CALIFORNIA
AIR RESOURCES BOARD

Top-down N_2O emission estimation in California using tower measurements and an inverse modeling technique

Yuyan Cui, Lei Guo, Ying-Kuang Hsu, Matthias Falk, Xiaoxi Liu, Ken Stroud, Jorn Herner, Abhilash Vijayan

California Air Resources Board

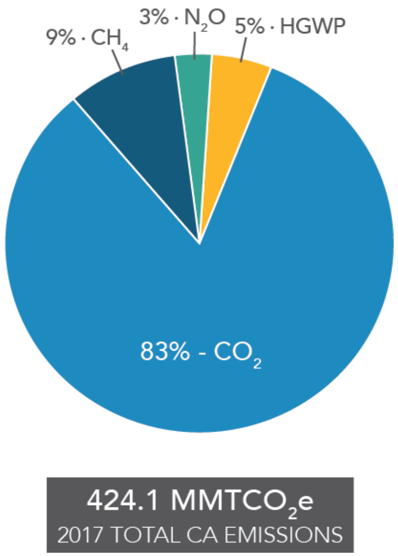
MAC-MAQ Conference, Sep 13-15, 2019

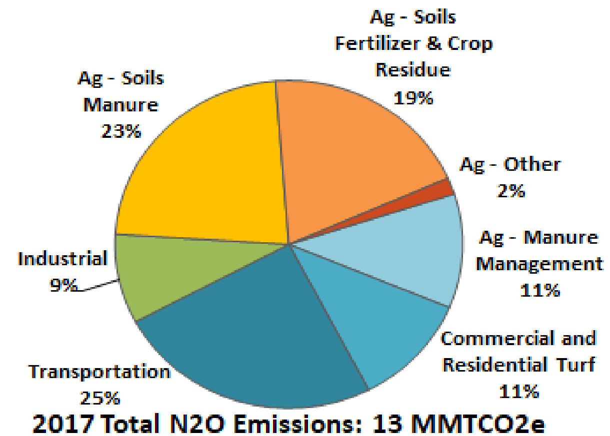
Background

- Nitrous oxide (N_2O) is a long-lived climate pollutant with a high global warming potential (GWP=265 for 100-year), and is a strong agent for stratospheric ozone depletion

- Recent studies have suggested that N_2O emissions may be significantly higher than current estimates in the bottom-up emission inventories in California (e.g Jeong et al. 2018)

- Accurate estimation of statewide N_2O emissions is essential for developing effective mitigation strategies to meet California's climate goals





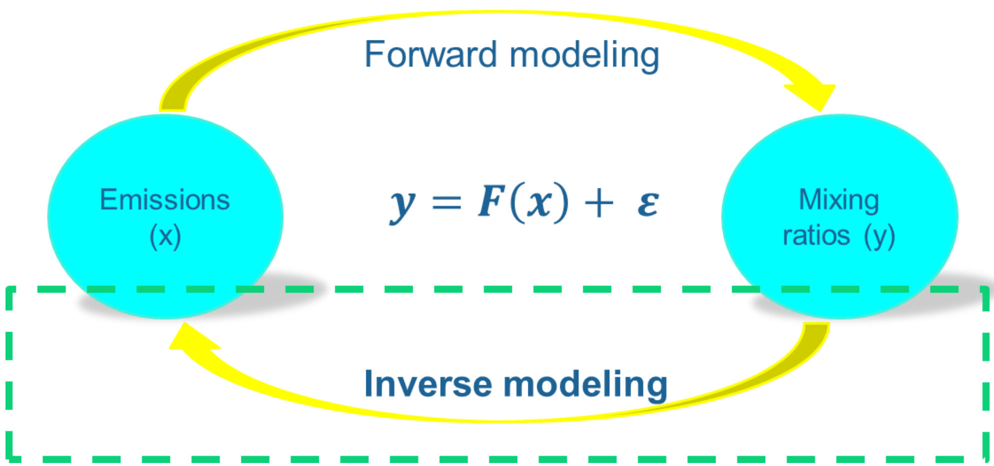
Objectives

- Top-down evaluation of statewide N_2O emissions in California (using inverse modeling and long-term ground-level measurements conducted at CARB GHG monitoring network sites)

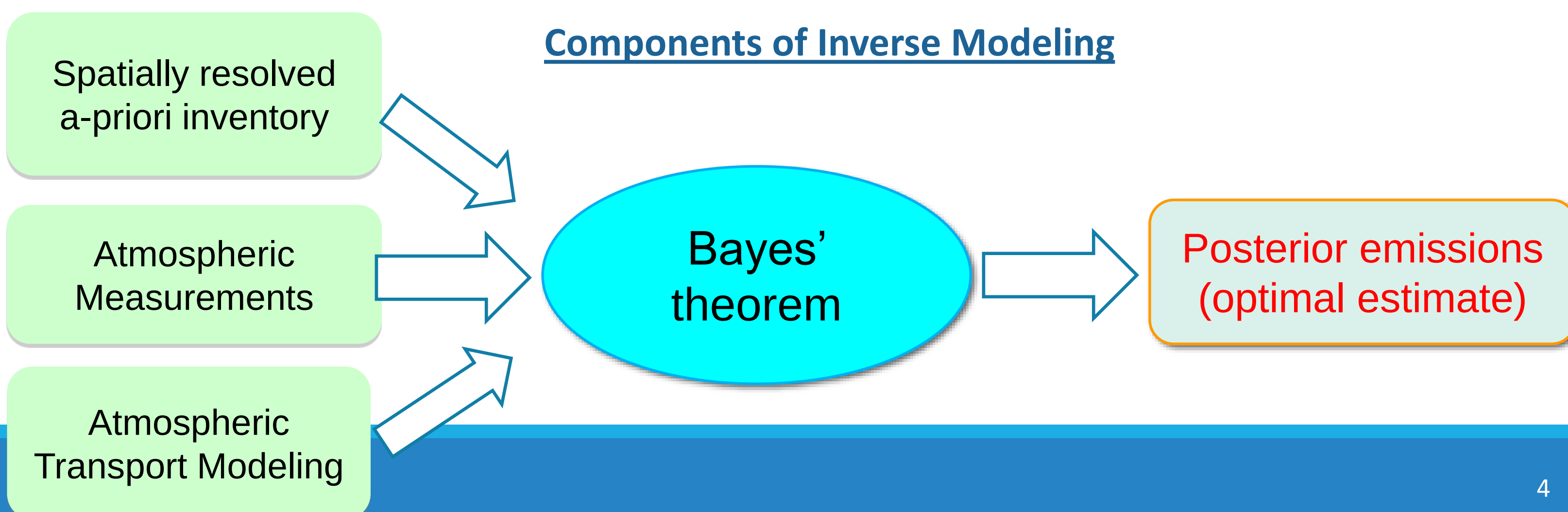
- Regional evaluation to characterize the spatio-temporal variations of N_2O emissions

- Multi-year evaluation to study the impact of precipitation and climate feedback to N_2O emissions in California

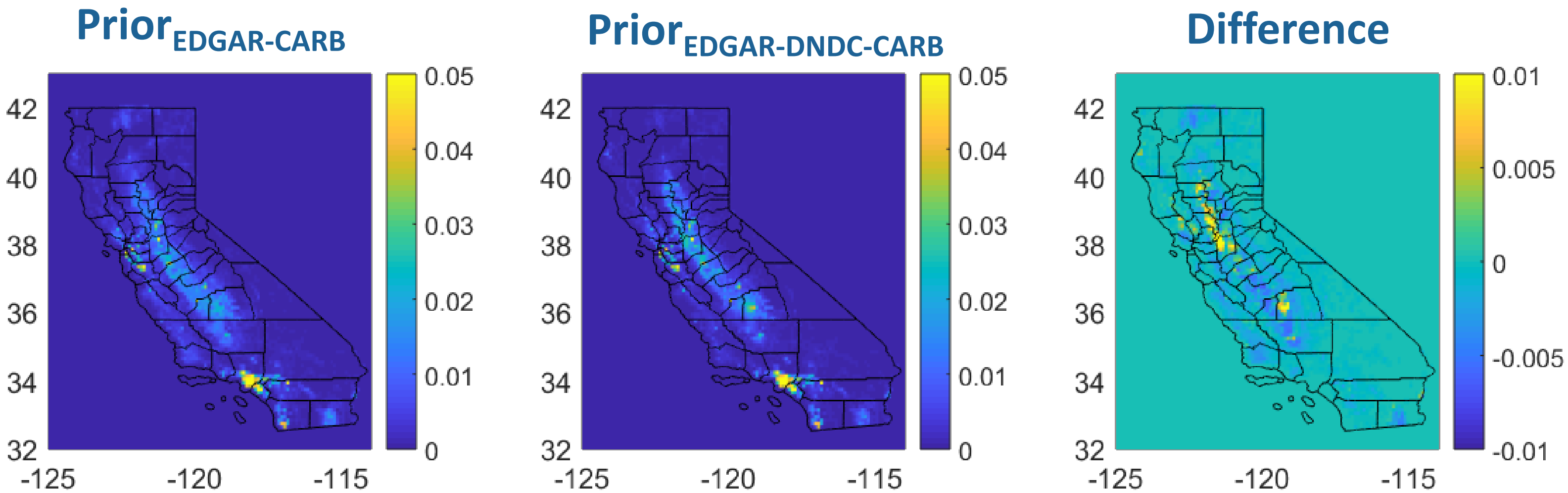
Inverse Modeling



Components of Inverse Modeling



Spatially Resolved a-Priori Inventories



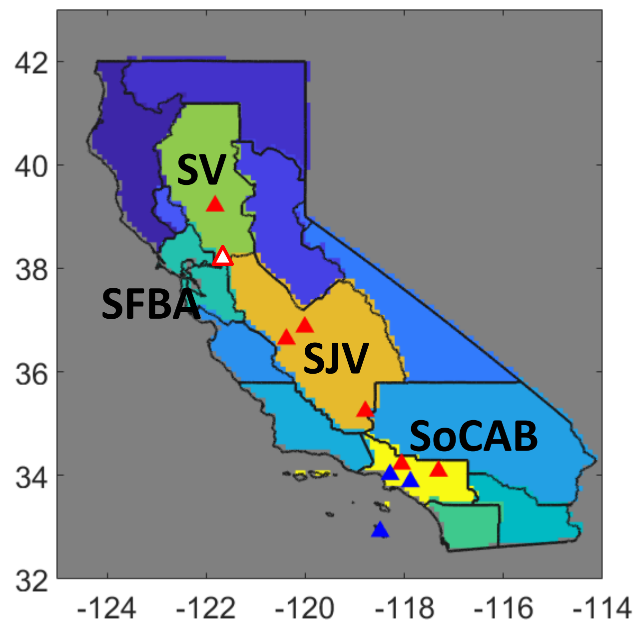
Jeong et al. (2018)

Courtesy of Jianjun Chen and Majiong Jiang (CARB)

Priors	Description	Emission (Gg N2O/yr)
$Prior_{EDGAR-CARB}$	Spatially resolved EDGAR v42 FT2010, scaled to match CARB 2012 inventory	48.2
$Prior_{EDGAR-DNDC-CARB}$	Similar to $Prior_{EDGAR-CARB}$, with updated agriculture soil sector emissions from spatially resolved DNDC (i.e., DeNitrification-DeComposition) model	42.3

Atmospheric Measurements

Sites & Air-Basins



N_2O Measurement Network

- CARB Statewide GHG Monitoring Network – 6 sites (2013-current)
- CARB-funded LA Megacities Network – 3 sites (2017-current)
- CARB-funded Walnut Grove Tower – 1 site (2015-2017)

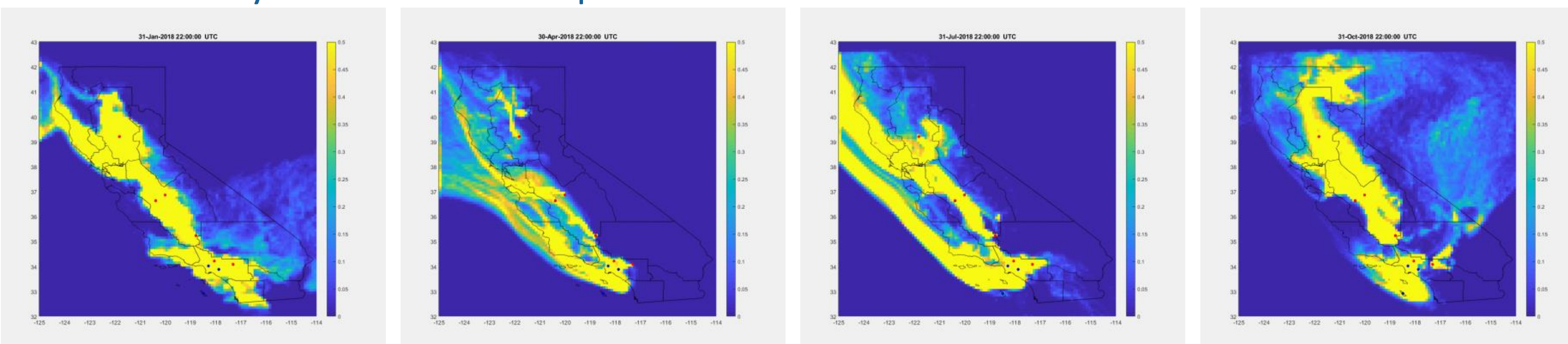
- High-quality and high frequency N_2O measurements

Background determination for ΔN_2O

- Mauna Loa Observatory (MLO) data for general background (maybe under-estimated?)
- Data from San Clemente Island (SCI, screened out NE and SE flows) for sites in the LA region

Atmospheric Transport Modeling

January April June October



FLEXPART-WRF (Brioude et al. 2013)

- FLEXPART was configured to release 5,000 particles at the height of tower receptors to model the transport of the particles backward in time for 3 days for each receptor
- WRF configuration is similar to Cui et al. (2019): long-term simulations using the Pleim-Xiu land-surface model coupled with the YSU boundary layer scheme; North American Regional Reanalysis data were used to provide the initial and boundary conditions
- WRF evaluations are following Cui et al. (2019), using different PBLH retrievals to evaluate the PBLH simulations

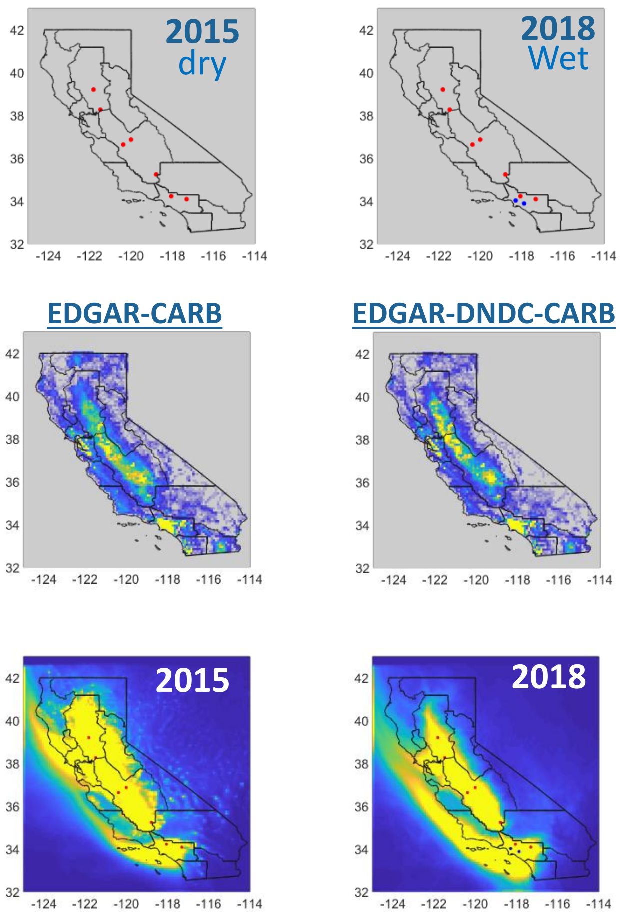
Cui et al. ES&T (2019)

Inverse Modeling Framework

Ambient measurements

a-Priori information

Atmospheric transport modeling



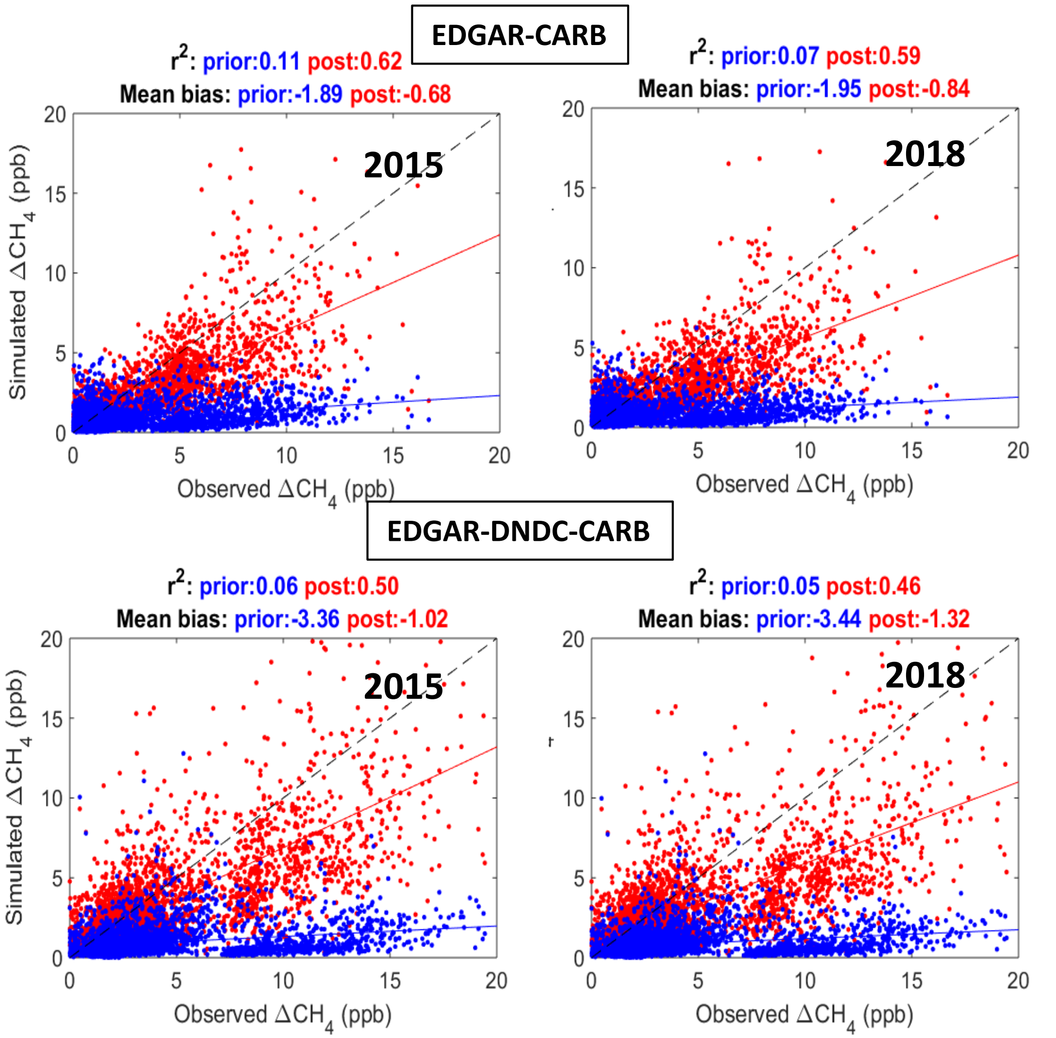
Bayes' theorem → Posterior emissions

Obs — **posterior** — a-Priori

$$J = \frac{(y - Hx)^2}{2R} + \frac{(x - x_0)^2}{2B}$$

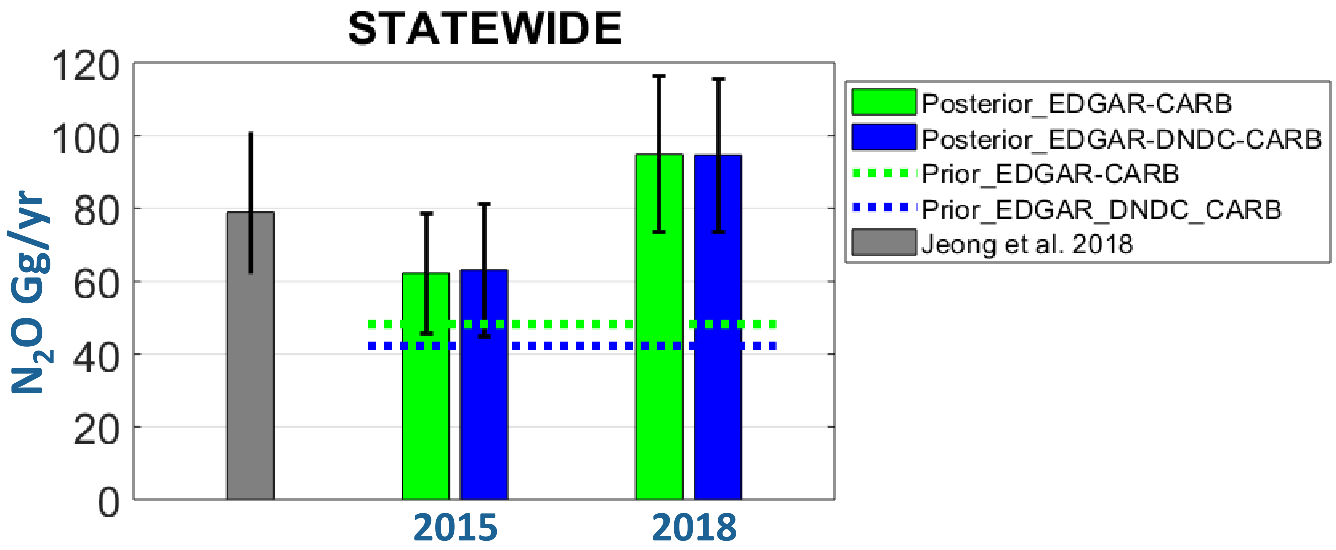
Transport modeling

Observed vs. Simulated N_2O (ppb)



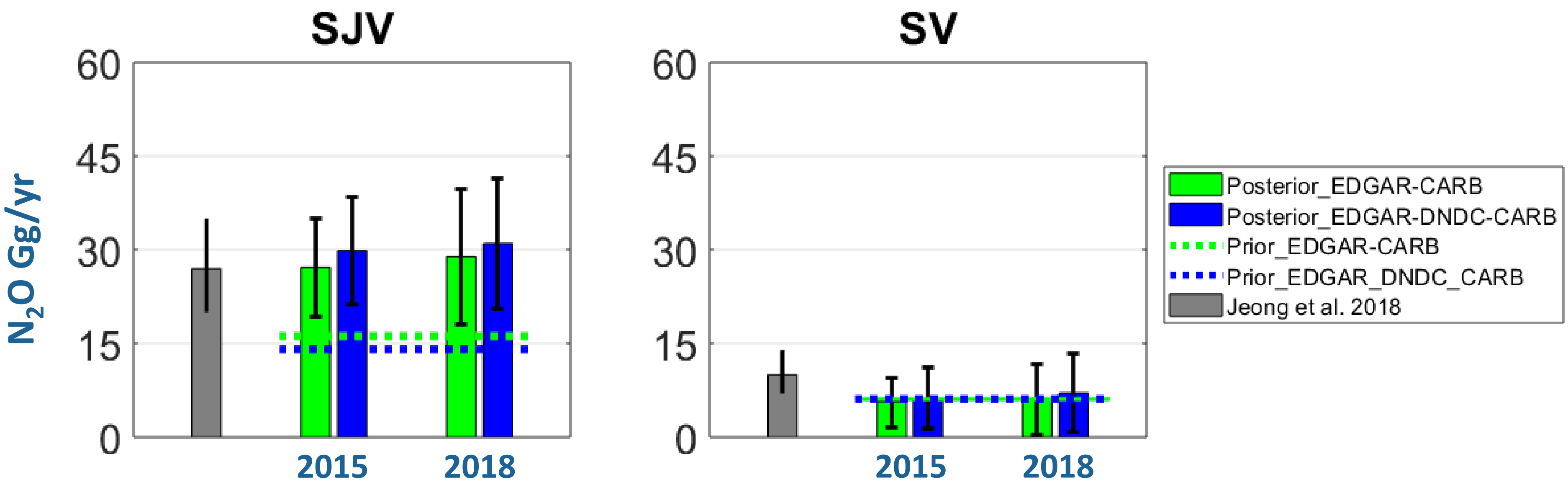
- N_2O enhancements using the a-priori inventories are lower than the observed concentrations
- After the optimization processing, we improved r^2 and reduced mean biases (ppb).

Results: Statewide Emissions



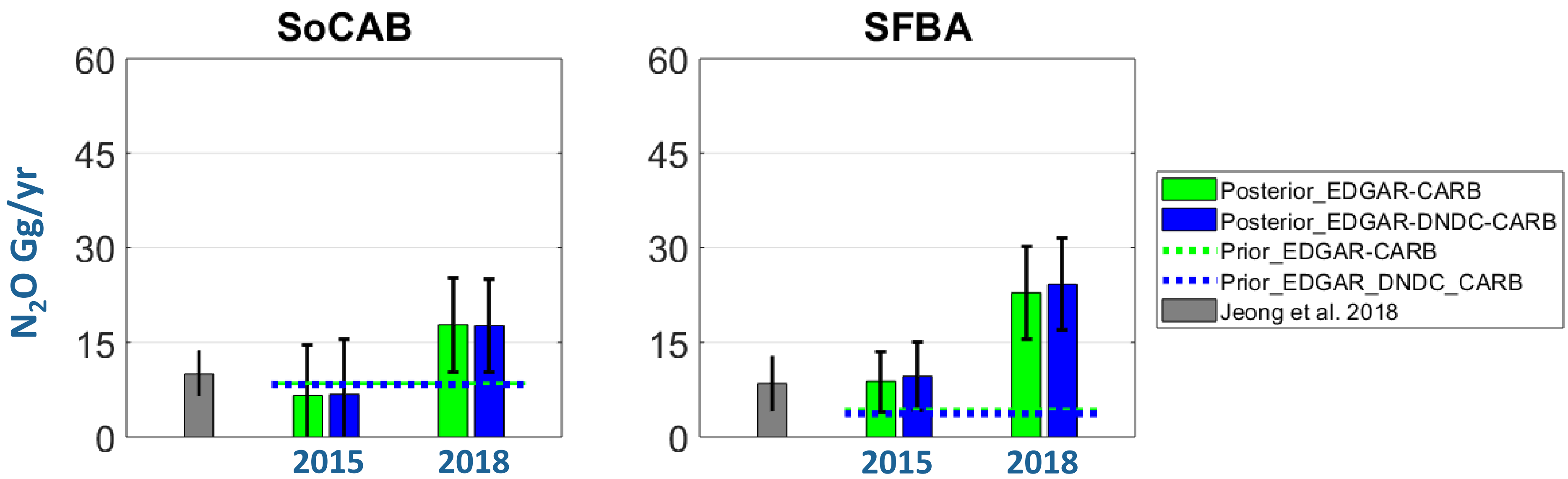
- Average statewide top-down N_2O emissions are 1.3 to 2 times the bottom-up estimates
- Top-down estimates capture all N_2O in the atmosphere, whereas bottom-up inventory may not capture non-anthropogenic sources (e.g. biogenic, natural sources, oceans, forest, etc.)
- Jeong et al (2018) estimated top-down emissions were 1.5-2.5 times bottom-up estimates
- N_2O emissions in 2018 (wet year) were higher than 2015 emissions (dry year) by roughly 40%

Results: Agricultural Emissions



- SJV region shows the largest absolute difference in top-down vs. bottom-up N_2O emissions estimates in the state (maybe due to manure-related emissions) , whereas SV emissions showed good agreement
- N_2O emissions in 2018 were only marginally higher than 2015 emissions
- Inversions using EDGAR-DNDC-CARB derived slightly higher emissions than EDGAR-CARB case

Results: Urban Emissions



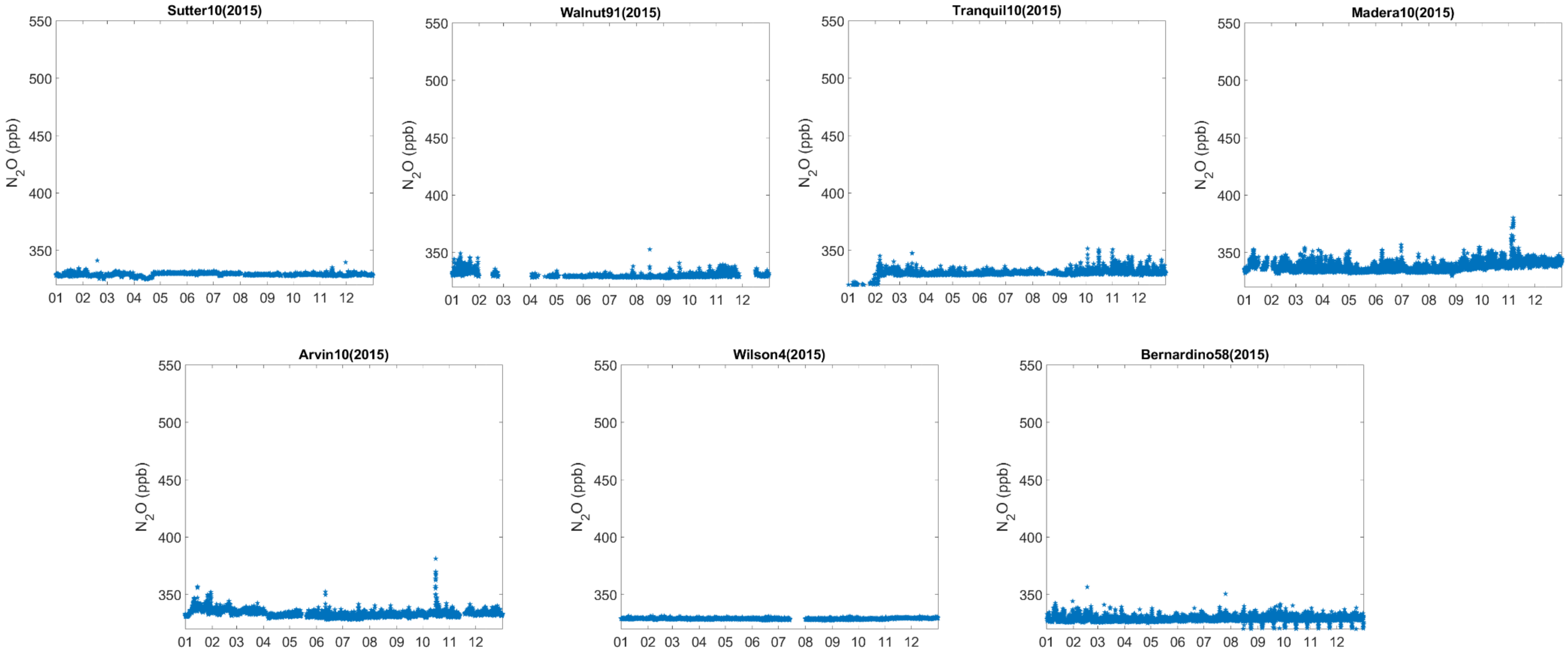
- SoCAB top-down estimates were in agreement with bottom-up estimates during dry period, while SFBA top-down estimates were above bottom-up estimates in both years
- Increase in N_2O emissions from 2015 (dry year) to 2018 (wet year) in urban regions
- The difference (2015 vs. 2018) may be due to changes in urban soil/fertilizer emissions with precipitation (need further investigation).

Conclusions

- This study found that average top-down N_2O emission in California were 1.3 to 2 times the bottom-up anthropogenic inventory estimates
- Some of these differences can be attributed to biogenic emissions and natural sources, such as ocean upwelling, forest, wildfires, etc.
- Study also found large differences in top-down and bottom-up emissions in SJV and SFBA
- Emission differences were larger during a wet year (2018) as compared to a dry year (2015)
  - This difference was more pronounced in urban regions
- Plans to conduct further investigation to better understand the changes in urban N_2O emissions with precipitation, transportation sector, as well as long-term evaluation (e.g. 2014-2018) to understand the impact of climate feedback and track trends

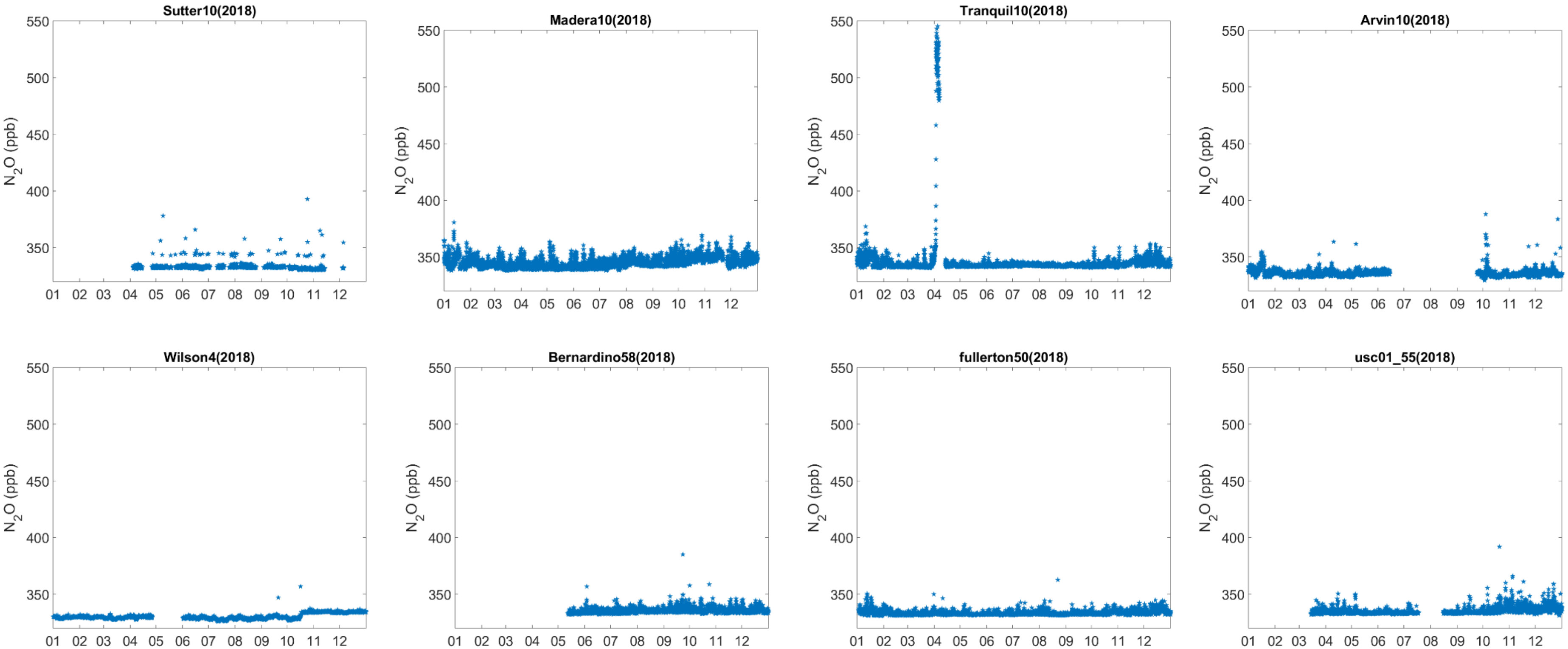
Extra slides

2015



month of year

2018



month of year

Diff (posterior-prior) in 2D maps