



Quantifying California's Anthropogenic Greenhouse Gas Budget

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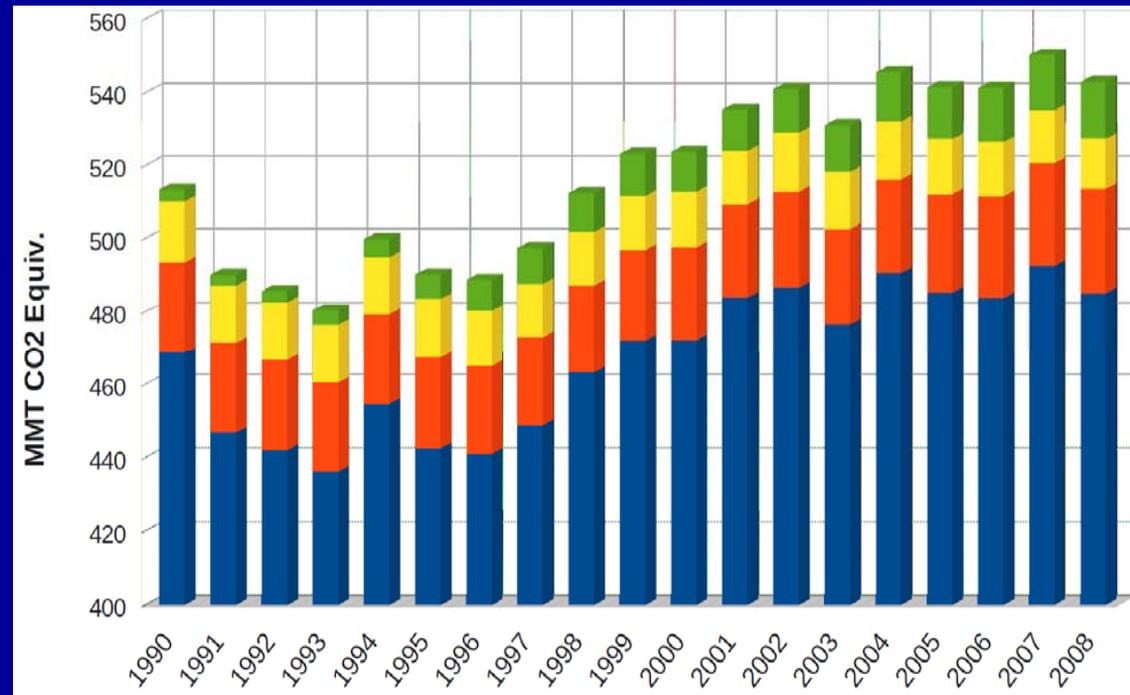
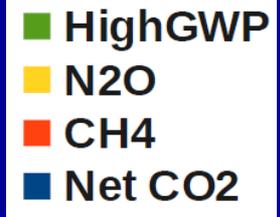


Outline

- Problem: Direct GHG emission measurements crucial for sound energy and environmental policy
- Approach: Quantify regional GHG emissions across California using atmospheric inverse estimation
- Results: Now capture major portions of CA GHG budget
 - Fossil CO₂ consistent (~ 10%) with CARB inventory
 - CH₄ & N₂O significantly greater than CARB inventory
 - Central CA HFC134a emissions overestimated in EDGAR4.2
- Conclusions: Current inventory requires revision
- Future Work: Considerations for new sites in Southern California

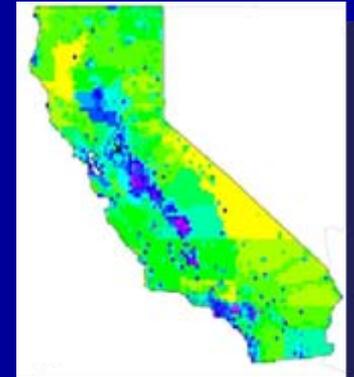
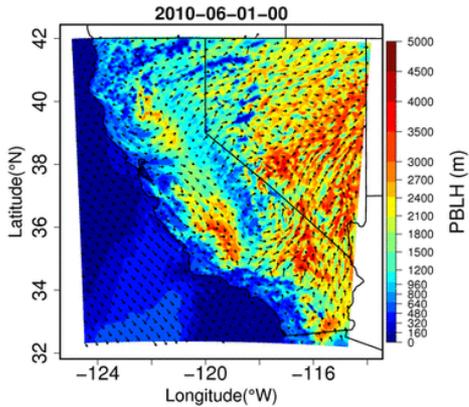
Non-CO₂ GHG Emissions

- California initiated GHG emission controls (AB-32)
 - Fossil fuel CO₂ dominant source
- Non-CO₂ sources not readily metered
 - Some sectors have uncertainties 10 to > 100% (NRC, 2010)
- Atmospheric inverse method provides independent check



CARB, 2010

Approach



Meteorology

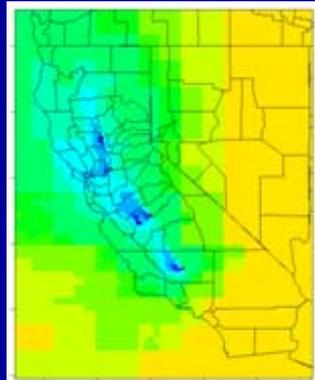
Measurements

Emission Model

Footprints

Bayesian Inversion

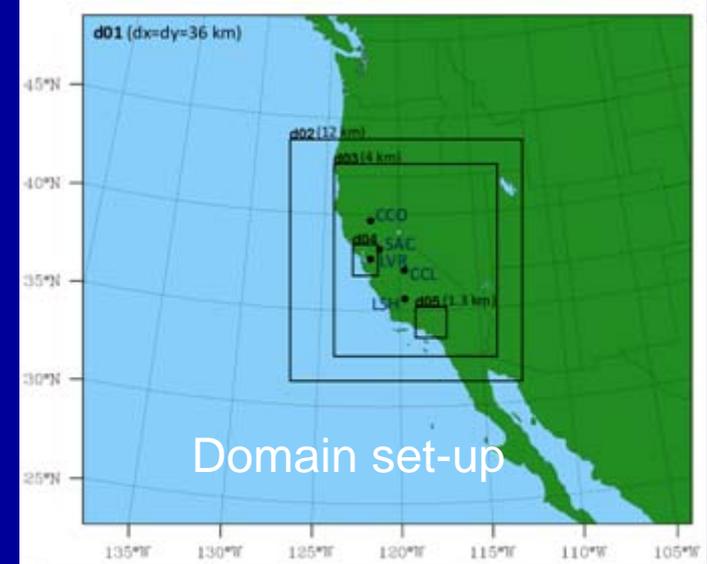
Emission Estimate



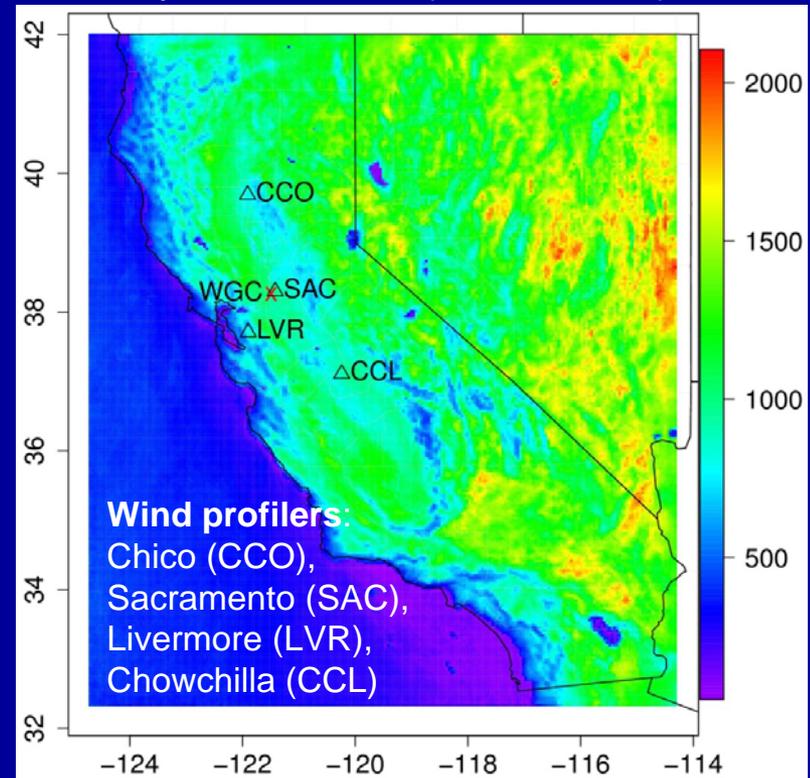
calgem.lbl.gov

Meteorological Model for California

- Weather Research Forecast (WRF) Model
 - Two-way nesting WRF in five domains to 1.3 km
 - 5-layer irrigated land model
- Evaluation with radar-wind profilers
 - PBL depth
 - Winds



Monthly mean PBL (10:00 local), June

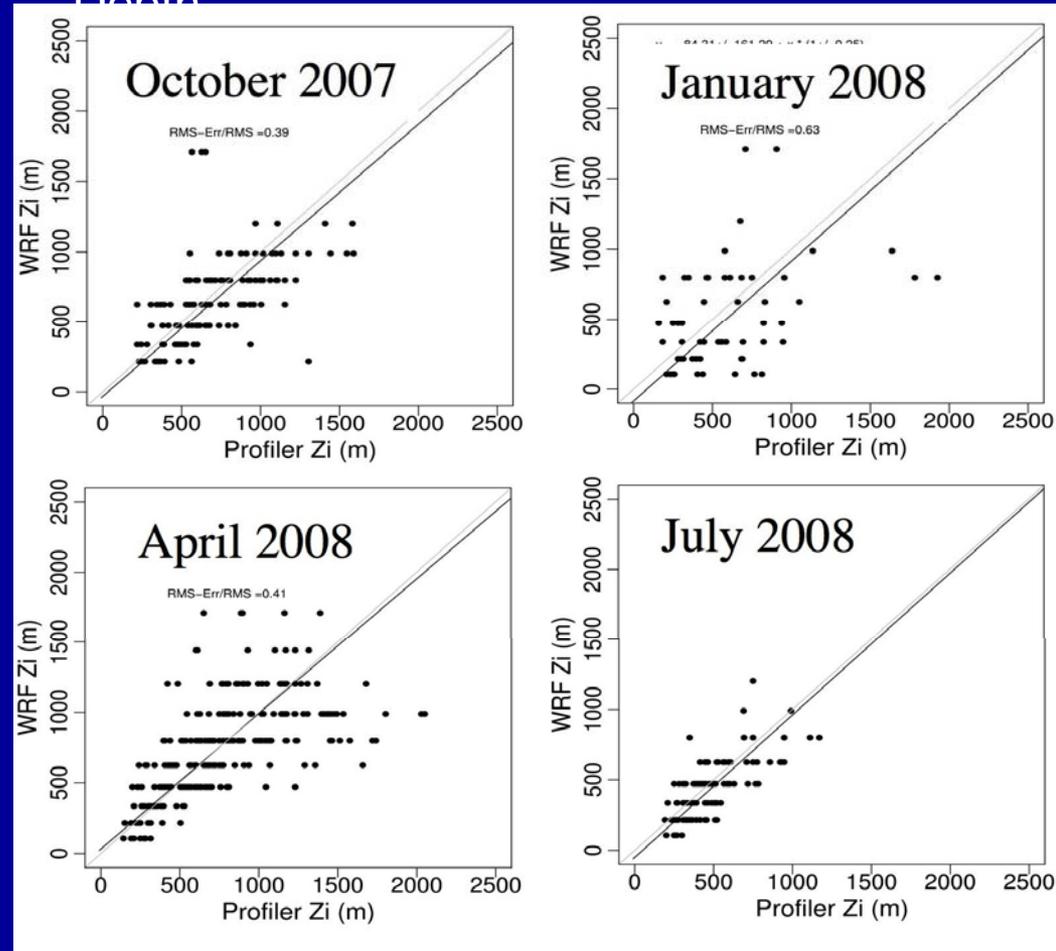


Model-Measurement Uncertainty

- Quantify error sources
- Propagate errors through modeling system to provide quantitative uncertainties
 - Boundary layer ~ 20-45 %
 - Wind Velocity ~ 10%
 - GHG background ~ 10-40 %
 - Inventory resolution ~ 10 %
 - Other ~ 10%
- Quadrature sum ~ 30-50% of signal for individual time points

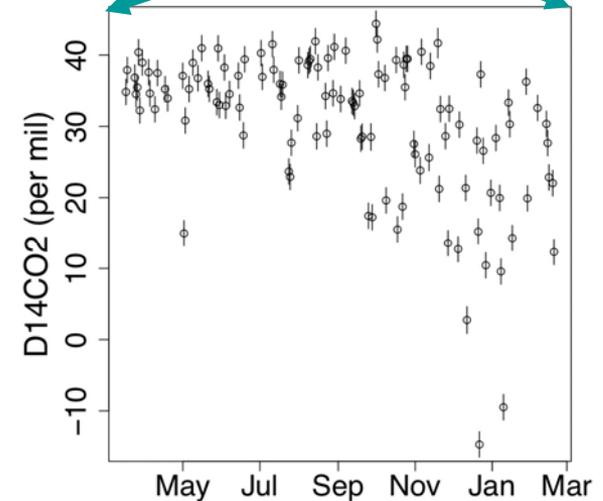
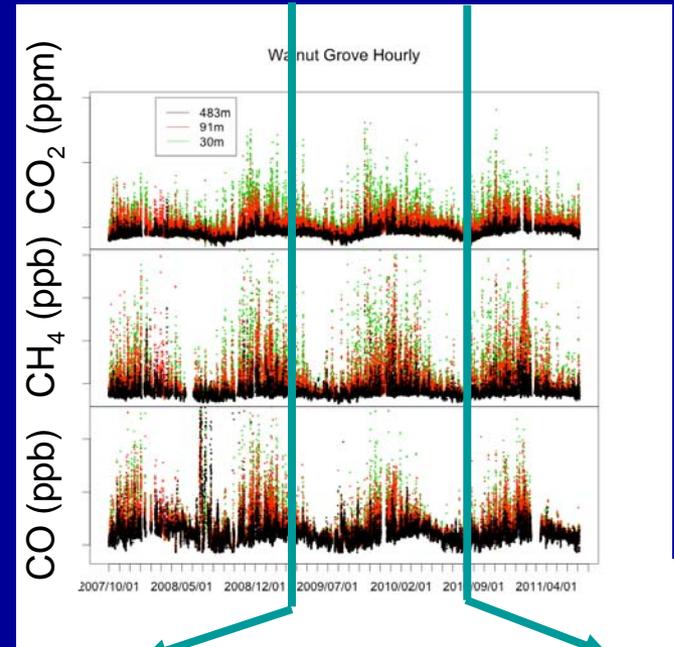
WRF-STILT versus SAC Profiler PBL

Depth



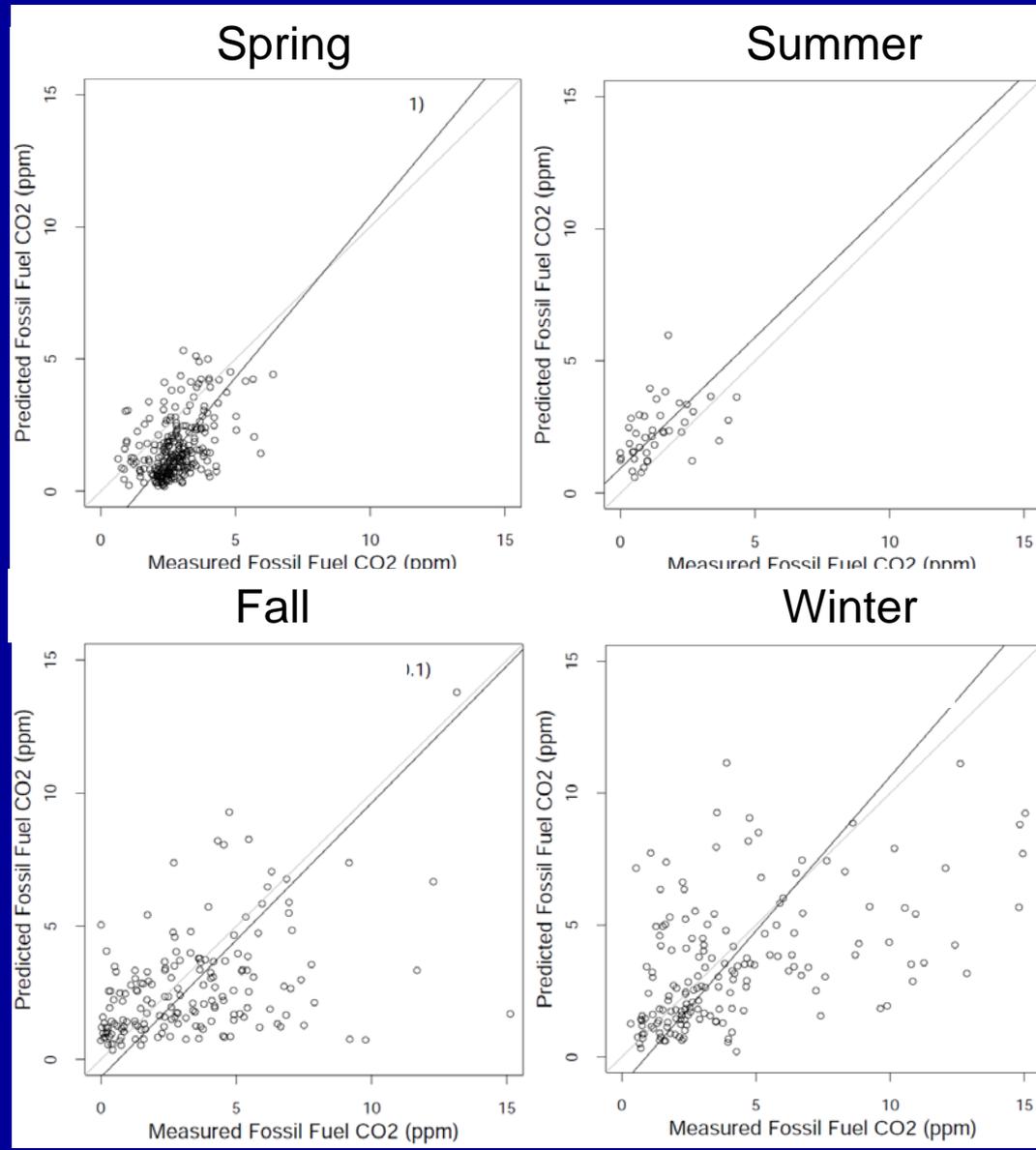
Fossil Fuel CO₂ at Walnut Grove

- Measured CO₂, CO enhancements (green, red) above background (black) capture regional emissions
- ffCO₂ from 1 year (Mar, 2008-Feb, 2009) radiocarbon ¹⁴CO₂ flask data
- Continuous ffCO₂ from CO and ¹⁴CO₂:CO ratio



Fossil Fuel CO₂ Emissions

- Predicted ffCO₂ calculated with Vulcan 2.0 and footprints
- Comparison of predicted and measured daytime signals
- Slopes consistent with unity +/- ~ 10 % at WGC
- Similar result obtained for May-June, 2010 data from CalTech



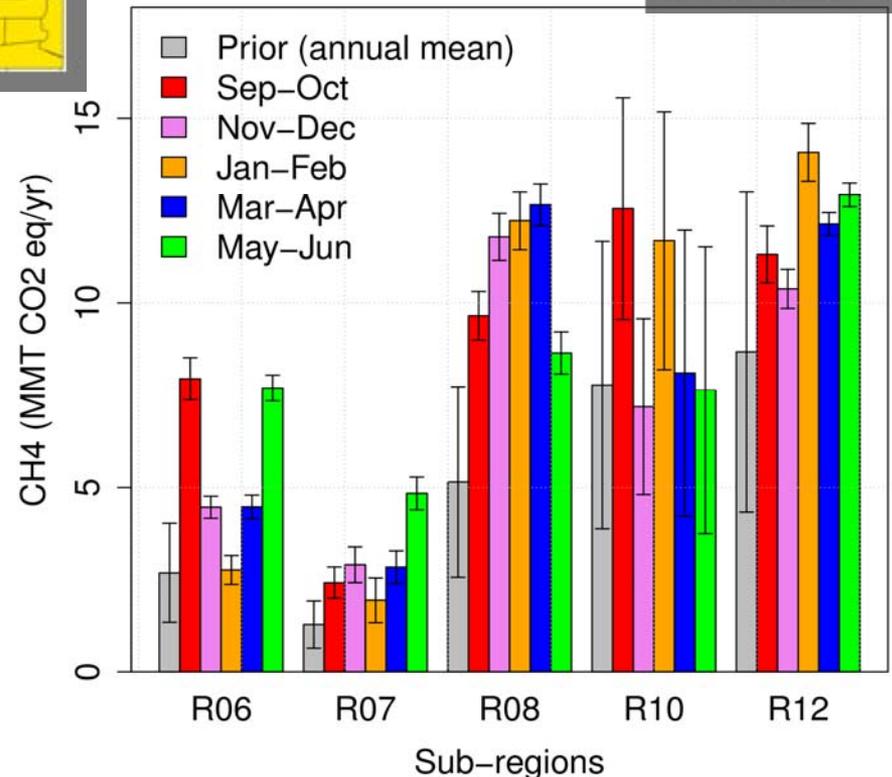
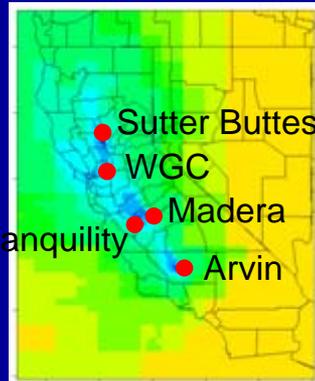
CH₄ Emissions

- CH₄ Tower Network 2010 – 2011

- Central Valley towers constrain ~ 90% of CA model CH₄ emissions

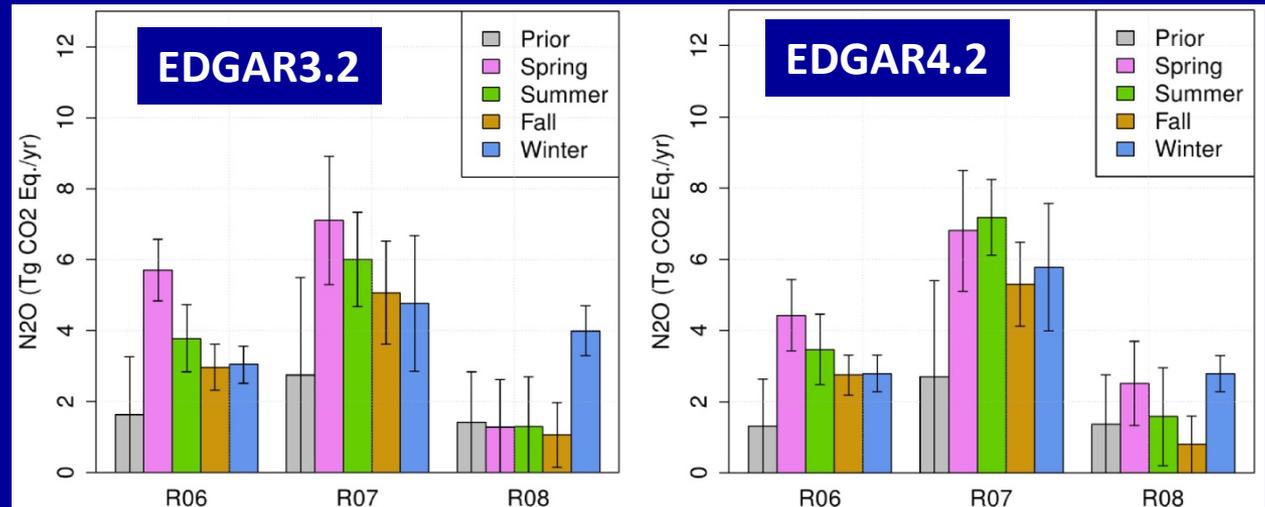
- Posterior emissions 1.6±0.1 times CARB inventory

- Observed seasonality in some regions indicative of underlying processes



N₂O Emissions

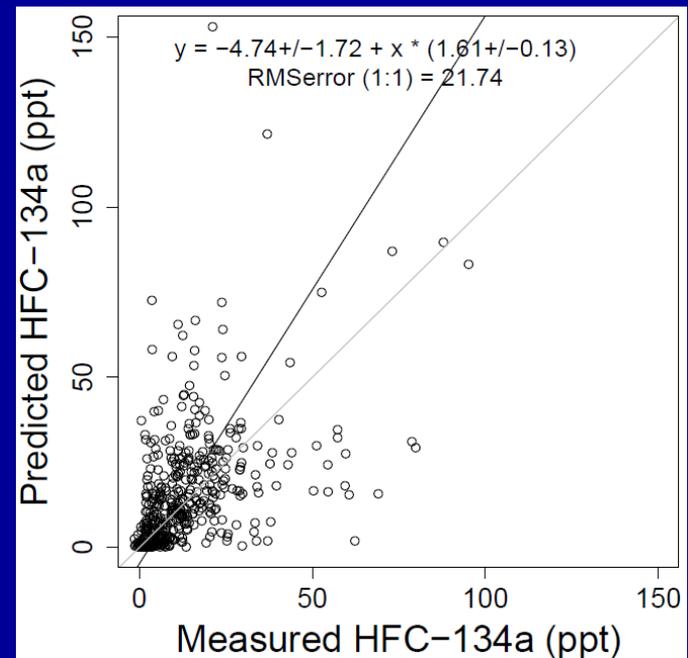
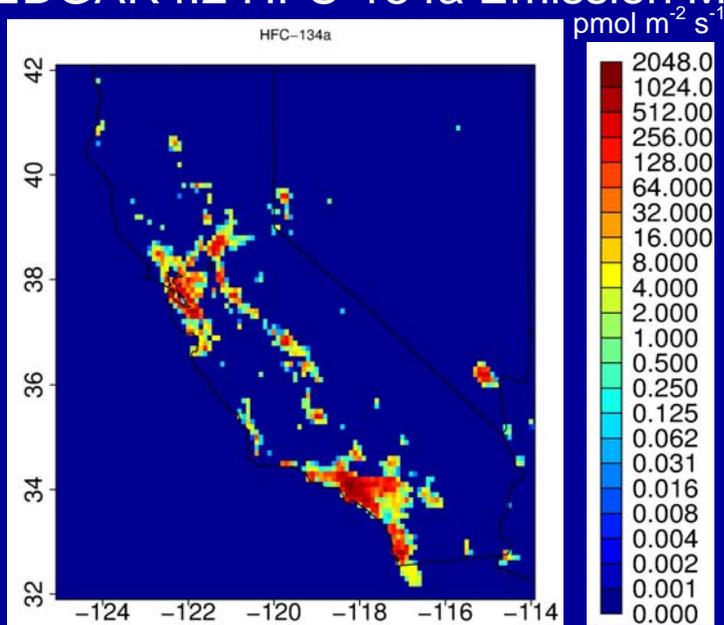
- Two years (2008 – 2009) Walnut Grove data
- Central CA emissions $2.1 \pm 0.4 \times$ EDGAR4.2
- If spatial distribution follows EDGAR then actual N₂O emissions 2.7 ± 0.5 times California 2012 inventory
- N₂O may constitute $\sim 10\%$ of total CA GHG emissions (Jeong et al., submitted)



HFC-134a Emissions

- 2 Years (2008-2009) Walnut Grove data
- If EDGAR captures spatial pattern, actual emissions ~ 0.6 x CARB inventory (CARB, 2012)
- Without significant seasonal variation

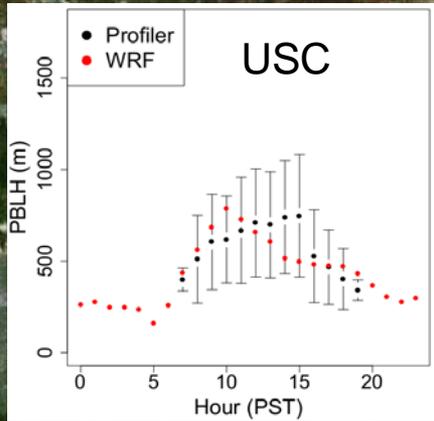
EDGAR4.2 HFC-134a Emission Map



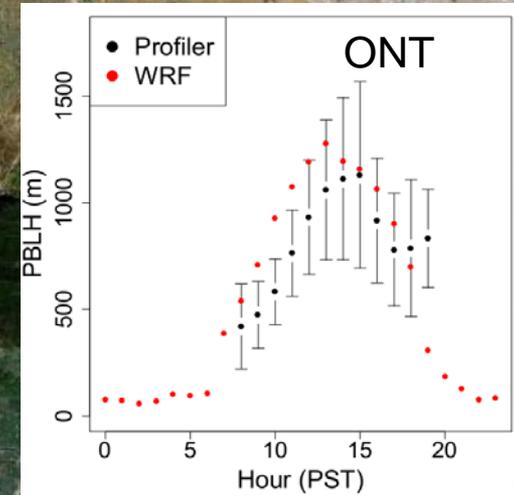
Conclusions

- Atmospheric measurements and inverse modeling provide a powerful independent constraint for emissions inventory validation
 - Fossil CO₂ consistent (~ 10%) with CARB inventory
 - CH₄ & N₂O significantly (1.5-3 x) greater than CARB inventories
 - HFC134a appears overestimated in CARB inventory (1.4x) for Central CA
- Coming efforts:
 - Continuous VOC (w/ UCB) & N₂O at WGC
 - GHG (CO₂, CH₄, N₂O, CO, ¹⁴CO₂) measurements (w/ CIT & CARB) at Riverside/San Bernardino tower
 - WRF modeling (w/ EN & UCSD) for SoCal urban region

GHG Tower for Riverside/San Bernardino



- Evaluating WRF at three S.Cal profiler sites
- WRF captures daytime PBL for May-June, 2010

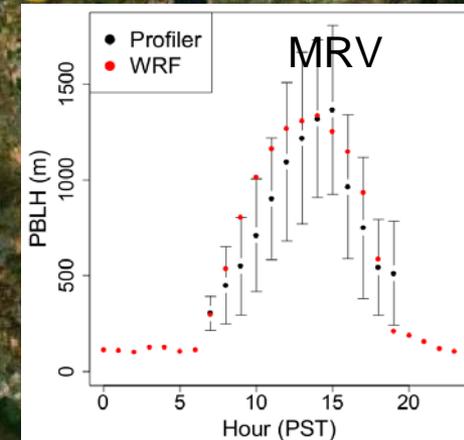


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Thank You