Methods of Improving Methane Emission Estimates in California Using Mesoscale and Particle Dispersion Modeling

Alex Turner
GCEP SURE Fellow

Marc L. Fischer
Lawrence Berkeley National Laboratories
Overview

• Why Methane is Important:
  – Assembly Bill 32
  – Radiative Forcing and Green House Gases

• Inverse Modeling:
  – What is Inverse Modeling?
  – How is it applied?

• The Weather Research & Forecasting Model:
  – Model Setup
  – Evaluation and Comparison
The Importance of Methane

- California's Assembly Bill 32 (AB32):
  - Passed in 2006
  - The law requires that California reduce the state's greenhouse gas emission levels to 1990 levels by the year 2020

- Greenhouse Gases* in order of Radiative Forcing:
  - Carbon Dioxide (CO₂)
  - Methane (CH₄)
  - Nitrous Oxide (N₂O)
  - Hydrofluorocarbons (HFCs)
  - Perfluorocarbons (PFCs)
  - Sulfur Hexafluoride (SF₆)

*as listed in Assembly Bill 32 and the Kyoto Protocol
Inverse Modeling

• Inverse Model:
  \[ G \equiv m \equiv d \]

• Goal:
  • Improve source emission estimates
  • Quantify uncertainty in the estimates

• Surface layer height is half the PBL Height:
  • Assumed to be well mixed
  • Emissions only come from surface layer

Figure 1: Box model of the atmosphere adapted from Handbook of Air Quality Management.
Inverse Modeling

• Coupled Model (WRF-STILT):
  • Regional Mesoscale Model:
    • Weather Research & Forecasting Model (WRF)
    • Lagrangian Particle Dispersion Model:
      • Stochastic Time-Inverted Lagrangian Transport Model (STILT)
  
• WRF provides meteorology data to drive the STILT model

• Critical Variables passed to STILT:
  • U-Wind Fields (East-West Component)
  • V-Wind Fields (North-South Component)
  • Planetary Boundary Layer (PBL) Height
WRF Model Output

• Radar wind profilers
  • Located in and around the Central Valley
  • Provide wind and PBL Height measurements

• Planetary Boundary Layer
  • Rises during the day and falls at night
  • Marine boundary layer stays relatively low

Figure 2: WRF calculated Wind Fields and Planetary Boundary Layer Heights during daytime hours in March 2008.
WRF Model Setup

• Model setup
  • 5 domains with 36 km, 12 km, 4 km, 1.333 km, and 1.333 km grid spacing respectively
  • Reinitialized the model daily with NARR data

• 3 Boundary Layer Schemes
  • Yonsei University (YSU)
  • Mellor-Yamada-Janic (MYJ)
    • LBNL reparametrization of the MYJ scheme (CZhao)

Figure 3: Map of the five WRF domains. The white points represent radar wind profilers and the black points represent Tower sites.
Predicted and Observed Winds

• WRF is matches very well with observations for some parameters
  • The model accurately captures most of the major wind events in all seasons

• Diagnosing model bias and uncertainty
  • Propagate the error through the inverse analysis

Figure 4: Time series plot of the observed and predicted North-South wind component at the Walnut Grove Creek Tower site (-121.49°, 38.27°) during March of 2008 at 487 m.
Predicted and Observed Winds

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  - The model accurately captures most of the major wind events in all seasons

- Diagnosing model bias and uncertainty
  - Propagate the error through the inverse analysis

\[ y = -0.83 + -0.14 + x \times (0.92 + -0.02) \]

RMSE=3.16

**Figure 5:** RMS scatter plot of the predicted vs. observed North-South wind component at the Walnut Grove Creek Tower site (-121.49°, 38.27°) during March of 2008 at 487 m.
Predicted and Observed PBL Heights

• Mean diurnal variation
  • Does not show any synoptic variation

• Model is reproducing the diurnal cycle

• Systematic Differences
  • MYJ produces highest PBL
  • CZhao produces lowest PBL

Figure 6: Monthly mean diurnal variation of PBL Heights at the Lost Hills (-119.69°, 35.62°) radar wind profiler during January of 2008.
Predicted and Observed PBL Heights

• PBL Heights are accurately simulated during Fall, Winter and Spring

• PBL Heights are over predicted in the summer
  • NOAH Land Surface Model (LSM) does not take irrigation into account
  • Incorrect balance of Latent and Sensible Heat

• CZhao scheme was designed to reduce this bias

Figure 7: RMS scatter plot of predicted vs. observed PBL Heights in June 2008 at the Sacramento (-121.30°, 38.20°) site.
Conclusions

• Both YSU and MYJ perform significantly better than the CZhao scheme for predicting PBL Heights with the exception of summer
  • Chuanfeng's parametrization was based on WRFv2.2 and needs to be modified
• Both YSU and MYJ are overestimating the PBL Height during the summer
  • The NOAH Land Surface Model does not include irrigation and may be causing WRF to poorly estimate the PBL Heights in California's Central Valley during the summer
• YSU performs slightly better than MYJ in all seasons for predicting PBL Heights
• YSU performs slightly better than MYJ in all seasons for predicting Wind Fields
  • Both YSU and MYJ do a good job of predicting the Wind Fields
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Questions?
References


Janjic, Z. I., 2001: Nonsingular Implementation of the Mellor-Yamada Level 2.5 Scheme in the NCEP Meso model. NOAA/NWS/NCEP Office Note #437

References cont.


Planetary Boundary Layer Schemes

• YSU PBL Scheme\(^1\)
  • Dependent on the buoyancy profile

• MYJ PBL Scheme\(^2\)
  • The upper limit is determined by the buoyancy profile and the wind shear

• CZhao PBL Scheme\(^3\)
  • An ad hoc reparametrization of the MYJ scheme developed by a former member of Dr. Fischer's group at LBNL.
  • Based on the Turbulent Kinetic Energy (TKE) profile and parametrized on radar wind profiler PBL height data

For a more detailed description see the following:

[1] Skamarock et al. [2008], Hong et al. [2006], Hu et al. [2010]
[3] Zhao et al. [In Progress]
Future Work

• Run the STILT model to generate signals and footprints
  • Generate emission maps from the WRF output

• Conduct an ensemble of model runs with perturbed initial conditions
  • Determine the model sensitivity to various parameters

• Assimilate soil moisture data into the NOAH Land Surface Model to more accurately depict California's Central Valley irrigation
  • Possibly collaborate with the California Irrigation Management Information System (CIMIS) to determine when farmers begin irrigating their crops.