Accounting for Wind Errors in Inverse Models to Estimate CH_4 Emissions for Central California

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Outline

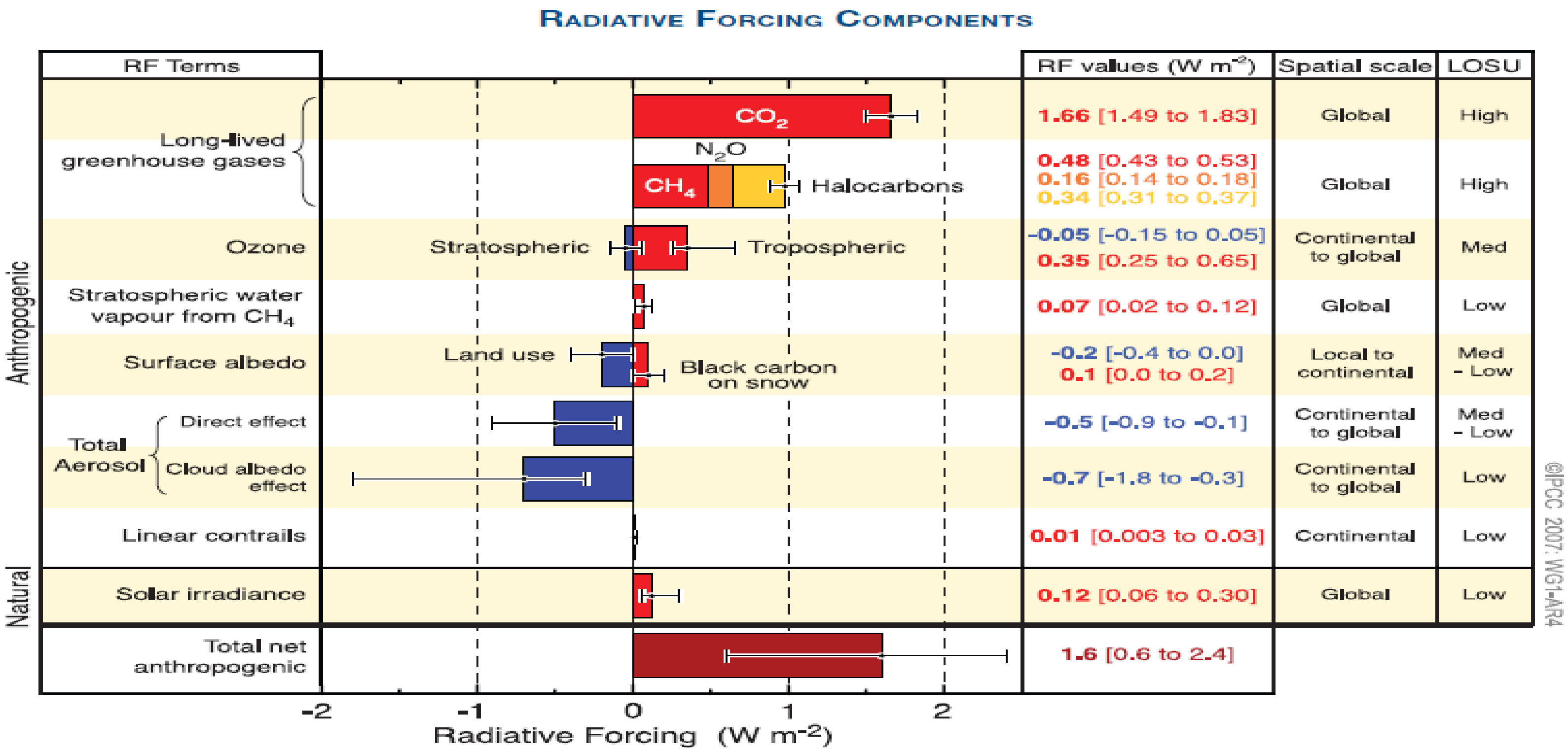
- Inverse modeling and relation to wind error: Slides 3-7
- Calculating wind error: Slides 8-10
- Wind error results and further analysis: Slides 11-18
- Conclusions: Slide 19

Key Terms & Acronyms

- A priori- Initial estimate before incorporating new data
- Posterior- Prediction combining initial estimate and new data
- Weather Research and Forecasting Model (WRF)-Meteorology Model
- Stochastic Time Inverted Lagrangian Model (STILT)-Particle Transport Model
- Inverse Bayesian Analysis-Optimizes fit between predicted and observed
- Footprint-Influence of surface emissions on measured mixing ratio signals ((ppb*(m^2)*s)/nmol)
- Radar Wind Profiler-Measures wind velocity

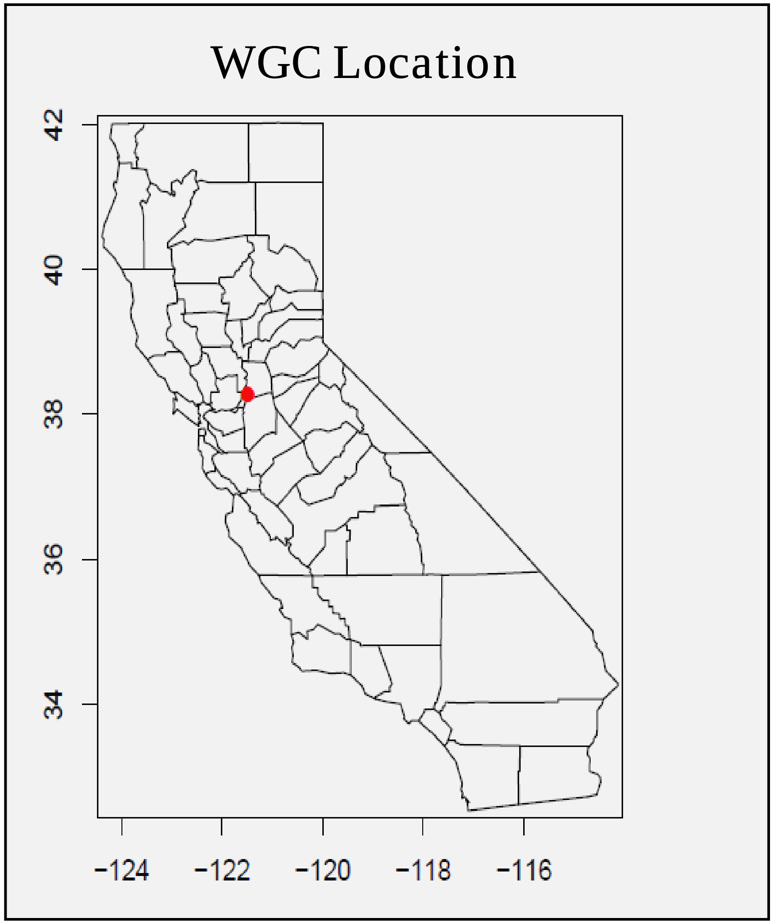
Why Quantify Methane Emissions?

Methane emissions significantly contribute to climate change



(IPCC, 2007)

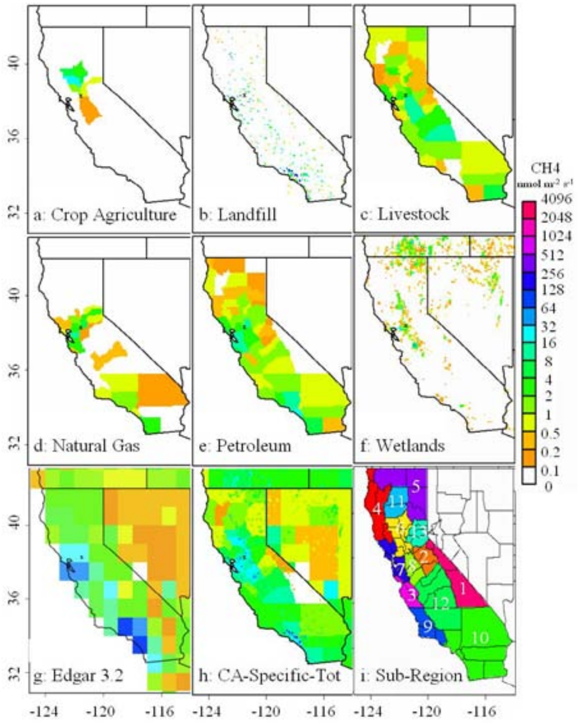
Background



- Research project: Extension of the work by Dr. Chuanfeng Zhao et al., detailed in "Atmospheric Inverse Estimates of Methane Emissions from Central California" (Zhao et al., 2009)
  - Estimates CH4 emissions from Central California by comparing measured with predicted CH4 mixing ratios at Walnut Grove, CA, WGC, for Oct-Dec '07 after applying inverse technique

Dynamics of Inverse Technique in Zhao's Work

A Priori Emission Maps for California



(Zhao et al., 2009)

- Measure CH4 mixing ratios at WGC
- Model transport of air masses, accounting for meteorology, to calculate footprints over California
- Apply inverse analysis: Multiply footprints by a priori emissions that are optimally scaled to produce predicted CH4 mixing ratios at WGC that best account for measured mixing ratios

(Zhao et al., 2009)

Predicted CH4 Emissions are Affected by Multiple Sources of Error

A priori and posterior scaling factors for CH4 emissions from sources in California

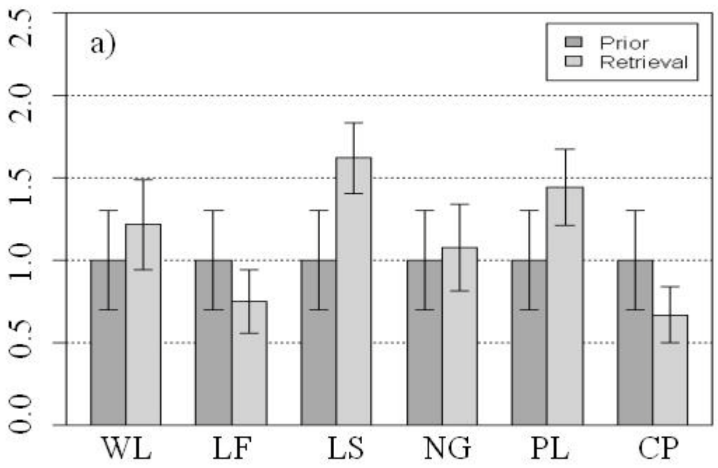
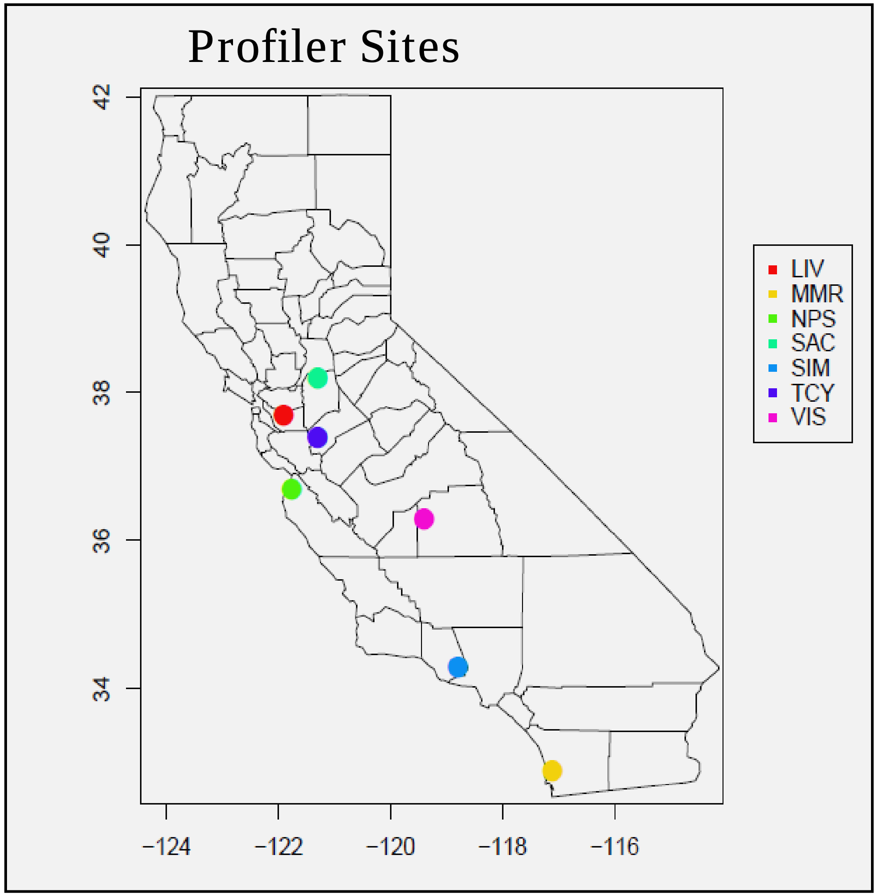


Figure Key:
WL-Wetlands; LF-Landfills; LS-Livestock;
NG-Natural gas; PL-Petroleum; CP-Crop Agriculture

(Zhao et al., 2009)

- Uncertainty of scaling factors calculated in inverse analysis accounts for errors involved in predicting CH4 mixing ratios
- Zhao et al., showed that wind velocity errors in WRF-STILT model produced error of ~ 8% in predicted signals
- Expand on Zhao et al. analysis to investigate wind errors for several sites

Methods



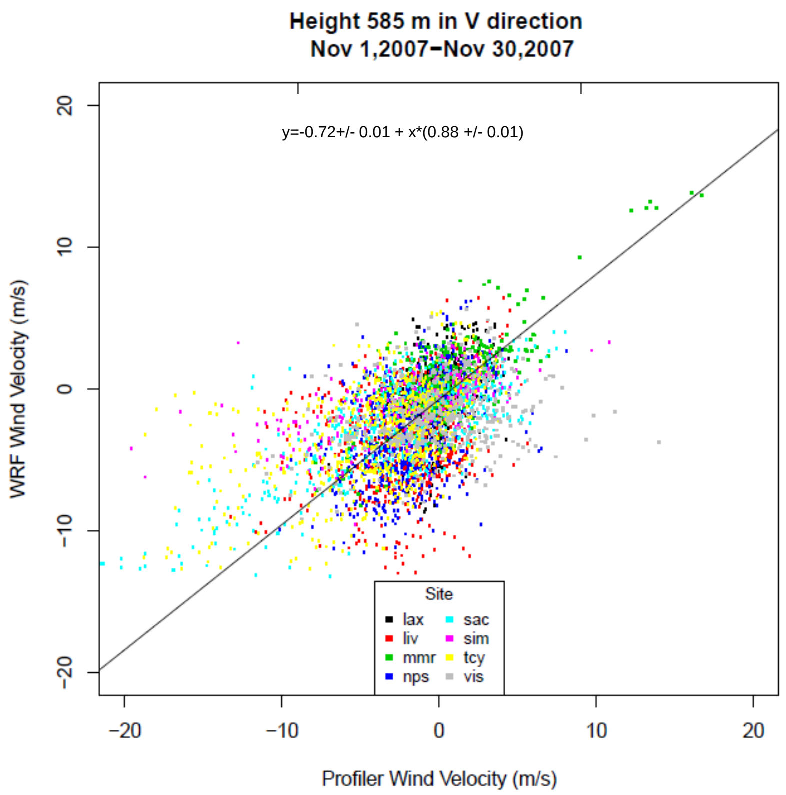
- Wind Error Evaluation
  - Compare WRF and profiler winds to quantify errors in wind velocity at multiple sites and heights
  - Analysis performed separately for each month from Oct '07 to Apr '08

Wind Error Evaluation

- Quantifying wind error
  - Match time points for WRF and profiler wind velocities
  - Calculate root mean square error in u and v (E-W, and N-S) winds
    - To exclude association btwn WRF and profiler wind velocities from RMS calculation, a linear geometric mean regression model is fit to WRF and profiler comparison
      - Assumes association is linear

Calculating RMS Error for Winds

Geometric mean regression line applied to WRF and profiler comparison



$$RMS = \sqrt{\frac{\sum (y - \hat{y})^2}{n}}$$

Where,

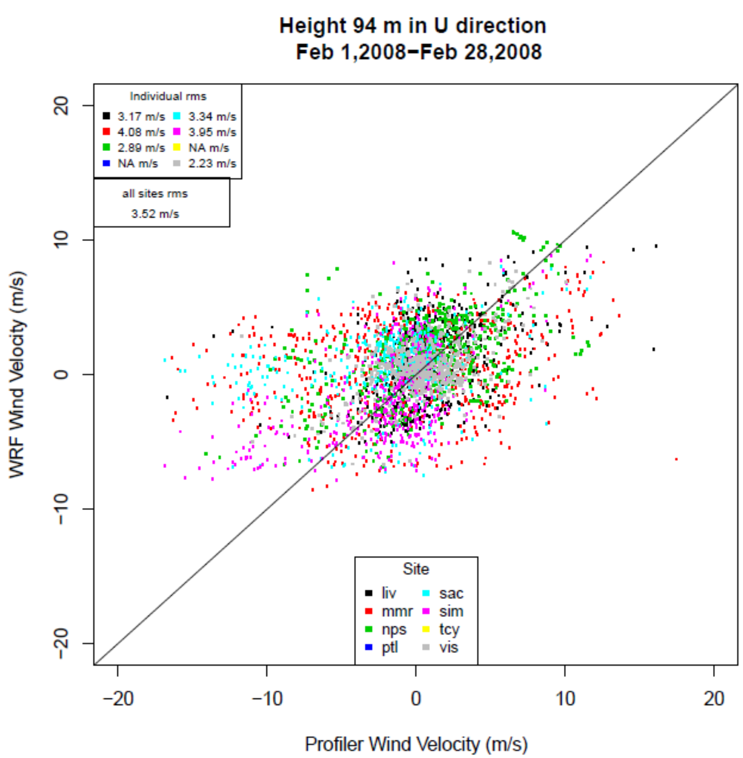
$\hat{y}$ is modeled wind velocity (m/s)

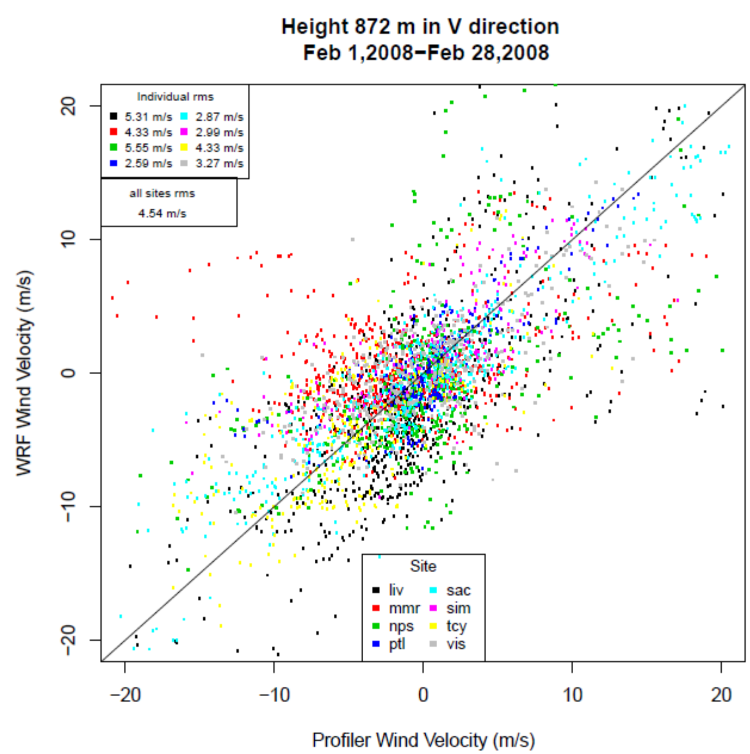
y is WRF Wind velocity (m/s)

n is total data points

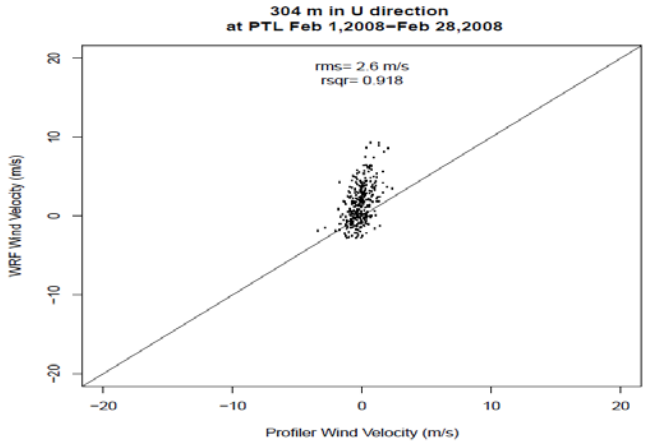
Results: WRF Vs. Profiler Observed Trends

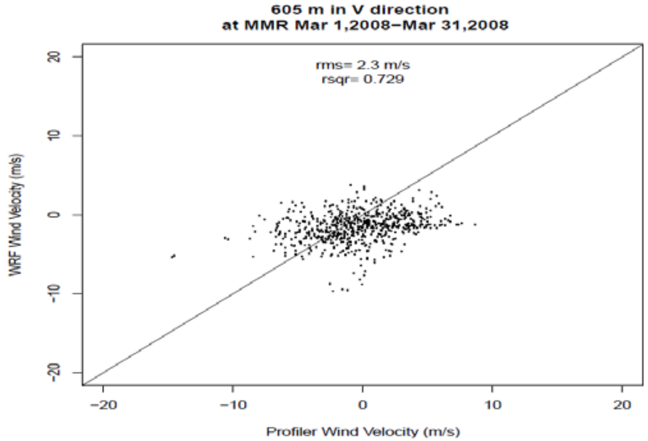
- Total RMS error ~ 2 - 5 m/s - roughly consistent with Zhao et al.
- Some difference from Zhao et al. in that RMS error for all sites increases with height





Wind Error Events in WRF and Profiler Wind Comparison





- Definition of wind error event: large systematic error
  - High slope wind error event: top figure
  - Low slope wind error event: bottom figure
- Wind error events appear for some sites when comparing WRF and profiler winds velocities

Possible Explanations for Wind Error Events

The three meteorology domains used by Zhao

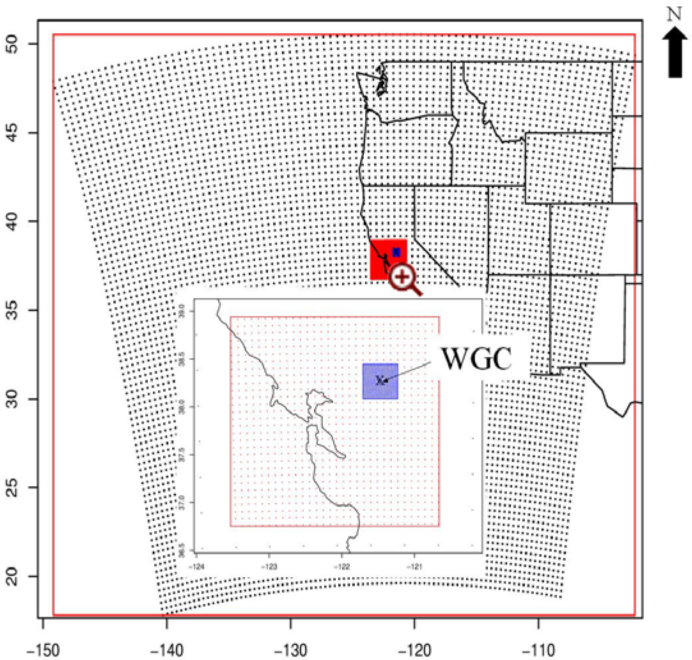


Figure: Domain 1- 40 km grid
Domain 2- 8 km grid
Domain 3- 1.6 km grid (Zhao et al, 2009)

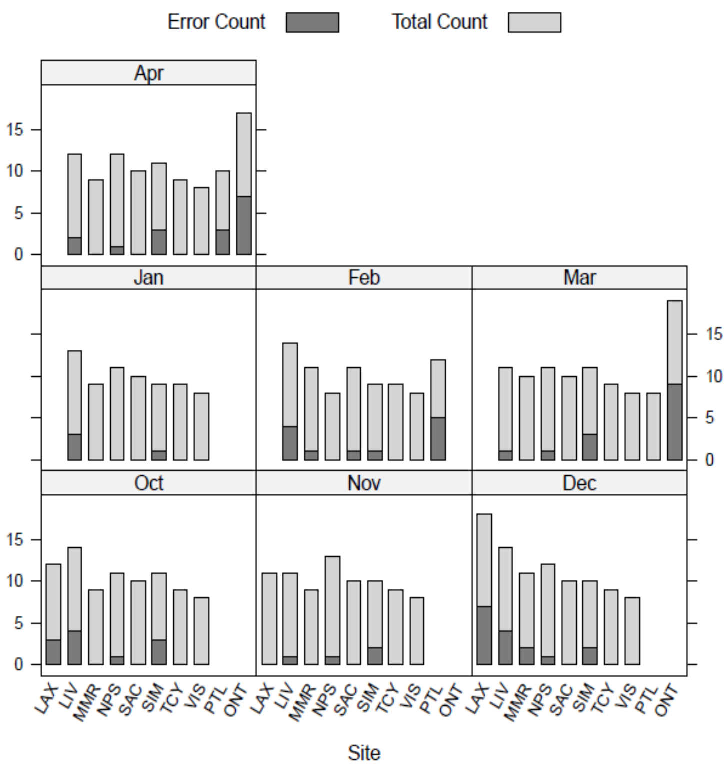
- WRF averages wind velocities within domains, thus doesn't account for local complex terrain
- Coarsest resolution, domain 1, is used in WRF for predicting wind velocity at profiler locations
- Profiler winds computed by automated algorithm that may produce artifacts

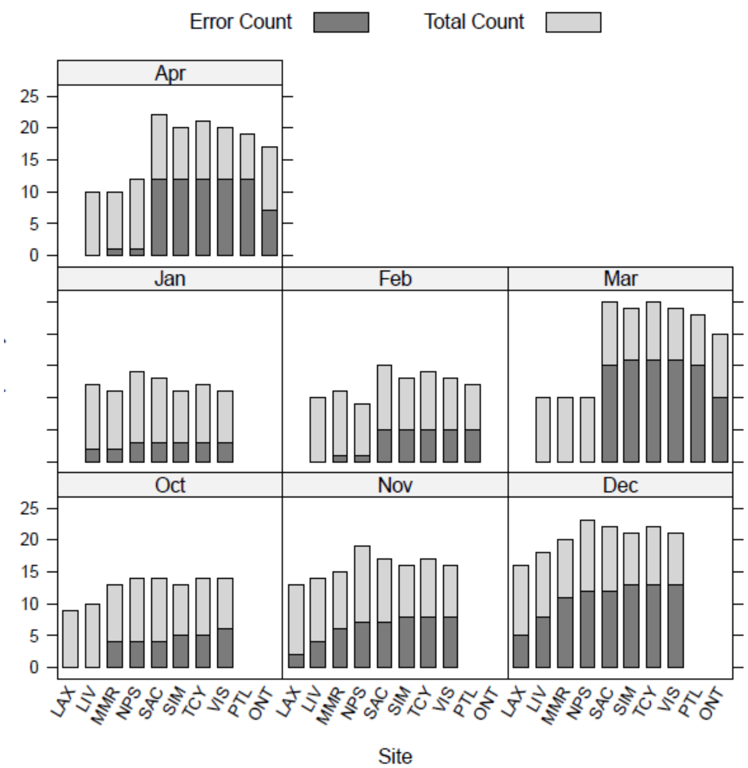
Wind Error Event Analysis

- Process of evaluating whether wind error events are result of complex terrain affecting profiler measurements and missed by WRF domain 1
  - Count each wind error event for each site and month available (Oct ‘07-Apr ‘08)
  - Flag each site that has at least one count each month for showing consistent vertical or horizontal wind error events
  - Examine all flagged and unflagged sites’ terrain on Google maps and determine if mountainous terrain around profiler site explain wind error events

Wind Error Event Analysis

High slope wind error event counts for Oct ‘07-Apr ‘08





Wind Error Event Analysis

Figure: Site SIM at scale 1 (considered immediate)
(Source: Google Maps)

Figure: Site ONT at scale 2
(Source: Google Maps)

Wind Error Event Analysis

Table reports flagged days for u and v direction

Site	**Mountainous**	**Proximity (If mountainous)**	**Flagged**
CXE	No	NA	No
PTL	ND	ND	Yes
LAX	No	NA	No
SIM	Yes	Immediate	Yes
TCY	Yes	Immediate	Yes
VIS	No	NA	Yes
MOV	Yes	Within 40 km	No
LIV	Yes	Within 40 km	Yes
MMR	Yes	Immediate	No
ONT	Yes	Within 40 km	Yes
NPS	Yes	Within 40 km	No
SAC	No	NA	Yes

Wind Error Event Comments

- Flagged sites don’t always correspond with mountainous terrain, nor flatter terrain with unflagged sites
- Other possible reason for wind error events
    - Automated wind velocity retrieval may contain errors and requires quality control

Conclusions

- RMS error incorporating all available sites at each height for Oct '07-Apr '08 are roughly consistent with those from Zhao et al. and will be used to improve uncertainty estimates for predicted CH4 emissions
- High error events were detected
  - Wind error events did not correlate obviously with terrain type
  - Higher resolution (4 km) WRF simulations will be compared with profiler winds
  - Profiler measurements likely need to be quality controlled

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Sources

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