# Evaluation of PBLH simulated by WRF using a new LiDAR network in California


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## Introduction

The planetary boundary layer height (PBLH) is a key parameter for air pollution and greenhouse gas (GHG) modeling. In California, most of the long-term PBLH measurement sites are located in coastal regions. However, a majority of the emission sources are concentrated in the inland area, especially in the San Joaquin Valley. This highlights the need for additional PBLH measurements in the inland areas.

## Previous Study

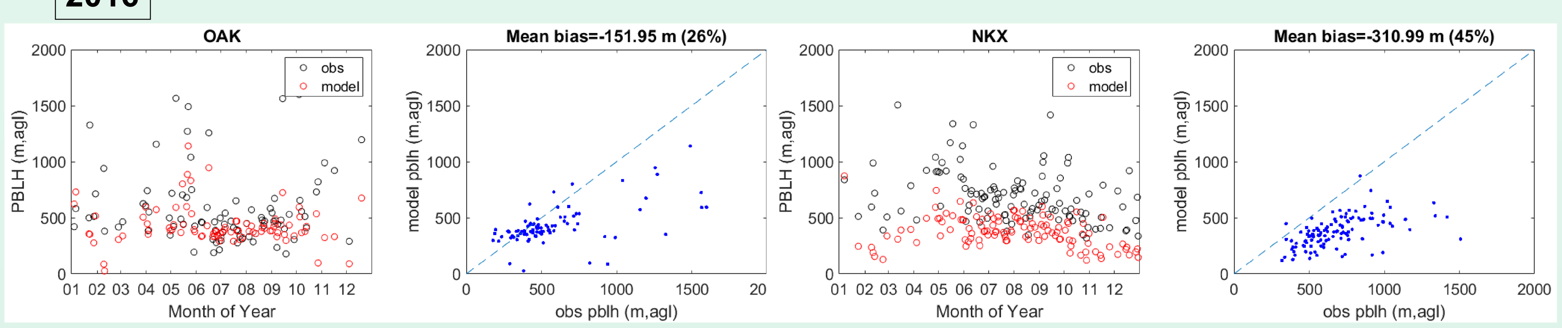
### Four PBLH retrievals

In our previous study (Cui et al. 2019), we evaluated WRF simulated PBLHs using PBLH retrievals from four different observation platforms, including radiosonde, wind radar profiler, ground-based LiDAR, and aircraft sounding, during 2014-2016.

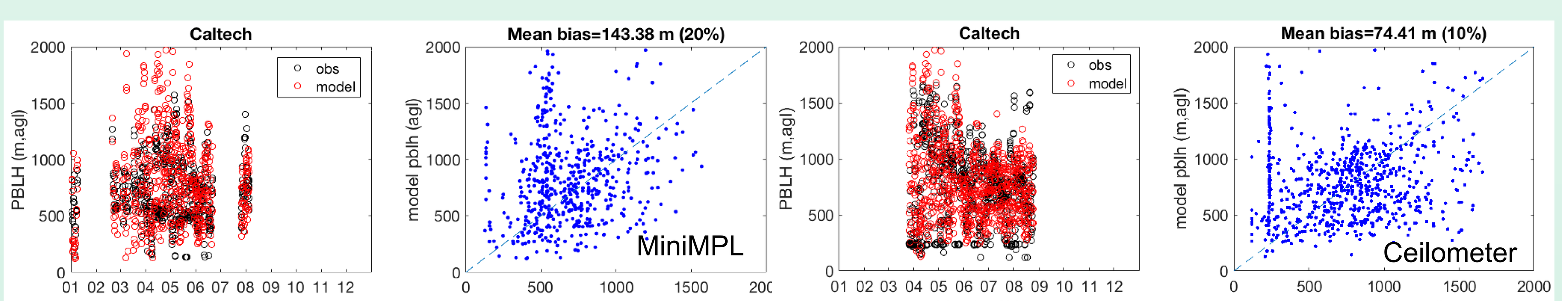
1) **Radiosonde**: We used the PBLH retrievals from two of the six stations ("OAK" and "NKX") available in California to evaluate the model performance. Radiosonde stations are only located along the coast, so that the representativeness of model evaluation are limited.
2) **Radar wind profiler**: Also used the available virtual temperature data from the Visalia radar wind profiler ("VIS") in the San Joaquin Valley to derive additional PBLH information. We used the Holzworth method to determine hourly PBLHs and focused on the time period of 12-17 LT.
3) **Aircraft sounding**: We retrieved PBLHs from available aircraft sounding data using the Holzworth method. The aircraft data were obtained from AIRCAR (provided by NCAR RDA).
4) **Ground-based LiDAR instrument**: We used year-long PBLH retrievals by a miniMPL and a co-located ceilometer in the CalTech site of the Megacities Carbon Project, during 2014-2016.

2016

Radiosonde

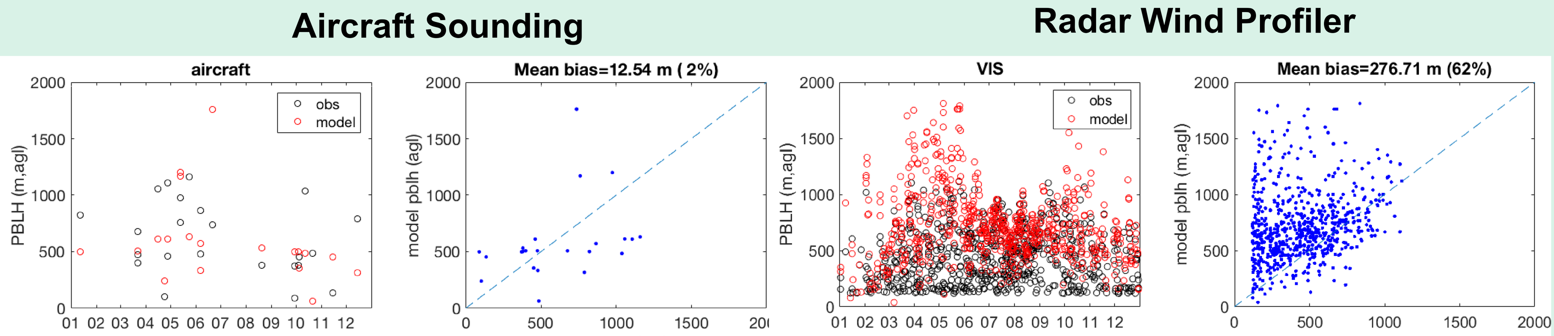



Ground-based LiDAR




Aircraft Sounding

Radar Wind Profiler

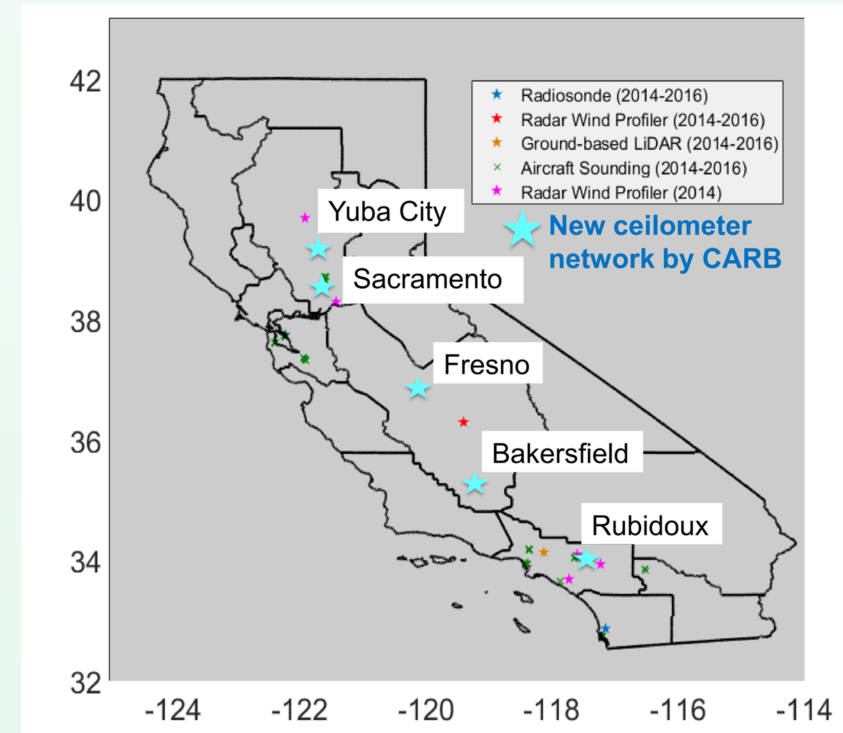



### Study Findings:

- ➢ Only one site in SJV was able to derive long-term PBLHs information (limited data for model uncertainty estimation)
- ➢ SJV has the highest concentration of GHG emission sources ($CH_4$ and $N_2O$), and the largest discrepancy in top-down emission estimates
- ➢ Therefore, additional PBLH retrievals in SJV are critical

## Project Overview

- California Air Resources Board has recently installed a new LiDAR network comprised of high-fidelity laser-based ceilometers at five ground-based sites across California to monitor atmospheric vertical layers based on the aerosol backscatter measurements.
- This is a first-of-its-kind statewide network developed to collect long-term, high-resolution, atmospheric vertical measurements.




### Study Objectives

- In this study, we will evaluate the utility of the ceilometer data for boundary layer assessment as a complement to the existing data streams
- We will also develop and test algorithms to extract useful data products from the ceilometer network for WRF-PBLH evaluations

## Instrumentation and Data Samples


### Measurement parameters

| | |
|---|---|
| Measuring range | 5 m – 15 km |
| Range Resolution | 5 m constant measurement interval over full range |
| NetCDF data file: Reported range resolution | 5 m – 30 m in 5 m steps (can be selected by user) 15 m (default value)<br>5 m in high resolution vector in the NetCDF file |
| Logging time & reporting cycle | 2 s to 600 s (programmable),<br>Standard values are 15 s, 30 s, 60 s |
| Targets | Aerosols & clouds (droplets, ice crystals) |
| Measured and target parameters | Backscatter raw data<br>Cloud base height up to 9 layers incl. penetration depth (cloud thickness), max detectable range (MXD), vertical visual range (VOR), sky condition (SCI), cloud amount (TCC, BCC), … |
| Measuring principle | Lidar (light detection and ranging) |

### Data availability

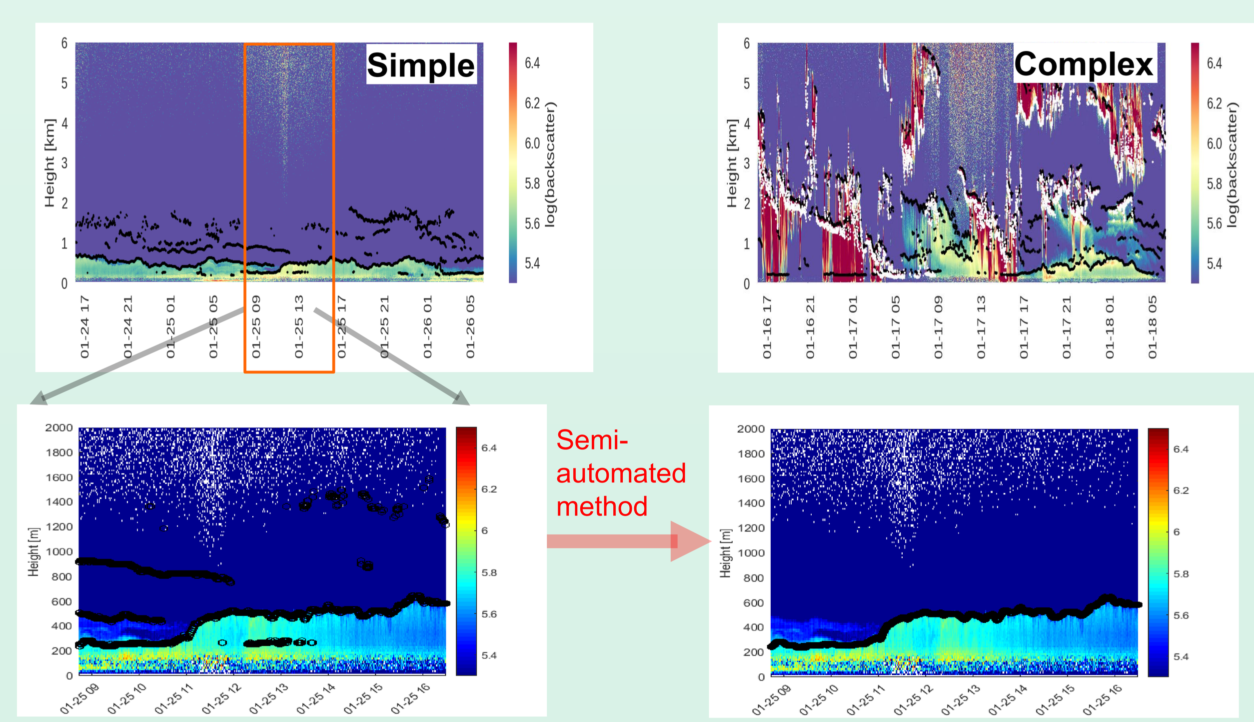
| | |
|---|---|
| Rubidoux | 10.14.2018-current |
| Bakersfield | 10.14.2018-current |
| Fresno | 10.14.2018-current |
| Sacramento | 01.22.2019-current |
| Yuba City | 01.22.2019-current |

### Data output

- ➢ Ceilometers generate continuous backscatter data (every 15s) from the near surface to 15km.

### Mixing layer height determination

- ➢ In the study, we only focused on "Simple" scenarios, using a semi-automated method to determine PBLH.
- ➢ In this study, we only focused on data collected between 8am-5pm LT.




## Model Evaluation

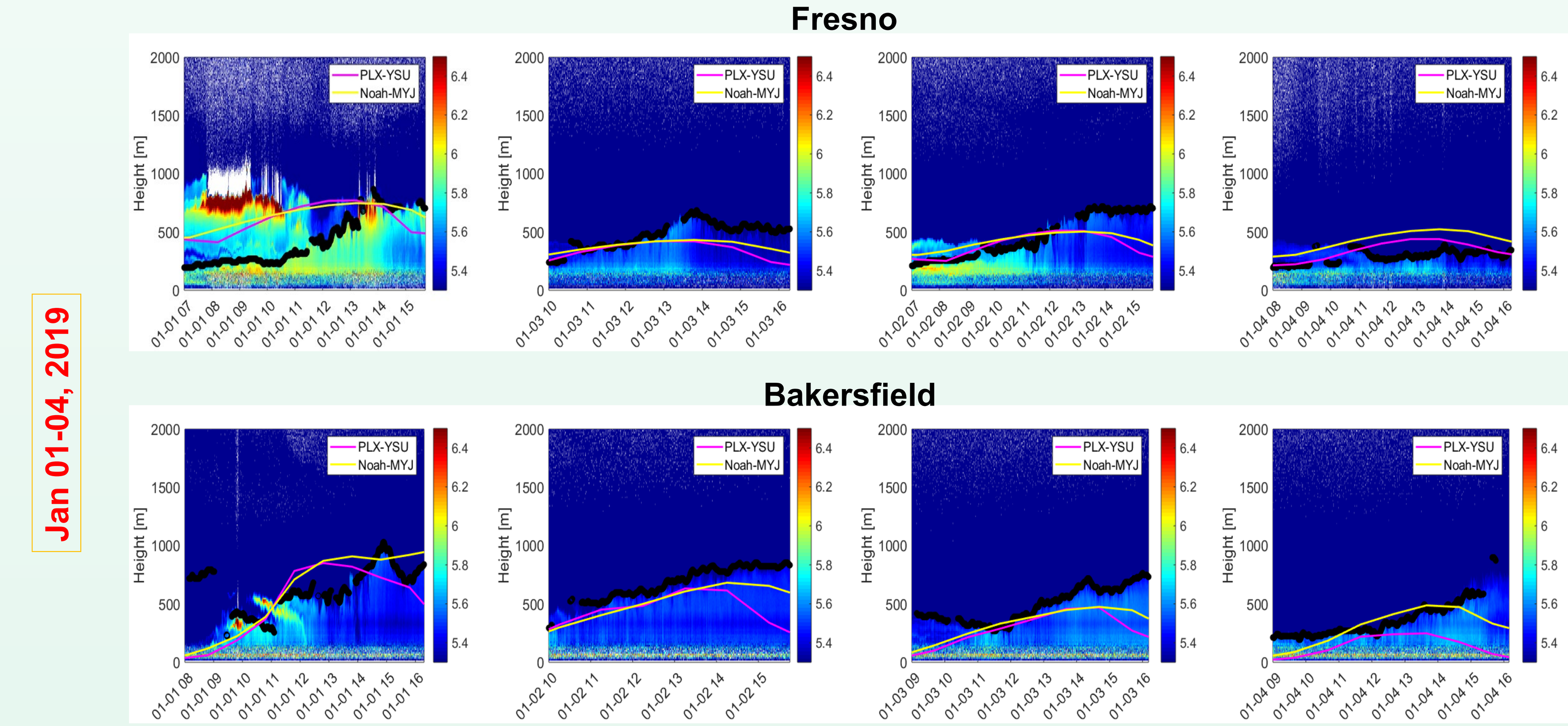
### WRF Configurations

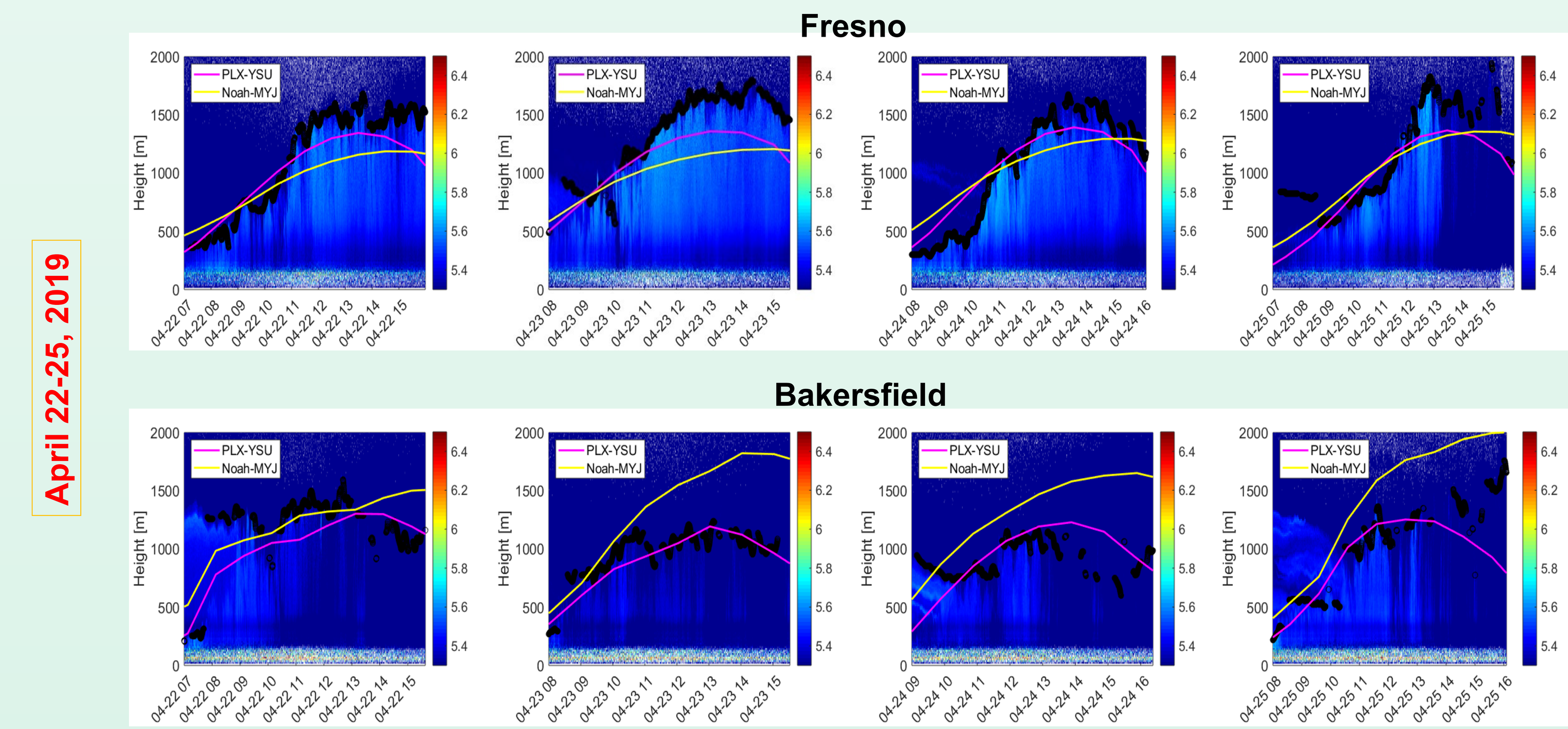
- ➢ WRF 3.7.1; North American Regional Reanalysis data were used to provide the initial and boundary conditions; three nested domains (36km, 12km, and 4km), and we focused on the inner 4-km domain in the study. Details in Cui et al. (2019).
- ➢ We evaluated PBLHs using two different WRF configurations as shown in the table:
- ➢ We selected two time periods in 2019 to conduct the evaluations: wet (01-04 Jan) and dry (22-29 April).

| Cases | Land surface models | PBL schemes |
|---|---|---|
| PLX-Xu | Pleim-Xiu | YSU |
| Noah-MYJ | Noah | MYJ |

## Results

### Ceilometer-based mixing height vs WRF-derived PBLH




Figures show the comparisons between ceilometer-based-daytime mixing heights and WRF-based PBLHs at two sites (Bakersfield and Fresno) in San Joaquin Valley:

- ➢ Ceilometer data is useful to characterize the boundary-layer and evaluate WRF PBLHs with the high temporal resolution.
- ➢ Model evaluation suggests that PLX+YSU scheme is likely better than Noah+MYJ, especially in April.
- ➢ For the evolution of boundary layer height, the PBLH simulated by the PLX+YSU decreased faster than the mixing heights determined by ceilometers during the late afternoon.

### Next Steps

- ➢ Conduct further improvements to the algorithm (e.g. applying wave covariance transform with first-derivative Gaussian wavelet and the Canny edge detection method, as well as a fuzzy logic algorithm (e.g. Ware et al. (2016); Hegarty et al. 2018))
- ➢ Conduct long-term WRF-PBLH evaluations using the ceilometer-based mixing height information.
- ➢ Evaluate whether the current ceilometer locations are appropriate for PBLH evaluation.
- ➢ Once the algorithm is finalized, CARB will post the data on our website.

## References


1. Cui et al. A Multiplatform Inversion Estimation of Statewide and Regional Methane Emissions in California during 2014–2016, ES&T, 2019
2. Hegarty et al. Analysis of the Planetary Boundary Layer Height during DISCOVER-AQ Baltimore–Washington, D.C., with Lidar and High-Resolution WRF Modeling, JAMC.2018.
3. Ware et al. Aerosol LiDAR observations of atmospheric mixing in Los Angeles: Climatology and implications for greenhouse gas observations, JGR. 2016.