Estimates of Spatially Complete, Observational Data-driven Planetary Boundary Layer Height over the Contiguous United States

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Introduction

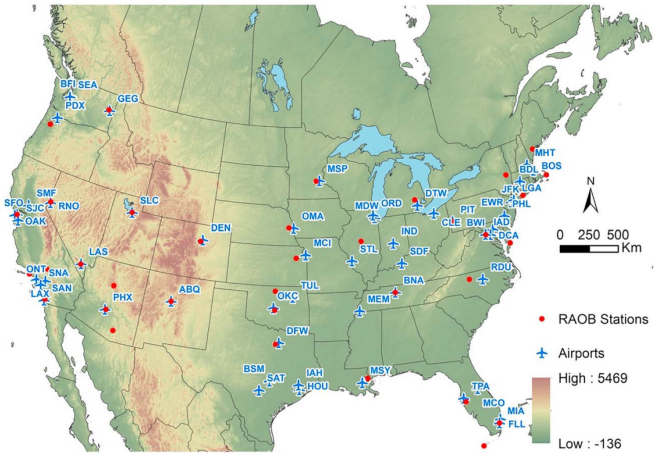
- The planetary boundary layer (PBL) is the turbulent lowest part of the atmosphere.
- It is the interaction layer between the atmosphere and the surface.
- The PBL height (PBLH) is important to accurately understand air pollution.

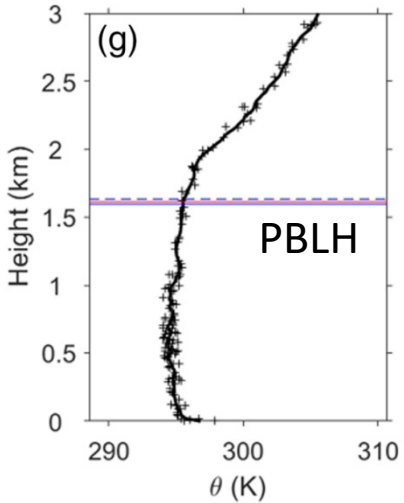
Motivation

- The observations of PBLH are sparse in space and time.
- The PBLH in current atmospheric models is often inaccurate, leading to biases in pollution simulation.
- This study aims to generate a reliable spatially complete PBLH product over the contiguous United States.

AMDAR PBLH Observations

- Aircraft Meteorological DAta Reporting (AMDAR) PBLH hourly profiles at 13:00 - 14:00 local solar time from 54 airports within the contiguous United States during 2007 – 2019 are used.
- Hourly PBLH is derived using the bulk Richardson number method.





Bulk Richardson number method:

$$Ri_b = \frac{(g/\theta_{v,s})(\theta_{v,z} - \theta_{v,s})(z - z_s)}{(u_z - u_s)^2 + (v_z - v_s)^2 + bu^{*2}}$$

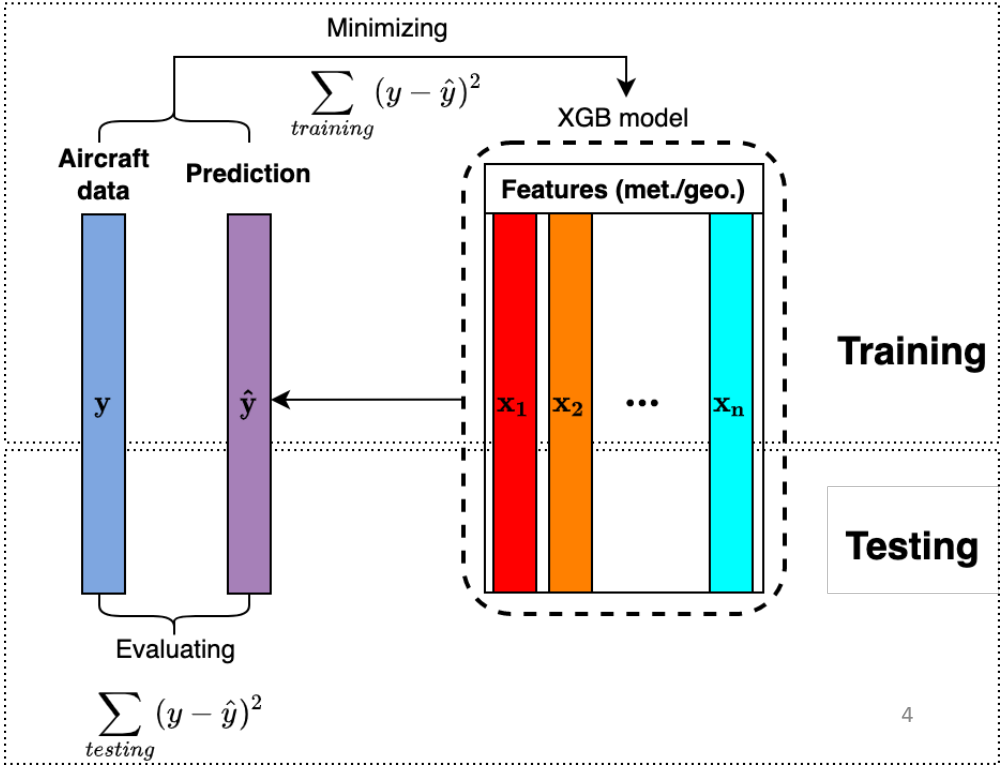
g: gravity acceleration
θ_v: virtual potential temperature
u and v: horizontal winds
u^*: surface friction velocity
z denotes vertical profile values
s denotes value at the lower boundary of PBL

Zhang et al., *Journal of Geophysical Research*, 2020

eXtreme Gradient Boosting (XGB) Model

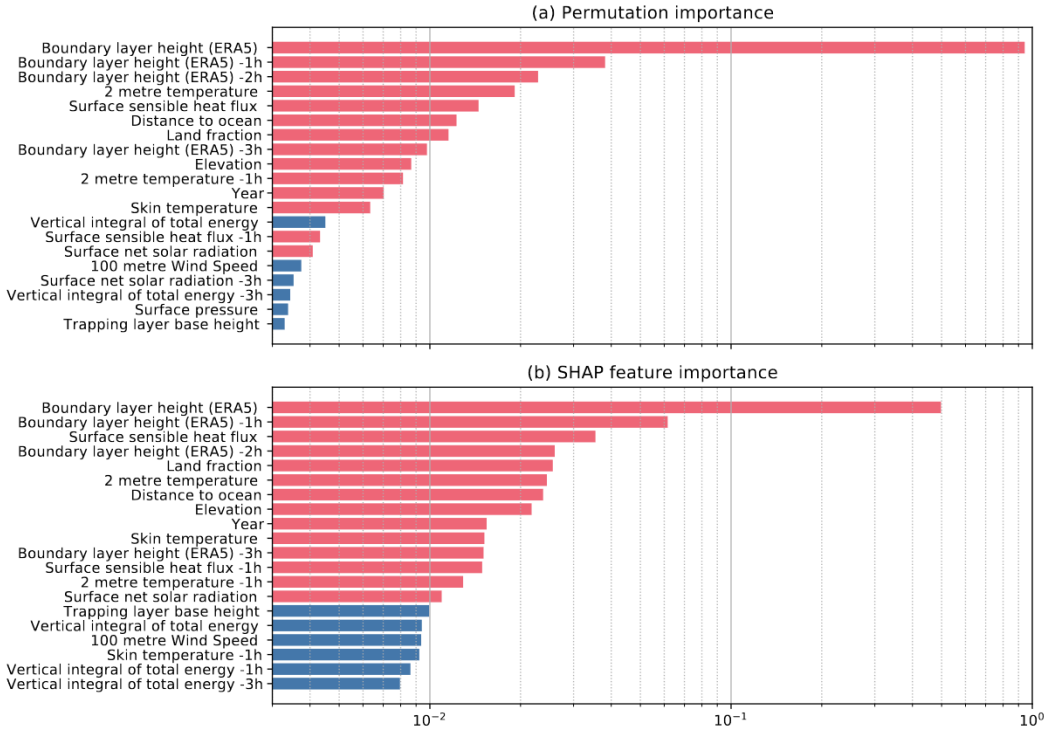
- The features include meteorological and geographical parameters.

- The meteorological datasets are from ERA5, a reanalysis model which provides state-of-the-art operational weather products.

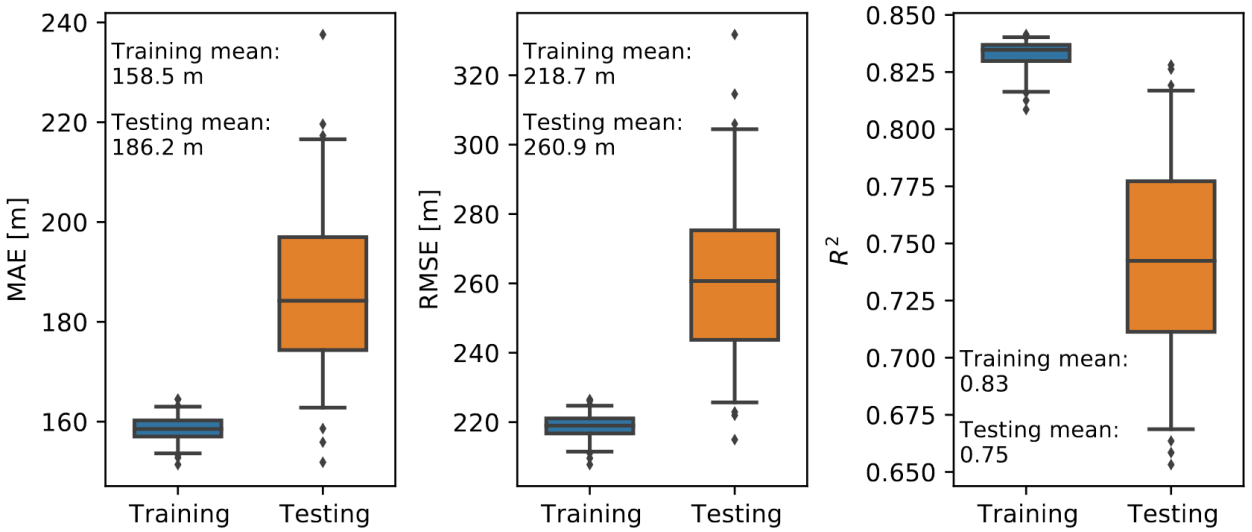


Model Features Selection

- 14 meteorological and geographical datasets are selected as the model features. They are available with a spatially complete coverage.

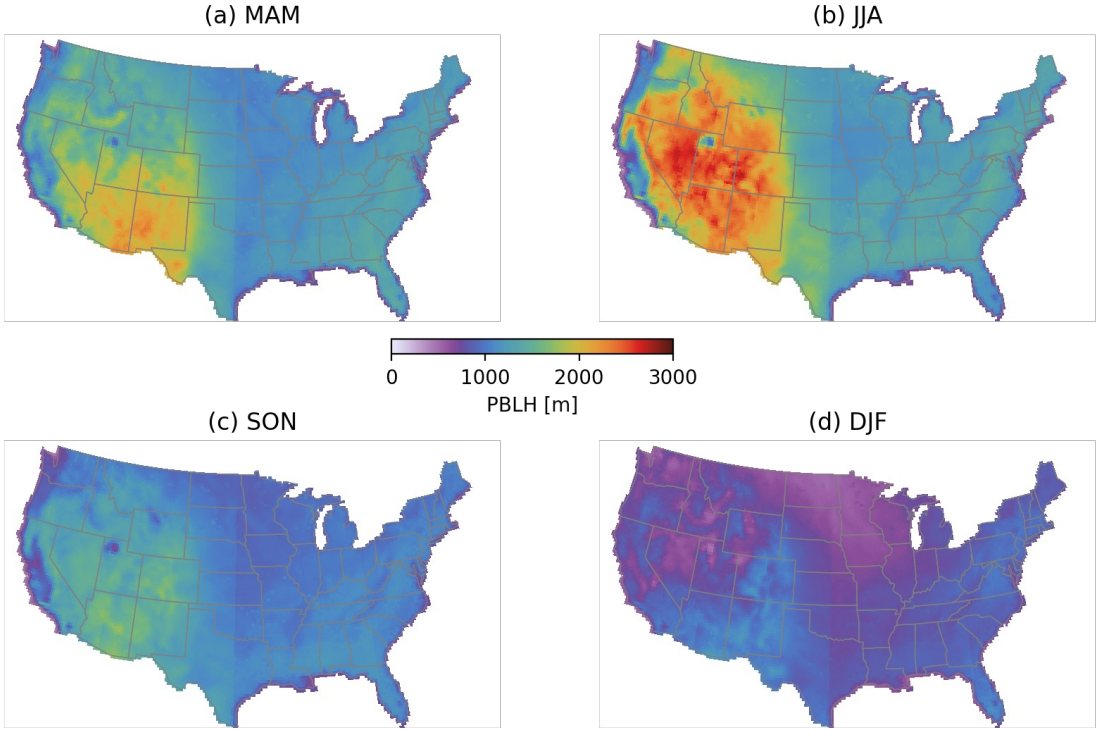


Model Performance



Predicted PBLH by XGB

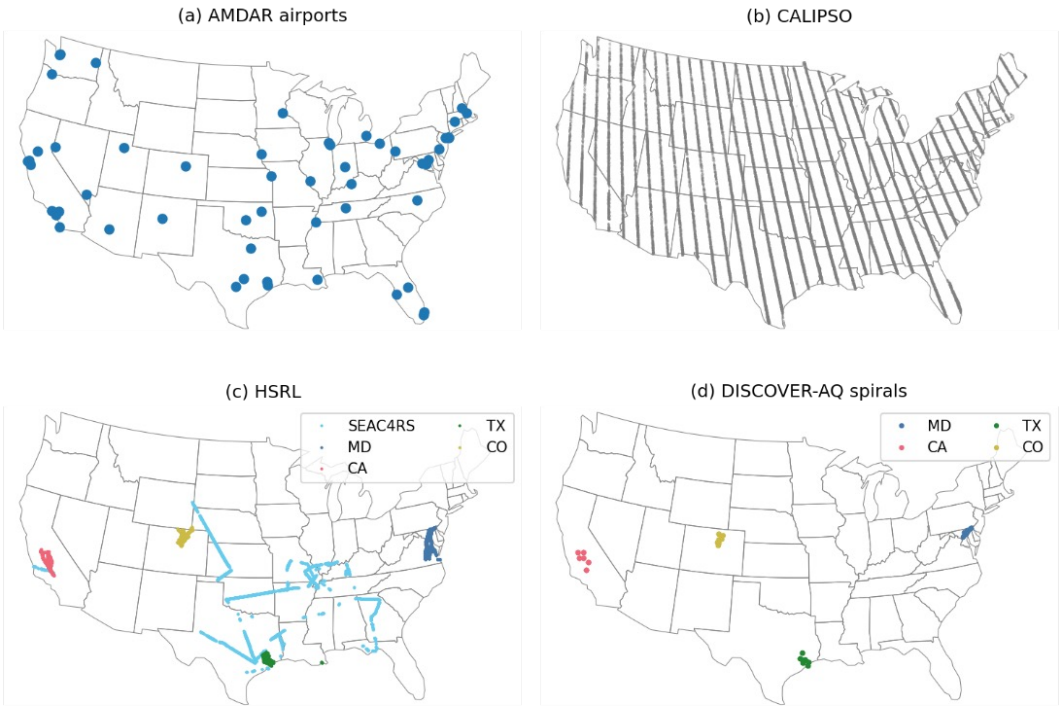
- The predicted PBLH product shows the seasonality of PBLH.



PBLH climatology at 1300 local time

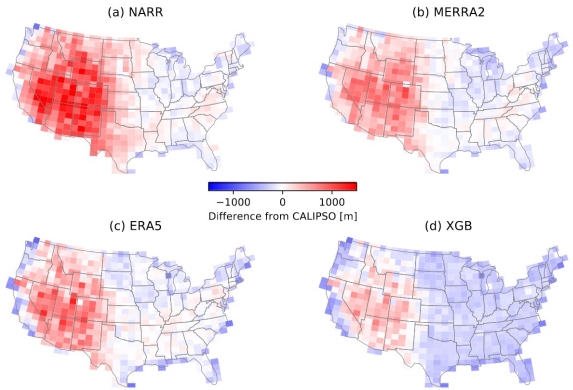
Model Validation

- Three independently observed PBLH dataset for validation:
  - CALIPSO (satellite lidar)
  - HSRL (airborne lidar)
  - Aircraft spirals
- Three reanalysis models for comparison:
  - ERA5 (European product, global)
  - MERRA-2 (NASA product, global)
  - NARR (NOAA product, North America)

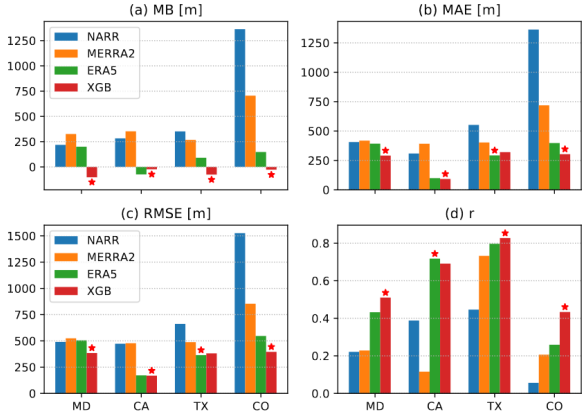


Evaluation of Predicted PBLH

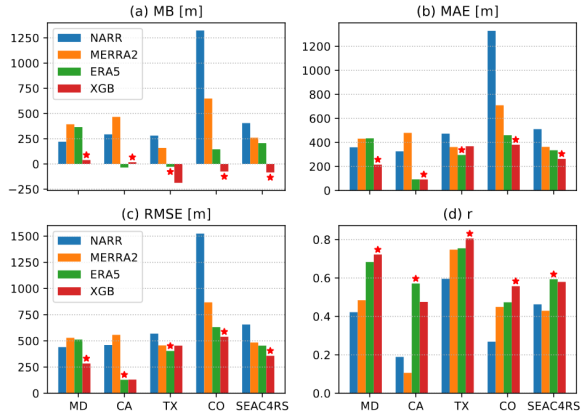
- Validations with 3 datasets indicate the spatially complete PBLH generally outperform other reanalysis.



Predicted PBLH vs. CALIPSO



Predicted PBLH vs. Aircraft Spiral



Predicted PBLH vs. Airborne Lidar

Summary

- eXtreme gradient boosting is a powerful tool to develop a spatially complete planetary boundary layer height.
- Model features are meteorological and geographical datasets that are available with a spatially complete coverage.
- The XGB product shows the seasonality of PBLH.
- Validations with 3 datasets indicate the spatially complete PBLH generally outperform other reanalysis.