# Regional Estimates of $CH_4$ and $N_2O$ Emissions from Central California

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# Outline

- Overview of California's GHG Emissions
- The California Greenhouse Gas Emission Measurement Project (CALGEM)
  - Tall-tower $CH_4$ and $N_2O$ Measurements
  - WRF-STILT meteorology and footprints
  - Estimated $CH_4$ and $N_2O$ emissions
- Design of a Regional GHG Emissions Measurement Network
- Conclusions

# California GHG Emissions

- CA assembly bill AB-32 mandates reduction to 1990 levels by 2020
- Non-$CO_2$ GHG emissions comparable to $CO_2$ but…
  - Largely from biological sources and not readily metered
  - Uncertainties in inventories are large
- Atmospheric inverse approaches provide independent
- Evaluation of uncertainties is an essential challenge

CEC, 2006 ; USEPA, 2007



CA GHG Emission Trends



2004 CA non-CO2 Emissions
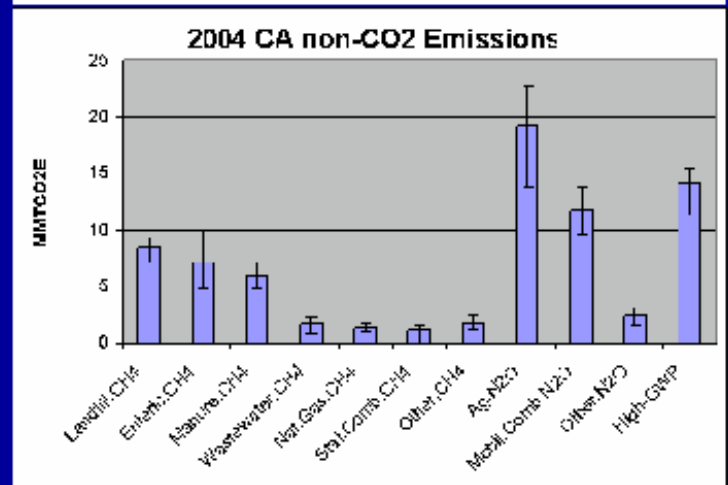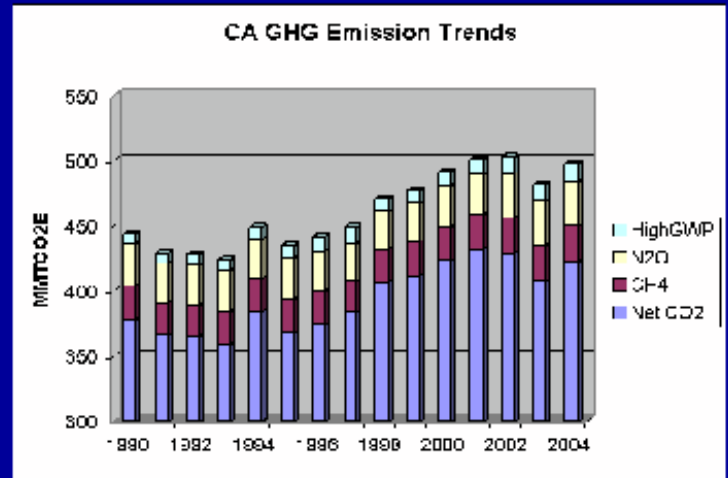
# LBNL-NOAA Collaboration:
# California Greenhouse Gas Emissions Measurement Project (CALGEM)

Sutro Tower (232 m agl)
Oceanic + urban

Walnut Grove (483 m agl)
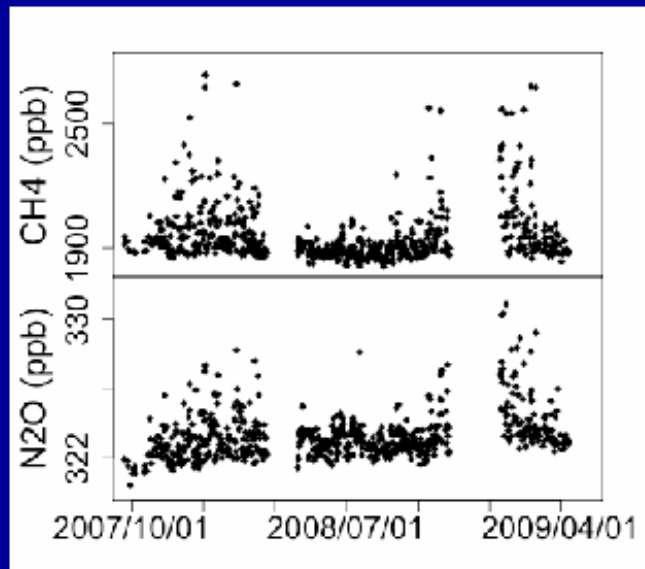Central Valley + Bay Area

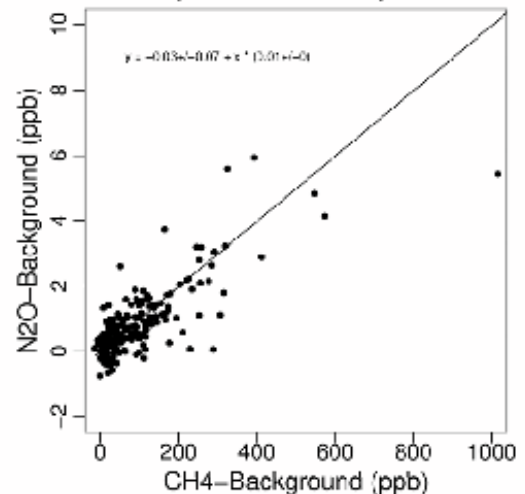in situ $CH_4$, $CO_2$, CO, $^{222}Rn$

Daily Flasks

# Walnut Grove CH$_4$ and N$_2$O



Fall-Winter (Oct - Dec, 2007)
WGC 91 m, Well Mixed, 1400 Local

- Seasonal cycles due to changing emissions and mixed layer depth
- CH$_4$ and N$_2$O share similar patterns (both dominated by valley emissions)

# *a priori* CH$_4$ Flux Maps

- Crop Agriculture (Salas)
- Landfill (point sources)
- Livestock (USDA)
- Natural gas dist./use
- Petroleum refining and use
- Wetlands (Potter et al.)
- Above sum to CA-specific
- EDGAR3.2 (1x1degree)
  - Landfills and petroleum extraction and refining ~ 2 x CA estimates
- Also: regional subdivision for spatial analysis
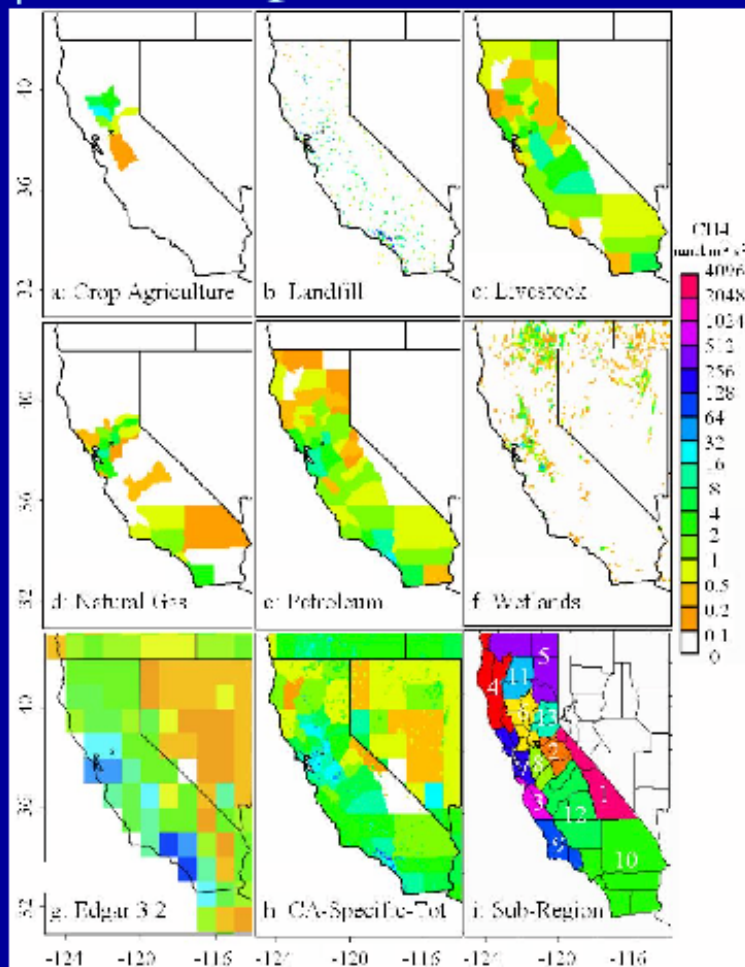
# WRF-STILT Footprints for WGC Tower

- WRF meteorology:
  - Nested grids (40,8,1.6 km)
  - NARR boundary forcing
  - Hourly averaged fields
- Example of average footprint for Oct-Dec, 2007 (from hourly maps)
- Largest surface influences (purple) for Bay Area and Central Valley
- Predict $CH_4$ signal =

  $F_{CH4}$ * footprint +

  Marine Background
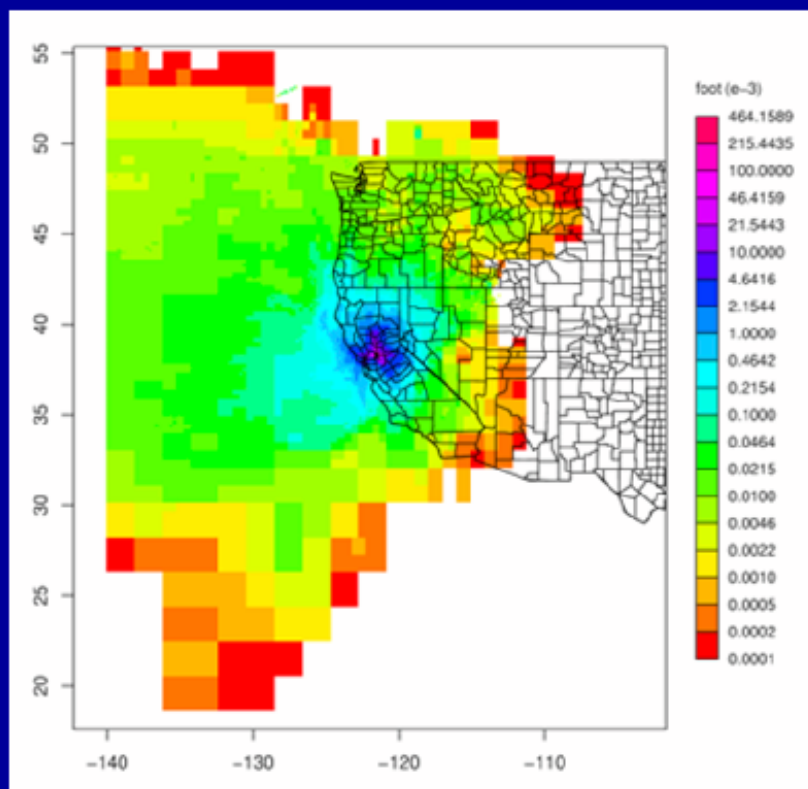
# Uncertainty Estimates



- In all cases, estimate error in underlying variable and propagate through model to expected error in predicted - measured signal difference

- Summary:
  - PBL errors ~ 25 %
  - Background error ~ 15 %
  - Wind errors ~ 10%
  - Emissions aggregation ~ 8 %
  - Others ~ 8%

- Quadrature sum ~ 32%
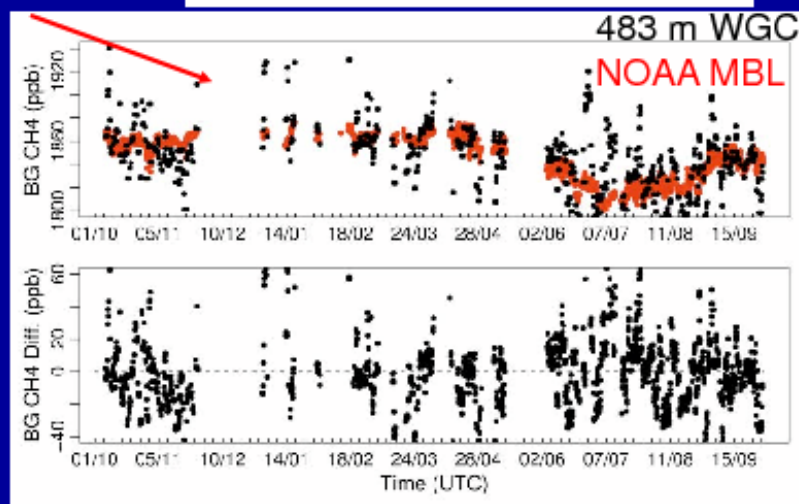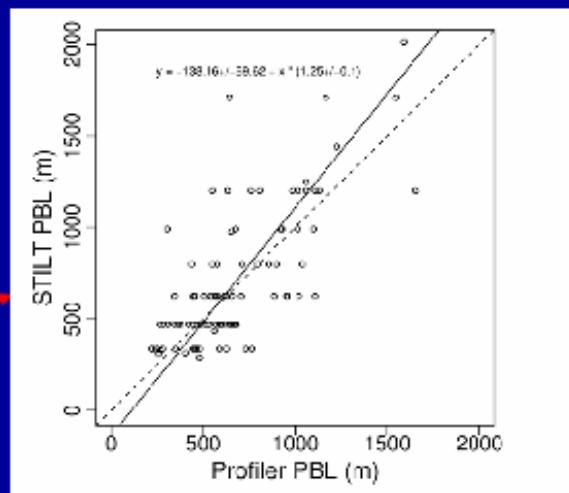
# Measured and Predicted CH$_4$ and N$_2$O

- 91 m Walnut Grove measurements
- Select well mixed periods using CH$_4$
  - 91 and 483 m CH$_4$ agree to 100 ppb
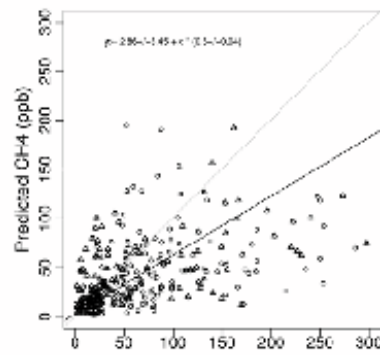- Flask N$_2$O are subset on same periods
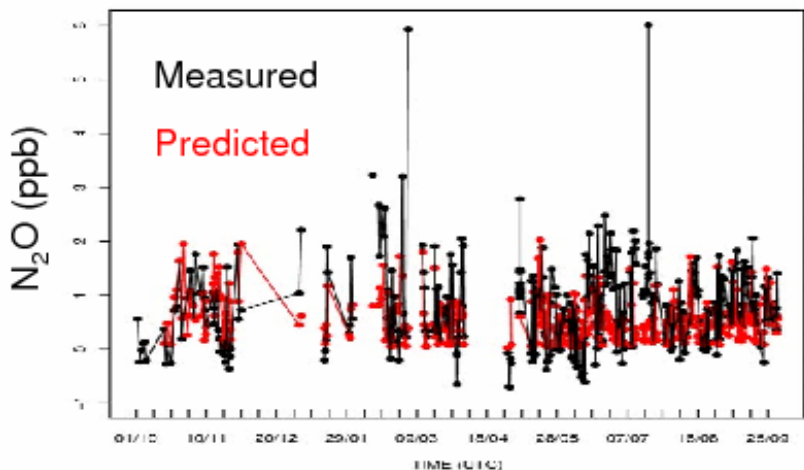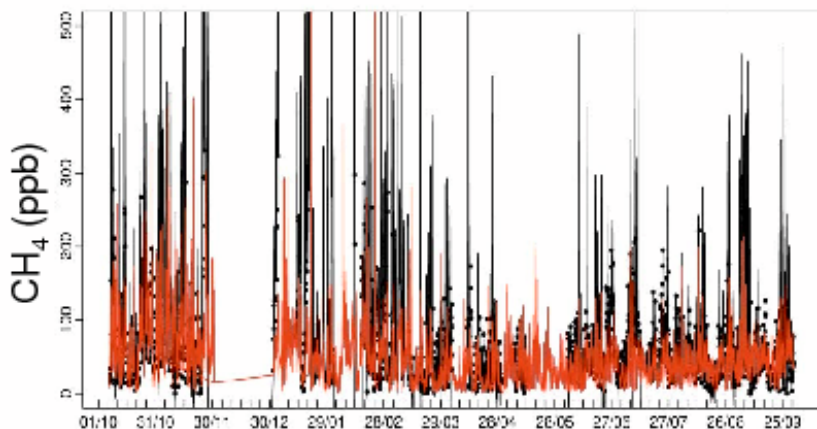
# Predicted vs. Measured CH$_4$ By Season

• Large scatter ~ consistent with estimated uncertainties and emissions model error

• CH$_4$ emissions appear underestimated in CA inventory for all periods studied
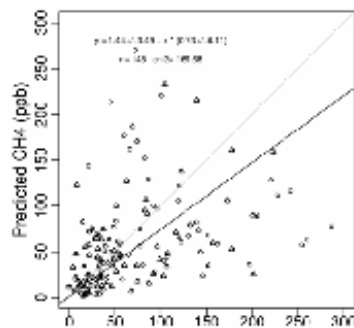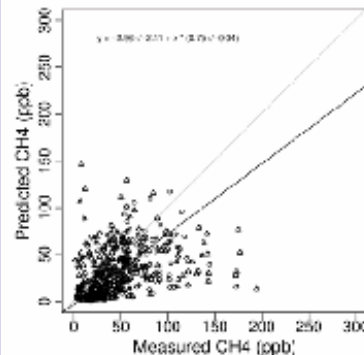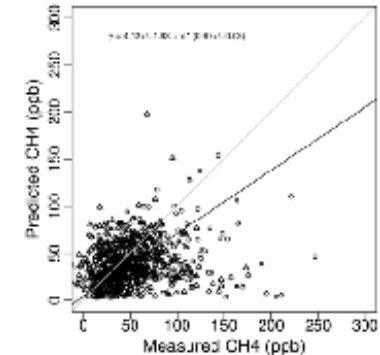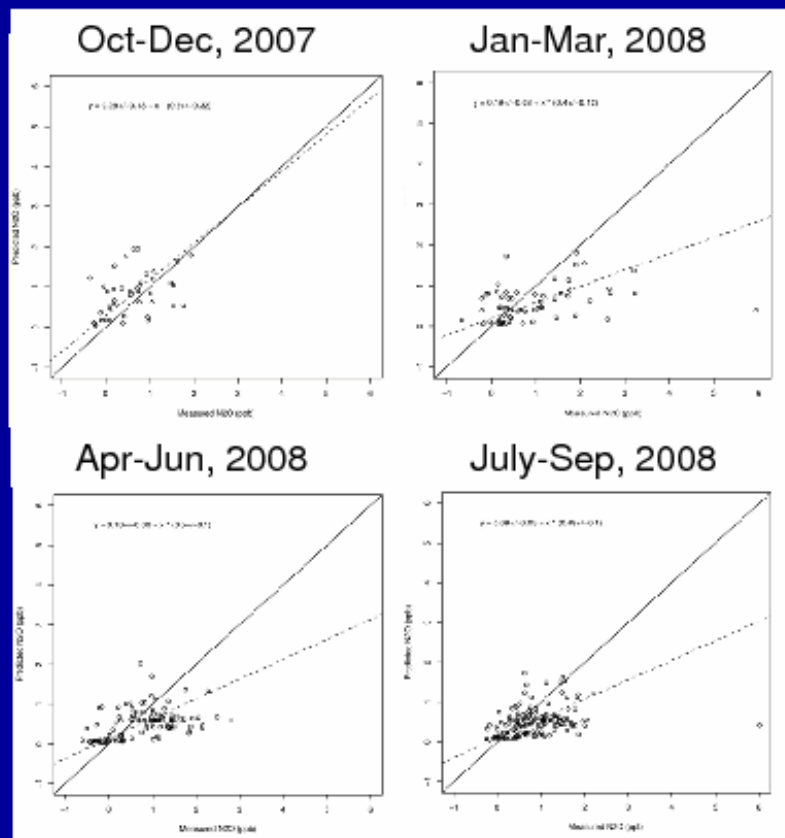
# Measured and Predicted N$_2$O

- N$_2$O flask data is sparse compared to *in situ* CH$_4$
- Slopes and estimated emissions vary with season
  - Fall 07 near unity: emissions not far off
  - Other seasons: slope ~ 1/2, suggesting emissions ~ 2 x Edgar inventory

# Estimated CH₄ Emissions (MMT CO$_{2equiv}$)

- Baysian estimate of scaling factor for each emission source or region (*a priori* errors assigned at 30%)

- Source analysis: only livestock significantly different from prior ( x 1.6 ± 0.15 )

- Region analysis:
  - only regions near WGC tower have errors reduced
  - regions 7 & 8 are larger than prior, consistent with source analysis



Wetland Landfill Livestock Nat Gas. Petro. Crops
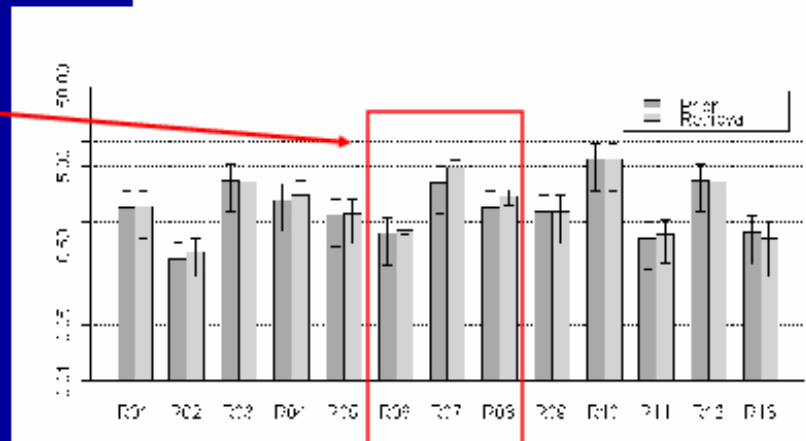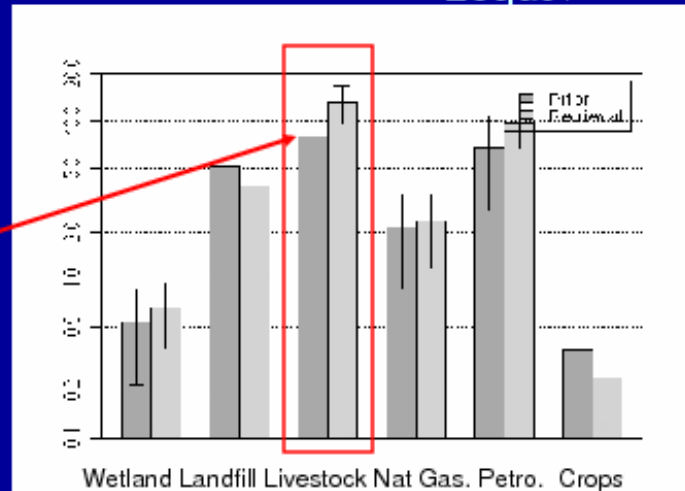
# Measurement Network Design

- Estimate effect of seven (3 valley, 4 costal) tower network

- WRF-STILT footprints show predicted regional coverage for Oct, 2007

- Psuedo-data generated from footprints, inventory CH4 emissions, and 32% random noise as estimated above

- Regional inverse estimates of posterior scaling factors show reduction in uncertainties for most regions
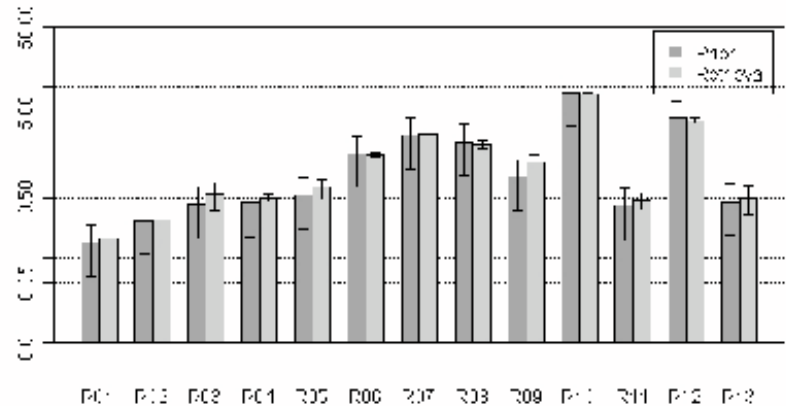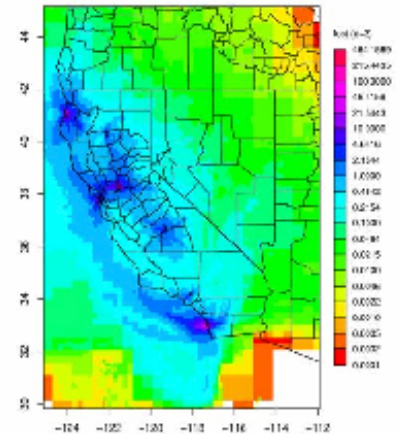
# Conclusions

- Careful attention to uncertainties essential for quantitative emission inventory assessment
  - Measurement errors are now small compared to other sources
- Meteorological uncertainty assessment requires multiple measurement sites and methods (e.g., wind profilers, tracer gases)
- Initial inverse estimates suggest:
  - $CH_4$ emissions underestimated in Central CA Valley region
  - $N_2O$ emissions also underestimated but vary significantly with season
- Even tall-tower measurements in valley appear to only constrain ~ 100-200km region surrounding tower (483 m height decouples)
- Network of towers required to capture regional emissions from California