Boundary layer dynamic, aerosol composition, and air quality in the urban background of Stuttgart in winter

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[30-Jun], [12:00 (UTC)]

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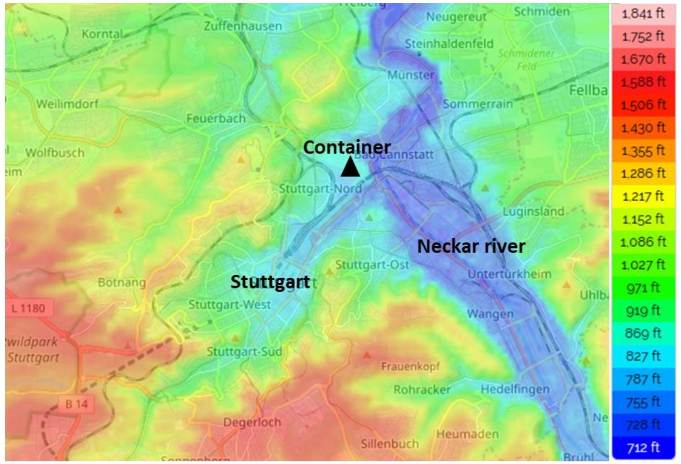
The 30th International Laser Radar Conference (ILRC) virtual conference, June 26th – July 1st, 2022.

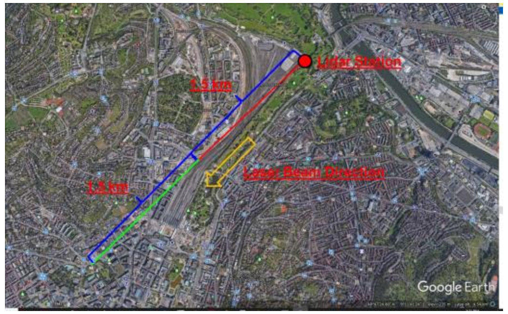
Motivation

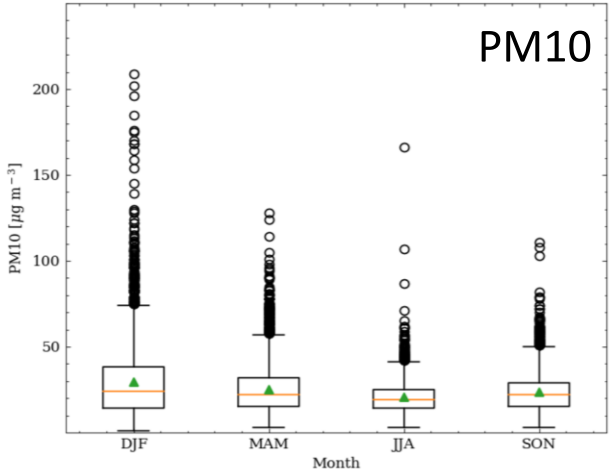
- Stuttgart, one of the most polluted cities in Germany
- Urban location with high traffic emissions (fossil fuel combustion)



LUBW, 2019
Schwartz et al., Environ Res, 1991

Downtown of Stuttgart





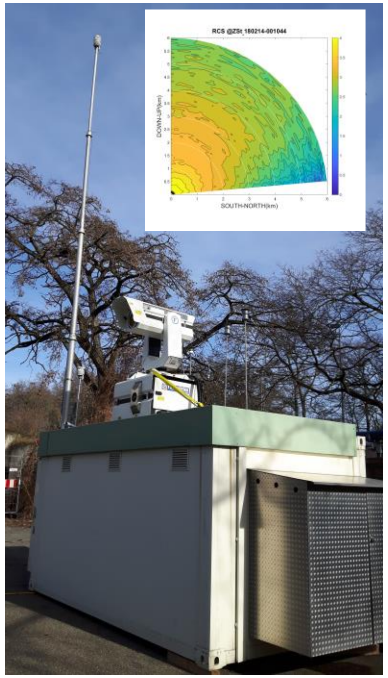
Main goals:

- ❑ **Boundary layer dynamic**
- ❑ **Aerosol composition**
- ❑ **Interaction of aerosol and boundary layer**

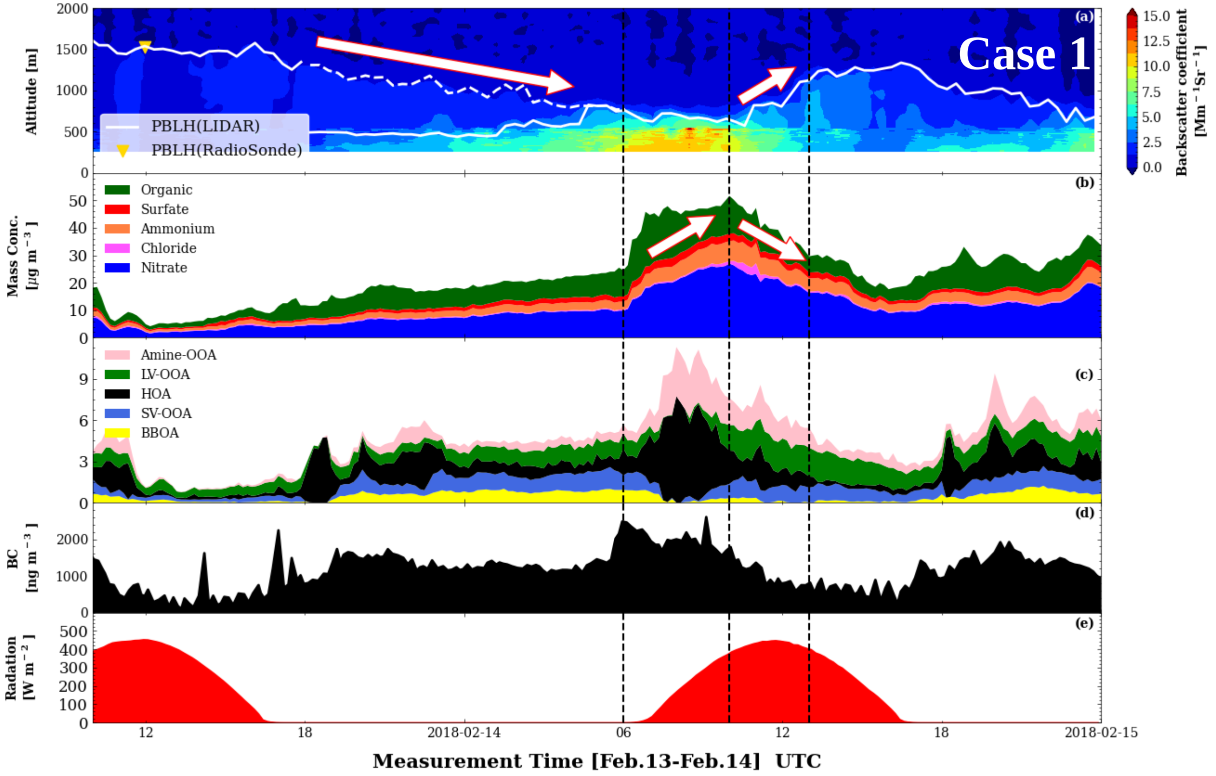
Methods

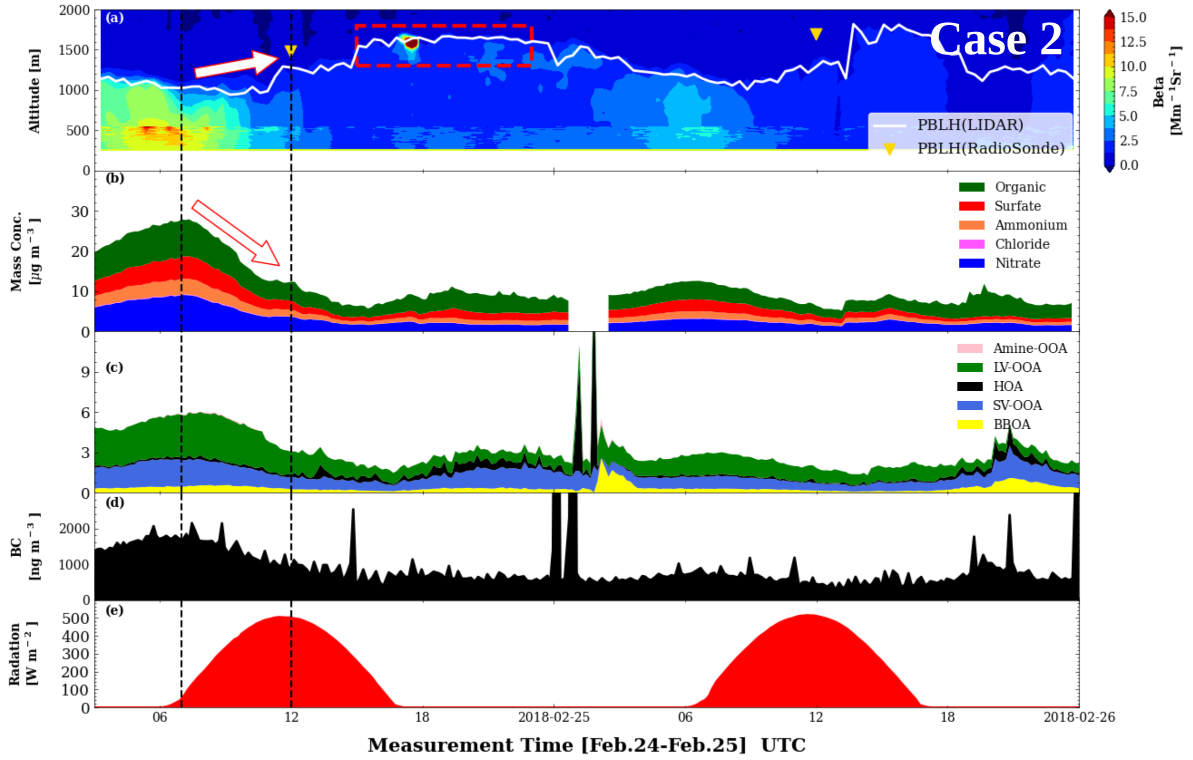
Measured Parameters	Main Instruments
Aerosol backscatter, N_2 Raman, depolarization at 355 nm	**Scanning depolarization Raman LiDAR**
Particle composition, Non-refractory species, e.g. organics, inorganics, 70 nm – 2.5 µm	Aerosol mass spectrometer (HR-ToF-AMS)
Aerosol particle number, size	Various particles sizers and counters
Trace gas: O_3, NO, NO_2, CO_2, SO_2, NH_3	Various gas monitors
Meteorological parameters	Lufft WS800
Vertical profiles of meteorological parameters	radio soundings, micro-wave radiometer
3D wind	Wind lidar (Windcube WLS8)

- ❑ Boundary layer dynamic, aerosol composition
- ❑ Scanning LiDAR allows us to get the vertical profile of aerosols from near ground level (overlap for vertical point LiDAR) to free troposphere.
- ❑ Scanning LiDAR allows independent determination of lidar ratio and corresponding extinction coefficients. (Zhang et al, remote sensing, 2022)
- ❑ PMF analysis for source apportionment



Results and Discussion

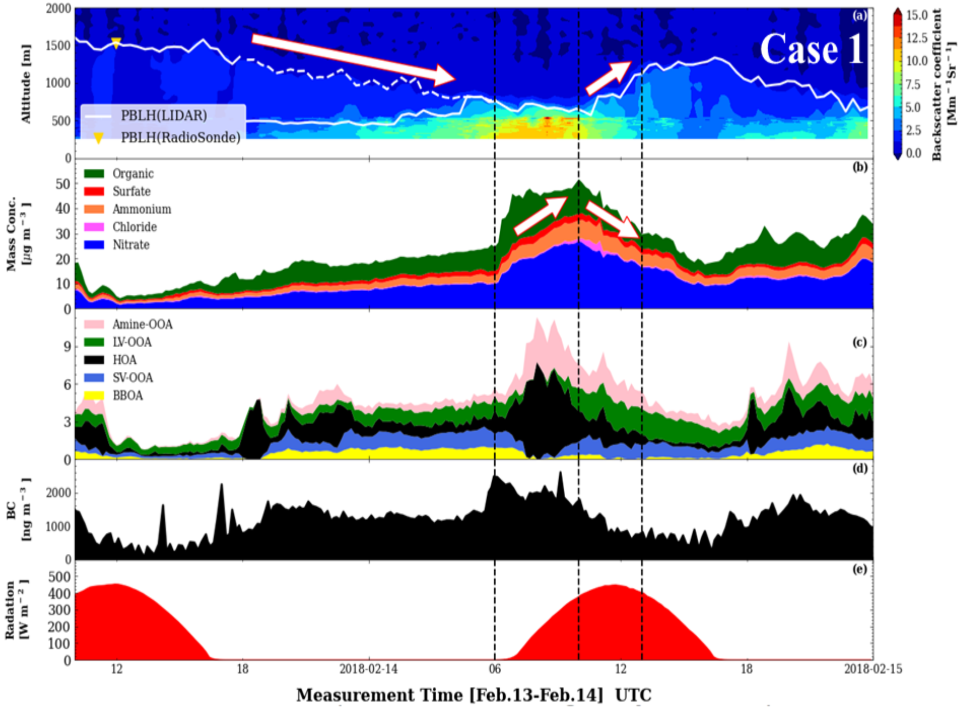


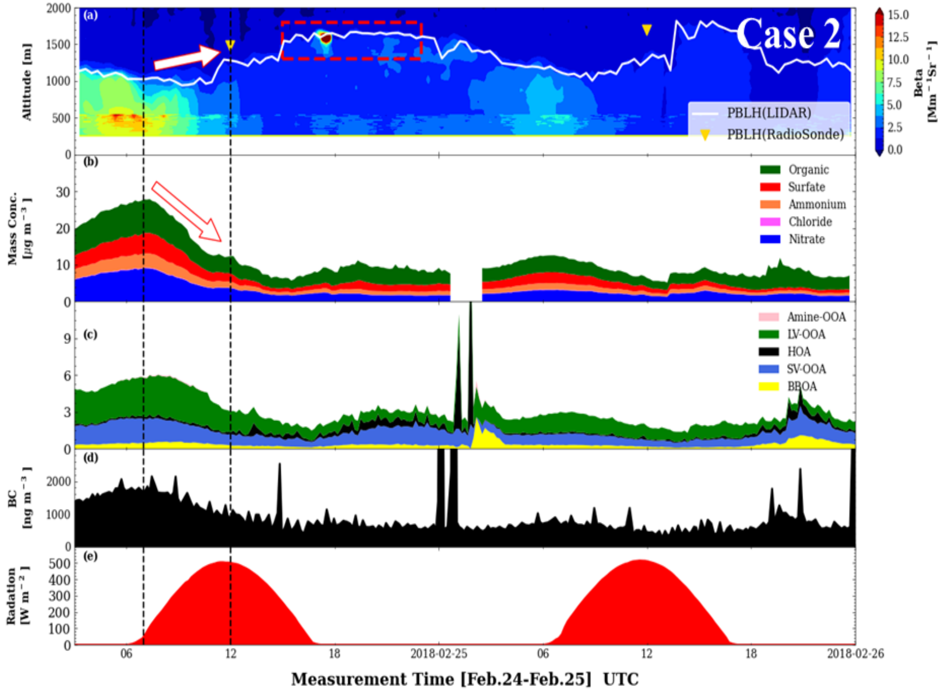


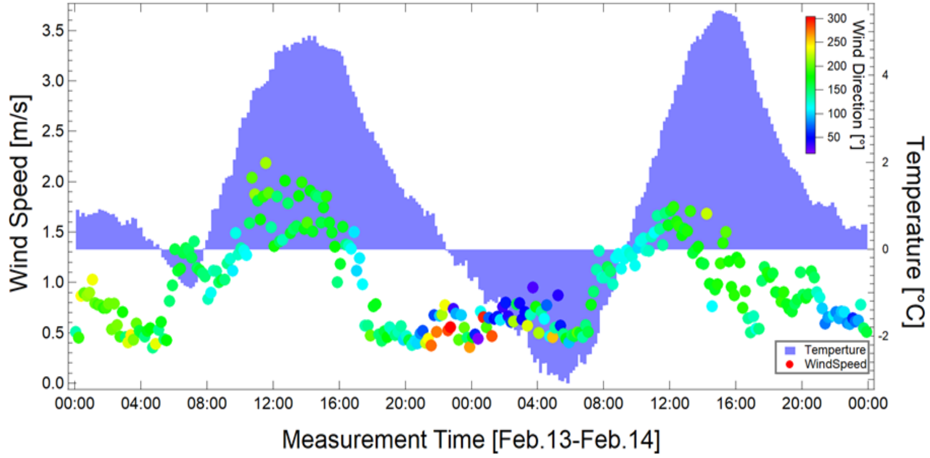
- ❑ Particles increased more during morning rush hour than in the evening (shallow PBL)
- ❑ Increasing PBL height leads to dilution of aerosols
- ❑ Increased aerosol during morning and evening rush hour is related to the emission of traffic (HOA) and industry (Amine-OOA)

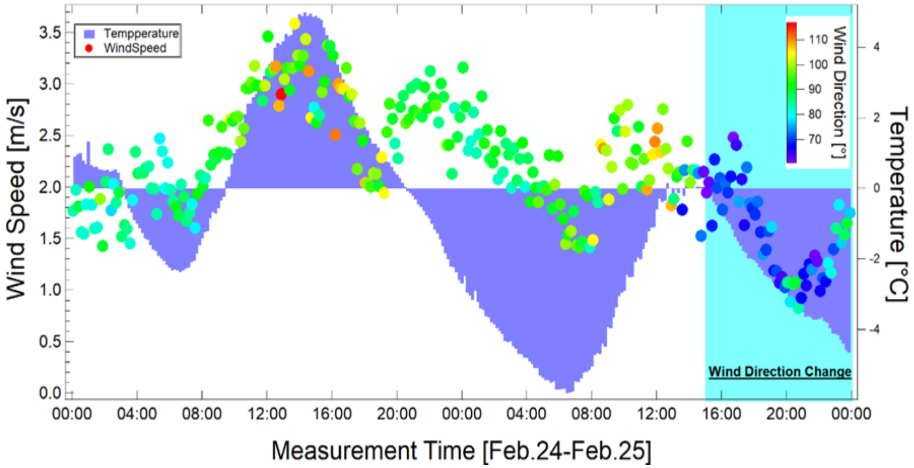
- ❑ PBLH did not decrease after sunset on Feb. 24th
- ❑ Particles decreased sharply even PBL height did not increase correspondingly too much
- ❑ Lower particle concentrations on Feb. 25th vs. Feb. 24th
- ❑ Large fraction of LV-OOA is related to long range transport

Results and Discussion



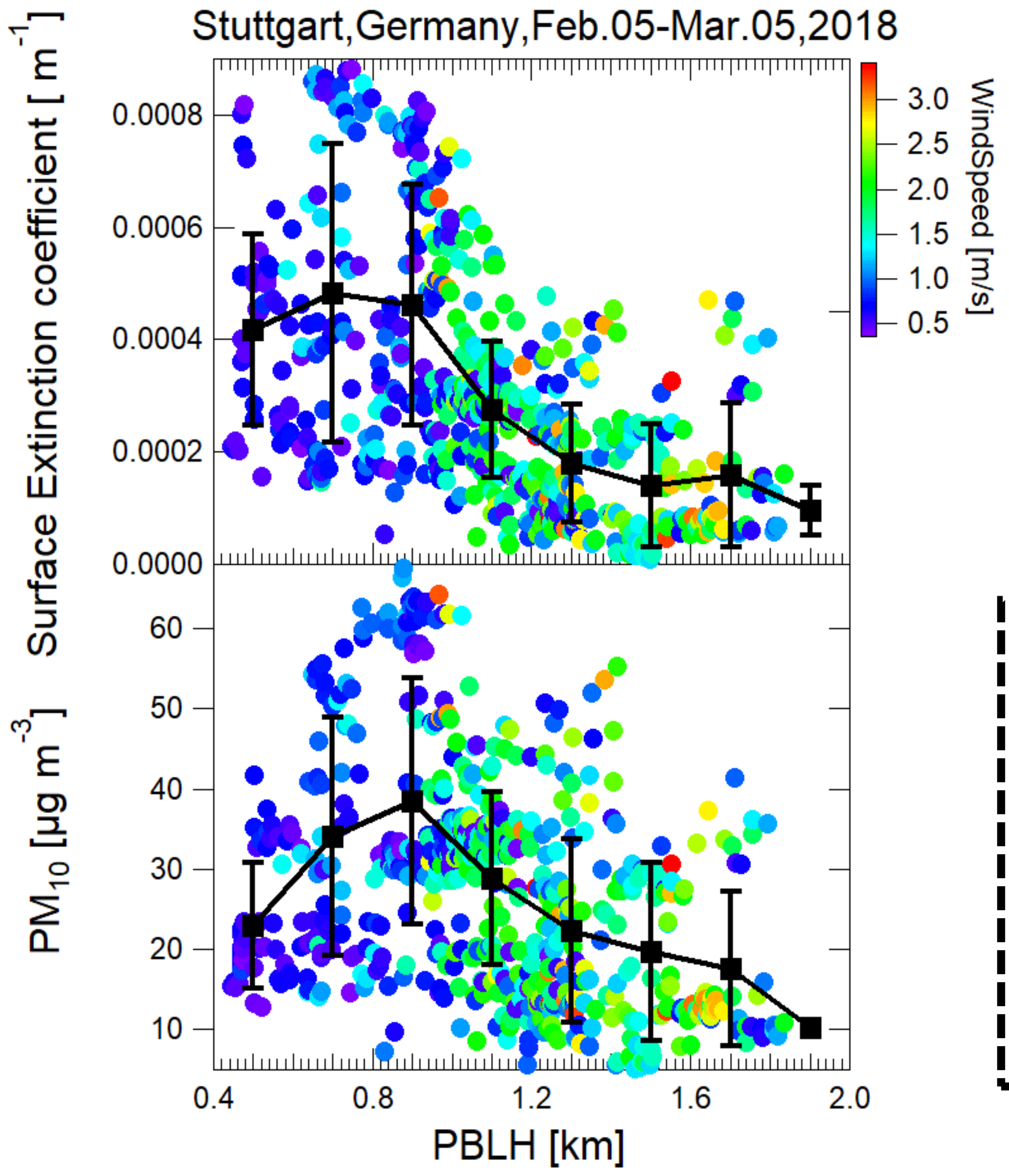


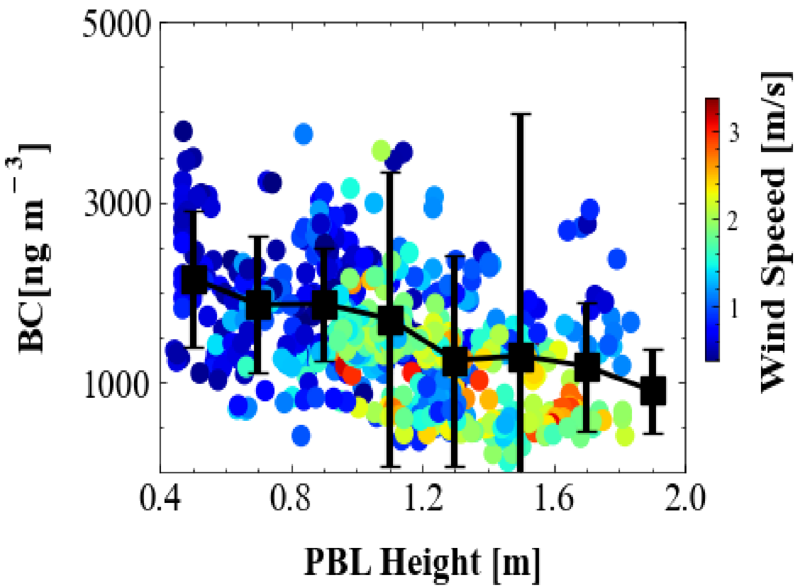




- ❑ Compared with case 1, case 2 has:
  - Higher wind speed
  - Lower temperature in the second half of experiment
- ❑ Cold front that came across observation station in case 2 affected the structure of boundary layer and surface aerosol concentration.

Results and Discussion





BC concentration always has Negative correlation with PBLH

- ❑ Negative correlation between surface aerosol concentration and PBLH
- ❑ Low wind speed
  - Stable, shallow boundary layer
  - Residual layer
  - Surface aerosol concentration not very high (in residual layer)

Conclusion and Outlook

- Scanning lidar allows determination of low-level boundary layer (SBL) and direct comparison with ground level aerosol measurements
- The boundary layer characterized by LIDAR and radiosonde are consistent.
- Synoptic meteorology affects boundary layer structure hence influences surface aerosol concentration.
- The ground aerosol concentrations are anti-correlated with the heights of the convective boundary layer but was correlated with the height of stable boundary layer whereas the black carbon is always anti-correlated with the heights of the boundary layer.
- Further work will focus on comparison of a high resolution LES model with multiple remote sensing (e.g. micro-wave radiometer, wind lidar, aerosol lidar) and other measurements (e.g. radio soundings).

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