Monitoring Dust Events in Iceland by Ground-based Doppler Lidar and Ceilometer

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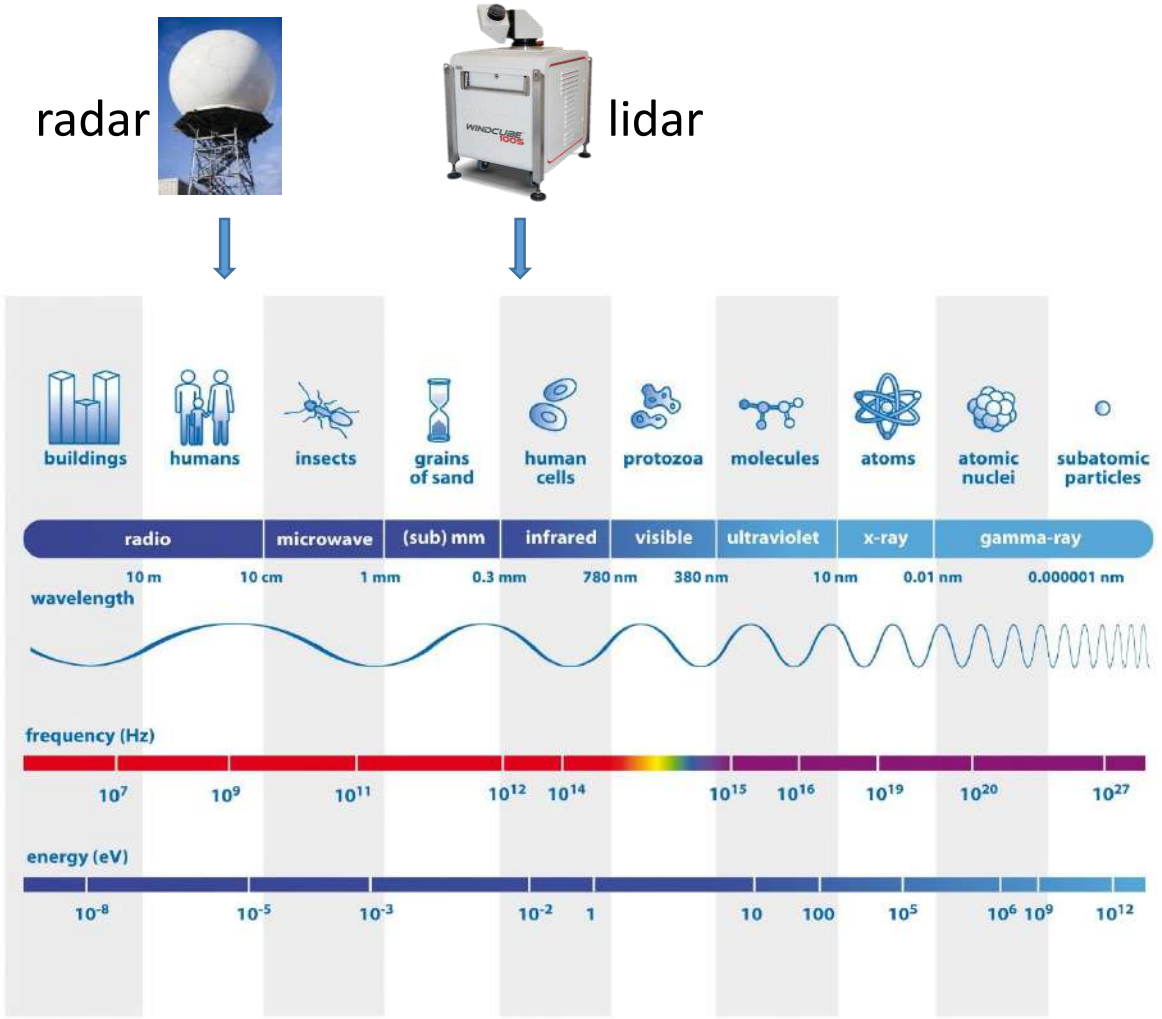
Photo: Doppler lidar at KEF
By S. von Löwis

Background: what is lidar?

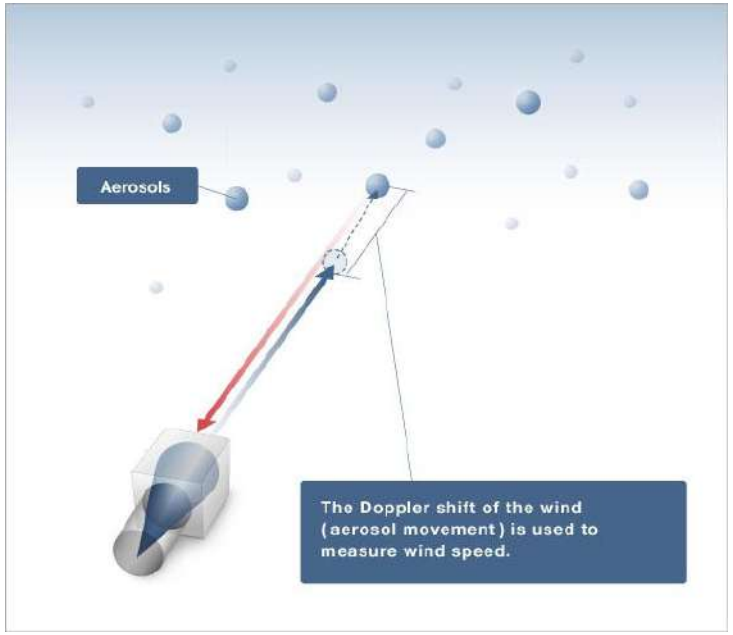
- Lidar stands for **Li**ght **D**etection **a**nd **R**anging method
- Similar to radar, but emitting laser pulse
- Better performance on smaller particles detection



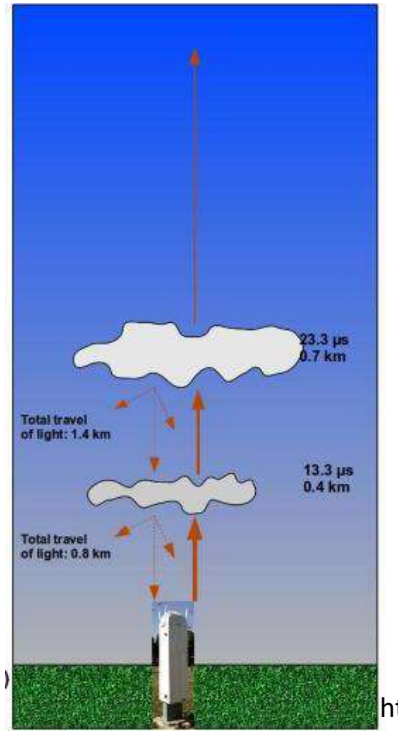
Source: http://solar-center.stanford.edu/about/uvlight.html

Background: Doppler lidar v.s. ceilometer

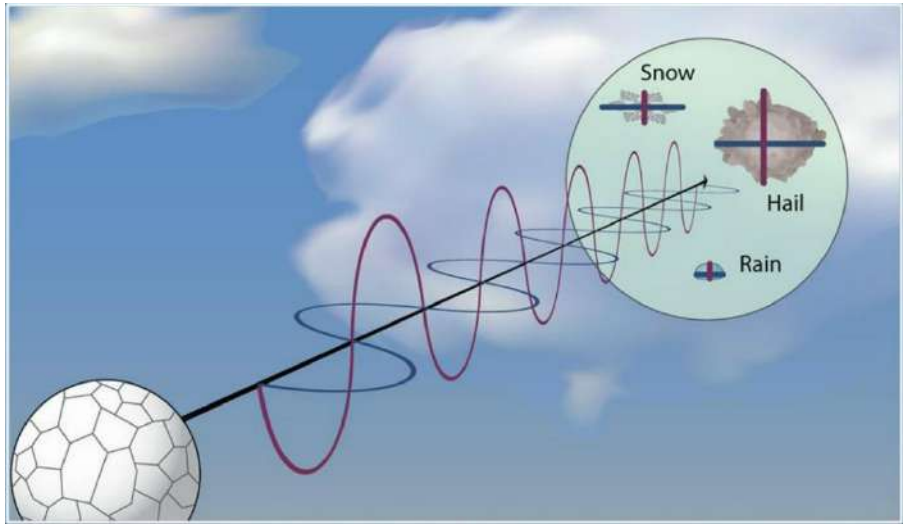
- Scanning Doppler lidar: measure the wind field from Doppler effect
- Depolarization lidar: distinguish the water phase between liquid and solid by depolarization ratio δ
- Ceilometer: a simple lidar that measures the cloud base height



http://www.mitsubishielectric.com/bu/lidar/lidar/principle/index.html



http://ozone.meteo.be/meteo/view/en/10860734-LIDAR+ceilometer.html



http://www.nws.noaa.gov/

Background: Lidars, aerosols, and Iceland

- The eruption of Eyjafjallajökull had a huge impact
- In principle, Doppler lidar and ceilometer should be able to detect aerosols, including volcanic ash, dust aerosols, etc.
- The only WindCube 200S Doppler lidar with depolarization channel
- Research question:
  - How can we use lidars to detect aerosols in Iceland

Methodology: joint field campaign with LMU

- Two measurement sites:
  - Reykjavik (RVK)
  - Keflavik (KEF), not presented here
- Active remote sensing: Doppler lidar and ceilometer
- Passive remote sensing: sun-photometer
- Other measurements:
  - Radiosonde
  - Weather stations
  - webcams
  - PM concentration from Environment Agency of Iceland
- Back trajectory: HYSPLIT

The mobile lidar/ceilometer trailer and the sun-photometer at IMO, Reykjavik.

Methodology: instruments

Table 2. The main specifications of the lidars and ceilometers operated in Iceland.

Feature	Lidar	Ceilometer	
Model	Windcube 200S	CL31	CL51
Manufacturer	Leosphere	Vaisala	Vaisala
Wavelength (μm)	1.54	0.91	0.91
Maximum detection range (km)	14	7.6	15
Range resolution (m)	100	10	10
Elevation angle (°)	−10–90	90	90
Azimuth angle (°)	0–360	N/A	N/A

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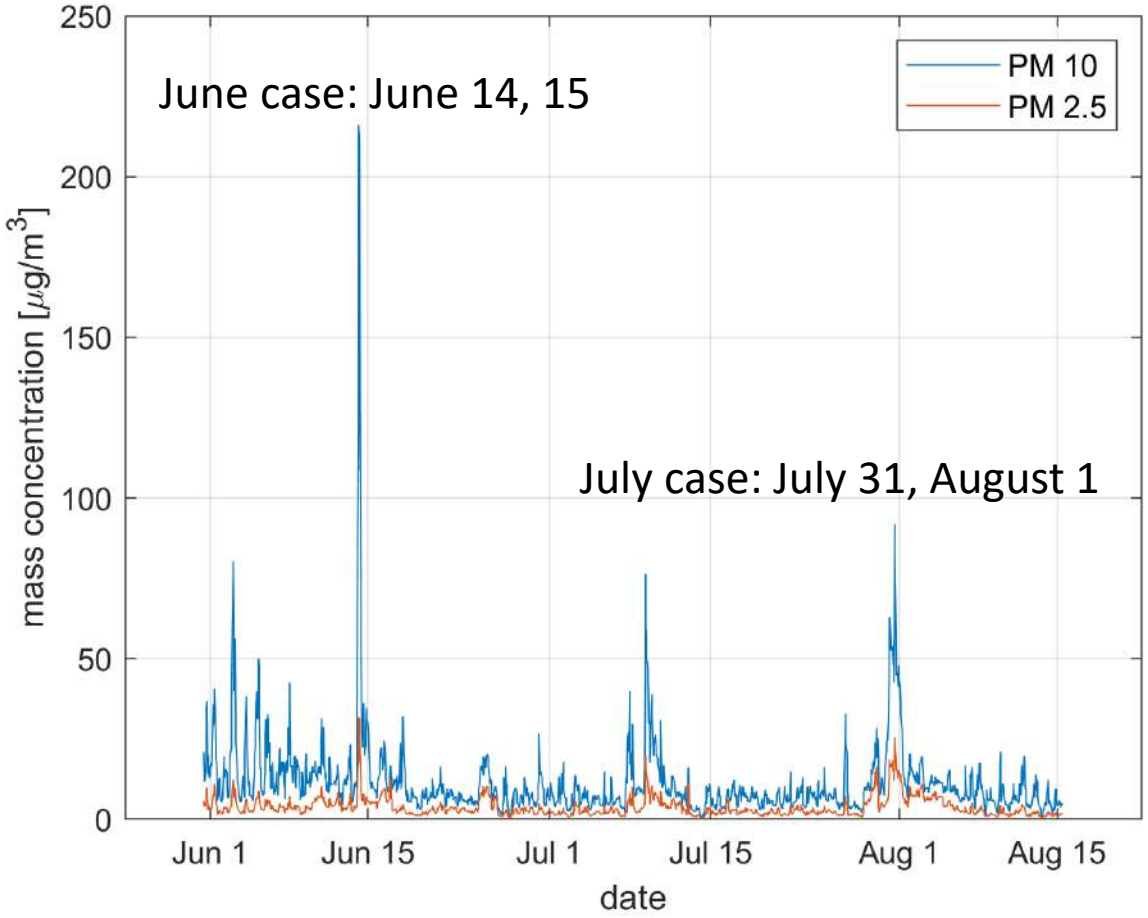
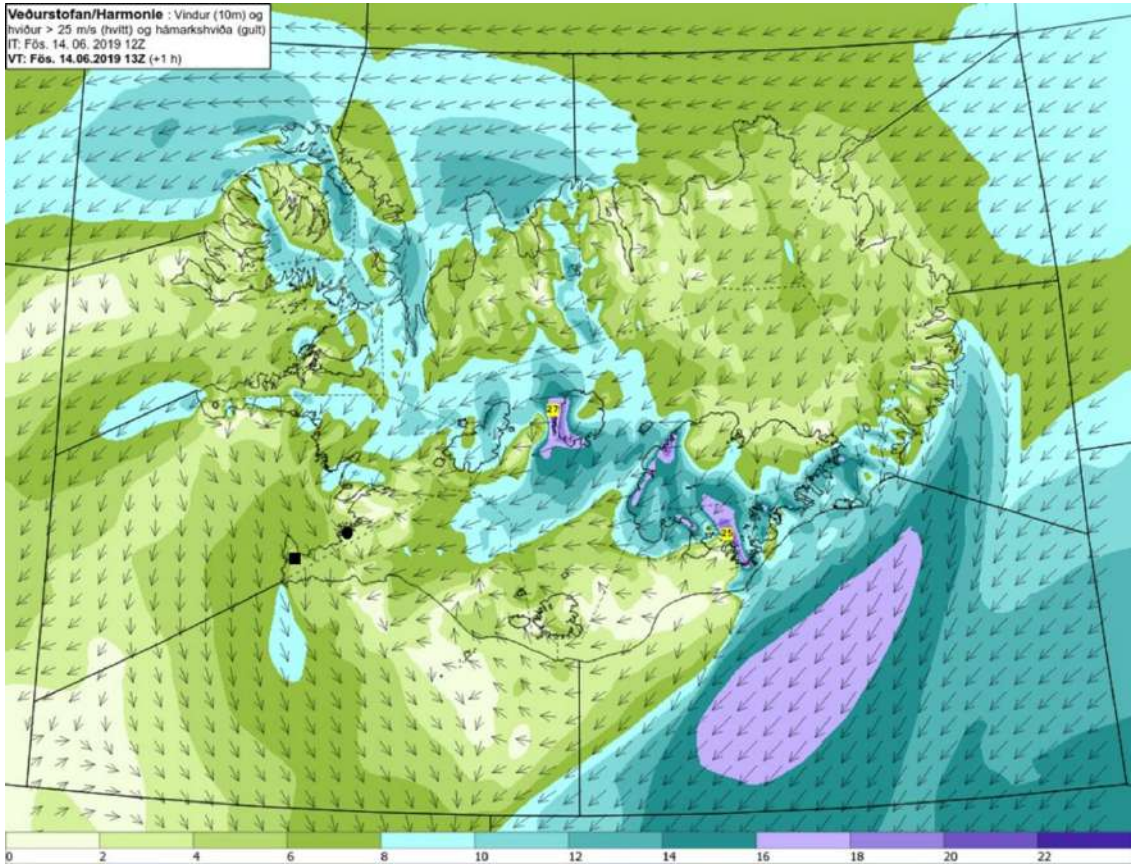
Results: two dust events

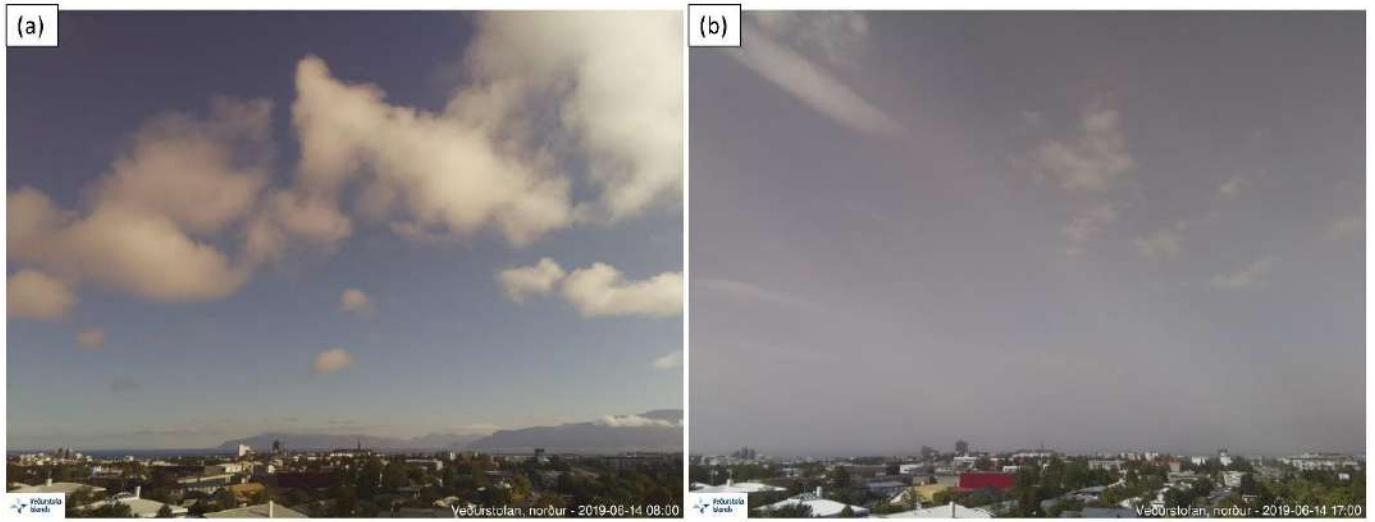


Hourly PM 10 (blue) and PM 2.5 (orange) concentration ([µm m^{-3}]) measured at Njorvasund, Reykjavik, by the Environment Agency of Iceland, from June 1 to August 15, 2019

Results: June case

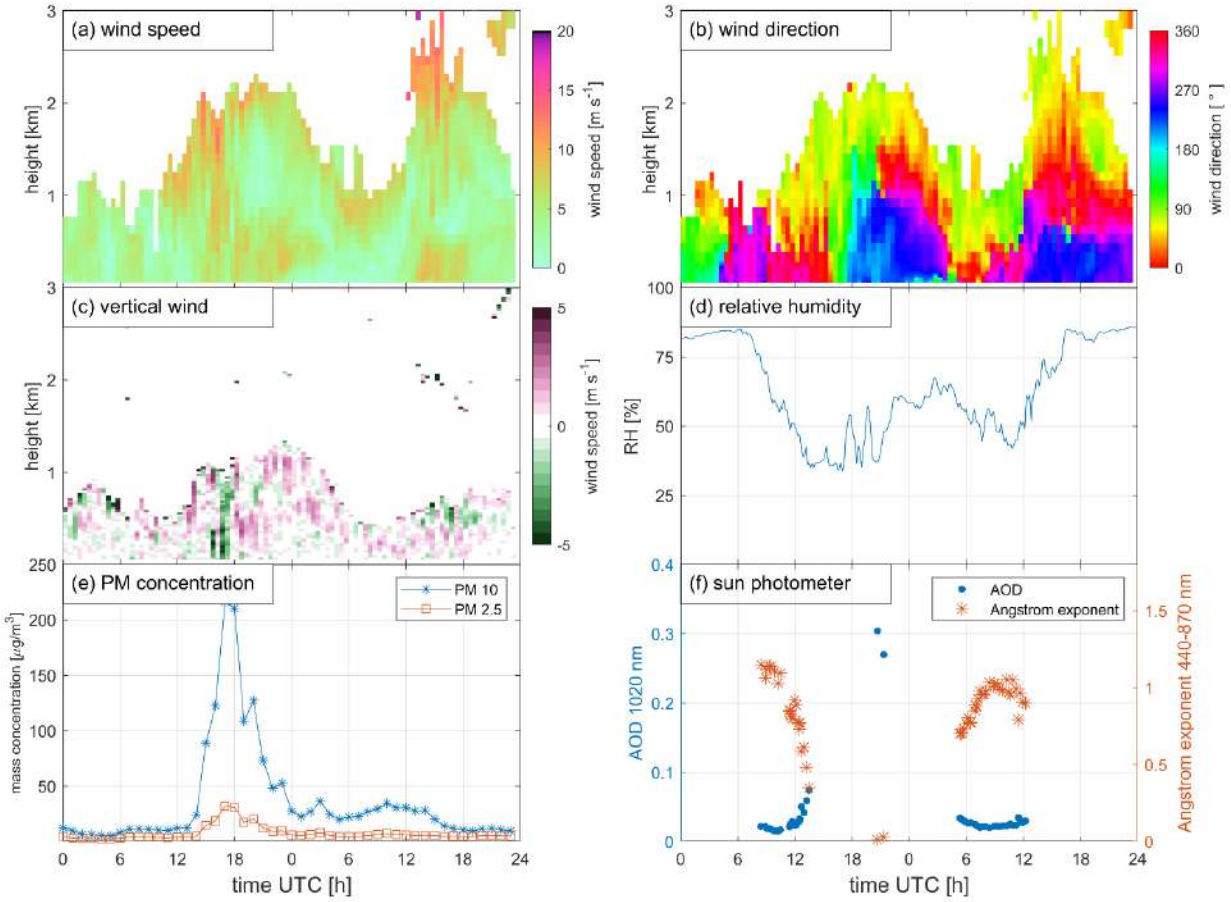


Wind conditions during the June case.
HARMONIE-AROME model forecast

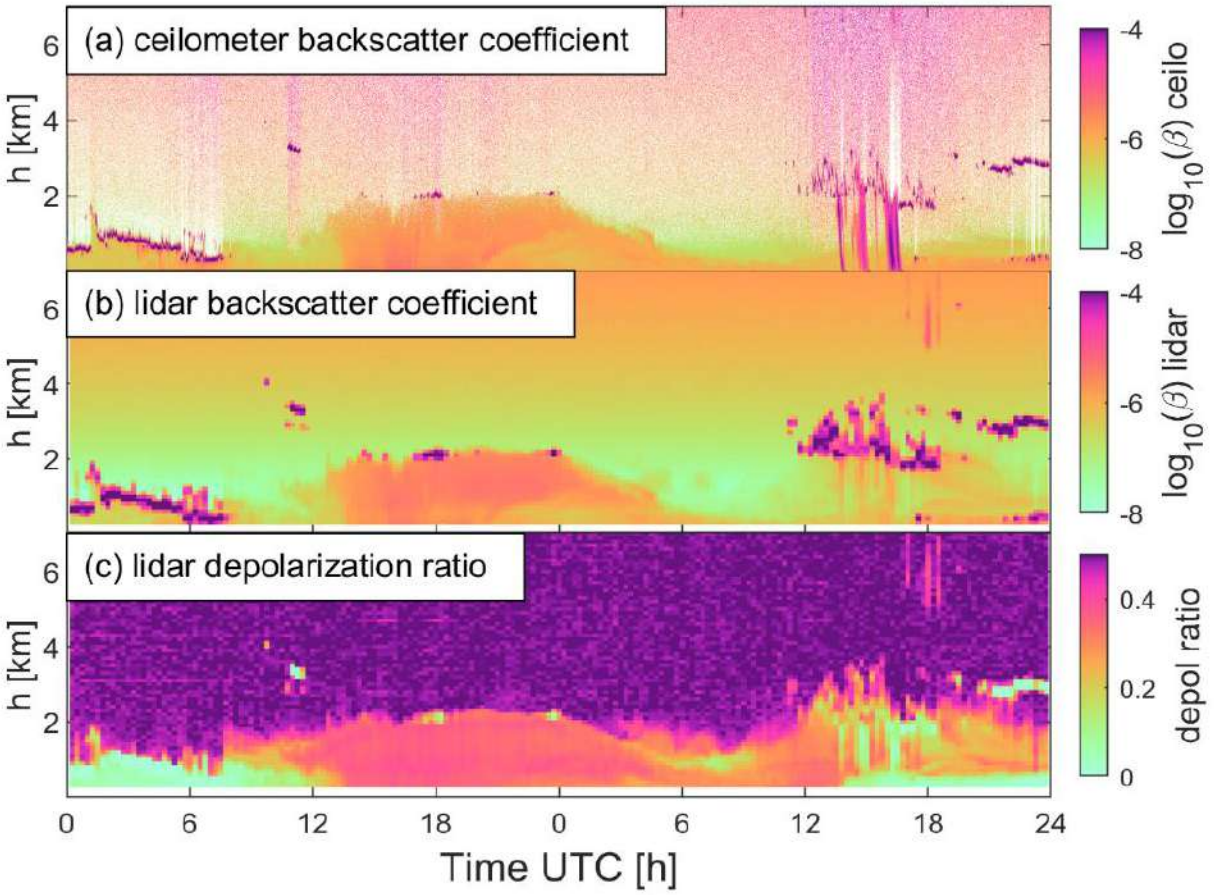


Photos taken by the web camera at IMO at 08:00 UTC (a) and 17:00 UTC (b), June 14, 2019, looking northward. The distant mountain on the right-hand side is Mt. Esja.

Results: June case

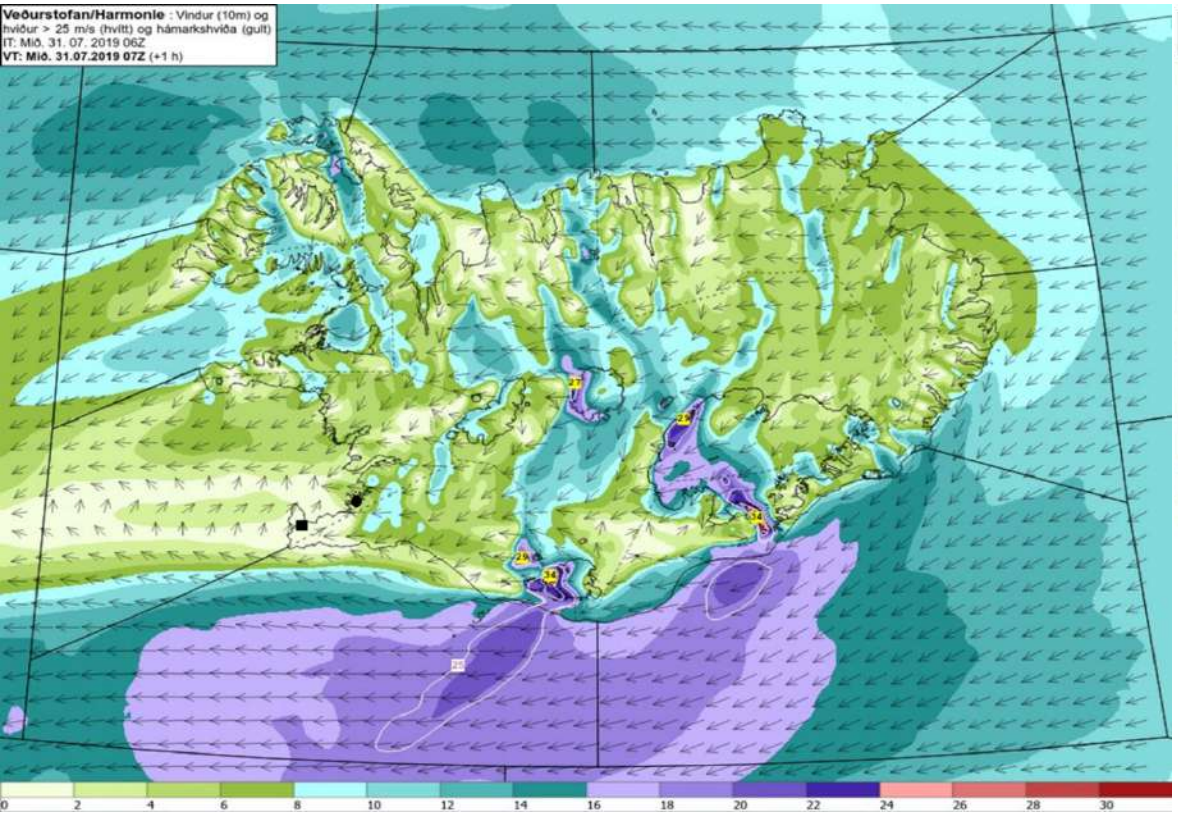


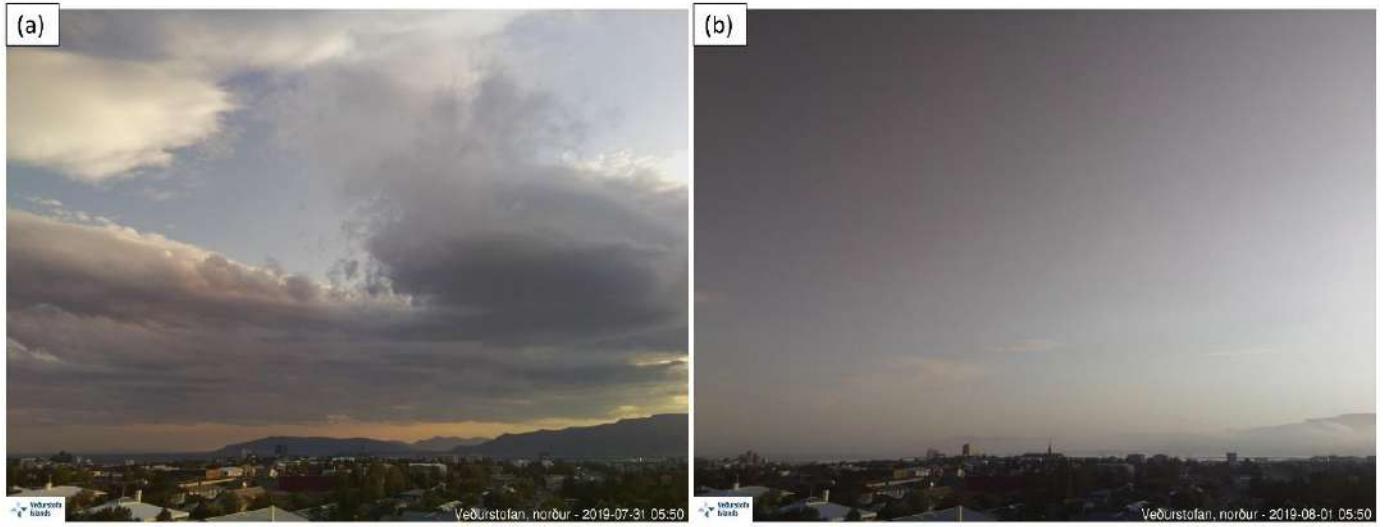
AOD: larger value=more aerosol
Angstrom exponent: larger value=smaller particles



Backscatter coefficient: larger value=more aerosols
Depolarization ratio: larger value=more non-spherical

Results: July case

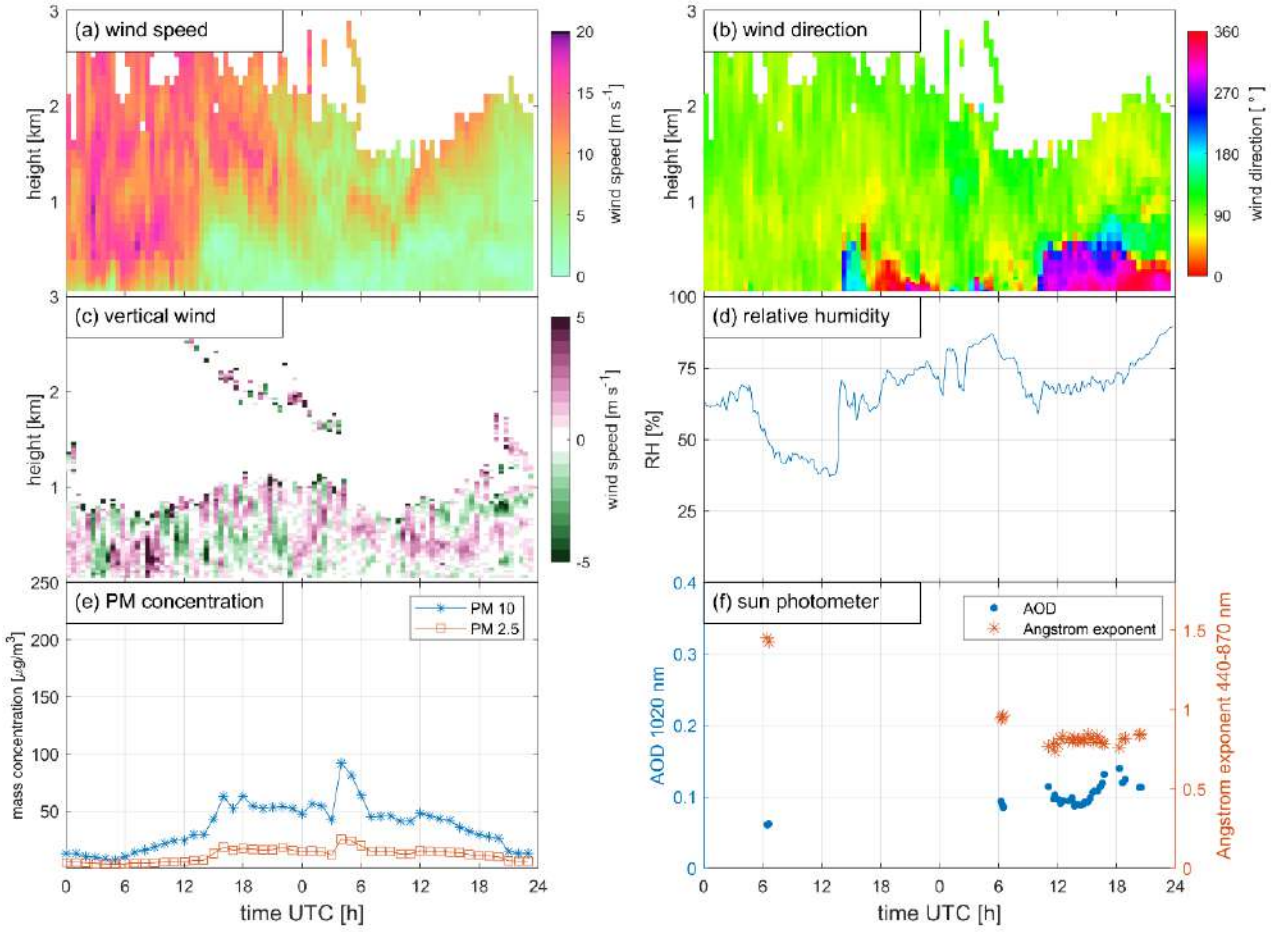


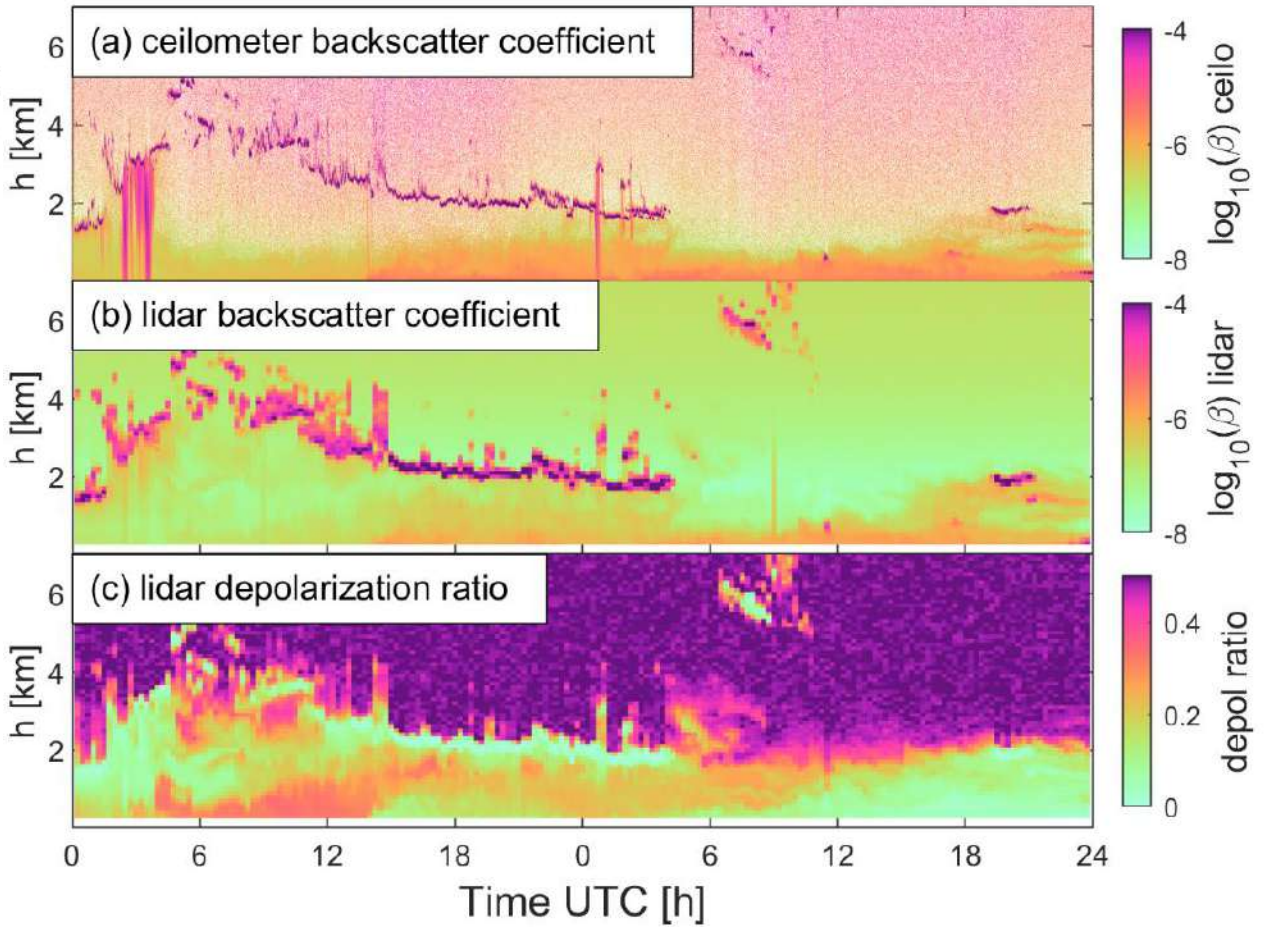


Photos taken by a web camera at IMO on July 31 (a) and August 1 (b), 2019, both dates at 05:00 UTC. The camera is looking northward

Wind conditions during the July case.
HARMONIE-AROME model forecast

Results: July case





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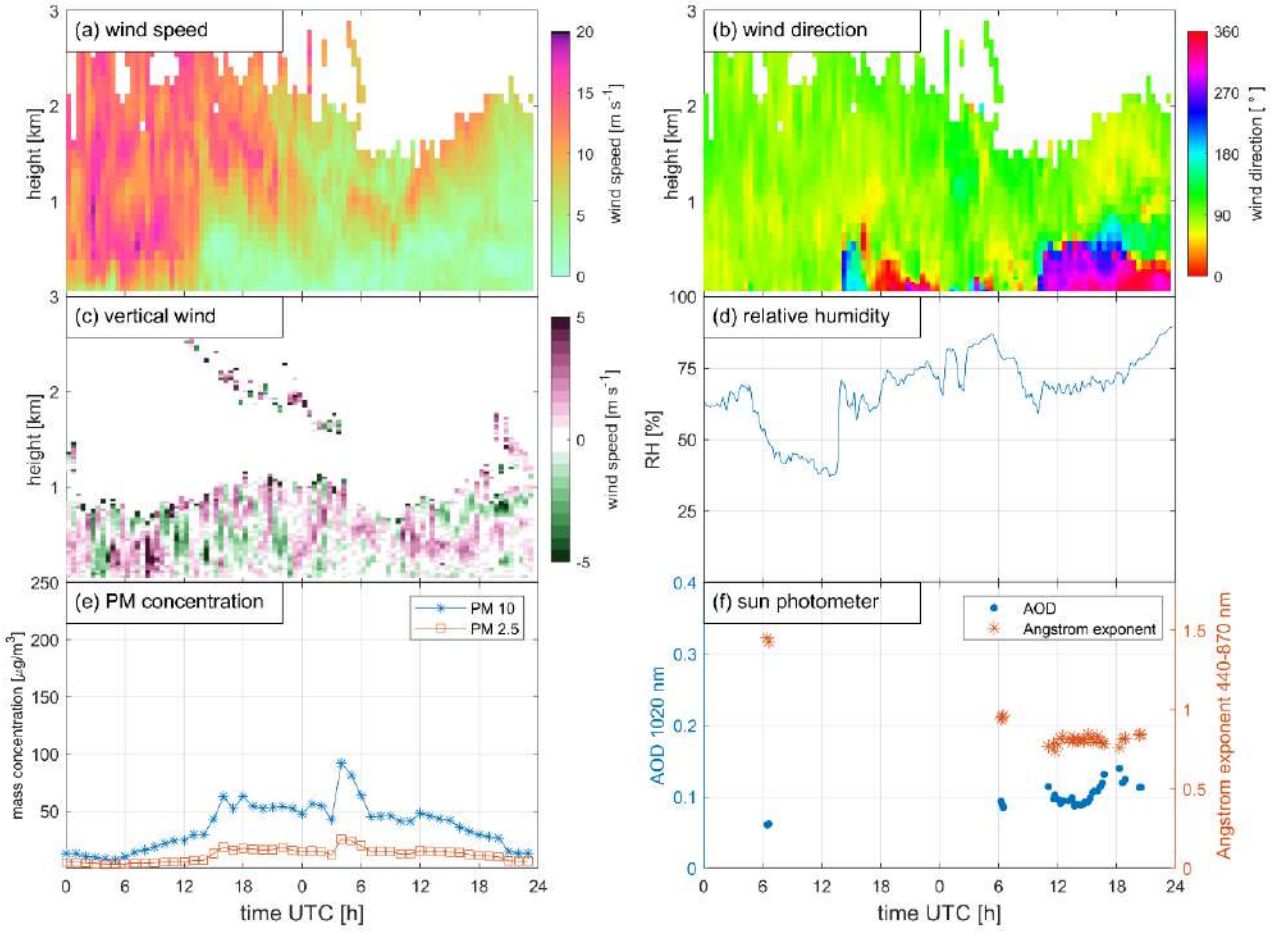
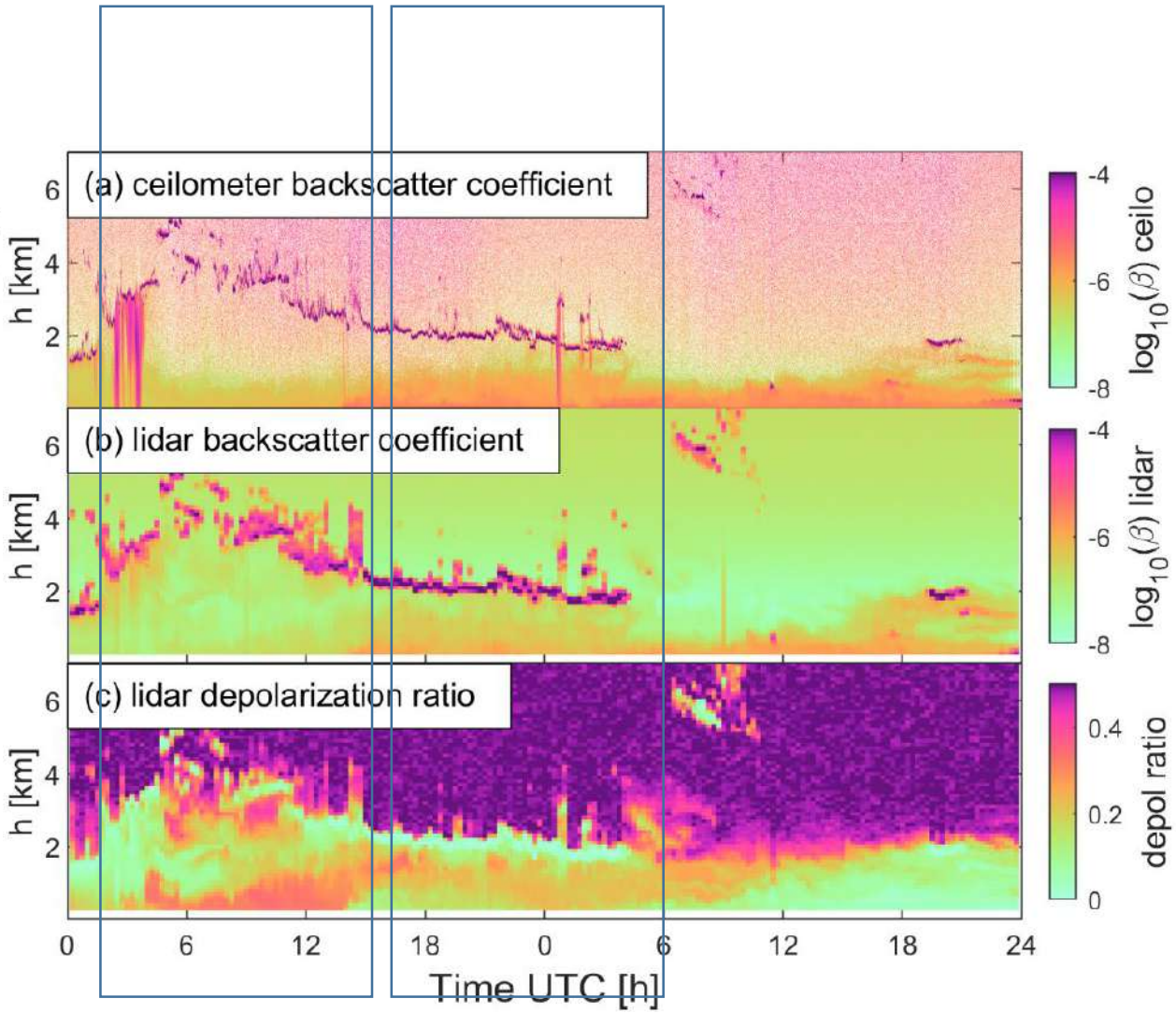
Results: July case





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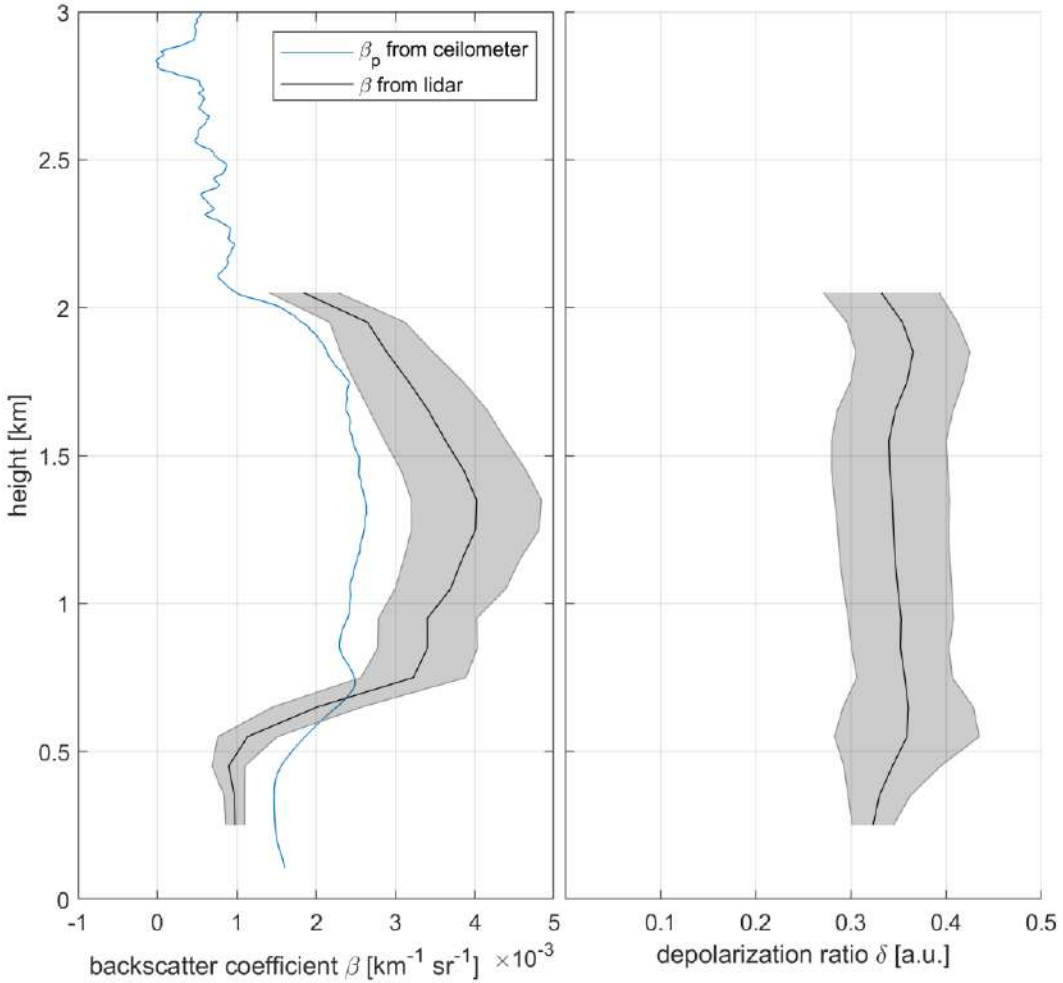
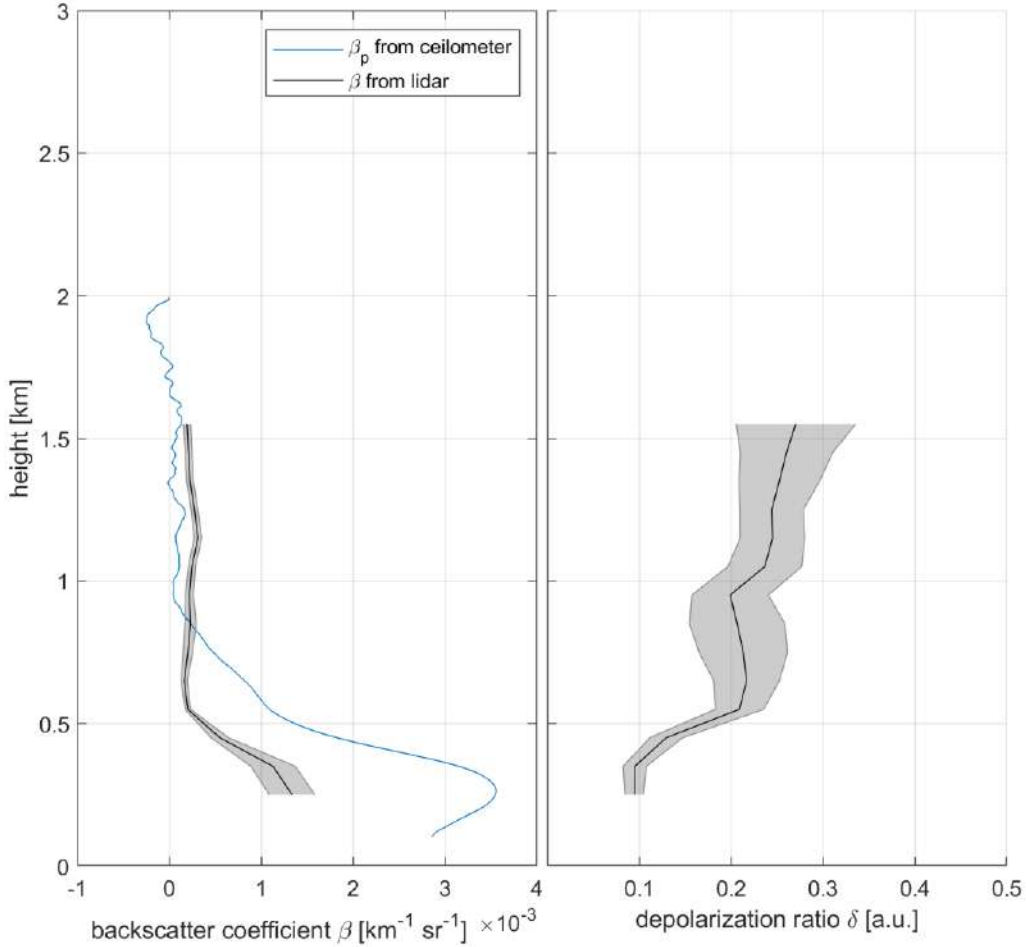
Results: June v.s. July



June case profile example



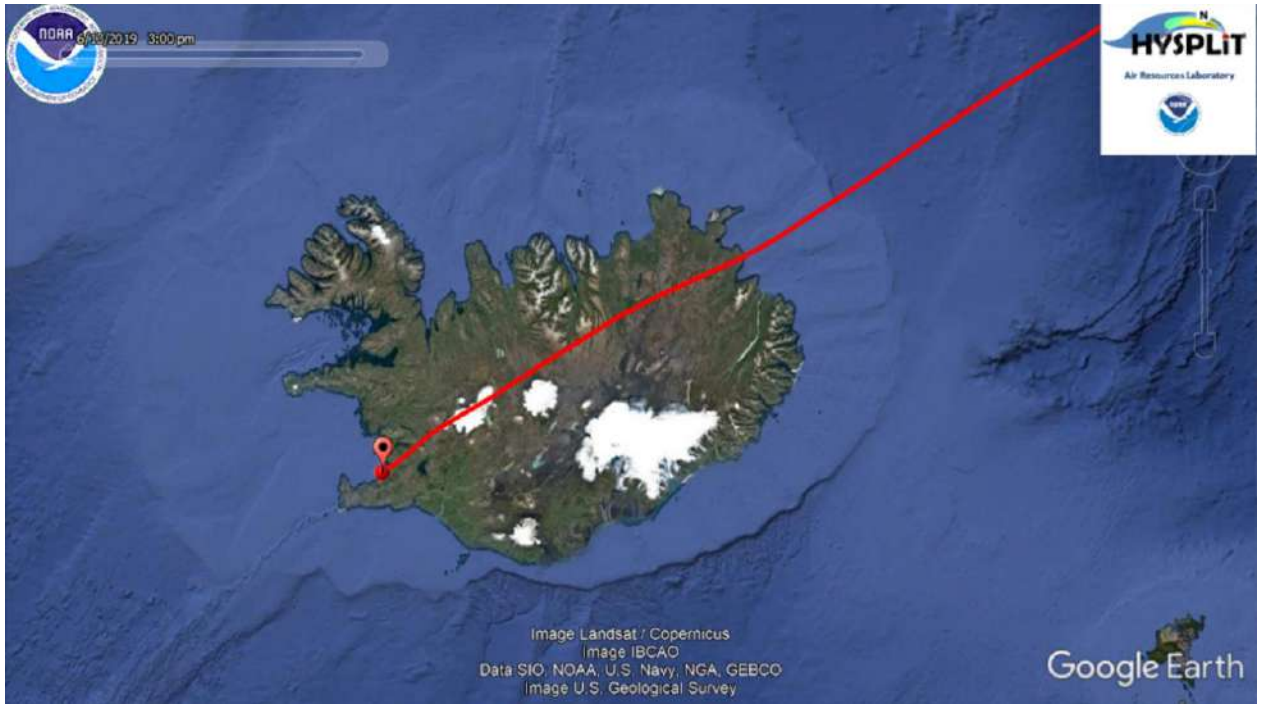
July case profile example

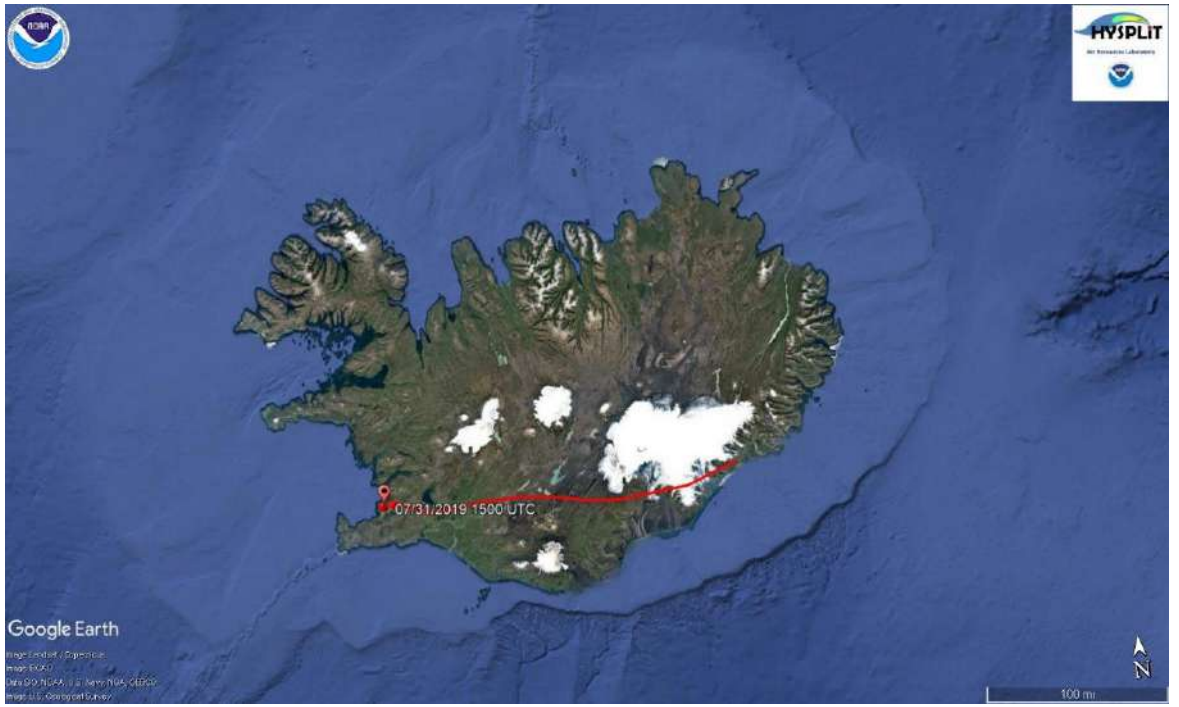
Discussion

- The backscatter coefficient (β) of dust layer varied:
  - June case: Doppler lidar > ceilometer
  - July case: Doppler lidar < ceilometer

- The backscatter coefficient (β) and depolarization ratio (δ) development varied:
  - June case: high β + high δ together with high PM concentration
  - July case: high β + low δ or low β + high δ

Discussion: different dust origins

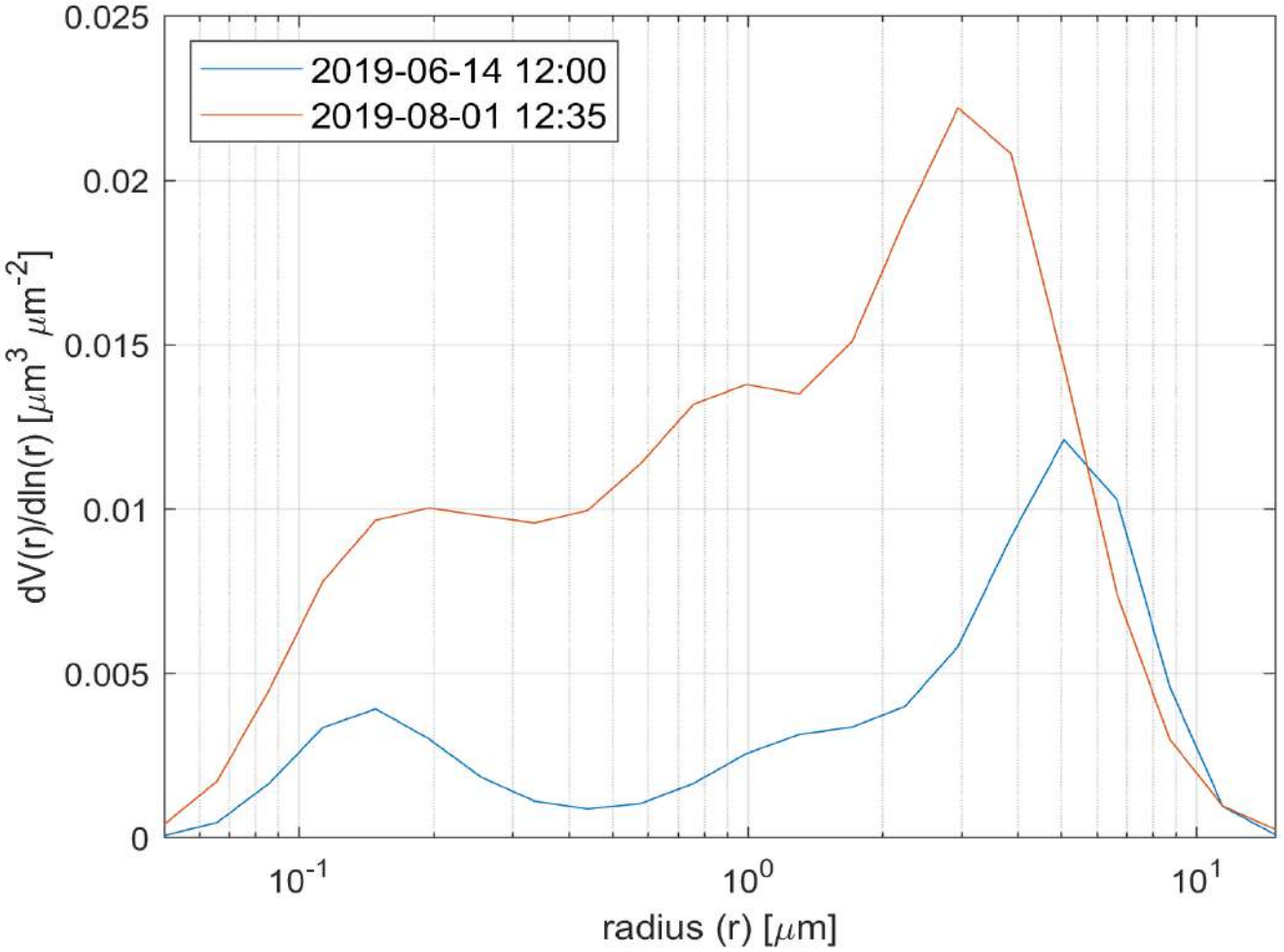




Back trajectory: June case
Source: Lake Hagavatn

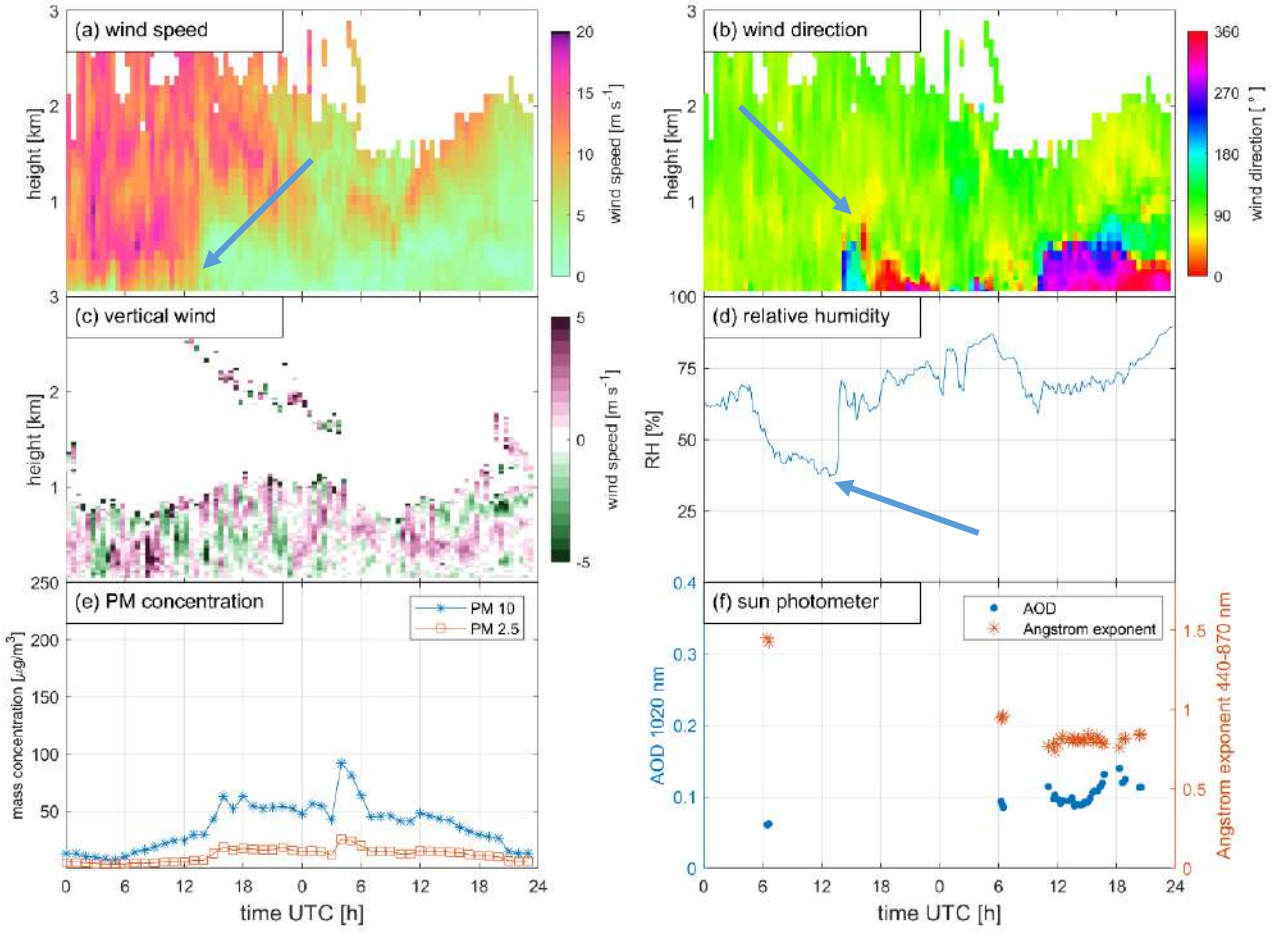
Back trajectory: July case
Source: Western Highlands

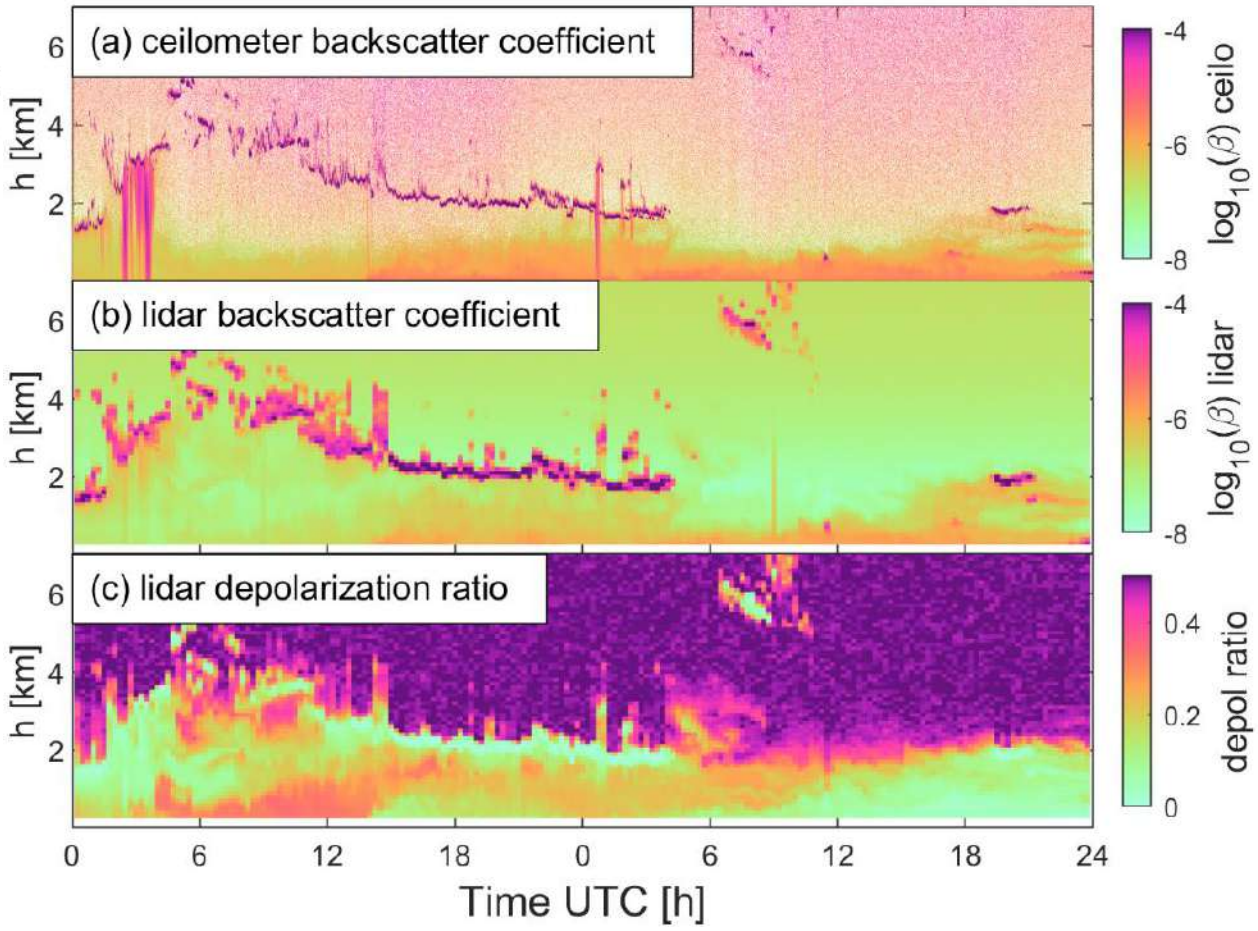
Discussion: different particle size



Size distribution from sun-photometer

Discussion: weather conditions





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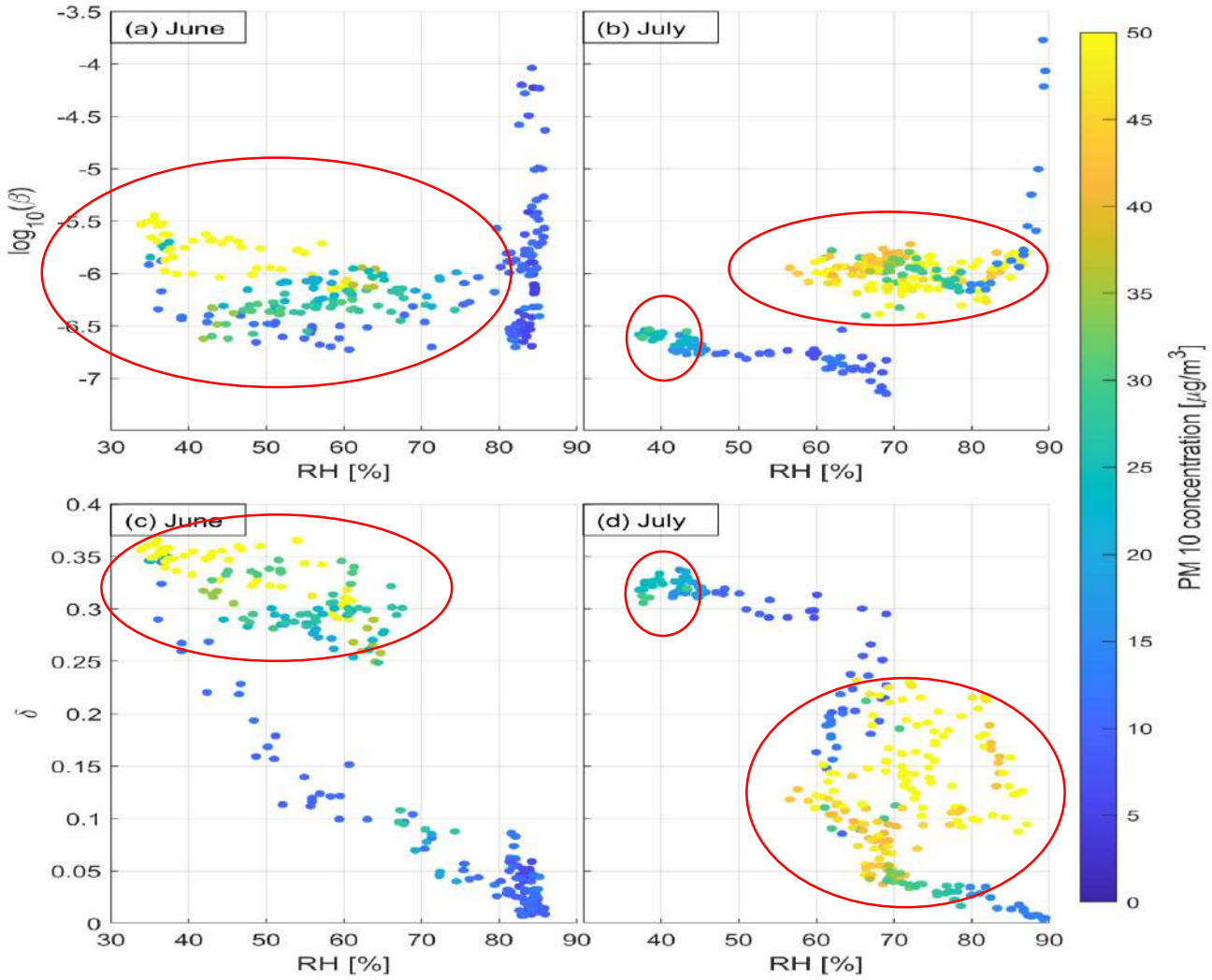
Discussion: weather conditions



Dust (high PM)

Conclusions

- A set of data processing methods and algorithms have been developed
- Doppler lidar and ceilometer can detect the dust layer in Iceland, similar temporal and spatial distribution observed
- The weather conditions and the particles physical properties can affect the lidar observations
- The lidars can be used for aerosols monitoring in Iceland
- Future work:
  - Machine learning application
  - Volcanic ash observation

Main references

- Yang, S., Preißler, J., Wiegner, M., von Löwis, S., Petersen, G. N., Parks, M. M., & Finger, D. C. (2020). Monitoring Dust Events Using Doppler Lidar and Ceilometer in Iceland. *Atmosphere*, *11*(12), 1294.
- Arnalds, O.; Dagsson-Waldhauserova, P.; Olafsson, H. The Icelandic volcanic aeolian environment: Processesand impacts—A review.Aeolian Res.2016,20, 176–195.
- Butwin, M.K.; Pfeffer, M.A.; von Löwis, S.; Støren, E.W.N.; Bali, E.; Thorsteinsson, T. Properties of dust sourcematerial and volcanic ash in Iceland.Sedimentology2020,67, 3067–3087