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Observations of Methane Emissions from California Dairies from Ground and Space: New Top-Down Constraints at Regional Scales

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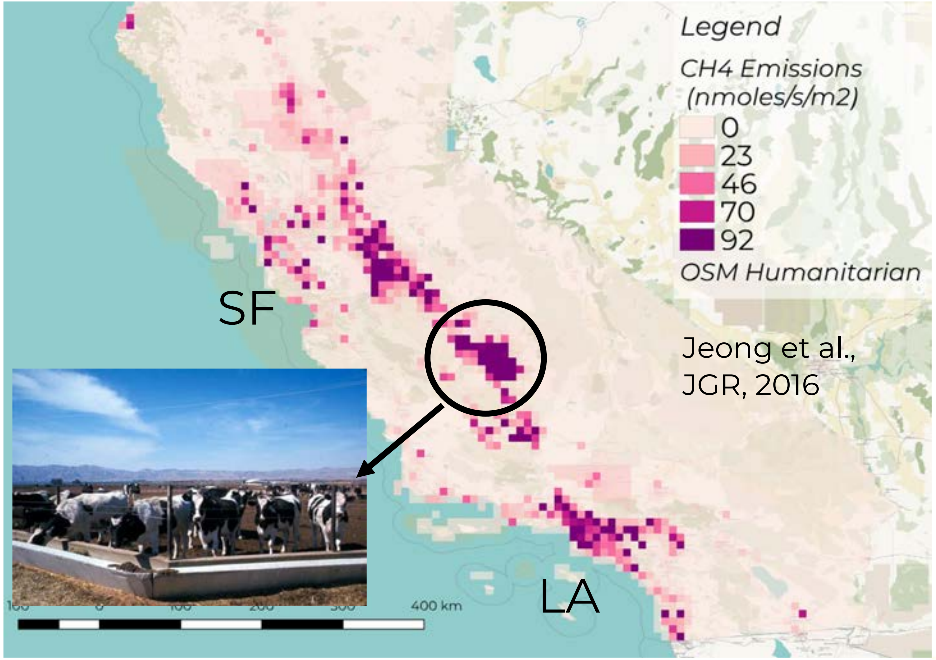
California Central Valley Hotspot: Dairies

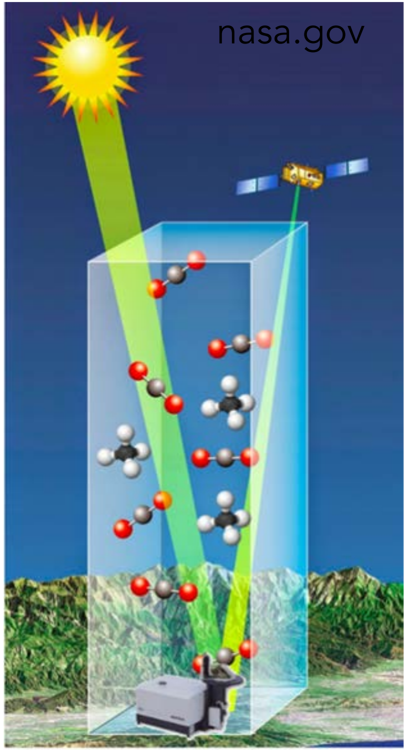
- 330 Gg/yr CH_4 inventory emissions[1] (~ LA basin's emissions[2])
- 80% from dairy industry[1]
- California committed to reduce CH_4 emissions [3]
- Emissions are uncertain[4], limits effective policy

[1]CALGEM, [2] e.g. Hedelius et al., ACP, 2018
[3] Assembly Bill 32



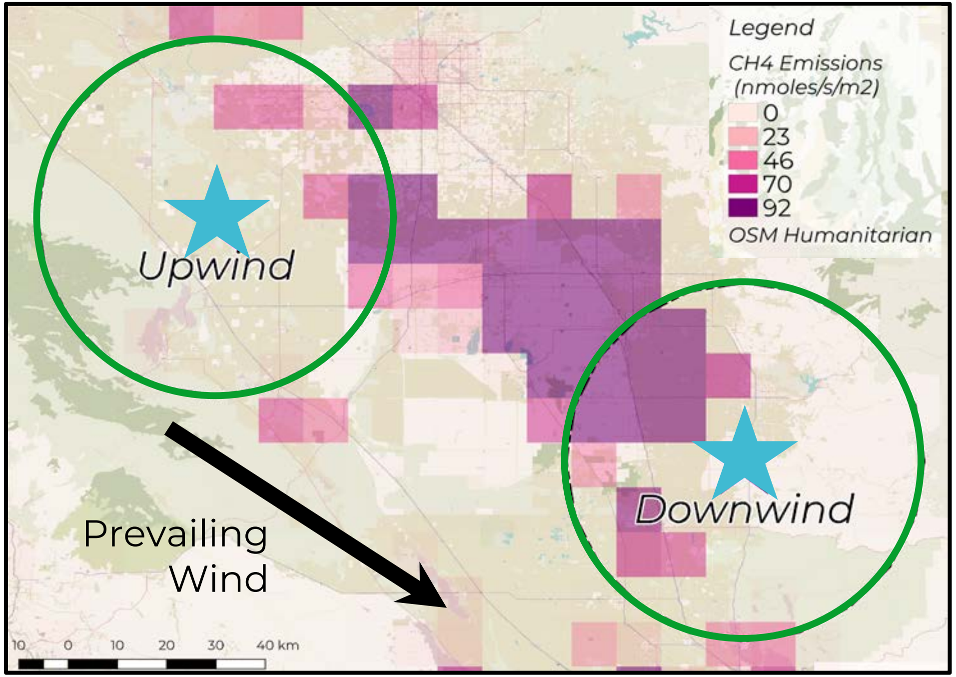
XCH_4 Measurements

- XCH_4 = Avg. CH_4 dry concentration in atmospheric column
- Derived from absorption spectra measured from ground or space
- Less sensitive to vertical mixing and boundary layer height



Measurement Setup

EM27/SUN portable ground spectrometer higher precision

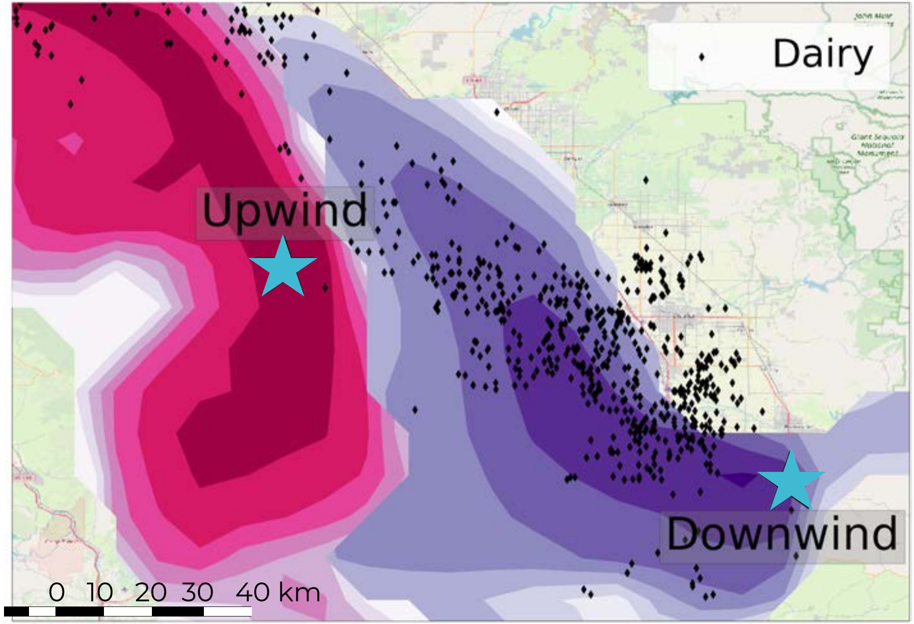


GoSAT satellite spectrometer lower precision, measures every 3 days

$$\Delta XCH_4 = \text{Downwind } XCH_4 - \text{Upwind } XCH_4$$

Atmospheric Transport Modeling

S. Heerah in prepn. 2020

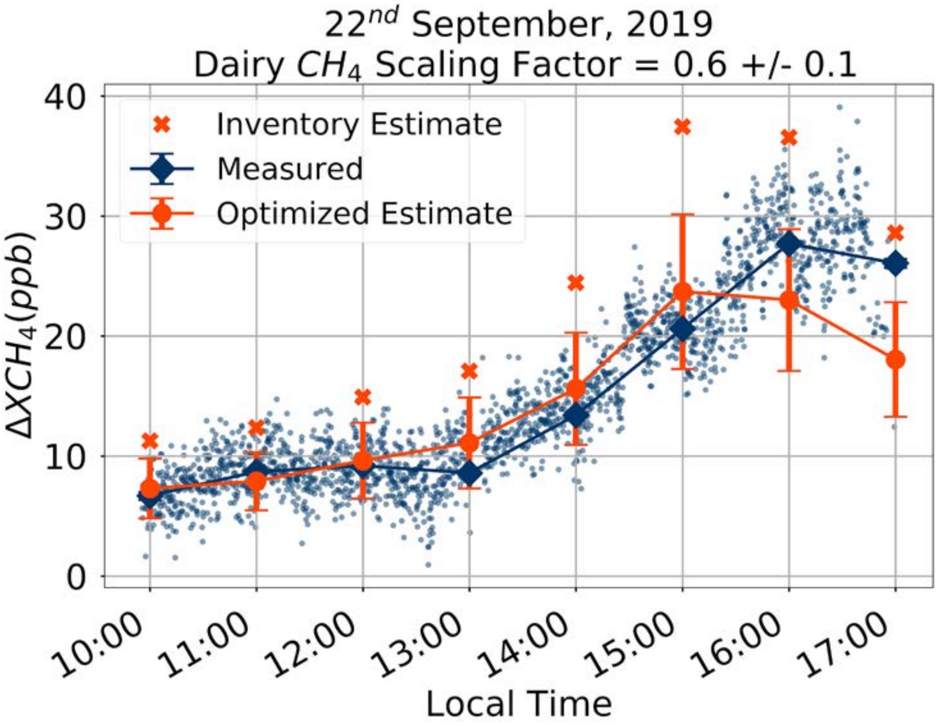


WRF-STILT [1] uses 3D wind field[2] to model CH_4 sources that the instruments are sensitive to. Run for 7 days to capture far field sensitivity.

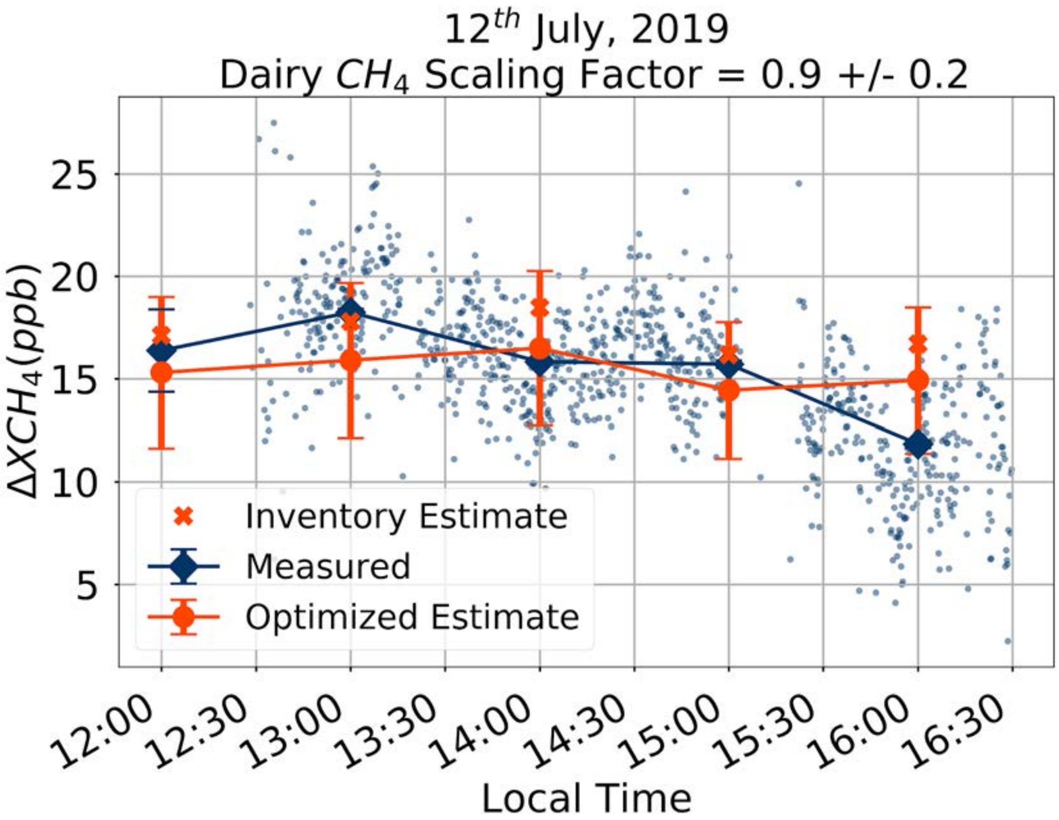
[1] EM27 model from T. Jones, [2] WRF runs from S. Jeong

Ground EM27/SUN ΔXCH_4 Emission Inversion

- Bayesian inversion with model error statistics from Zhao et al., 2009
- During field measurement days in Summer and Fall 2019, CALGEM emissions are high compared to measurements
- 4 days of winter data collected in 2020 being analyzed

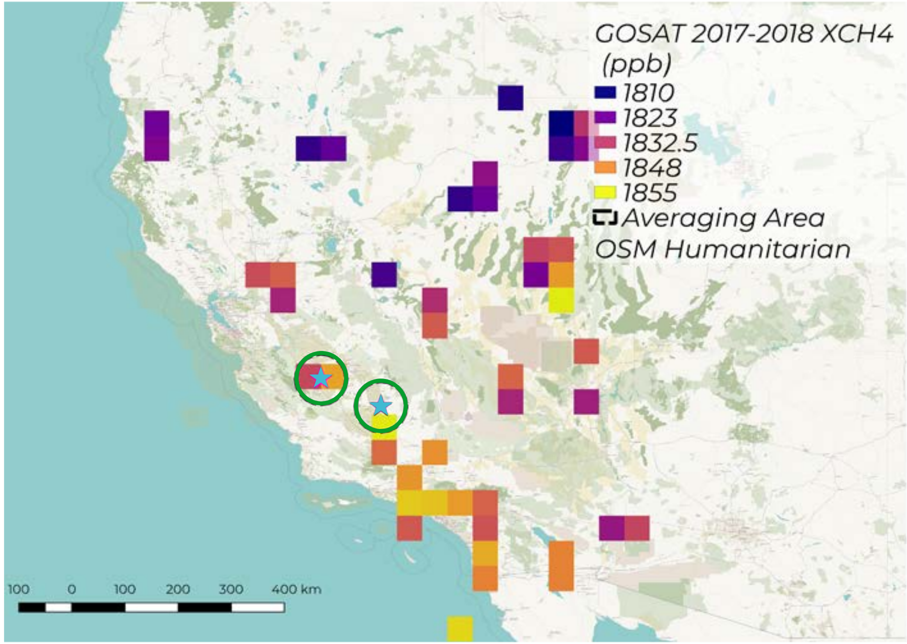


Scale Factor = 0.6 +/- 0.1, 9/22/19



Scale Factor = 0.9 +/- 0.2, 7/12/19

Space-based GOSAT ΔXCH_4

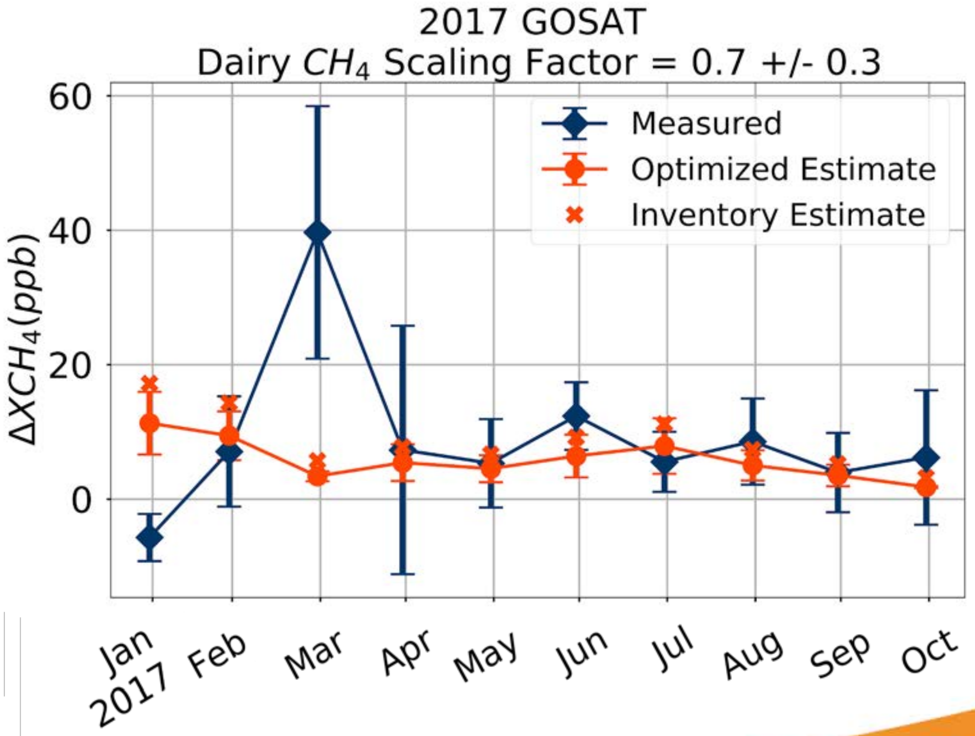


[1]SRON 2.3.9 Proxy L2 data

- GoSat measurements in hotspot in 2017[1]
- Look at soundings within 0.5° of EM27 locations
- 65 ΔXCH_4 measurements in early afternoon

Space-based GOSAT Emission Inversion

- ❖ Error statistics based on monthly standard errors for model runs and soundings
- ❖ 2017 GoSat inversion[1]: ***0.7 ± 0.3*** dairy scaling factor
- ❖ Overlaps with ground based factors



[1] NAM 12 km fields from arl.gov

Top-down SJV CH_4 Emissions Comparisons

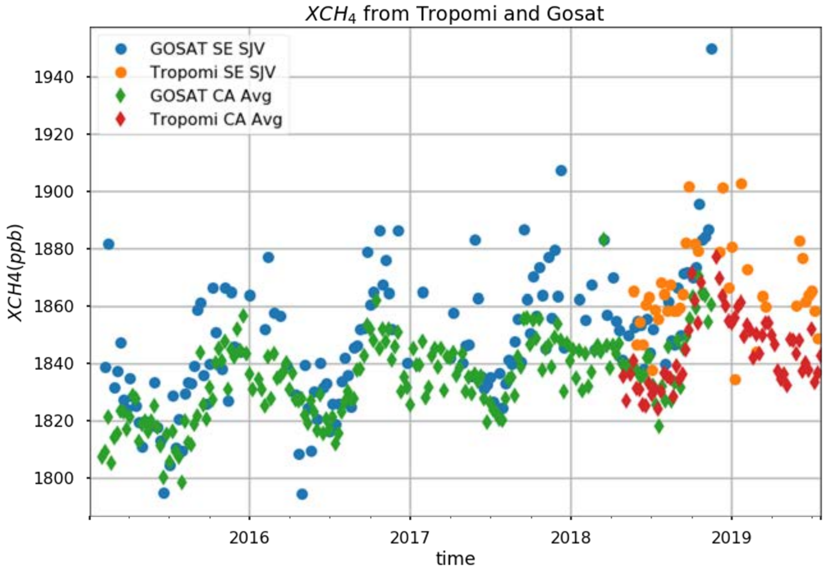
Study	Measurement	Period	CALGEM ***x Scale Factor***
Cui et al., 2015	***CALNEX aircraft [CH_4]***	4 afternoon Flights in May & June 2010	Inventory ***low*** by ***x1.7***
Jeong et. al, 2016	***In-situ Tower Network***	Afternoons June 2013 - May 2014	Inventory ***low*** by ***x1.5***
Heerah et al, in prep. 2020	***EM27/SUN***	2 days July & September, 2019	Inventory ***high*** by ***x0.8***
Heerah et al, in prep. 2020	***GOSAT***	65 afternoon soundings 2017	Inventory ***high*** by ***x0.7***

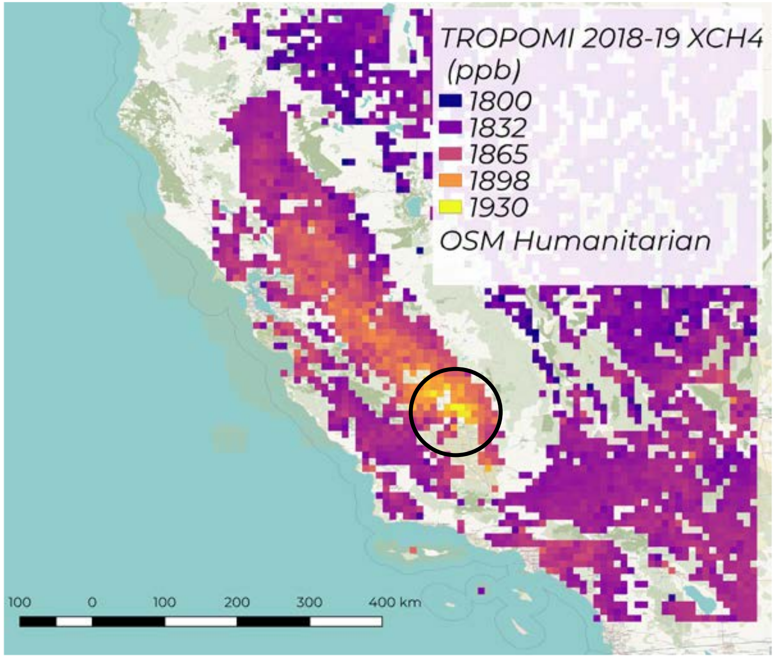
Why our inversions are lower than published studies?

- Different source sensitivity within SJV between studies
- Biases in modelling XCH_4 with WRF-STILT e.g. averaging kernels, treatment of free troposphere & stratosphere etc.
- Larger sensitivity footprints in XCH_4 measurements make them *more sensitive to night-time* emissions which are likely lower for dairy sources *(less activity, cooler temperature)*
- Changes in dairy industry practices since older studies

We are working to assess these effect to resolve discrepancies

Future Work: TROPOMI Satellite





TROPOMI XCH_4 matches GoSat

Offers potential to map and constrain emissions at much higher resolution but a lot of data in region filtered out by qc flags

Conclusions

- Methane gradients from both ground and space observed at SJV and attributed to dairies.
- Our top-down XCH_4 analysis do not show an under-estimate in bottom-up emission inventories for the periods and footprints that we sampled.