The value of Doppler LiDAR systems to monitor turbulence intensity in Iceland

A joint research project between Icelandic Met Office (IMO), ISAVIA and Reykjavik University(RU)

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Photo: LiDAR at KEF
By S. von Löwis

Objective: enhancing aviation safety in Iceland

Task 1:
Detection of turbulence

Task 2:
Detection of aerosols and ash

en.wikipedia.org

Lidar (also written LIDAR, LiDAR or LADAR) is a surveying technology that measures distance by illuminating a target with a laser light.

Photo: LiDAR at KEF
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Outline

1. Introduction
2. Methodology
3. Results
4. Summary

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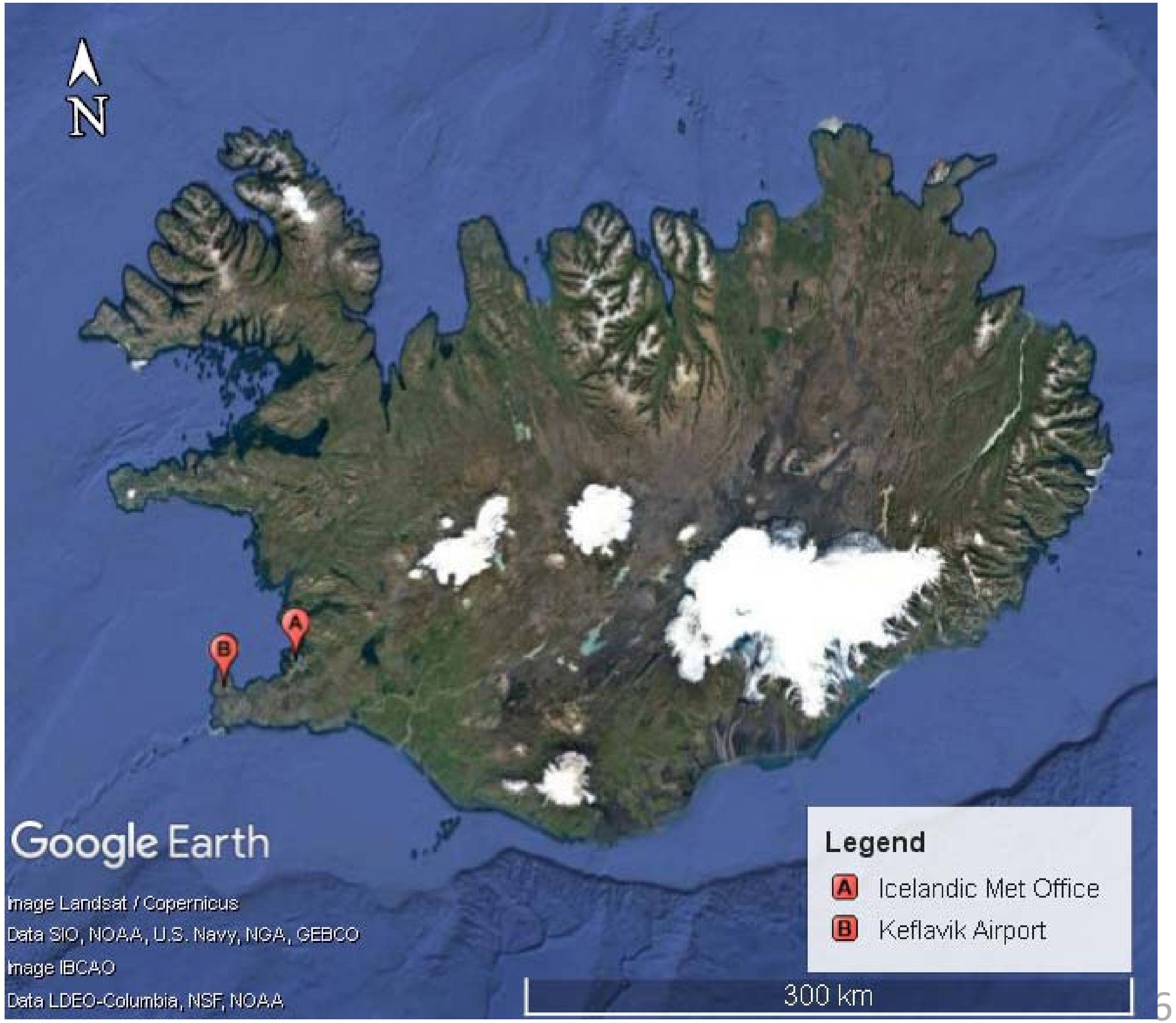
Introduction: motivation

Cross wind landing

Introduction: LiDAR Specifications

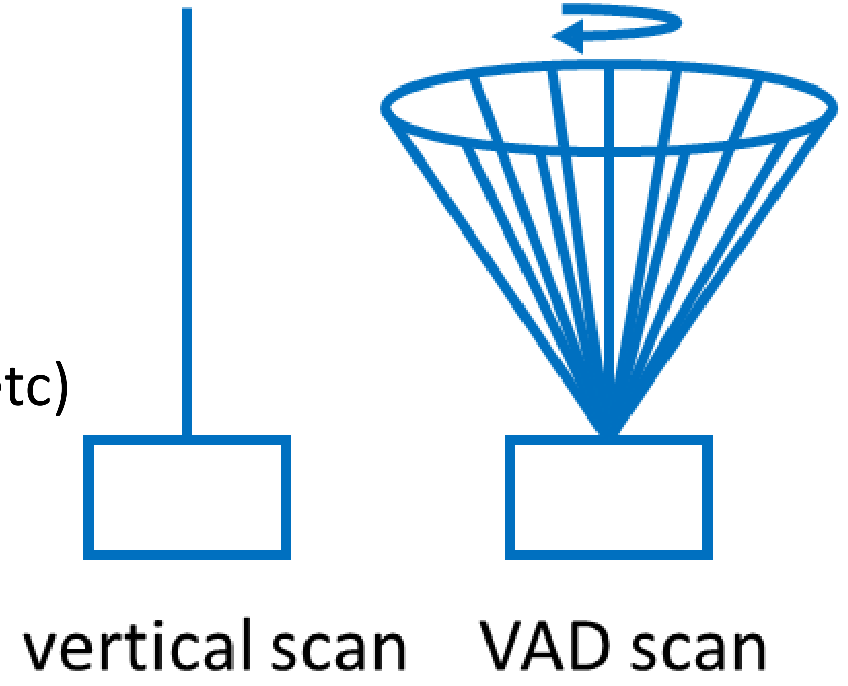
- Leosphere Windcube 200s with dual polarization
- One fixed at Keflavik Airport and one mobile at IMO currently

	Specification
Company	LEOSPHERE GROUP
Model	WINDCUBE 200s
Wavelength	1.54 [µm]
Maximum Power	5 [mW]
Maximum detection range	12 [km]
Azimuthal angle range	0~360 [°]
Elevation angle range	-10~190 [°]



Introduction: LiDAR Scans Set-up

- 8 VAD Scans per hour
  - VAD (Velocity Azimuth Display) keeps elevation angle and change azimuth angle
  - 30 ° interval (1 VAD = 12 LOS, line-of-sight)
  - Elevation angle: 15° and 75 °, every 15 minutes
- vertical scan (LOS 90°) in rest of time
  - Keep elevation angle at 90 degree, towards sky
  - Used as validation (O'Connor et al., 2010)
- Special scan once per day (hard targets detection etc)



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Methodology: EDR algorithm

- The Eddy Dissipation Rate(EDR) can be an indicator of turbulence intensity
- The Kolmogorov model:

$$D_v = C_v \epsilon^{2/3} s^{2/3}$$

where C_v is Kolmogorov constant, ϵ is EDR, s is spatial difference between two points

- ϵ can be solved if D_v is known

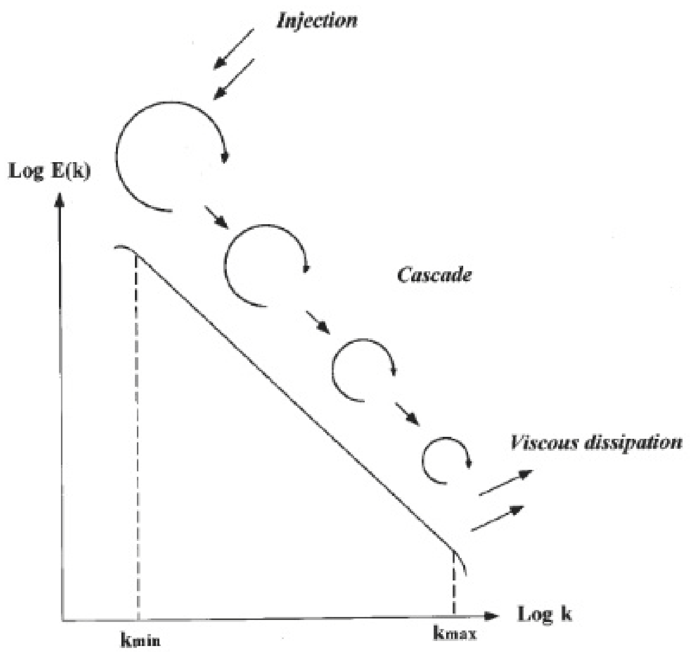
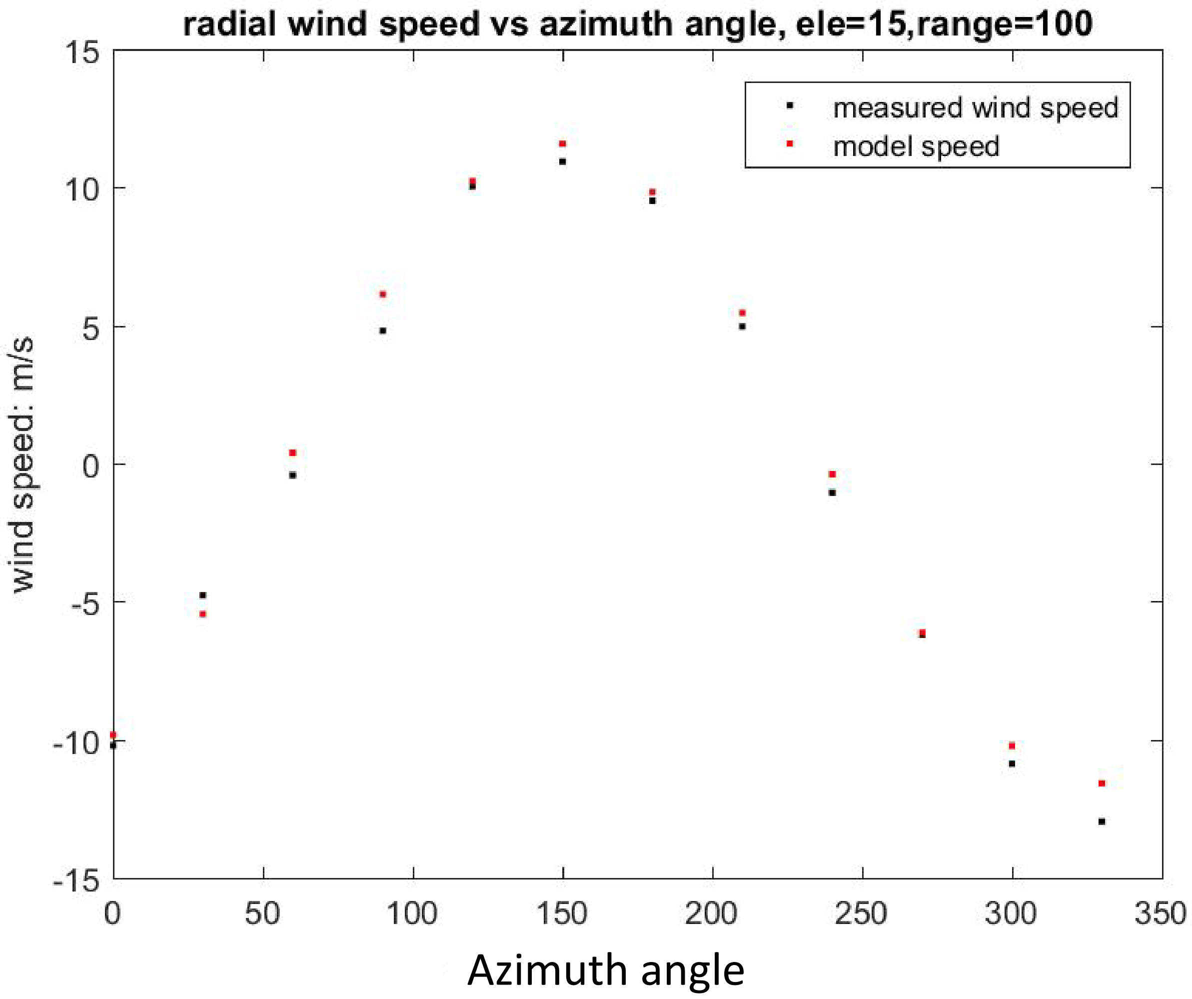


Fig. 1. Schematic representation showing the form of the frequency spectrum of turbulent velocity cascade, where $E(k)$ is the spectral density (variance units/k)^2 and k is a wavenumber (m^{-1}). The kinetic energy generated by large-scale processes (e.g. wind or tide) cascades through a hierarchy of eddies of decreasing size to the viscous subrange where it is dissipated into heat. The change in variance with wavenumber (i.e. slope of power spectrum) is scale invariant with a –5/3 slope as predicted by the theoretical Kolmogorov–Obukhov power law. The wavenumbers k_{max} and k_{min}, respectively, show the largest scale of creation of turbulence and the smallest scale (i.e. Kolmogorov length scale) reached by turbulent eddies where turbulent motions are smoothed out by viscous effects.

Seuront et al., 1999

Methodology: Structure function

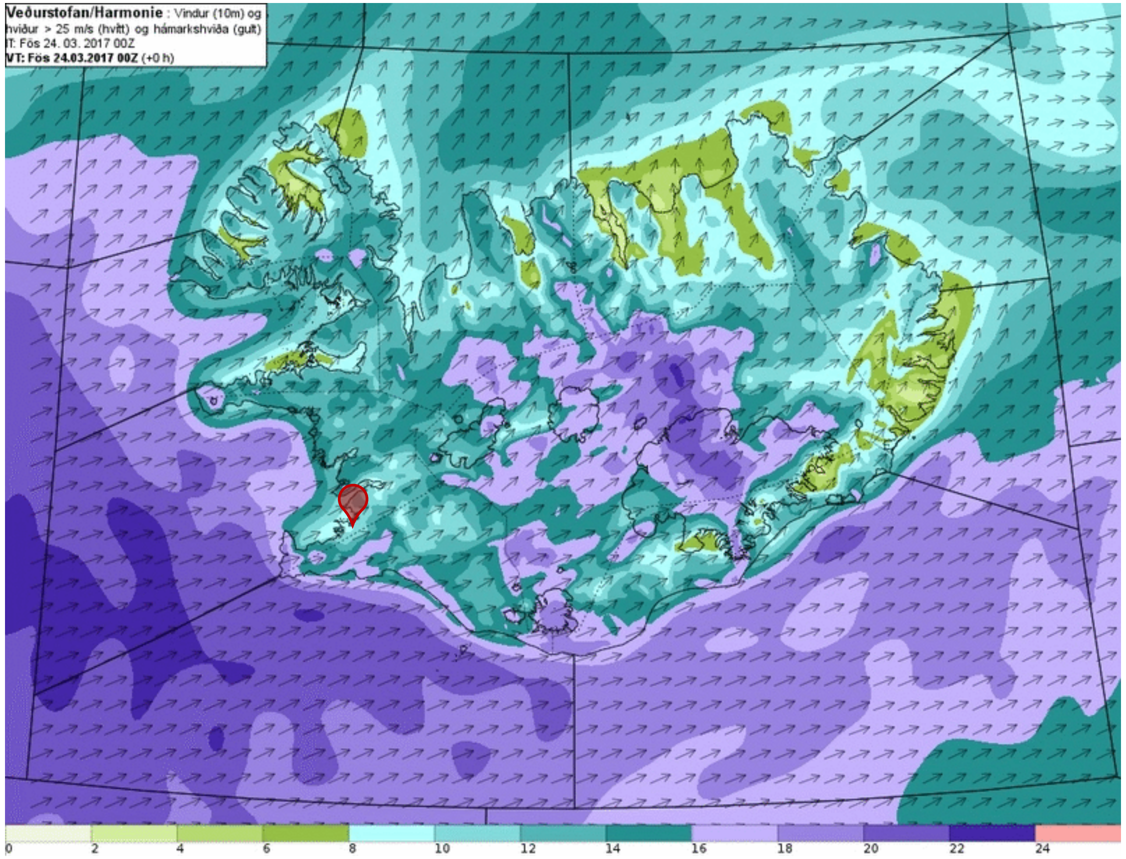
- Structure function
  - Azimuthal:
    $D_v(s) = < [v'(r,\varphi,\theta) - v'(r,\varphi+\Delta\varphi,\theta)]^2 >$
  - Longitudinal:
    $D_v(s) = < [v'(r,\varphi,\theta) - v'(r+s,\varphi,\theta)]^2 >$
  - $v'(r,\varphi,\theta)$ are the fluctuations



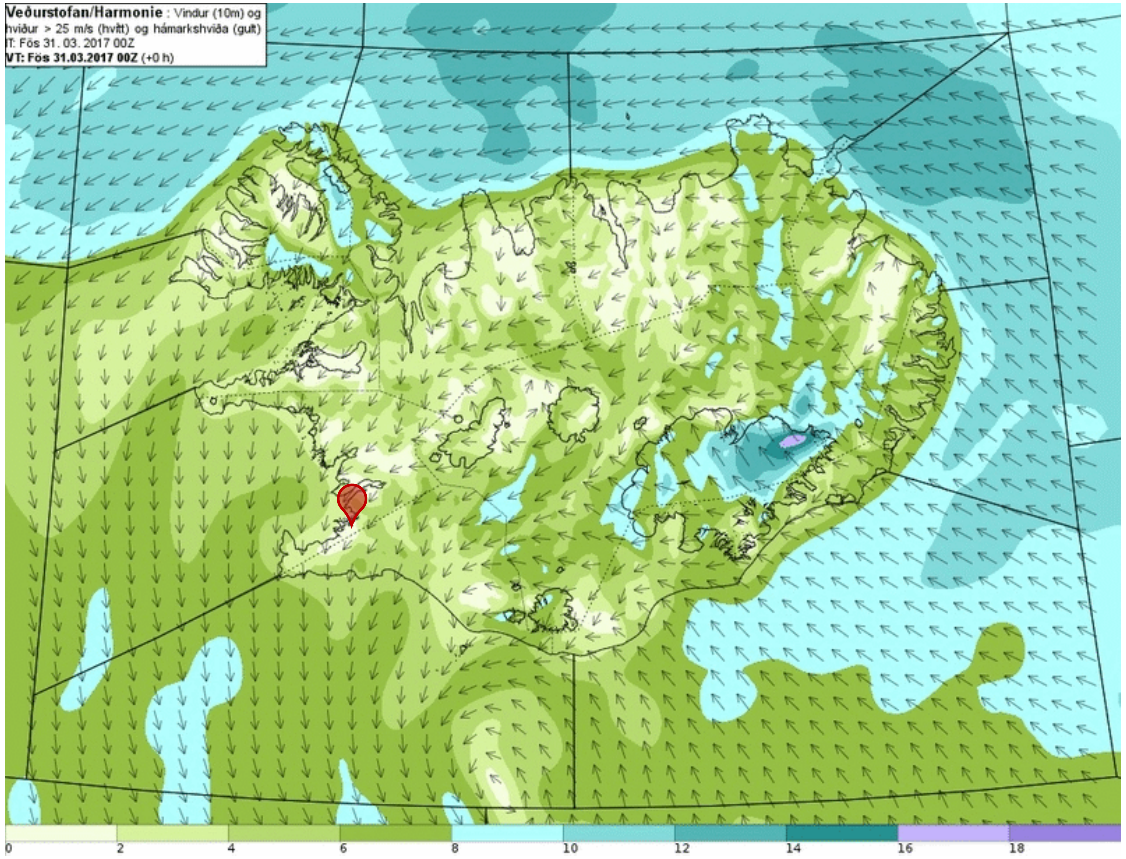
Methodology: Case Study

HARMONIE 24h forecast, 2.5 km resolution, hourly, 10 m wind velocity

Reykjavik (RVK), the capital city



24 March 2017, a turbulent day



31 March 2017, a calm day

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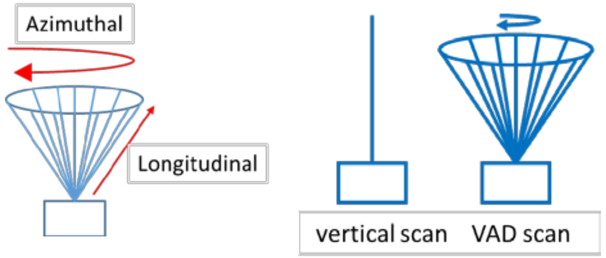
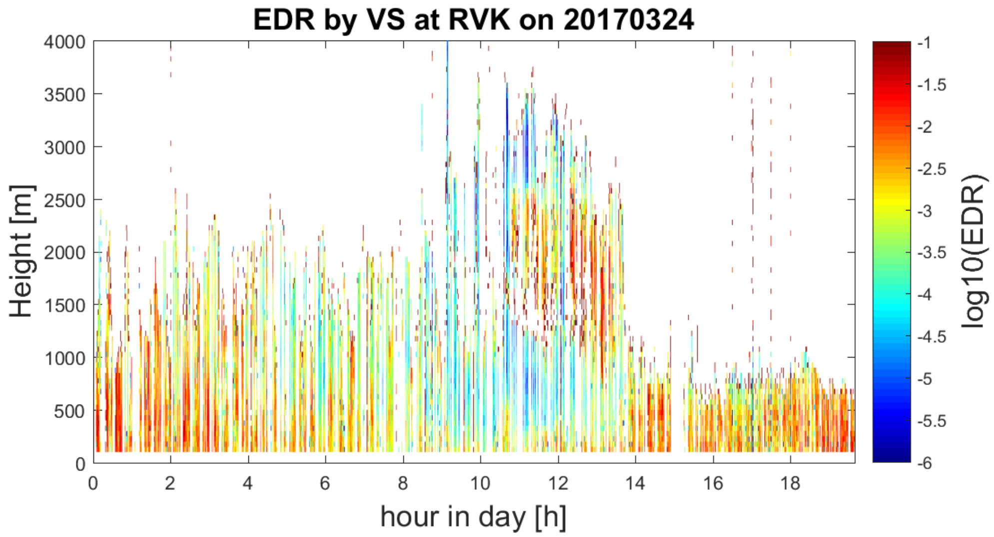
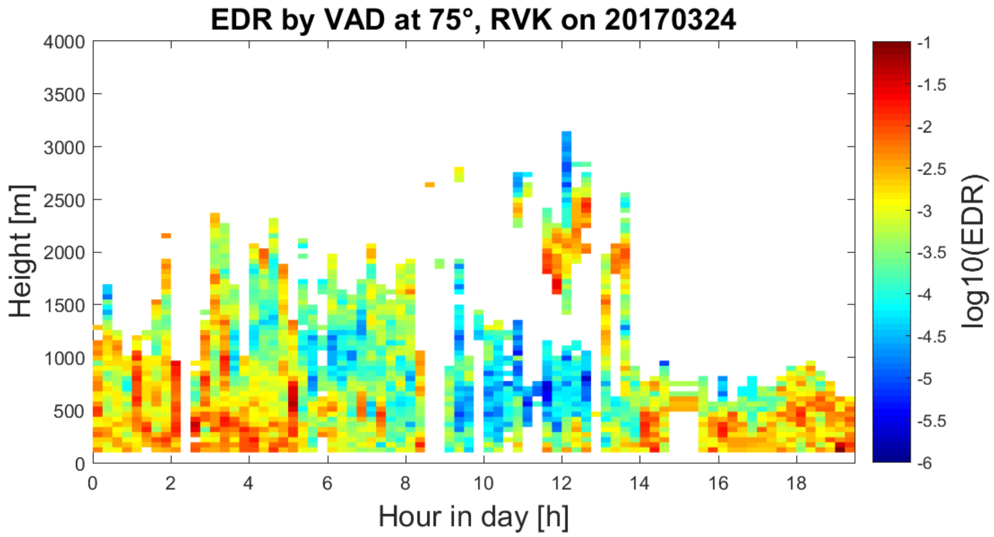
Results: 24 March 2017, turbulent day



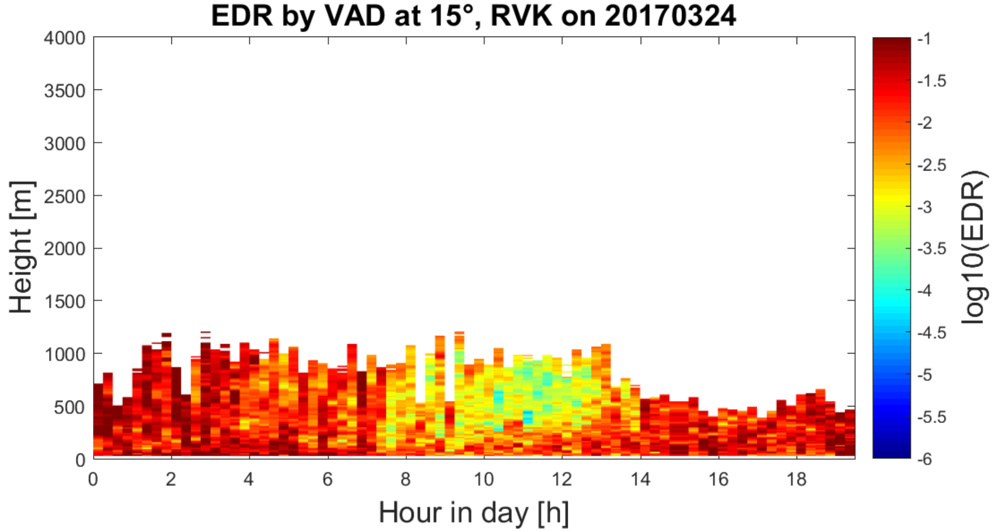
Vertical scan



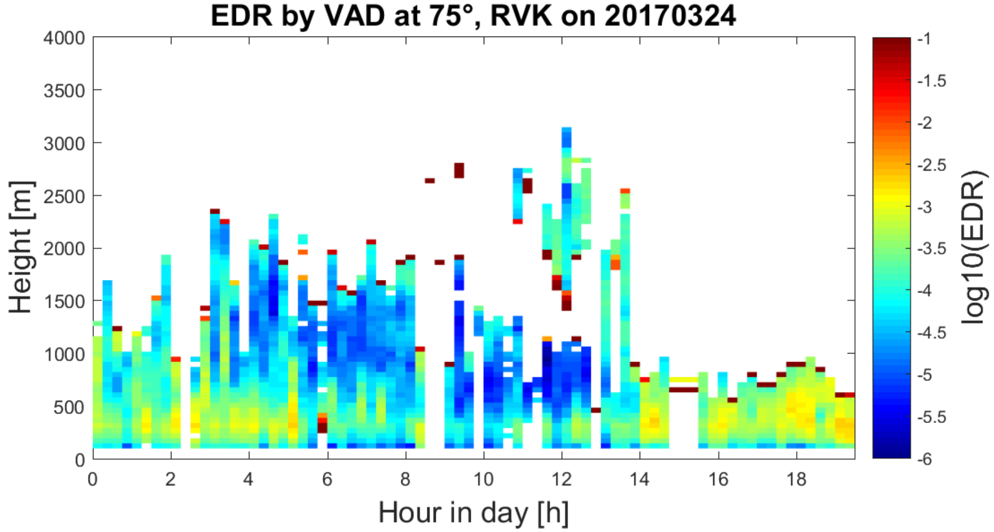
VAD, 75° Azimuthal



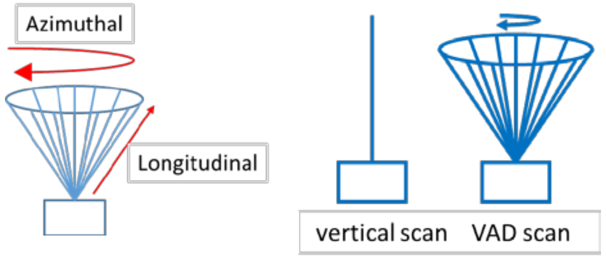
VAD, 15° Azimuthal



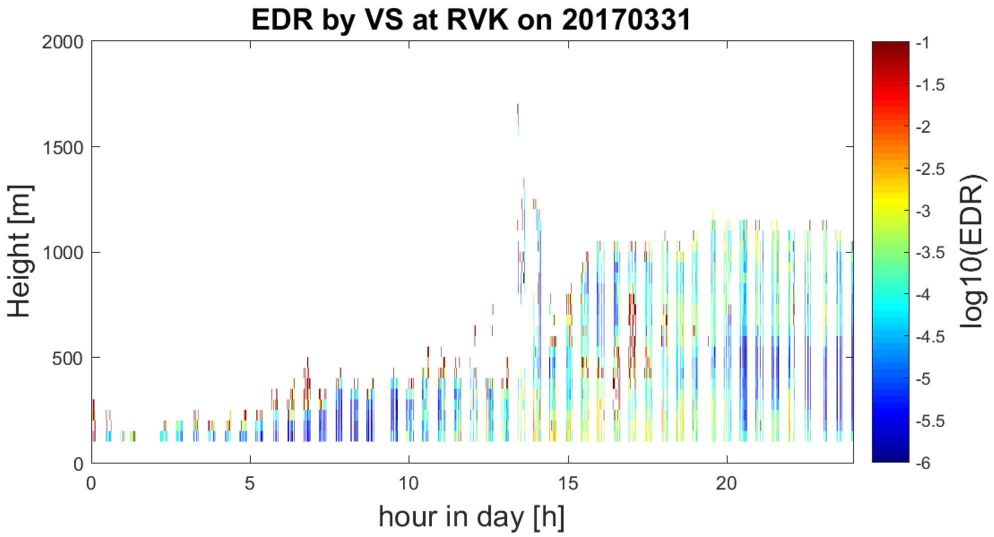
VAD, 75° Longitudinal



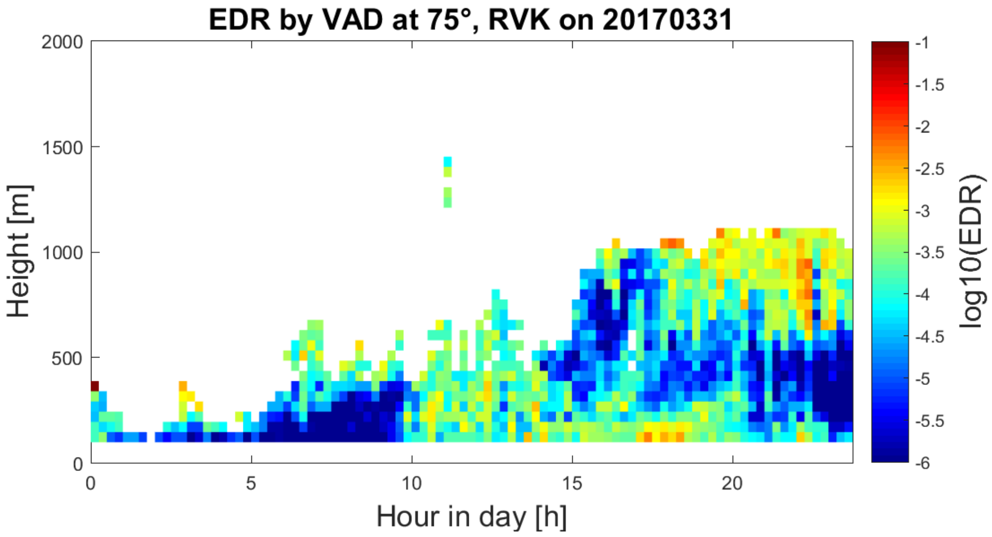
Results: 31 March 2017, calm day



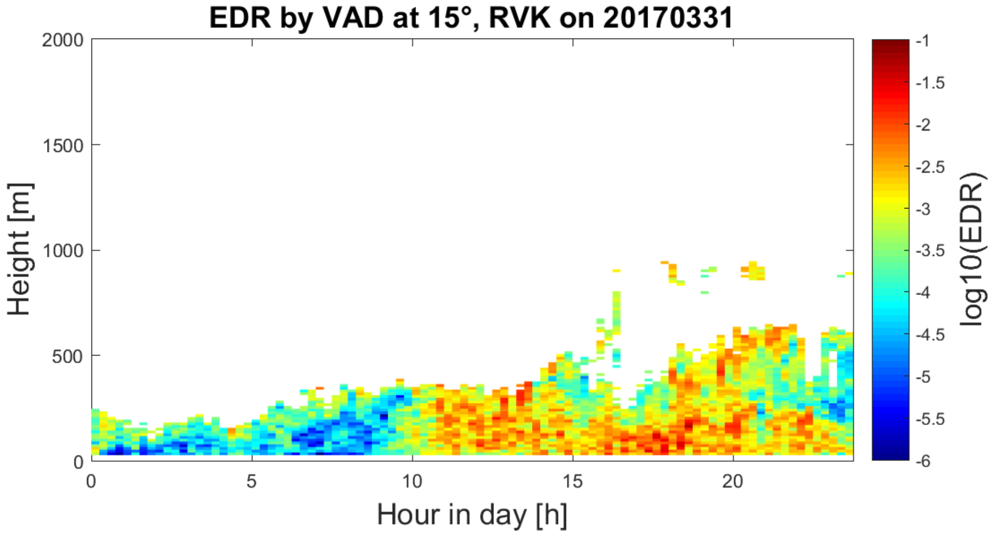
Vertical scan



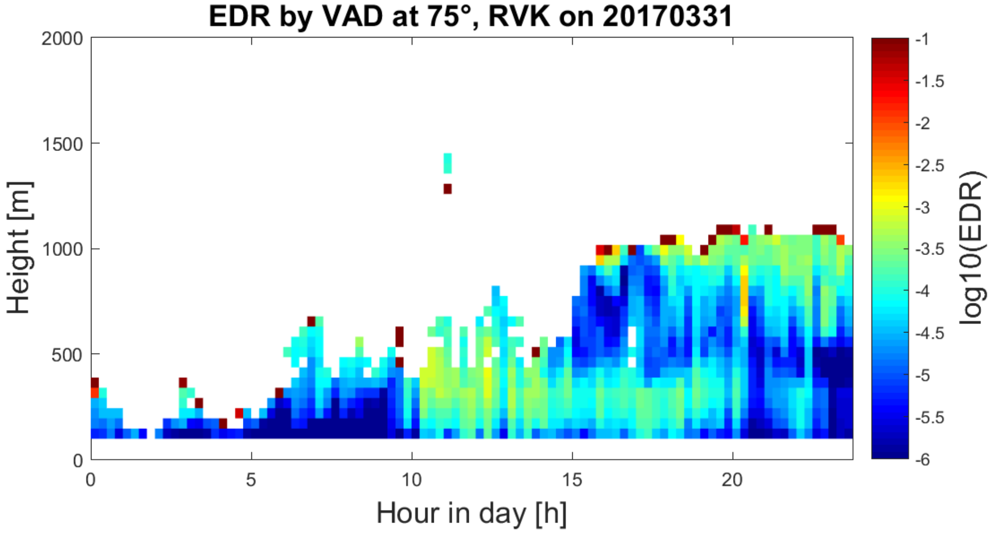
VAD, 75° Azimuthal



VAD, 15° Azimuthal



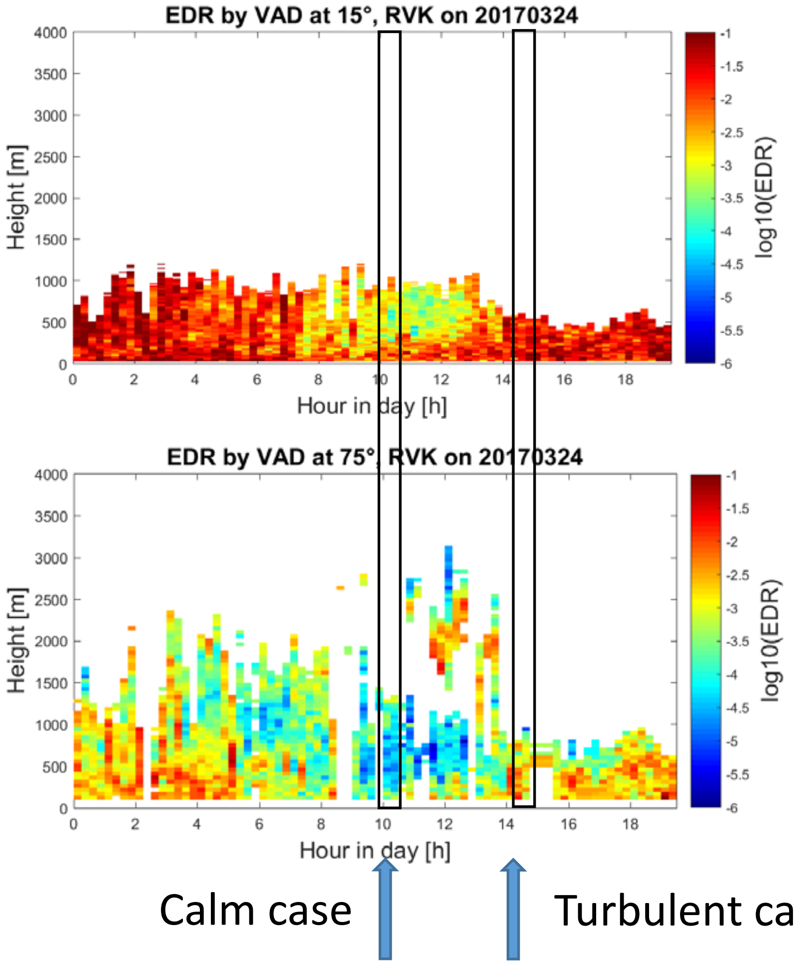
VAD, 75° Longitudinal



Results: EDR map using longitudinal approach

VAD, 15°
Azimuthal

VAD, 75°
Azimuthal

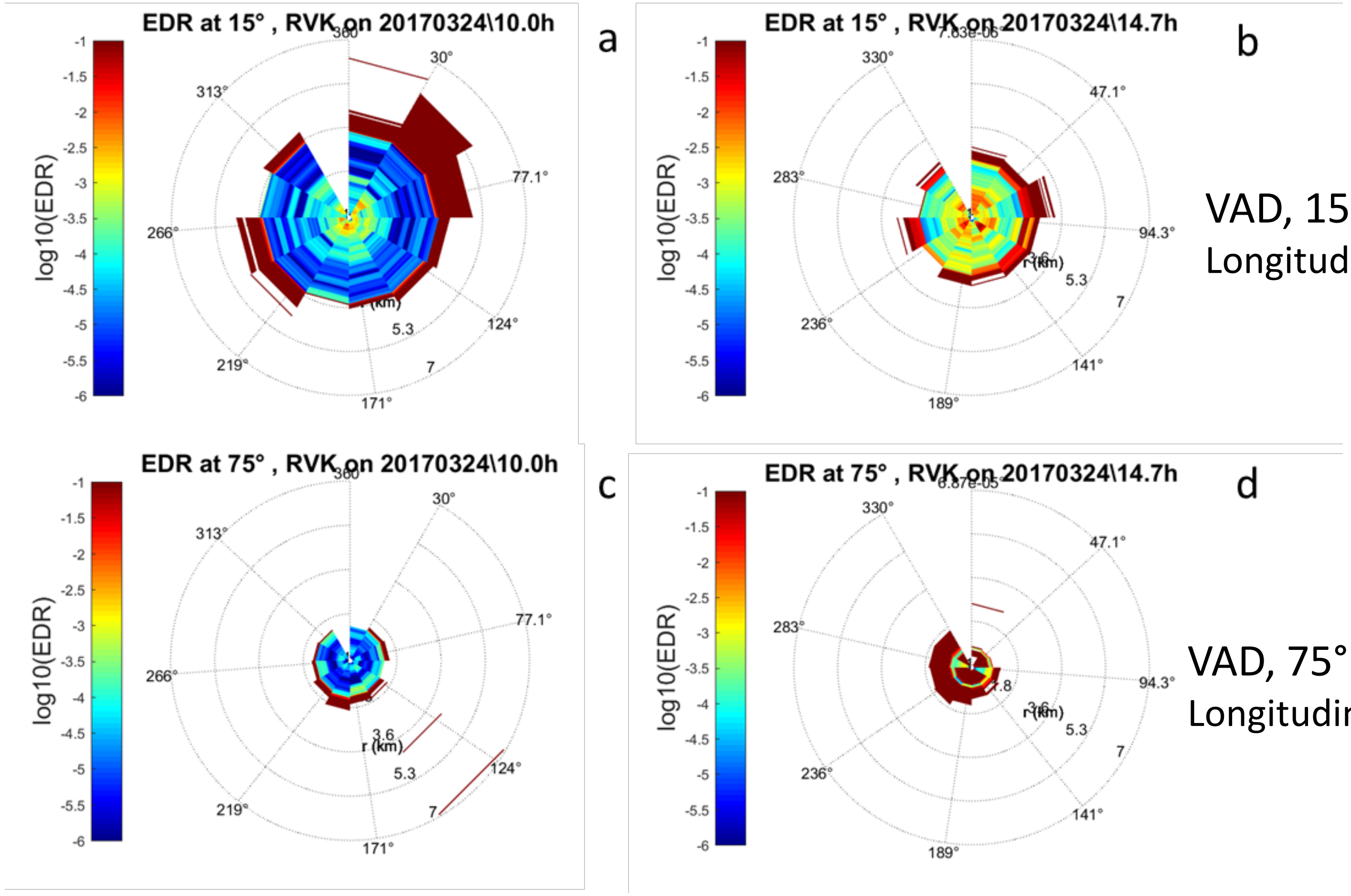


Calm case

Turbulent case

Calm case

Turbulent case



VAD, 15°
Longitudinal

VAD, 75°
Longitudinal

Results: EDR map using longitudinal approach

24 March 2017
Elevation angle = 15°

31 March 2017
Elevation angle = 15°

24 March 2017
Elevation angle = 75°

31 March 2017
Elevation angle = 75°

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Summary

- Turbulence intensity can be retrieved from radial wind speed data by VAD scans. The results agree with vertical scans temporally and spatially in pattern.
- The azimuthal approach performance better than the longitudinal, considering the time series, while with the longitudinal approach can see the turbulence distribution.
- Outlook
  - More validation method would be better.
  - Noise filtering algorithm can be improved.

Thank you

References

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