A Comprehensive Dataset of Boundary Layer Heights using Micropulse Lidars at Multiple ARM sites

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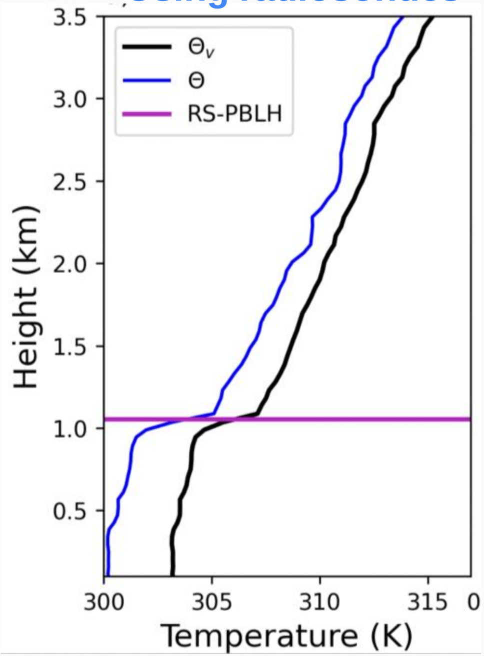
August 9, 2023

Project name: Investigation of Cloud-Surface Coupling over Land Using ARM Observations and Model Simulations

Introduction

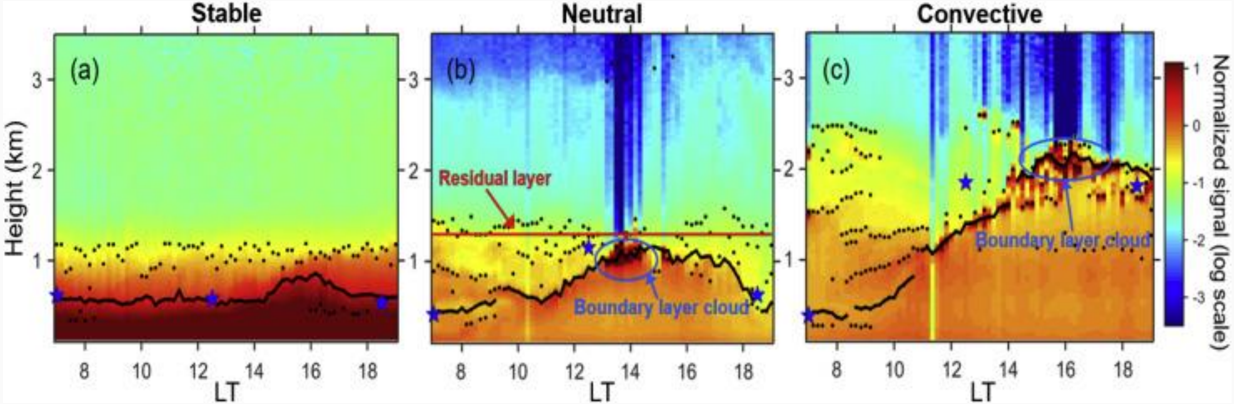
Measuring and modeling the planetary boundary layer height (PBLH) faces challenges due to its variability and observational limitations. There are several methods to compute the PBLH:

Using radiosondes



Limited temporal resolutions

Remote sensing methods: LIDAR or CEILOMETER



Su et al. (2020), RSE

Higher temporal resolutions

However, in both cases, difficulties arise

a) in stratified situations
b) under stable conditions

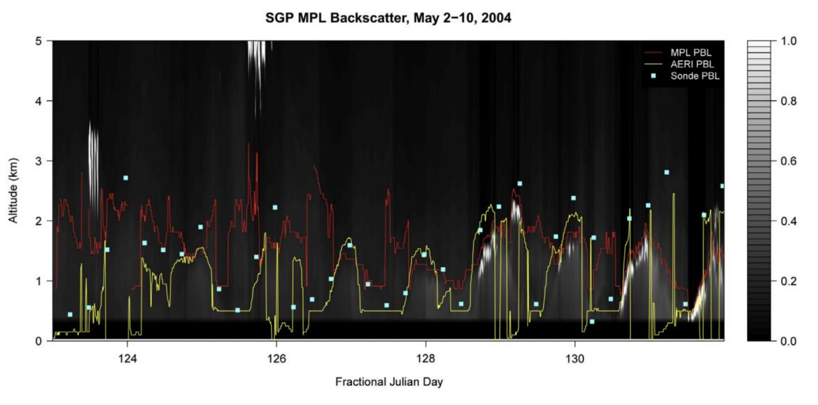
Introduction

Lidar techniques allow us to track the diurnal variation of the PBLH, which is not possible with radiosonde estimations.

However, traditional methods, such as the gradient and wavelet methods, have several problems:

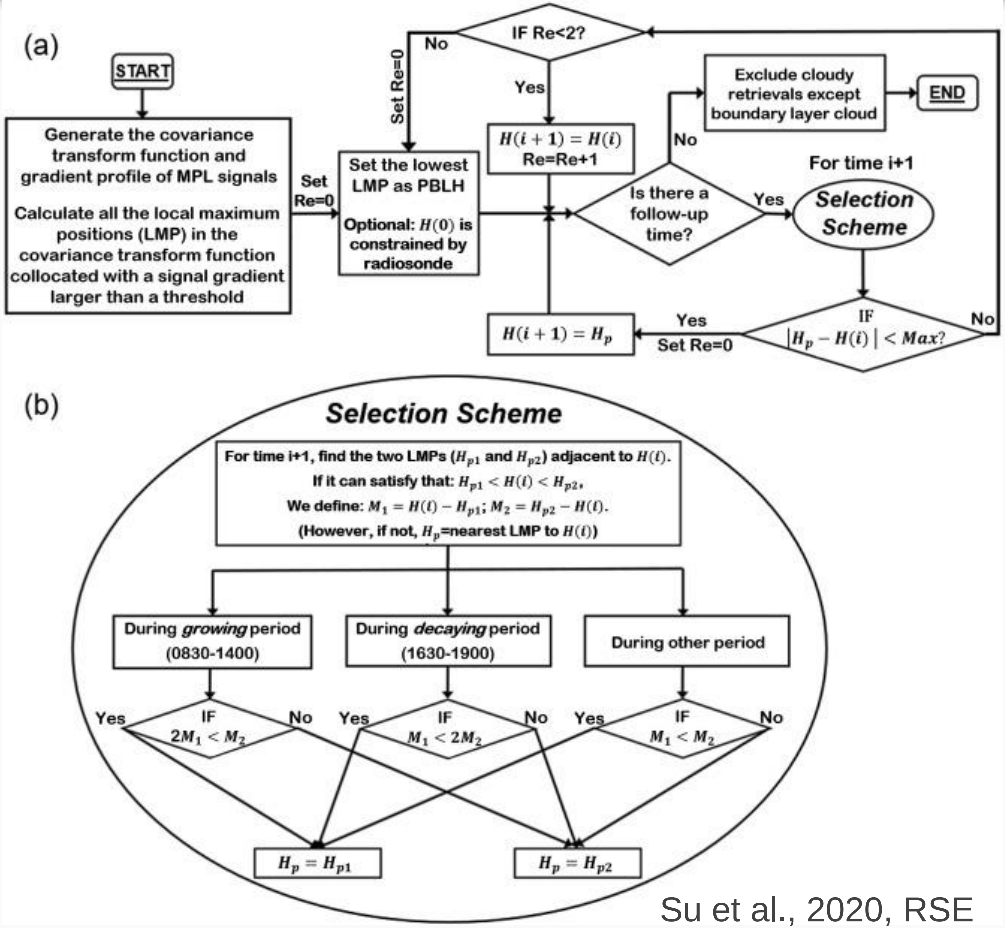
- Only use a single backscatter profile
- Difficulties estimating the PBLH under cloudy conditions
- Fail to identify the PBLH under stable conditions

Su et al. (2020) have developed a new method named **Different Thermo-Dynamic Stabilities (DTDS)** that outperforms traditional methods for most thermodynamic situations.



Sawyer & Li (2013). Atmospheric Environment

Introduction



Su et al., 2020, RSE

Different Thermo-Dynamic Stabilities (DTDS)

- Combines the gradient and wavelet methods
- Considers the diurnal variability of the PBL, leading to vertical consistency and temporal continuity
- Handles cloudy conditions by assessing the cloud-surface coupling (Su et al., 2022, ACP)

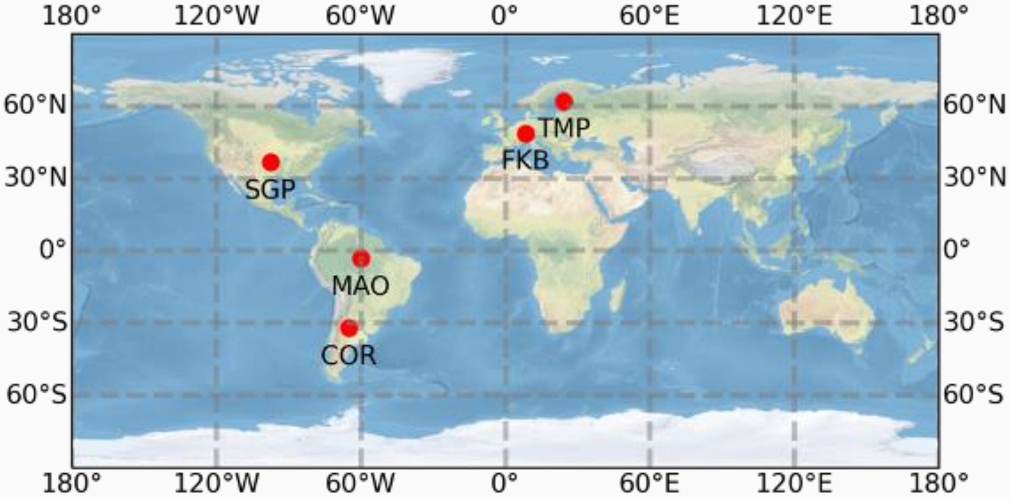
DTDS was **originally** applied to **8** years of data from the **SGP** site.

Here, we applied DTDS to data from **5 ARM sites**, including more than **20** years of data from **SGP**.

Methodology

Adjustments at each site:

- Time zone
- Blind zone
- Morning PBLH based on the lifting condensation level rather than radiosonde information
- Quality-control flag



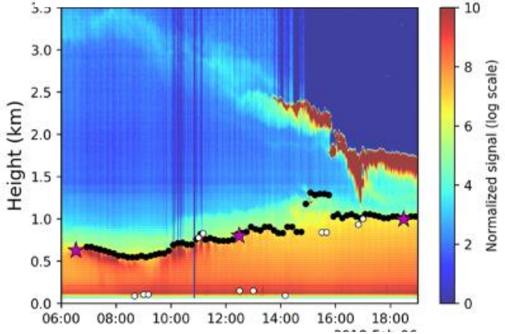
Data:

- Radiosonde data
- ARM ceilometer PBLH product (Ceil-PBLH)
- Micropulse lidar data
- Surface meteorology
- Cloud boundaries

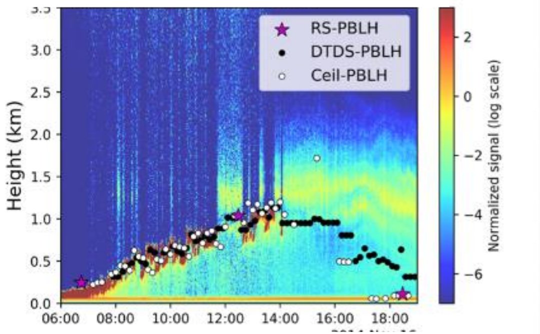
SGP - Oklahoma
Apr. 1998 – Nov. 2018
MAO - Amazon
1 Jan. 2014 – 30 Nov. 2015
TMP - Finland
1 Feb. 2014 – 13 Sep. 2014
COR - Argentina
1 Oct. 2018 – 30 Apr. 2019
FKB - Germany
2 Apr. 2007 – 31 Dec. 2007

Results: Overview of the DTDS-PBLH Product

SGP (Oklahoma, USA)



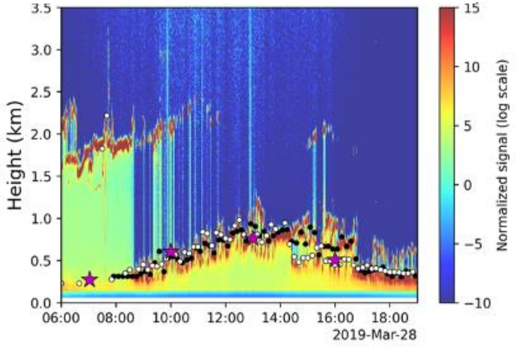
MAO (Amazon, Brazil)



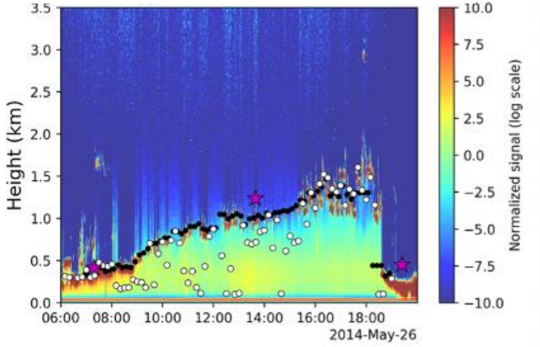
DTDS is effective in estimating PBLH at different ARM observatories.

DTDS is superior over the ceilometer-based retrieval method.

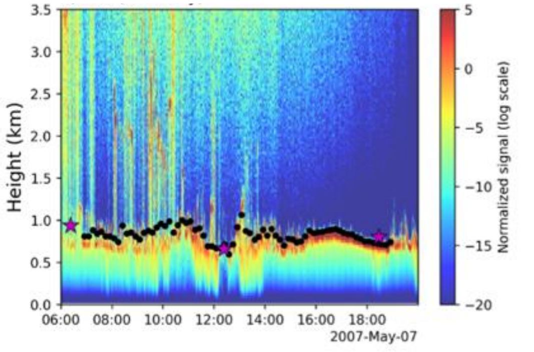
COR (Córdoba, Argentina)



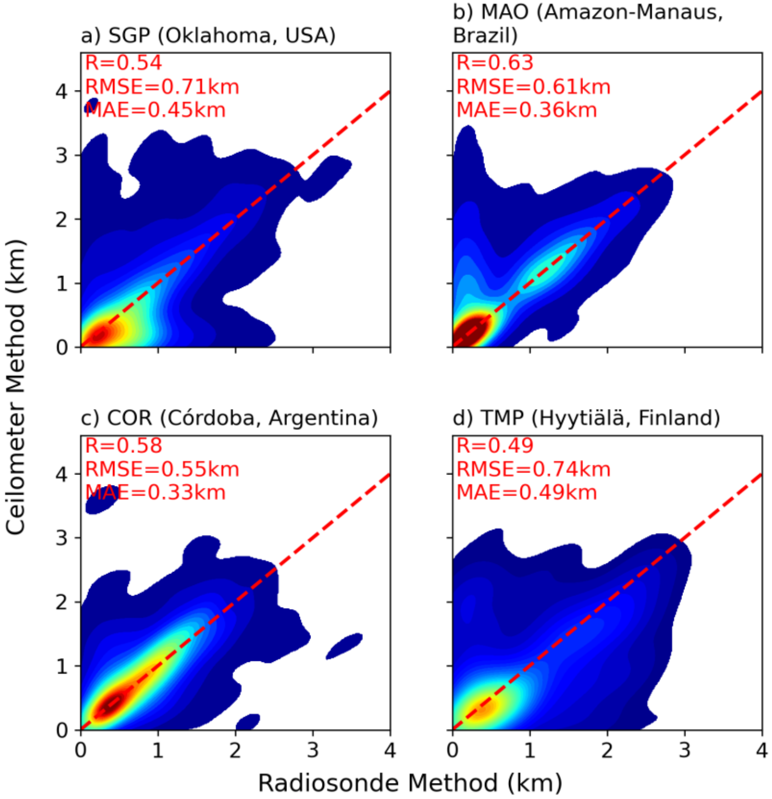
TMP (Hyytiälä, Finland)



FKB (Black Forest, Germany)



Results: Evaluation of the DTDS-PBLH Product



Note: Ceil-PBLH product not available for the FKB site

- The publicly available lidar-based PBLH product on the ARM website provides ceilometer-estimated PBLHs.
- Ceil-PBLH and radiosonde-based PBLH estimates at the ARM sites vary.

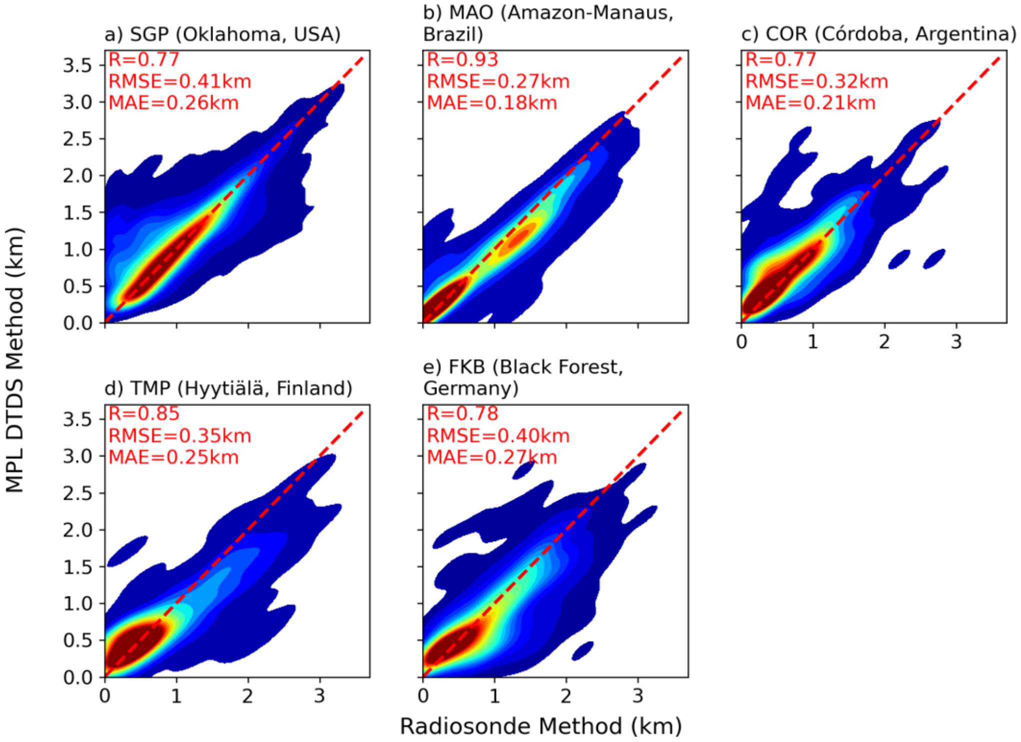
R ranges from **0.49** to **0.63**

RMSE ranges from **0.55** to **0.74 km**

MAE ranges from **0.33** to **0.49 km**

R: correlation coefficient
RMSE: root-mean-square error
MAE: mean absolute error

Results: Evaluation of the DTDS-PBLH Product



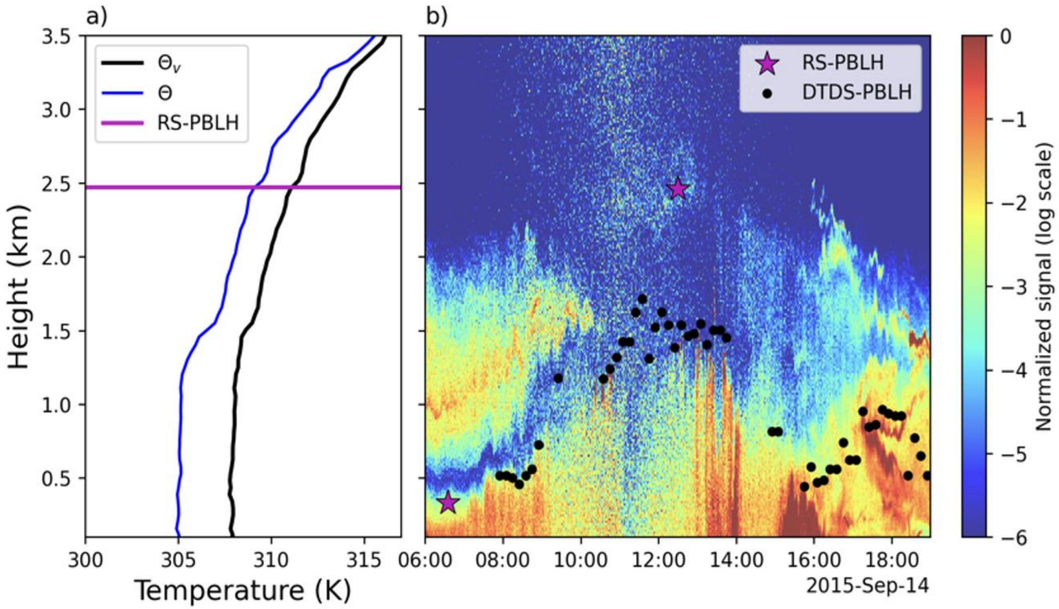
- DTDS PBLH estimates agree better with radiosonde estimates than do Ceil-PBLH estimates at the SGP, MAO, COR, and TMP sites.

R ranges from **0.77** to **0.93**

RMSE ranges from **0.27** to **0.41 km**

MAE ranges from **0.18** to **0.26 km**

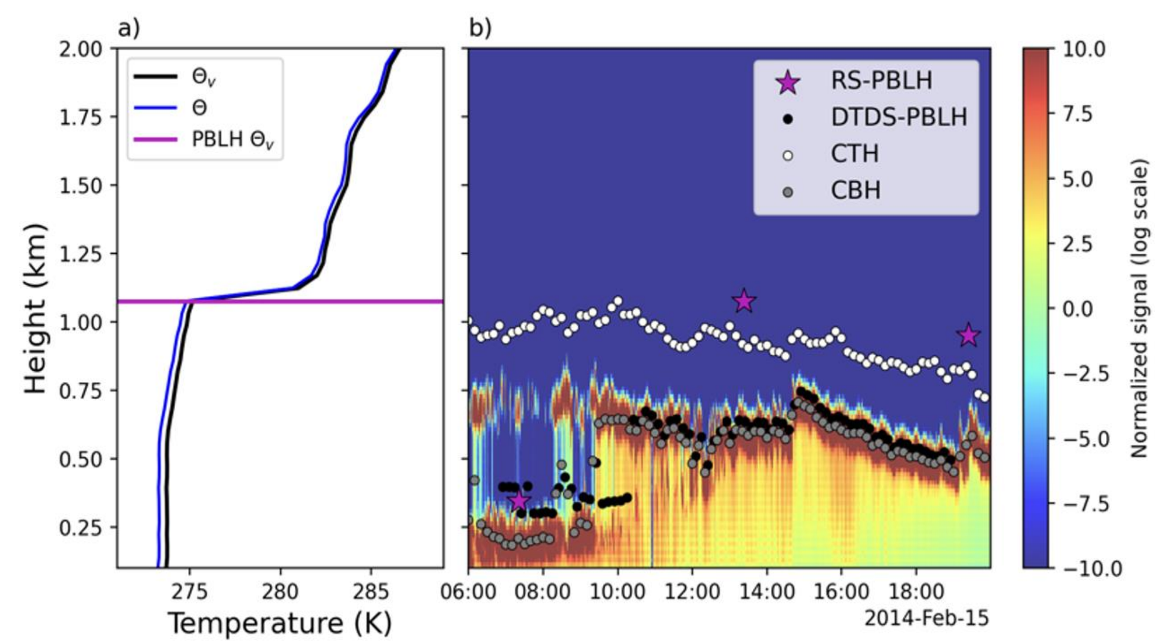
Analysis of Errors and Limitations: Radiosonde



Errors associated with radiosonde-estimated PBLHs can arise from:

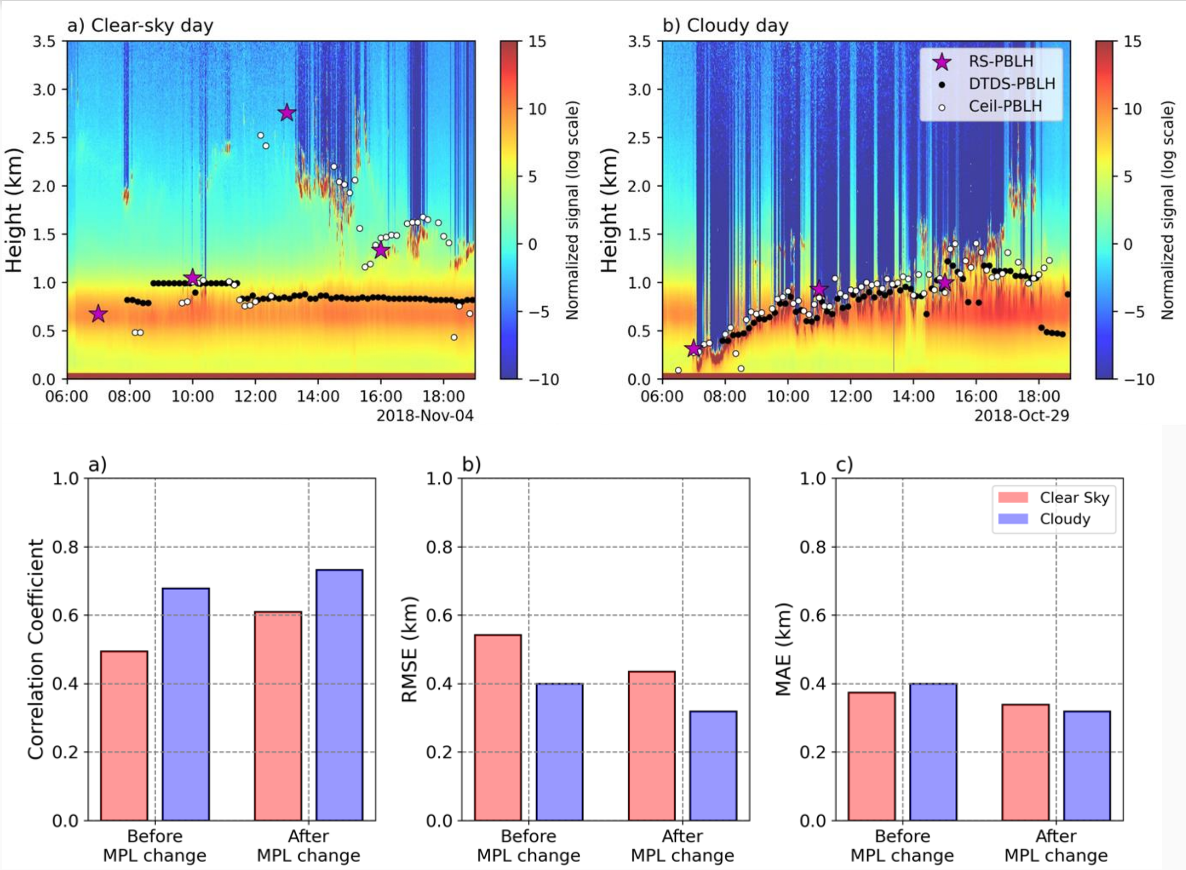
- Ambiguous thermodynamic profiles
- Multiple inversion layers
- Sensitivity to chosen thermodynamic variables

Analysis of Errors and Limitations: Micropulse Lidar



Lidar limitations, such as the obstruction of MPL backscatter information when there is a stratocumulus-topped boundary layer, introduce errors in DTDS-estimated PBLHs under cloudy conditions.

Analysis of Errors and Limitations: Micropulse Lidar



Comparison of DTDS performance before and after replacing the MPL

The performance of DTDS is significantly impacted when the lidar is not operating properly.

The misalignment of the MPL at COR led to spurious signals and inaccurate PBLH estimates.

PBLH estimates improved after replacing the MPL.

Summary and Conclusions

1. The DTDS algorithm shows robust performance in calculating PBLH, exhibiting high correlations with radiosonde-derived PBLH and smaller errors compared to existing lidar-based PBLH products.
2. Limitations and potential errors in the DTDS algorithm arise from lidar measurements, uncertainties in radiosonde-based PBLH estimates, and the complexities of atmospheric conditions, highlighting the need for continuous improvements and a comprehensive understanding of these factors.
3. Using lidar systems for estimating PBLH offers advantages over traditional radiosonde methods, such as continuous monitoring and enhanced temporal resolutions, but uncertainties and biases still exist.