Sandia's Work on Verifying CH$_4$ Emissions

Capabilities:

- *In situ* measurements of CH$_4$ and *source tracers* (e.g., ^{13}CH$_4$, C$_2$H$_6$, CO, etc.)
- High-resolution modeling of atmospheric CH$_4$ (using CMAQ and FLEXPART)
- Inverse modeling using Sandia's *advanced uncertainty quantification tools*

Ongoing Projects:

- Verifying Oil & Gas CH$_4$ emissions in South-Central US and California
  – *Sandia internal LDRD funding (2011 - 2014)*
- Understanding Arctic CH$_4$ sources and the climate implications
  – *Sandia internal LDRD funding (2013-2016)*
- Attribution of CH$_4$ sources in the Southeastern U.S.
  – *NOAA funding (2014-2017)*

Our strength and focus area:

*Reduce and understand uncertainty to facilitate decision-making*

Mapping Oil and Gas CH$_4$ emissions in the U.S.
(Collaborating with US EPA)

Upstream: Production

Downstream:
Processing, transmission & storage, distribution
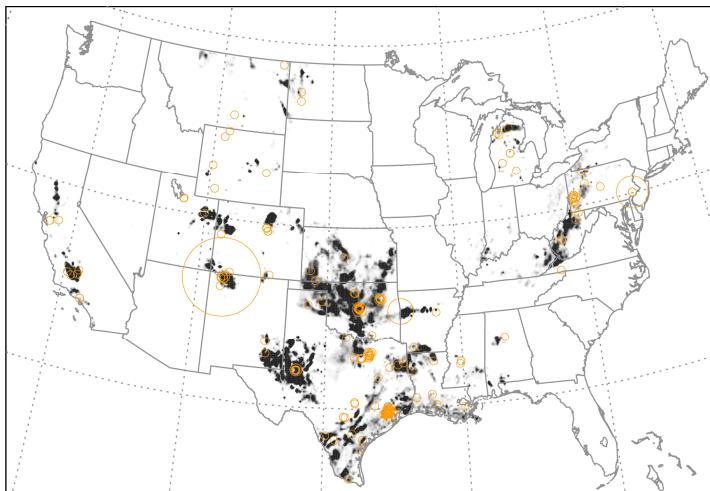

Source: US EPA (NEI-2011); ERG Inc.

Oil and gas production facilities that emit greater than 25,000 metric tons CO$_2$e per year; circle size scaled to emission amount
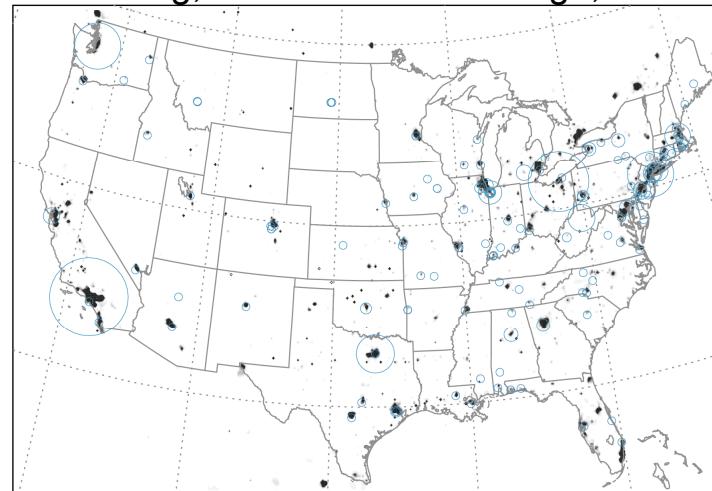
Source: US EPA GHGI; EDGAR v4.2 spatial distribution

Natural gas distribution companies that emit greater than 25,000 metric tons CO$_2$e per year; circle size scaled to emission amount

Mostly (~80%) from natural gas systems

- Production
- Downstream

EDGAR v4.2 (2008)

EPA/GHGI O&G (2011)

Hybrid O&G (2011) (This work)

Tg CH$_4$ a^{-1}

[Liu et al. in prep for PNAS]
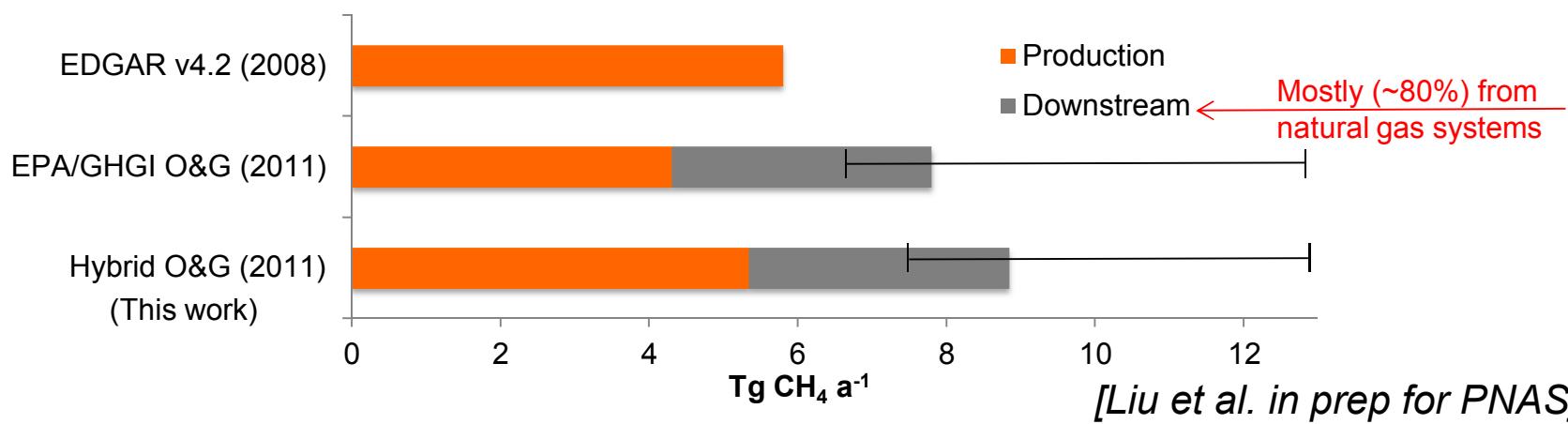
Oil and Gas CH$_4$ Emissions in California
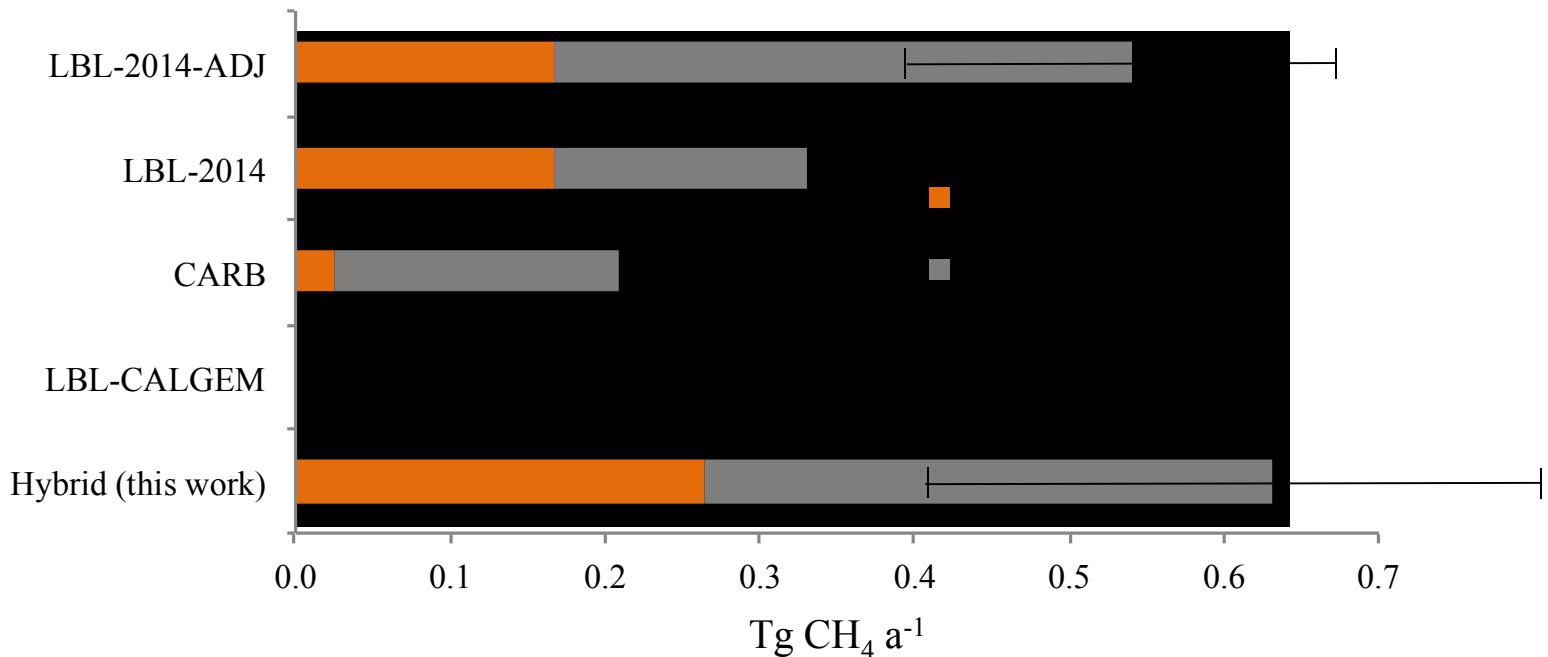
Challenges:
1. Inconsistent bottom-up inventories;
2. Complex uncertainties in atmospheric top-down inversion
3. Interference of other uncertain (but often large) CH$_4$ sources

Our approach:
1. Process-based bottom-up estimates
2. Advanced uncertainty quantification tools for top-down estimates
3. Measuring tracers to constrain CH$_4$ from different sources

Oil and Gas Production CH₄ emissions in the South-Central US (TX/OK/KS)

Footprints for the DOE/SGP site
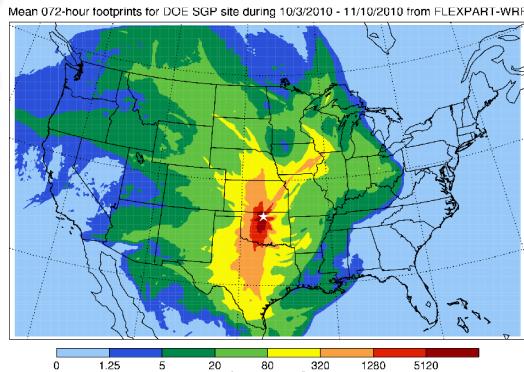
Observed vs. Modeled CH₄ at the DOE Southern Great Plains ARM site in Oct. 2010
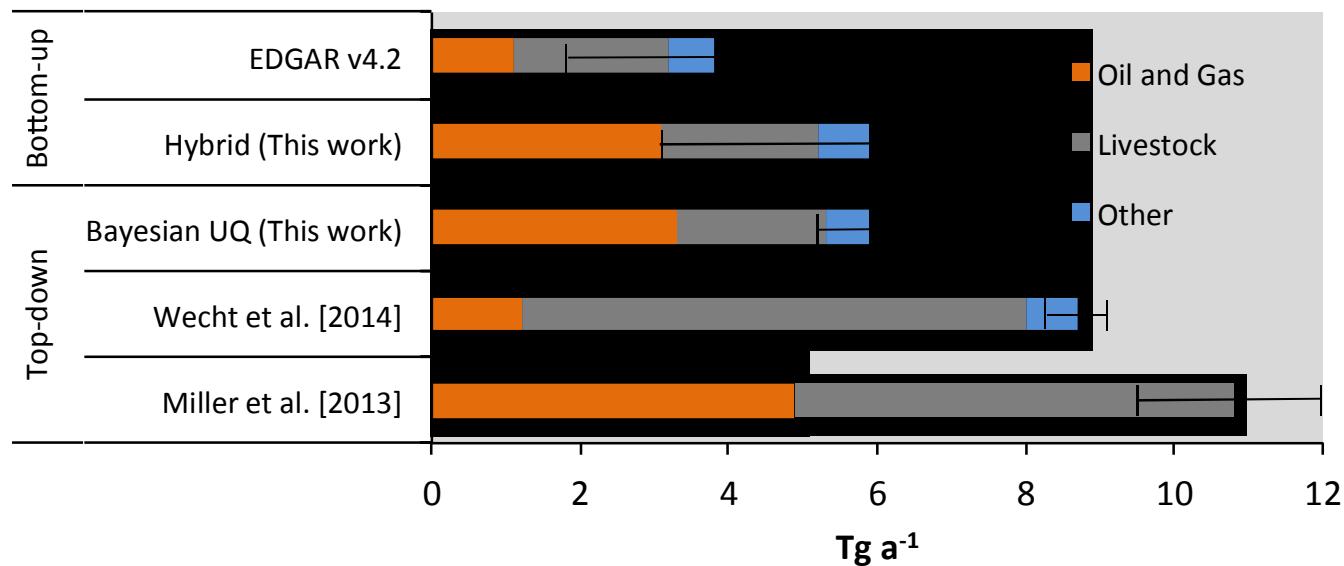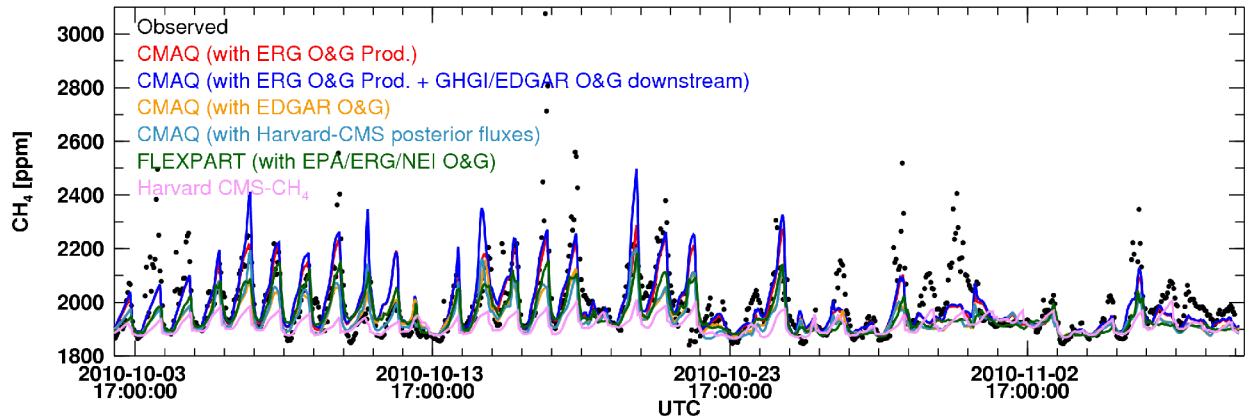
[Liu et al. in prep for PNAS]

Measurements and Modeling of CO_2 and CH_4 in Livermore, California

Location: ~150 m above sea level, 64 km south-east of San Francisco

Tower: Two inlet heights: 9 m, 27 m above ground level

Truck: Climate-controlled 30-ft mobile laboratory

Measured GHGs and Tracers for Emissions Sectors:

Transportation: NO_x, CO, specific volatile organic compounds (VOCs), BC, CO_2

Biomass burning: CO, BC, VOCs, CO_2, CH_4, H_2O

Fossil-fuel combustion: SO_2, specific VOCs, CO_2, $^{13}CO_2$, ^{18}OCO, CO

Oil and gas production: $^{13}CH_4$, $^{12}CH_4$, C_2H_6

Biogenic emissions: specific VOCs, CO_2, $^{13}CO_2$, ^{18}OCO, OCS, CO_2 fluxes

Measurements for atmospheric state:

Winds: meteorological data

Boundary layer height: ceilometer

Measured and Modeled CO_2 and CH_4 (May 2014)
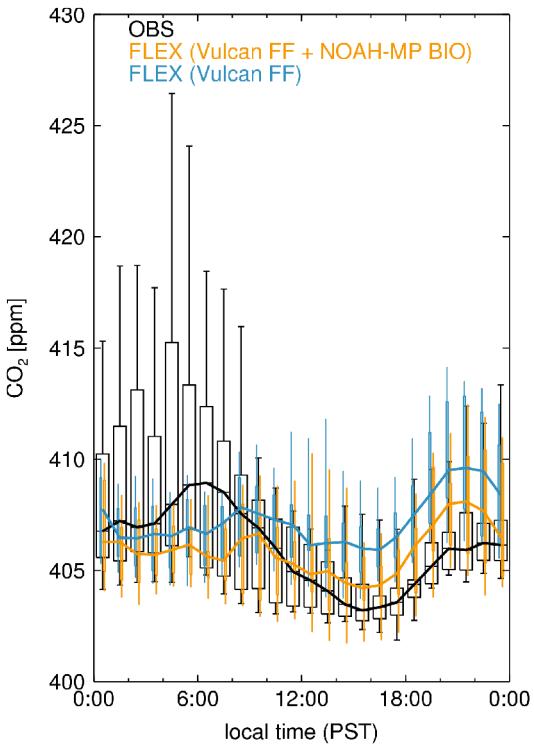
CO_2
Large biospheric interference
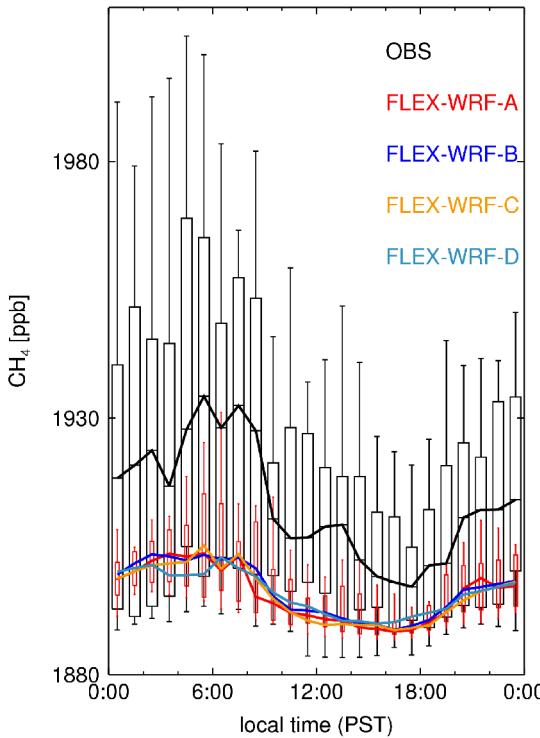
CH_4
Emissions underestimation?

What is the missing source of CH₄ at Livermore?



Footprints of Livermore measurements
(2013-2014)

10^{-4} ppb /(nmol/m^2/s)
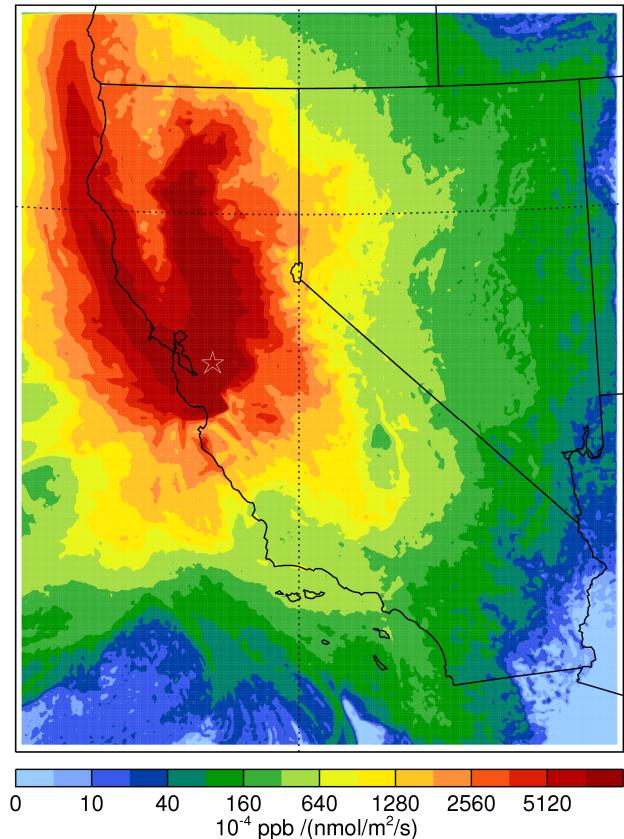
Sampling Bay-area and Northern
California emissions at Sandia

Livermore Source Attribution

- wetlands 12%
- wastewater 2%
- petroleum 3%
- natural gas 5%
- crop agriculture 14%
- non-dairy livestock 7%
- dairy livestock 11%
- landfills 46%
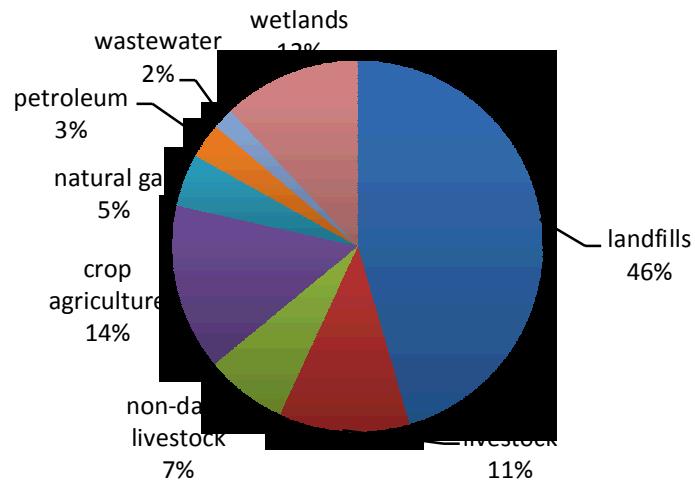
CALGEM California State Total

- wastewater 7%
- wetlands 3%
- petroleum 4%
- natural gas 7%
- crop agriculture 2%
- non-dairy livestock 11%
- dairy livestock 43%
- landfills 24%
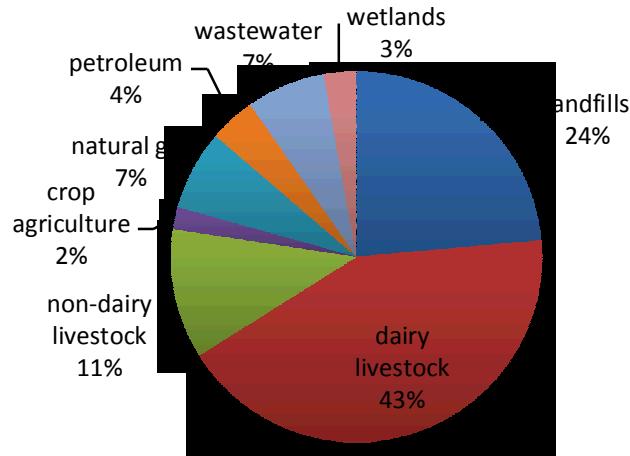
CALGEM: gridded CH₄ emissions inventory for California
(http://calgem.lbl.gov/)

Sandia National Laboratories