The use of ground-based Doppler lidar in Iceland: turbulence measurement, dust detection, and the application of machine learning

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Summary

In this project, we investigate the use of Doppler lidar in Iceland, especially for enhancing aviation safety. By analyzing the data colldeted in Reykjavik and Keflavik, three main tasks have been tackled: i) atmospheric turbulence measurements; ii) airborne aerosol detection; iii) real-time lidar signal classification with machine learning algorithms. The results indicate that the Doppler lidar may significantly improve aviation safety and complement meteorological measurements by detecting atmospheric turbulence or volcanic ash clouds in Iceland.

LiDAR Specifications

The Leosphere WindCube 200s LiDAR

- Wavelength: 1.54 µm
- Maximum range: 12 km
- Azimuth angle: 0 ~ 360°
- Elevation angle: -10 ~ 190°
- Depolarization channel

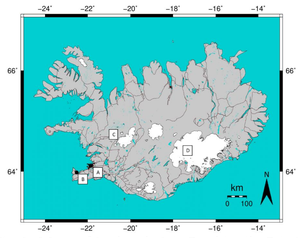


Fig 1. Map of Iceland. A is Reykjavik, B is Keflavik

Turbulence measurements: results

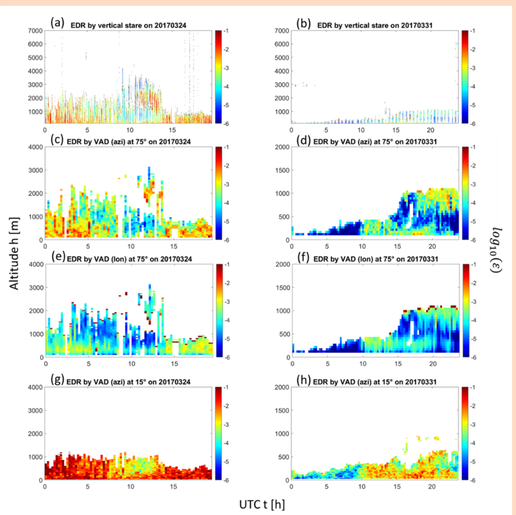


Fig 2. Comparison of EDR on a turbulent day (left panels) and calm day 2017 (right panels). EDR is derived from the vertical stare (a and b), VAD scans using the azimuthal approach (azi) with 75° elevation angle (c and d), longitudinal approach (lon) with 75° angle (e and f), and azimuthal approach with 15° elevation angle (g and h).

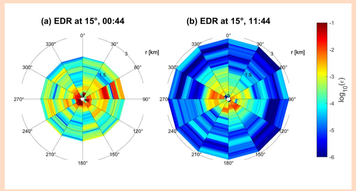


Figure 3. Beam-circular $\log_{10}$(EDR) maps for two cases at 00:44 UTC (left) and 11:44 UTC (right) on 24 March 2017. The data is from VAD scans, at 15° elevation angle, using the longitudinal approach.

Aerosol detection: two dust events

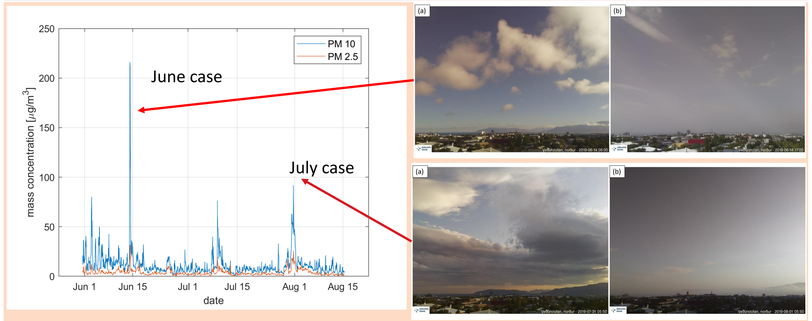


Figure 4. Left panel: PM concentration measured at Reykjavik in the summer of 2019. 2 dust events are identified: the June case (2019-06-14 ~ 2019-06-15); the July case (2019-07-31 ~ 2019-08-01). Right panel: the photo captured by the webcam at IMO, before (a) and during (b) the dust events.

Aerosol detection: results

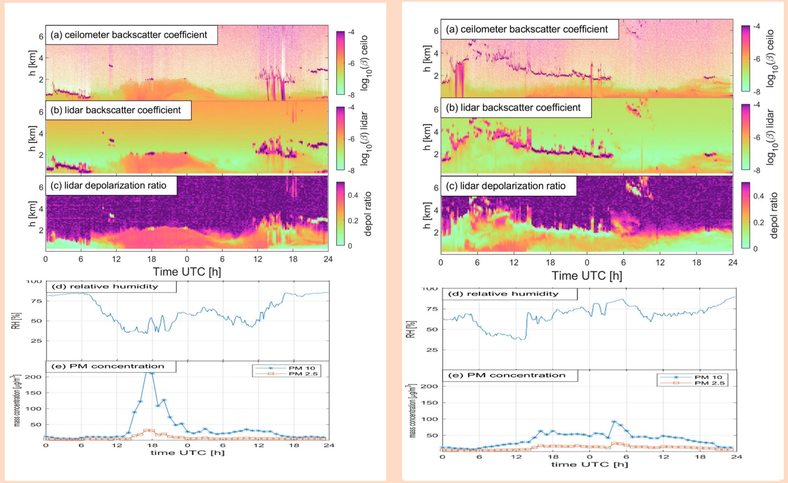


Figure 5. Results of lidar detected dust event in June case (left) and July case (right) in Reykjavik. From top to bottom: (a) backscatter coefficient from ceilometer; (b) backscatter coefficient from Doppler lidar; (c) depolarization ratio from Doppler lidar; (d) relative humidity from weather station nearby; (e) PM concentration in Reykjavik.

The lidar measurement is effected by the weather conditions (especially relative humidity), and the origin of the dust particles, which may impact the physical properties of the particles

Lidar classification: machine learning

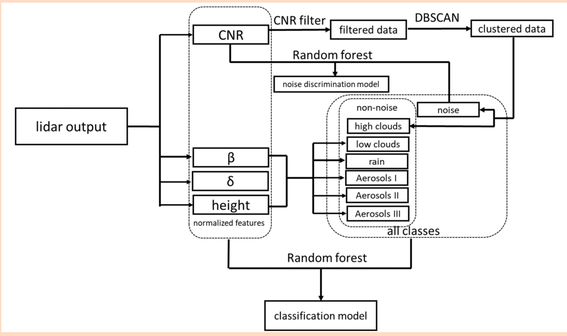


Figure 6. Overview of the process of the method. The noise discrimination model and the classification model are the two trained models.

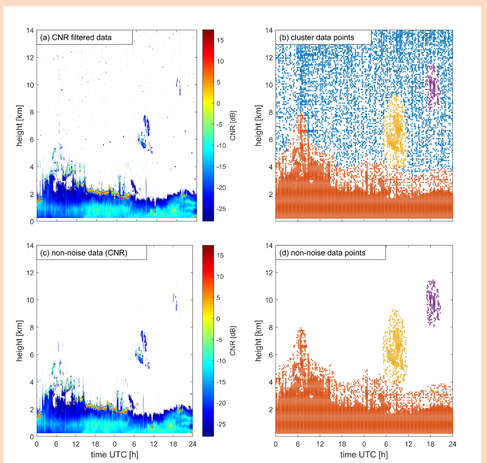
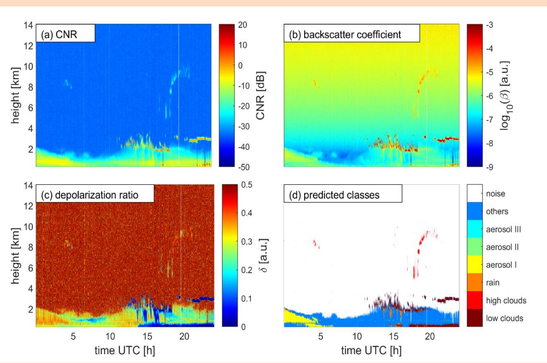


Figure 7. Preparing data for training the noise discrimination model with the DBSCAN clustering algorithm. The left panel (a, c) is the CNR data while the right panel (b, d) is the clustered data points accordingly. All data are collected on July 31 and August 1, 2019. (a) CNR (> -28 dB) value of lidar; (b) same data with (a), while the colour indicates the data groups clustered by DBSCAN algorithm.



The lidar measurement on June 15, 2019 at Reykjavik (a. CNR, b. backscatter coefficient, c. depolarization ratio) and the machine learning classification result (d. predicted classes).

More details

Yang, Shu, et al. "Determination of eddy dissipation rate by Doppler lidar in Reykjavik, Iceland." Meteorological Applications 27.5 (2020): e1951.
Yang, Shu, et al. "Monitoring Dust Events Using Doppler Lidar and Ceilometer in Iceland." Atmosphere 11.12 (2020): 1294.