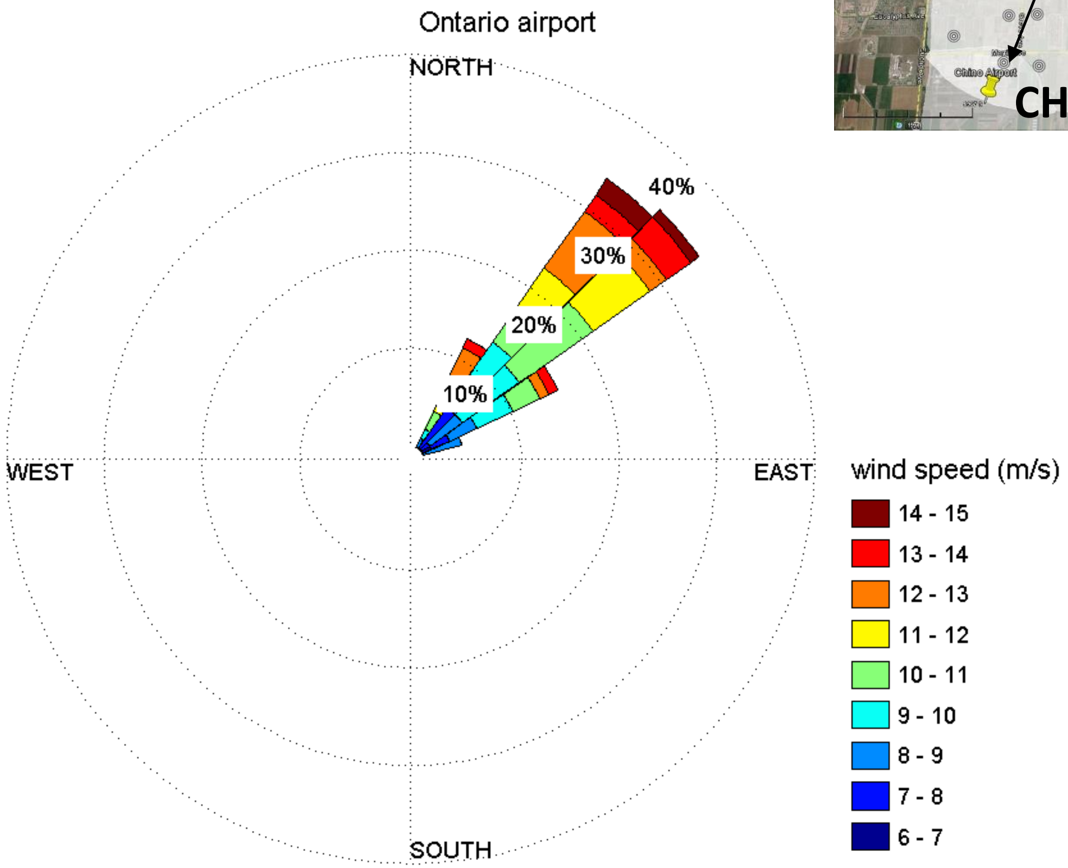
- EM27 clearly are able to measure local GHG from local point source (< 10km)

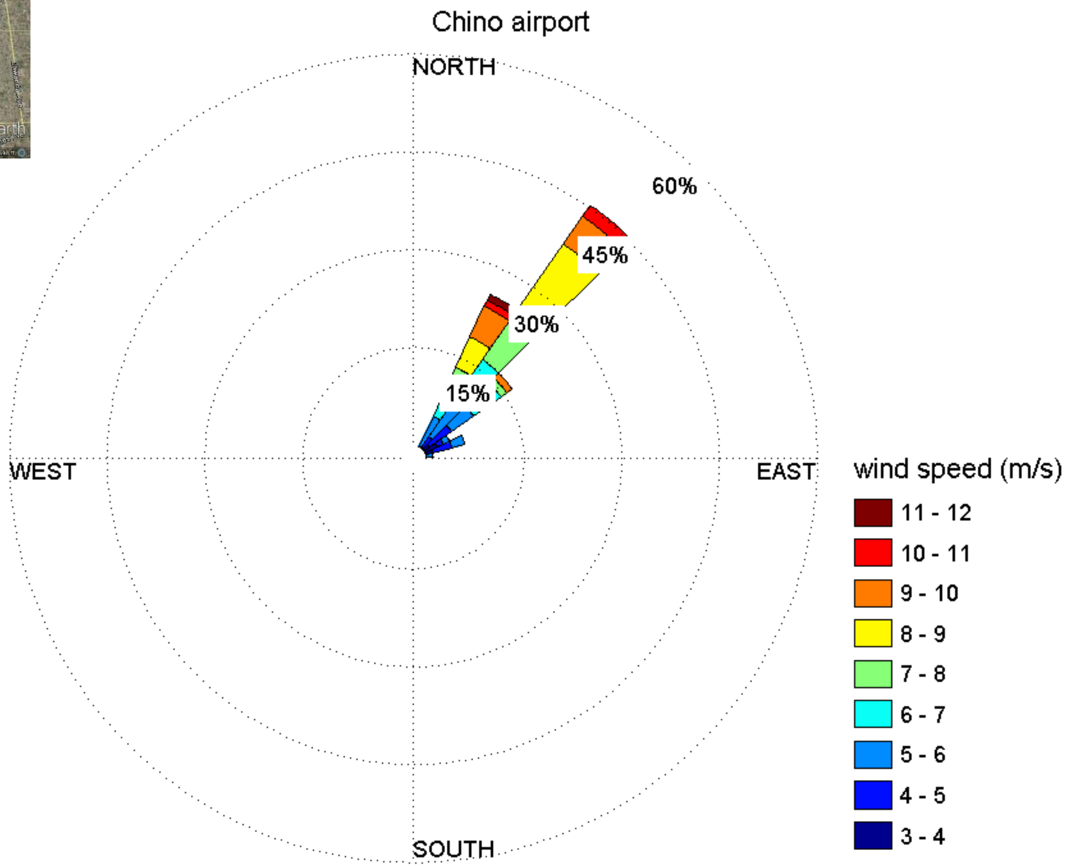
[Chen J. et al.: Differential Column Methodology Using Compact Solar-Tracking Fourier Transform Spectrometers, to be submitted in GRL]

January 24th locations

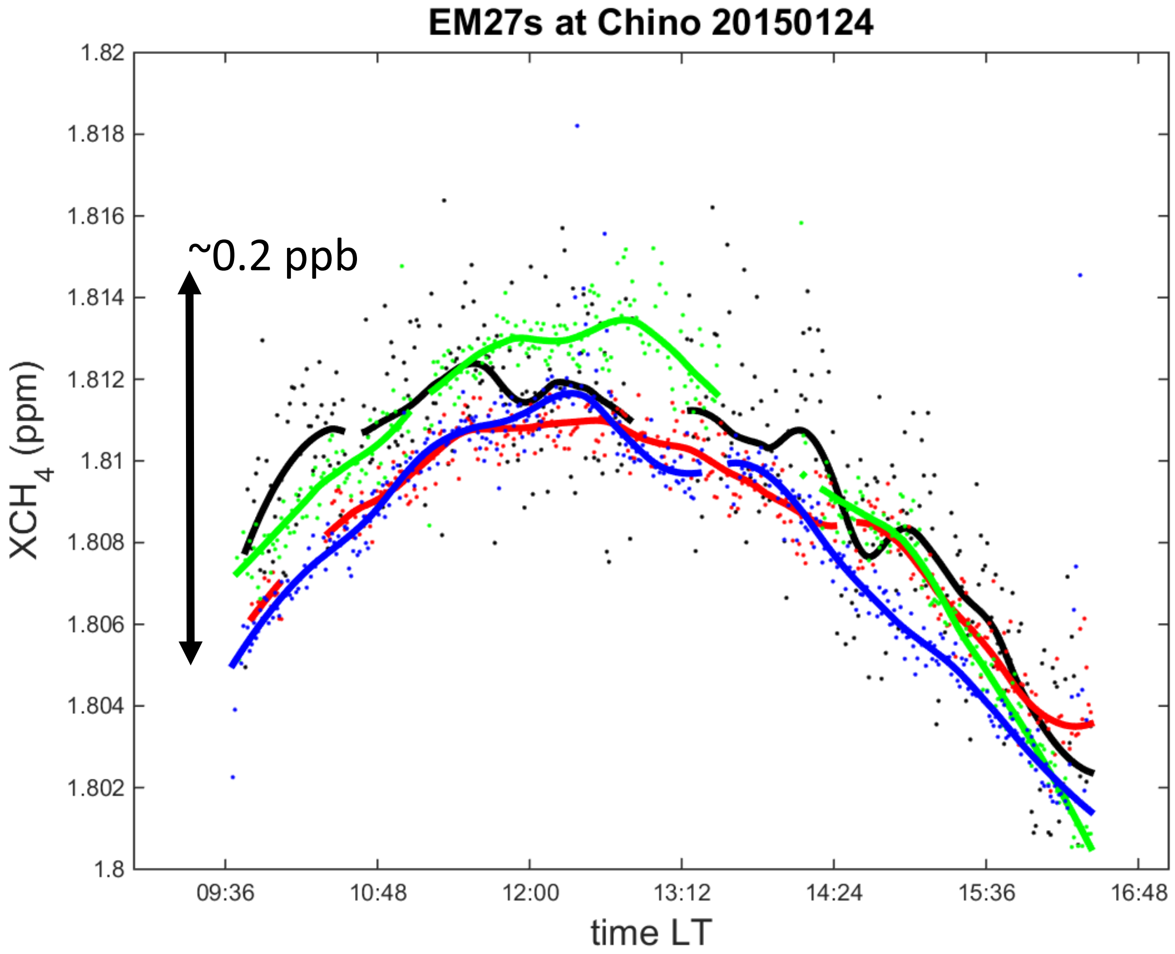
January 24th wind measurements

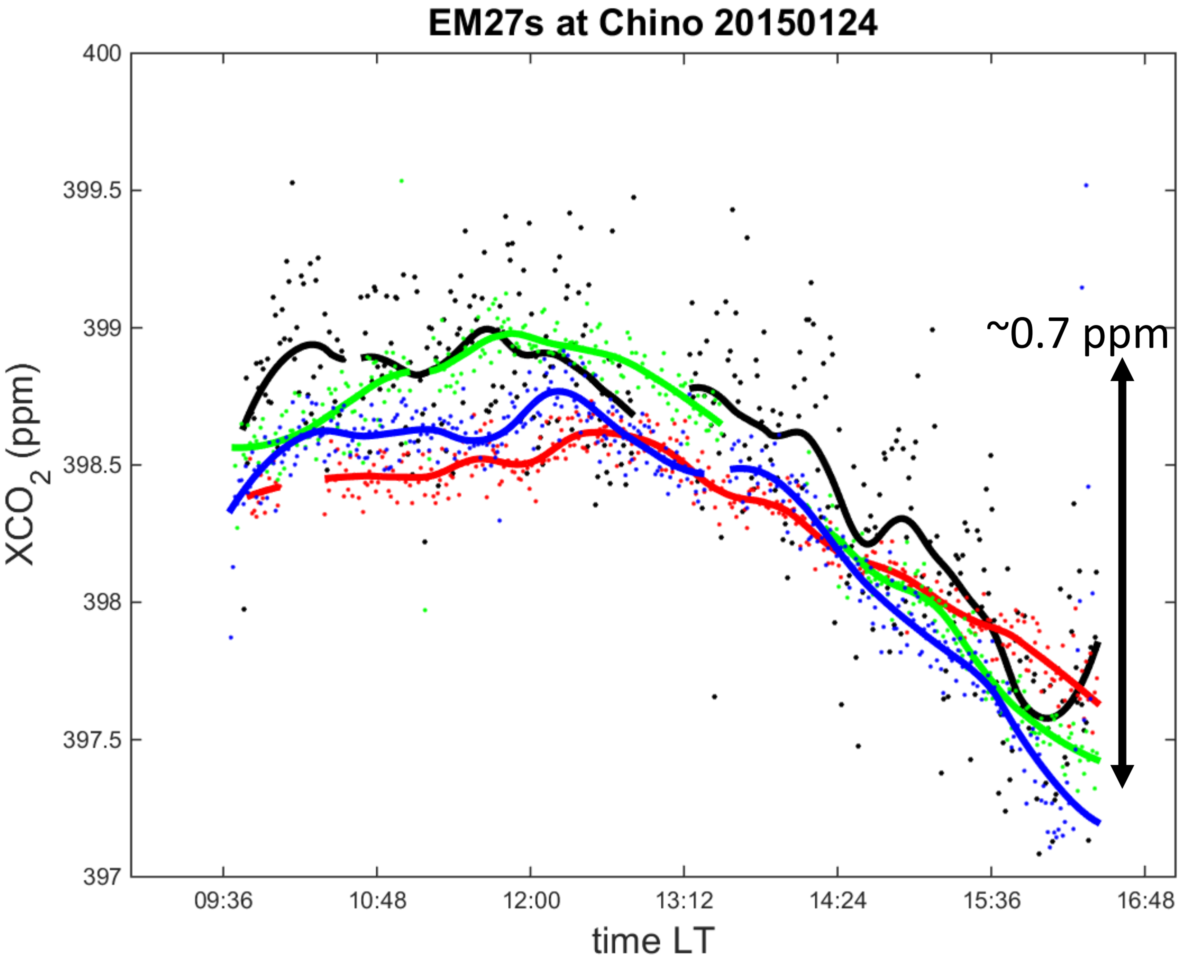






January 24th GHG gradients





Wind speed is high (~10m.s^{-1}) and steady direction

Flux estimate

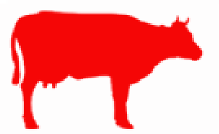
At Chino

“Top-down” approach

- Using a differential approach (upwind / downwind)
- Using an inverse modelling with WRF-LES

➢ Develop a methodology including all FTS measurements and characterize the errors

“Bottom-up” approach



1 dairy cow

95000 dairy cows

From CARB (2012):

~ 150 kg CH_4/yr (enteric) +

~ 18 kg CH_4/yr (dry manure) +

~ 336 kg CH_4/yr (anaerobic lagoon)

Fluxes at Chino per year:

~ 14.2 Gg CH_4/yr

~ 16.0 Gg CH_4/yr

~ 48.0 Gg CH_4/yr

Flux estimate

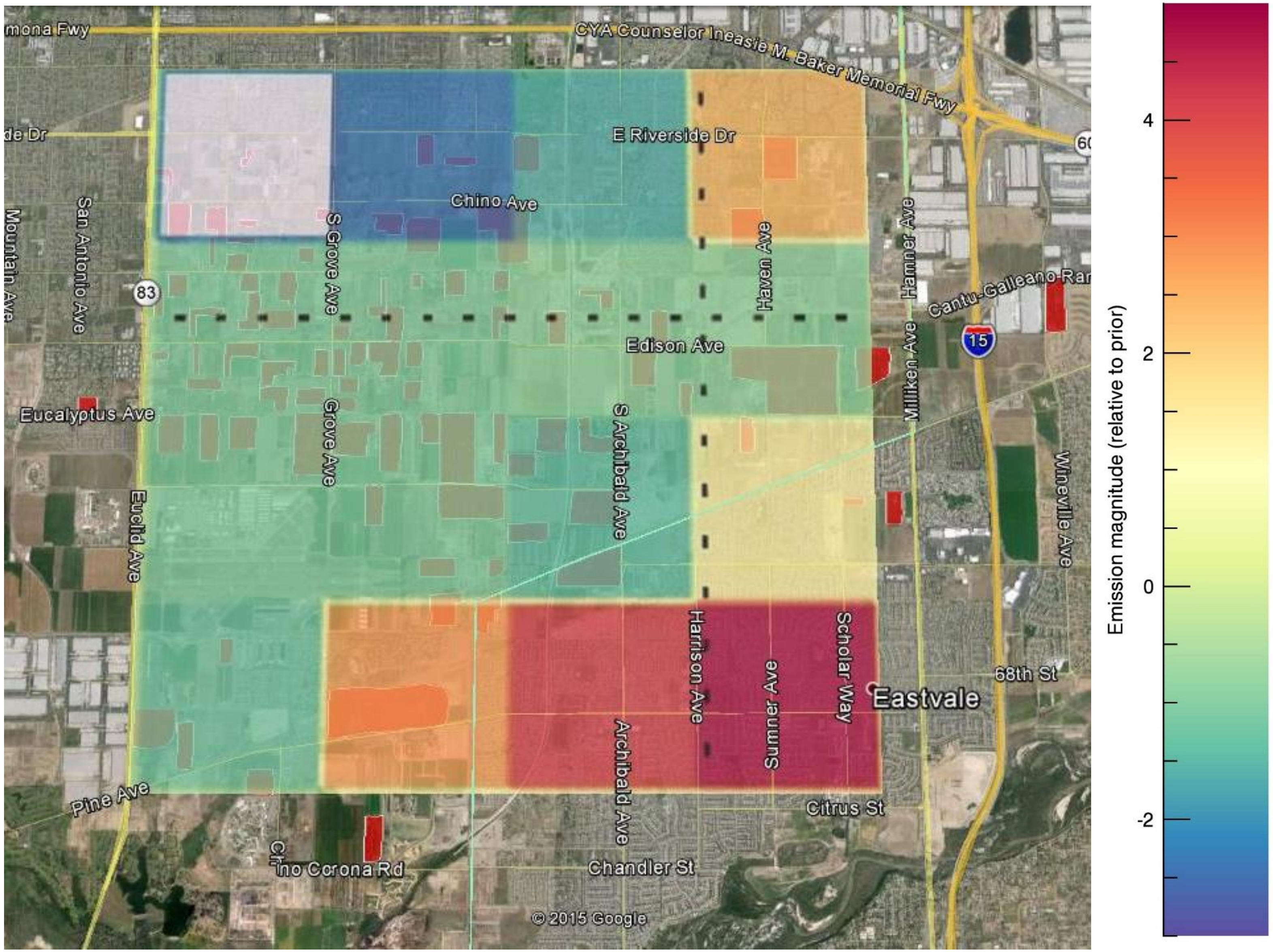
- A priori fluxes from CARB 2012 (cow + dry manure) [Peischl et al., 2013]

- A posteriori fluxes from WRF-LES

Higher fluxes

Same fluxes

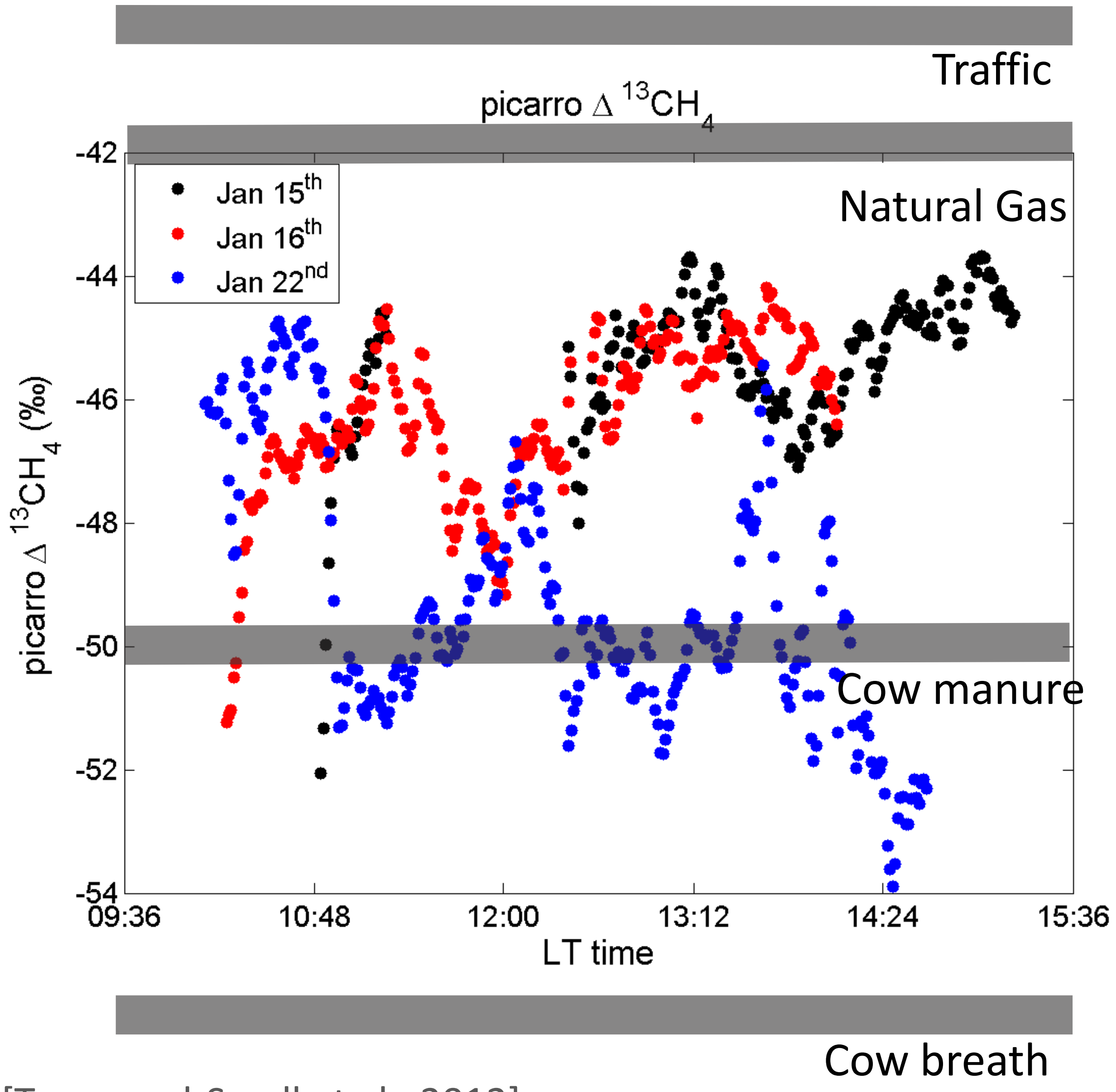
Lower fluxes



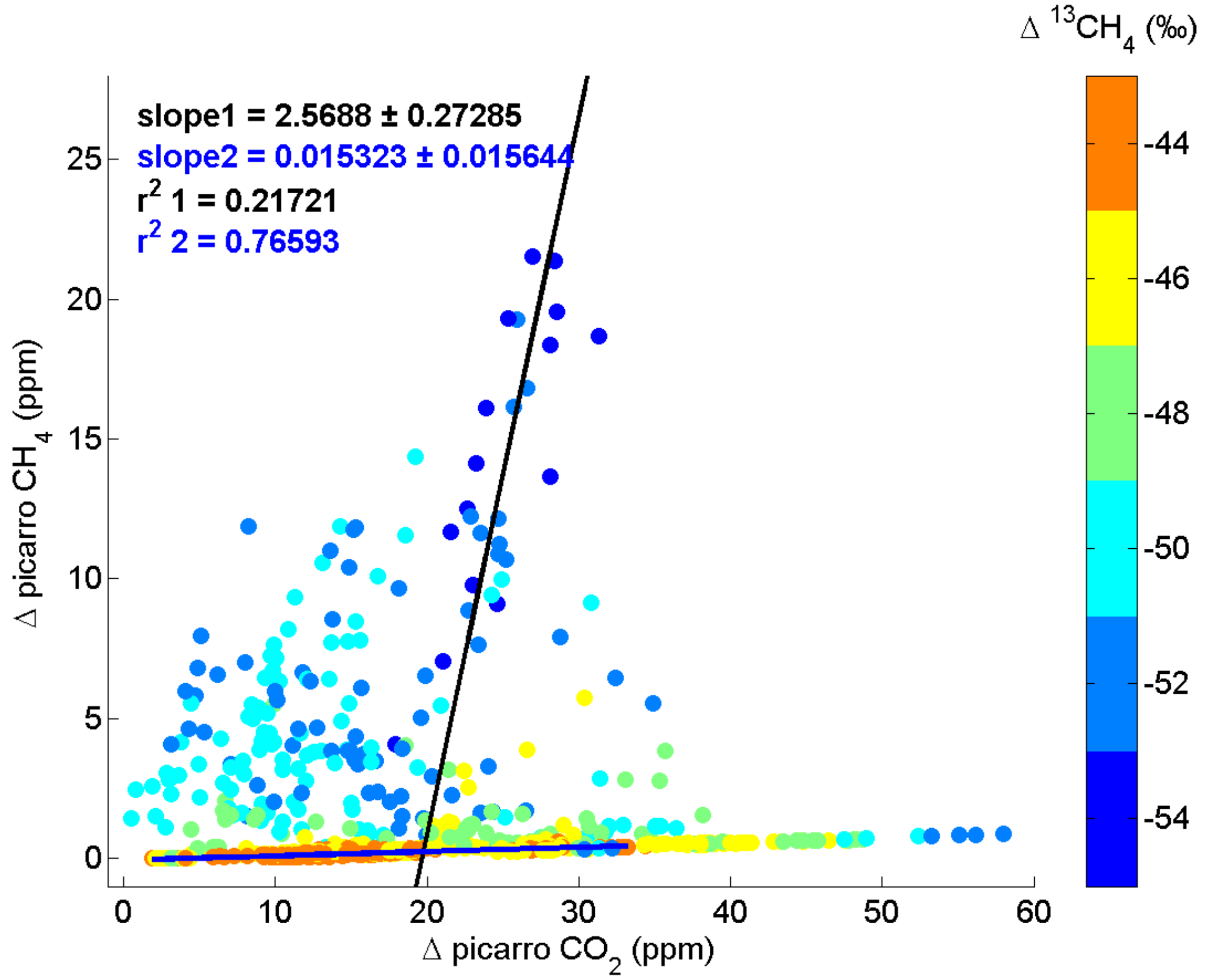
- WRF-LES simulations suggest not an homogeneous source

Lauvaux T., Gaudet B., Deng A. J.

Picarro data

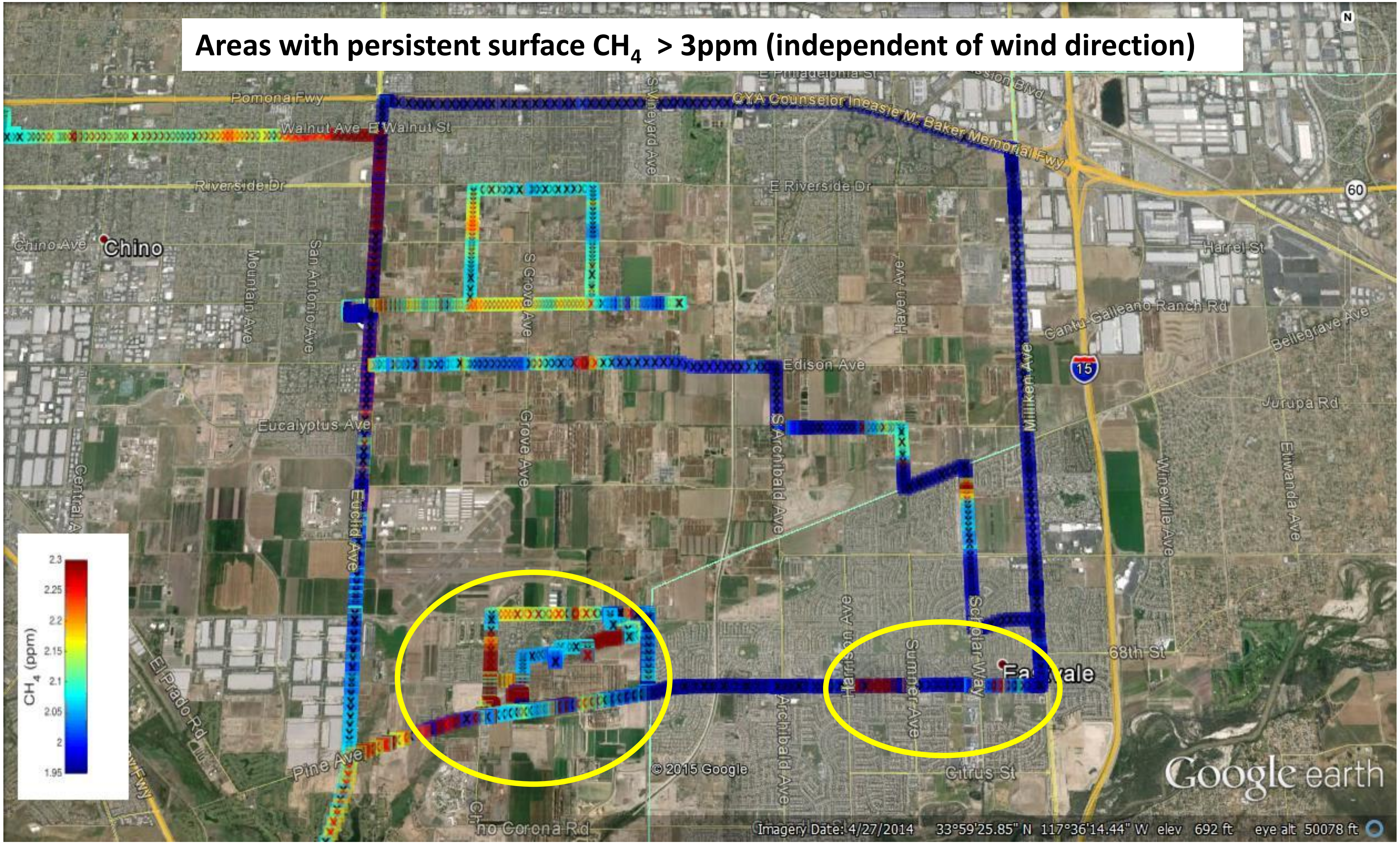


Mixture of biogenic and anthropogenic
➔ two tendencies



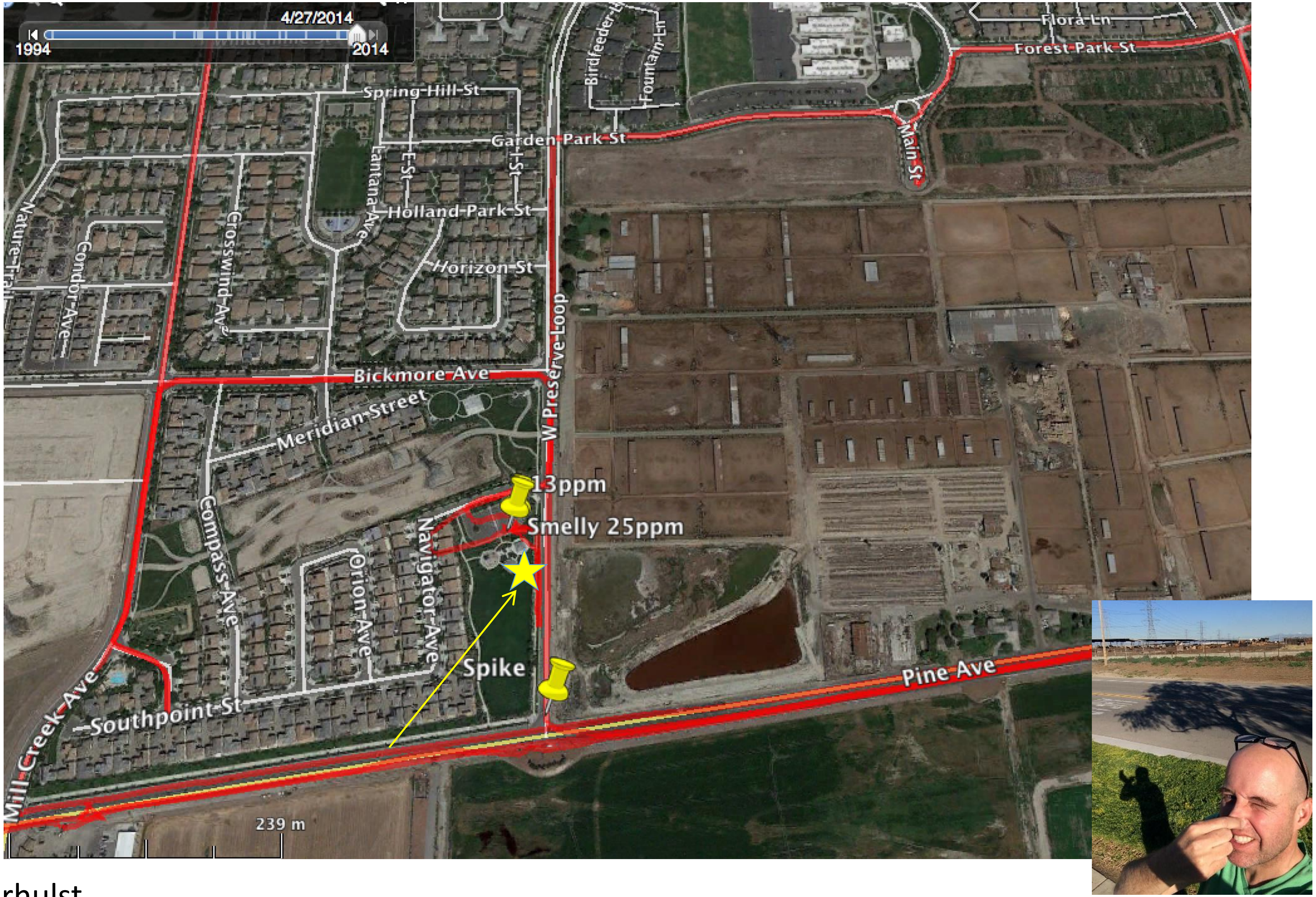
[Townsend-Small et al., 2012]

Picarro data



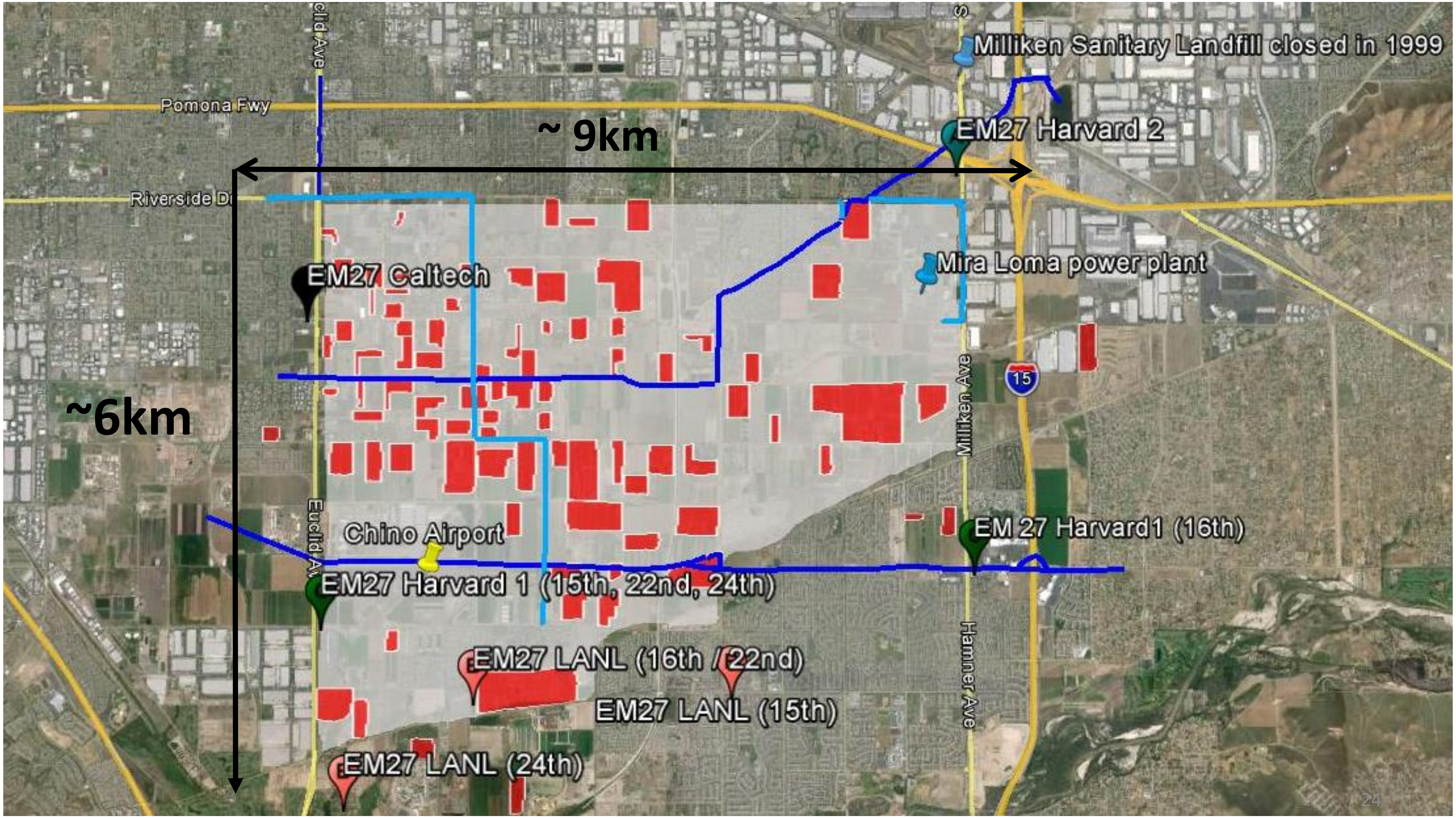
R. Duren and K. Verhulst

Picarro data



R. Duren and K. Verhulst

Chino - California



Conclusions

- EM27 are able to measure local gradients (scale: < 10 km and ~< 5 min)

- Methane emissions at Chino seem to be not that trivial (many sources, …)

- Flux estimate is done (ongoing) using:
  - a mass balance approach
  - an LES-model inversion

➢ Develop a methodology and assess the errors on flux estimates.

[C. Viatte et al.: Estimation of methane fluxes from dairy farms in the Los Angeles Basin using four mobile FTS and WRF model, to be submitted in ACP]

Thank you for your attention

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