Measurement of wind profiles in the Atmospheric Boundary Layer

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Wind profiles in the Atmospheric Boundary Layer

Overview

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in situ

mast
balloon

radiosonde
tethered balloon
kite
aircraft

ground-based
active r.s.

remote sensing

RADAR

RADAR = **RA**dio **D**etection **A**nd **R**anging
LIDAR = **LI**ght **D**etection **A**nd **R**anging
SODAR = **SO**und **D**etection **A**nd **R**anging

SODAR

LIDAR

advantages and
disadvantages

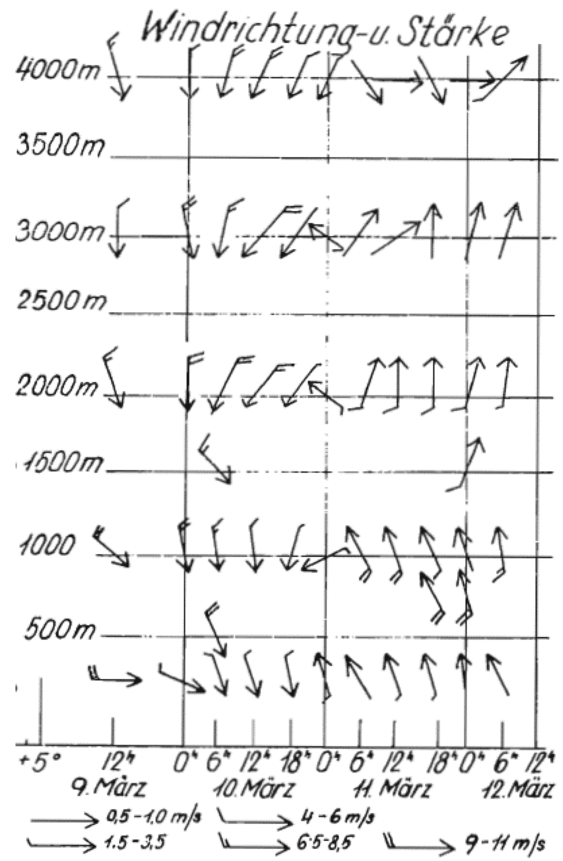
examples

Early wind profiling instrumentation

Since 1920ies: profile measurements with radiosonde balloons, kites and tethered balloons

Tethered balloon with a fixed-point-meteorograph at Lindenberg, Germany 1938

source: Neisser and Steinhagen (2005) promet 31, 2-4



Radiosoundings at Vienna, Austria
March 9th to 12th 1965
source: Schwarzl (1965)
Wetter und Leben 17(11-12), 241-243

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Radiosondes and commercial aircraft

Radiosondes and pilot balloons

- winds usually computed from about 1 or 2 minutes of signals, corresponding to a **vertical resolution of 300 or 600 m**

Aircraft

- vertical resolution usually better than with radiosonde
- rate of ascent or descent of the aircraft similar to that of a radiosonde ascent, but aircraft winds computed from a sample lasting 10 s or less – **vertical resolution likely to be better than 50 m**.

WMO AMDAR SYSTEM

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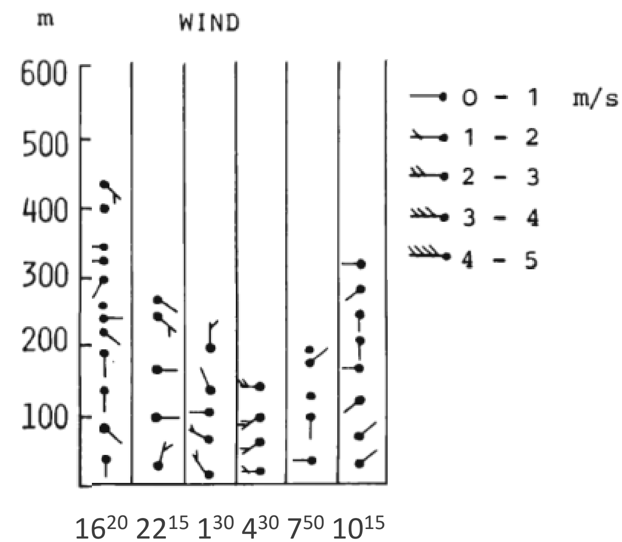
Early wind profiling instrumentation

Tethered balloon soundings in Austria in the **early 1980ies**

Right: test of „rescue device“ for tethered balloon sonde (= remote activation of fire at rope)



Wind profiles on 8th/9th Dec. 1984 at Voitsberg, Austria

source: Piringer (1986) Wetter und Leben 38, 76 - 87

Tethered balloon soundings

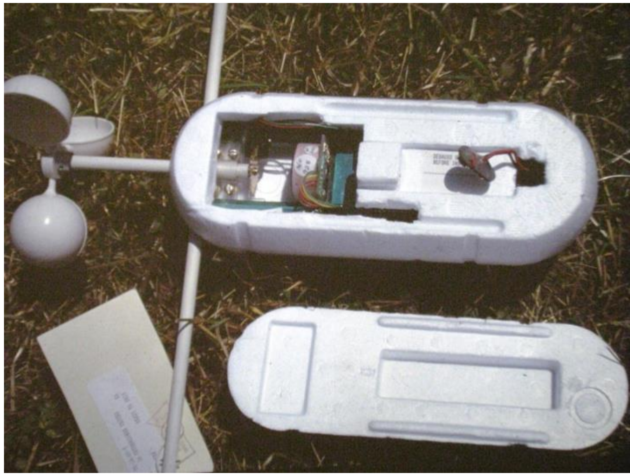
- in situ-measurements of wind, temp., humidity, ozone, …
- 0 m – max. 1000 m above ground

advantages

- high temporal and vertical resolution
- „continuous“ measurements with „tower“ system with several sondes fixed to the wire

drawbacks

- requirements: min. 2 persons
  operating winch & balloon / data transmission control
  4 to 6 persons for 72 hours campaign
- **air traffic clearance** >500m gnd
- limited use at **high wind speeds**



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Tethered balloon measurements – valley winds at Graz/Austria

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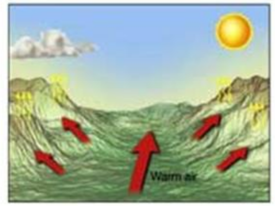
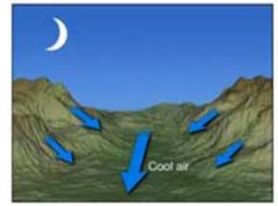
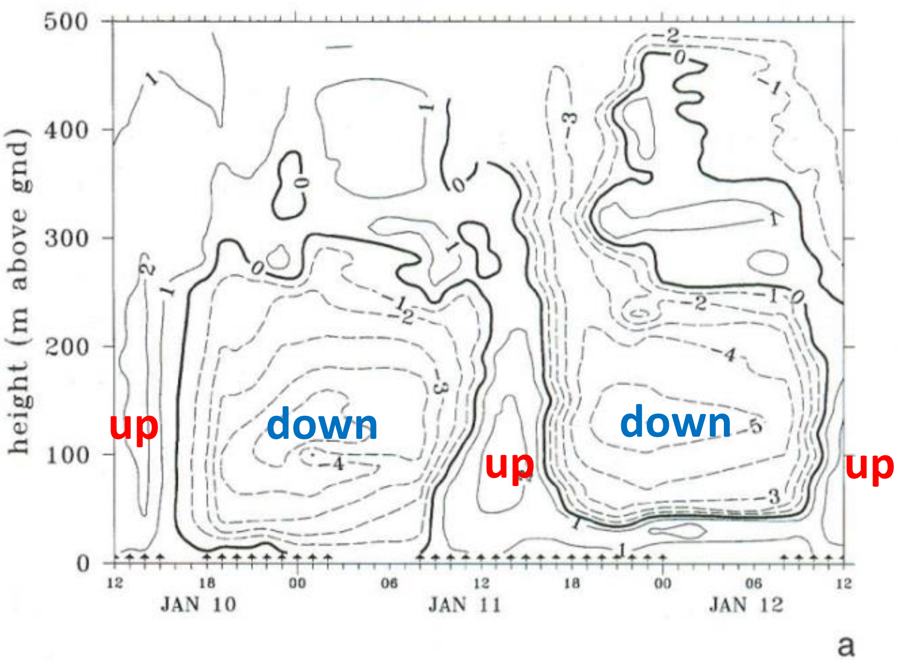


up-valley winds

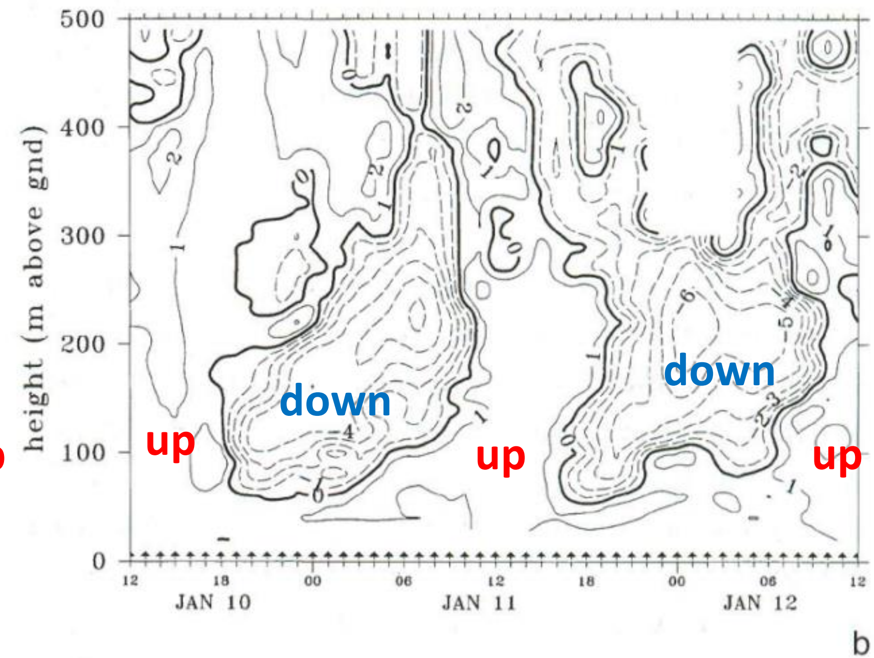


down-valley winds

north of Graz



south of Graz



source: Piringer and Baumann (1999) Meteorol. Atmos. Phys. **71**, 117 - 125

Active Remote Sensing - Measurement principle

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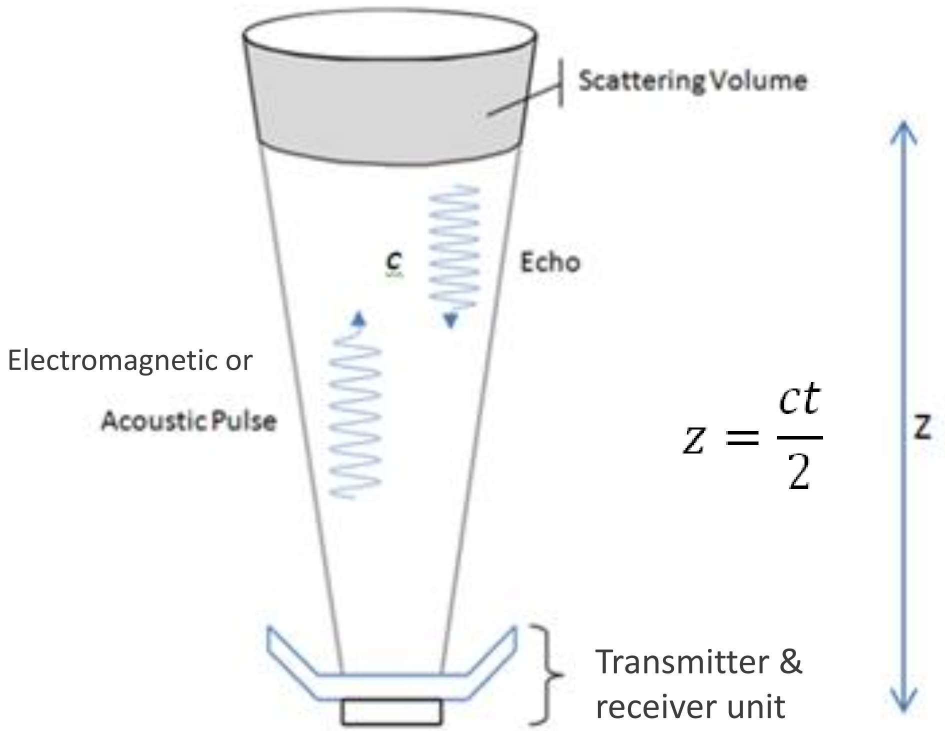
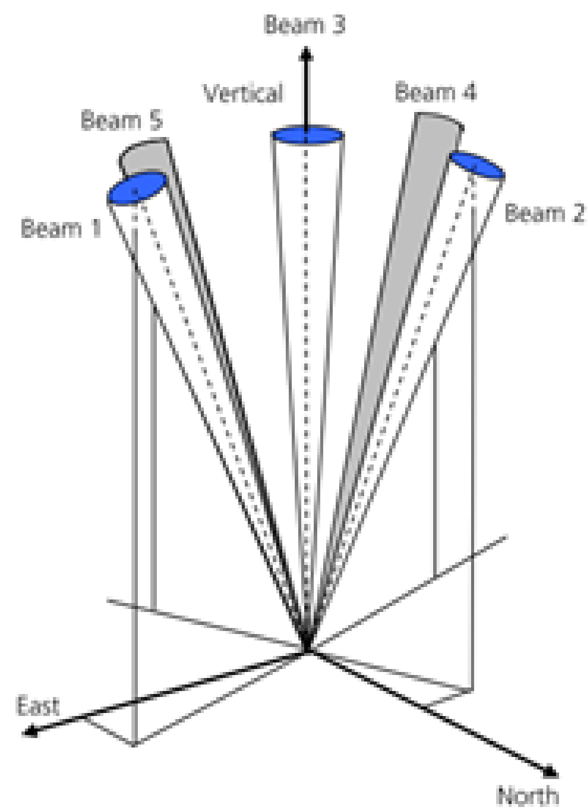


$$z = \frac{ct}{2}$$

©adapted after Isaac Brana



„Doppler Beam Swinging“

Doppler shift

Frequency shift proportional to component of the speed of the scatterer along the beam axis (= radial velocity)

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Electromagnetic wave spectrum

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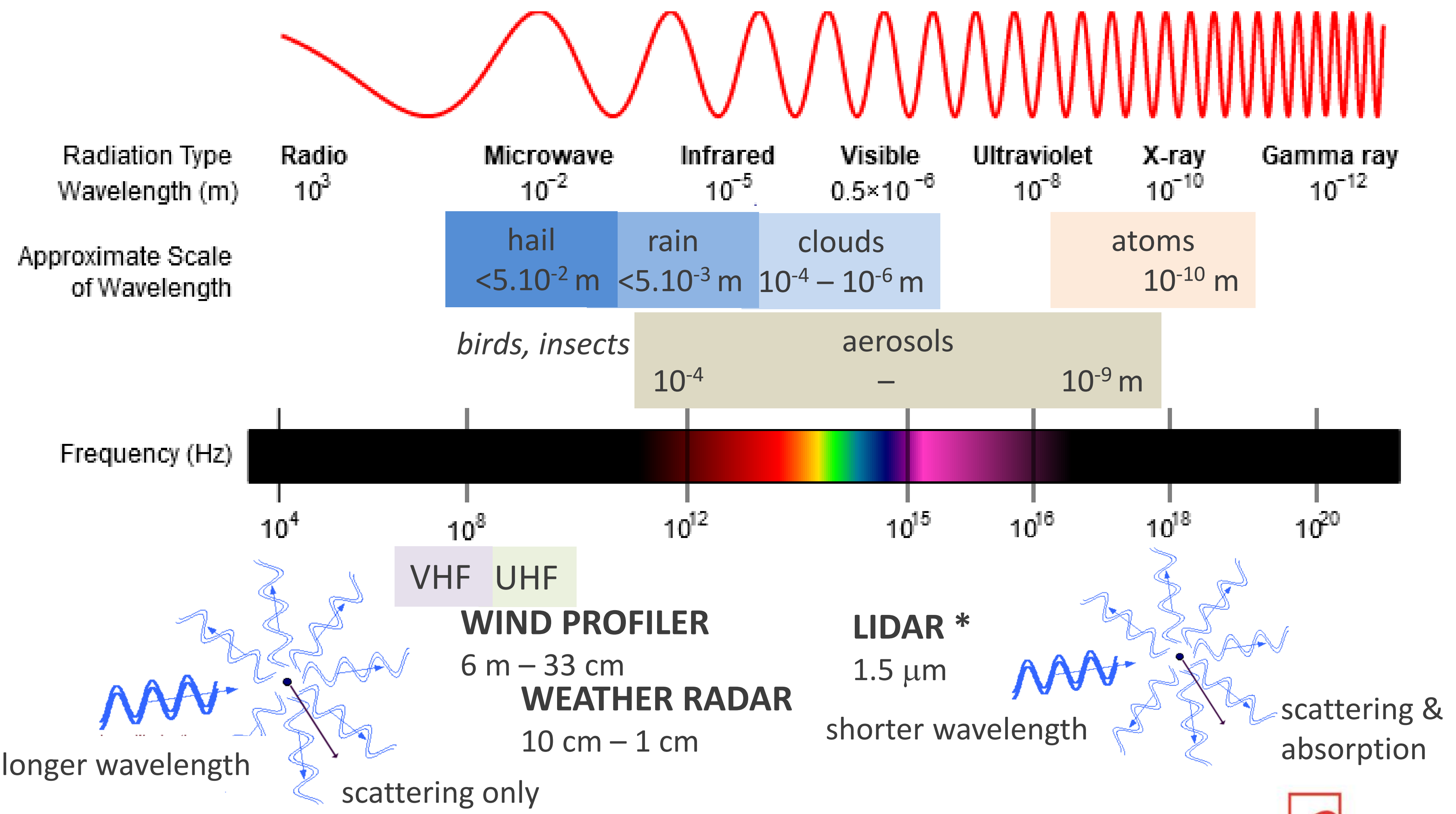
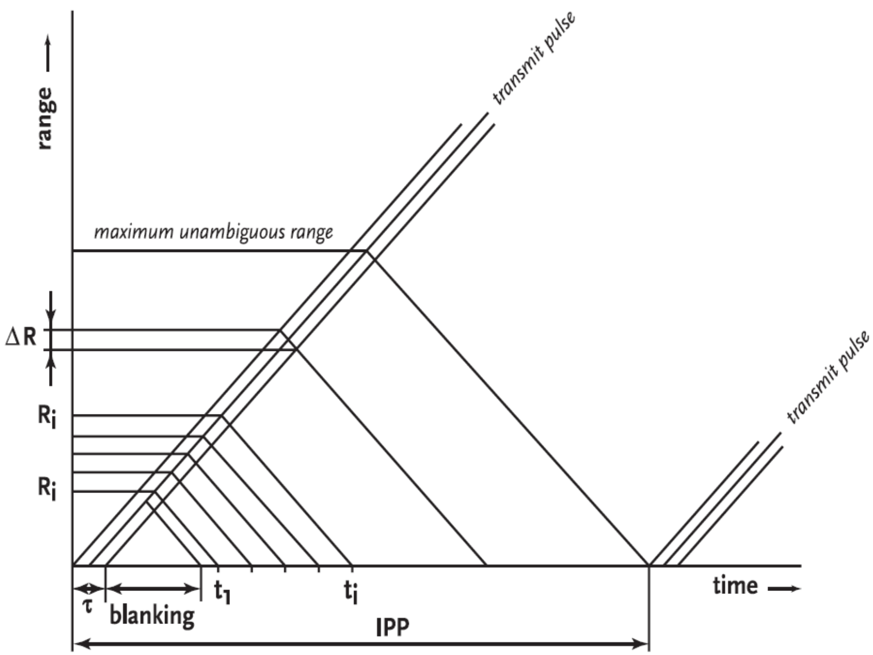
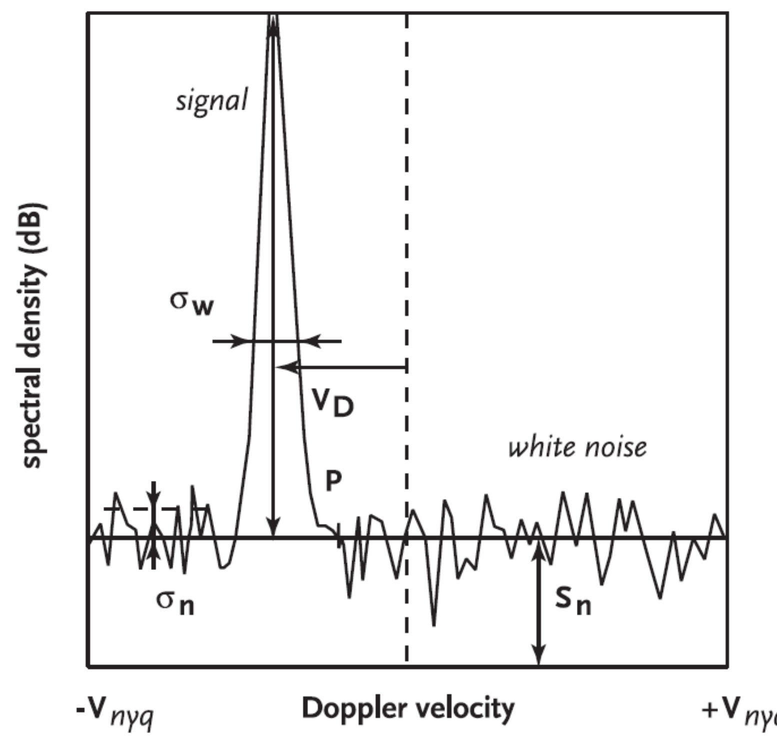


Pulse sequence and sampling

- Wind Profilers use typically a **pulse repetition rate** in the order of tens of microseconds.
- typical correlation time of the atmospheric processes is in the order of a second - **several samples used to estimate Doppler shift**





Spectrum may contain **peaks (signals) from non-atmospheric targets**
e.g. ground clutter, intermittent clutter like birds or aircraft, interference

Wind Profiler

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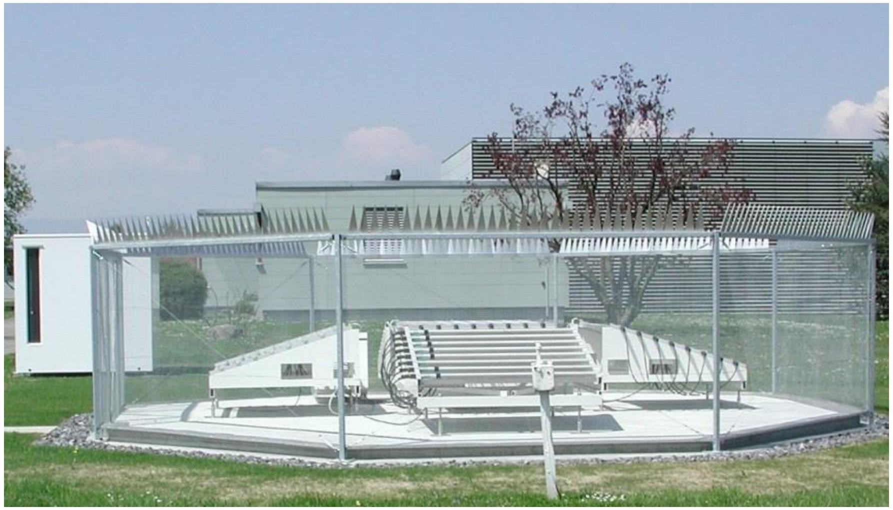
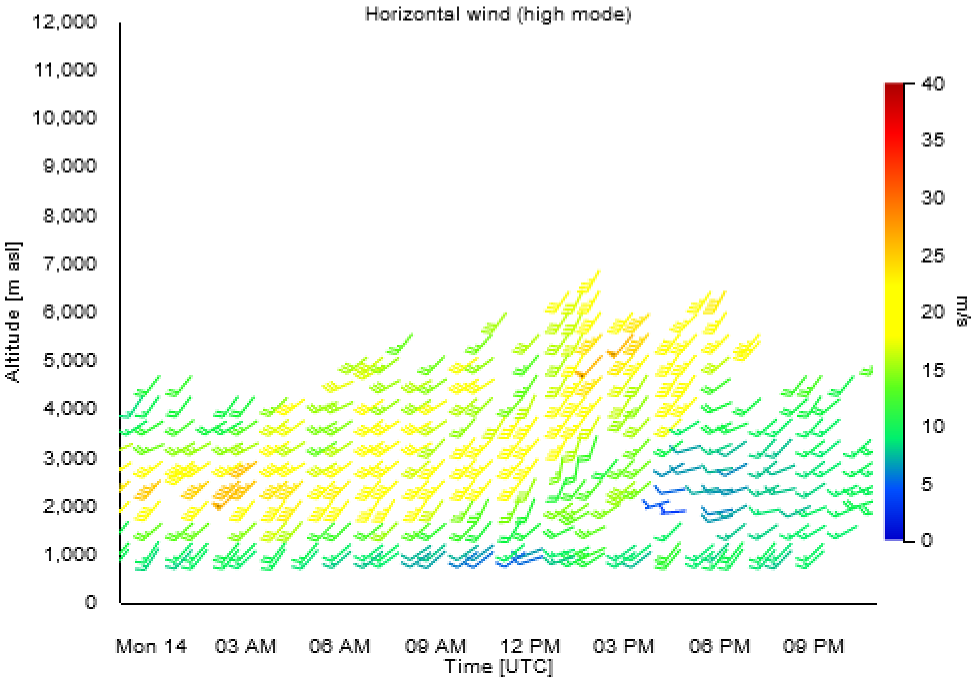


e.g. Wind Profiler at aeronautical station **Payerne**, **Switzerland**.

The fence around the antenna protects radio echos from near-ground objects.



https://www.meteoswiss.admin.ch/home/measurement-and-forecasting-systems/atmosphere/windprofiler.html

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Wind Profiler & Weather Radar

https://e-profile.eu

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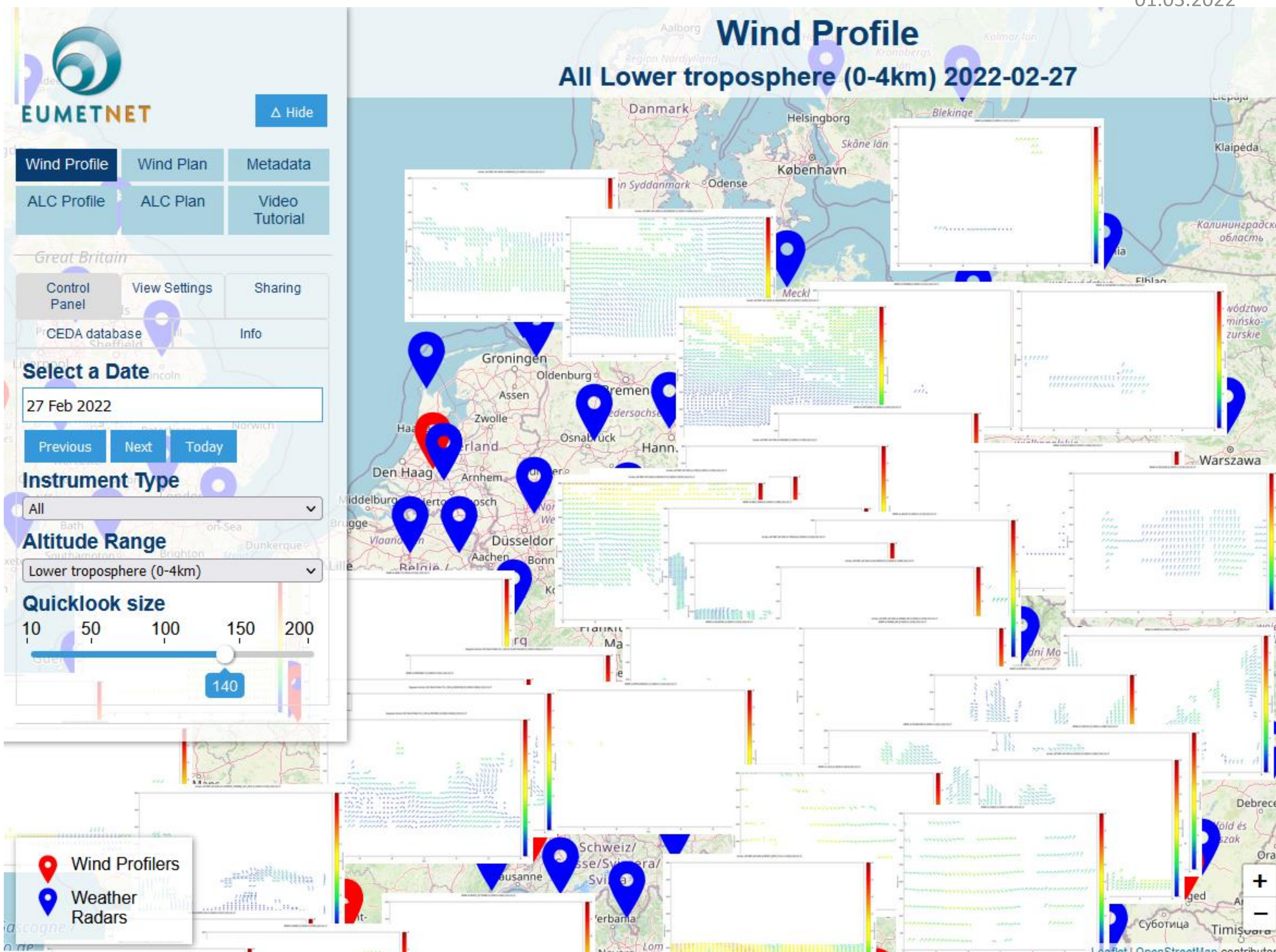

EUMETNET

Example: wind profiler and weather radar

13th December 2000 (© COST Action 76 final report)

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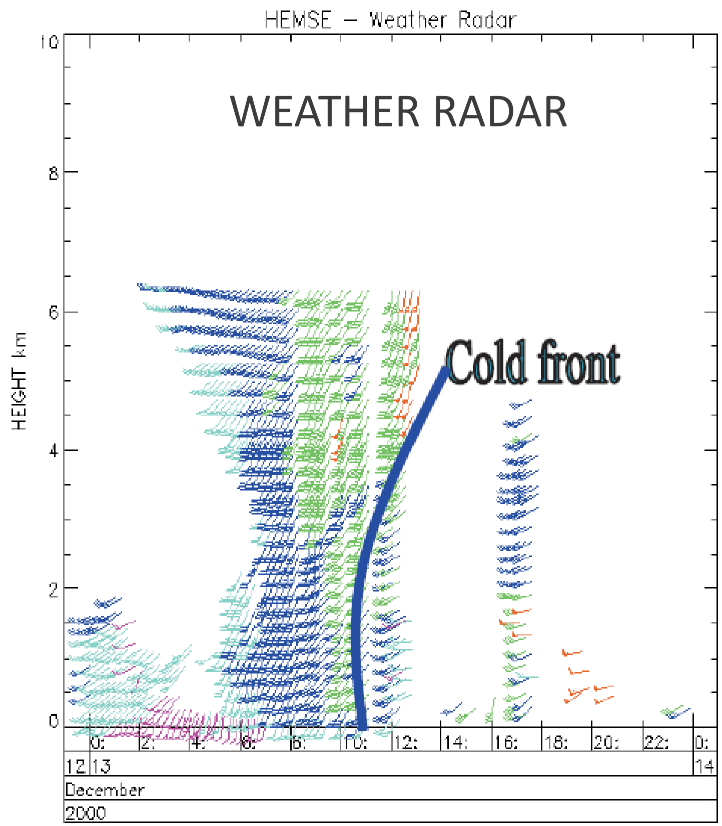

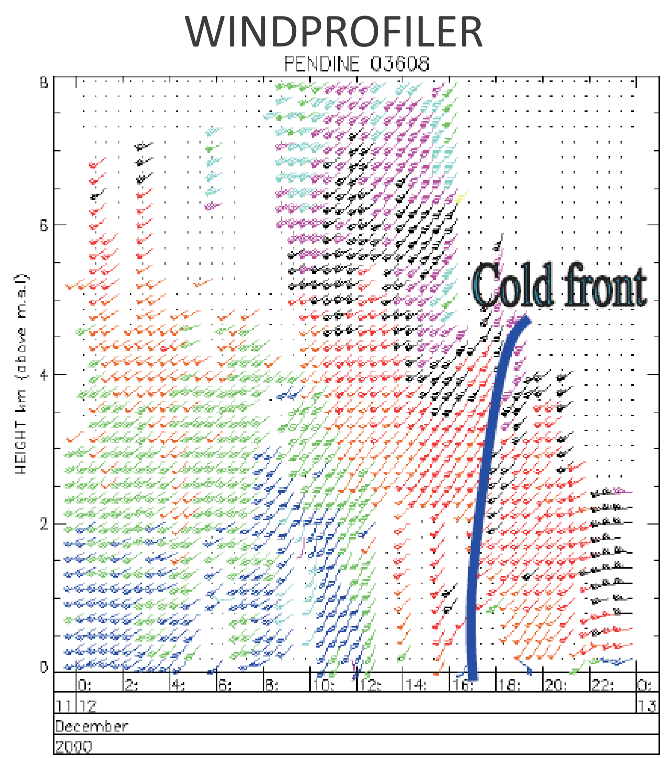

Weather Radar: large diameter of the scan In the middle troposphere may smooth out some of the wind variations

- tend to agree better with larger scale numerical analyses
- **no wind data in dry air**

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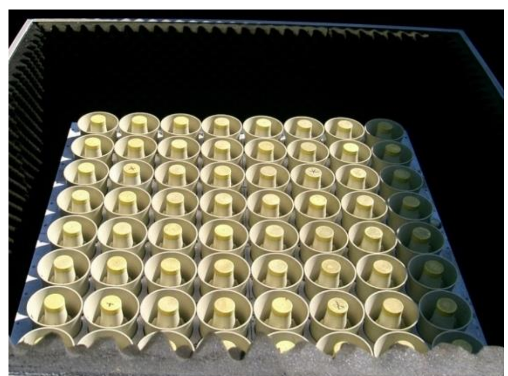
SODAR


Remtech PA0 ©ZAMG


Remtech PA2 ©ZAMG


METEK PCS 2000-64 ©ZAMG

METEK SODAR
source: Angevine and Senff (2015) Encyclopedia of Atmospheric Sciences (2nd Edition)


Antenna panel ©ZAMG


METEK PCS 2000-24/LP ©ZAMG

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SODAR

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Acoustic wavelengths 10^{-1} m
Sound frequencies 1 to 3 kHz

Sound speed is sensitive to temperature and (to less extent) to humidity.

Micro-turbulent fluctuations of air temperature and humidity cause spatial/temporal variations of the sound speed → clear-air scattering of acoustic waves.

Sound waves are subject to **significant attenuation**
- strongest absorption **under dry conditions**
- temperature with strongest absorption increases with frequency

	r_{10}			
sound frequency	from	at	to	at
1000 Hz	240 m	5 °C, 10 % rH	1430 m	30 °C, 90 % rH
2000 Hz	104 m	13 °C, 10 % rH	610 m	30 °C, 90 % rH
4000 Hz	45 m	22 °C, 10 % rH	400 m	-10 °C, 10 % rH

Table 7.1.5.1.1: Extreme values of r_{10} and corresponding atmospheric conditions.

Noise sources for SODAR:
- natural noise, e.g. birds, trees/leaves in the wind, man made noise as surface and air traffic
- wind noise
- noise by raindrops hitting microphones or adjacent structures

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Example: average profiles/diurnal courses from SODAR campaigns

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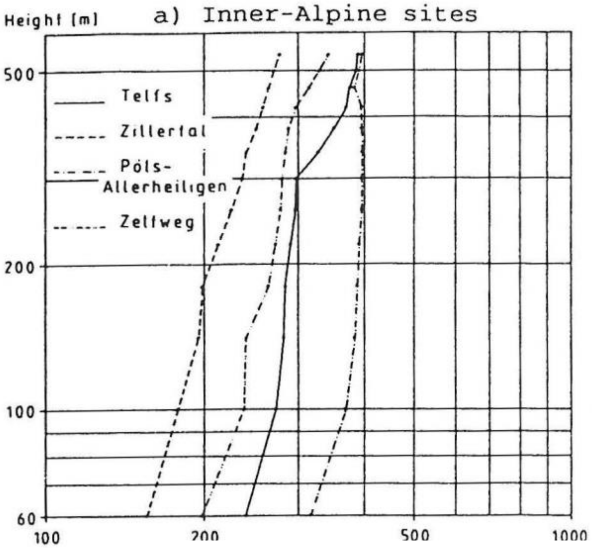
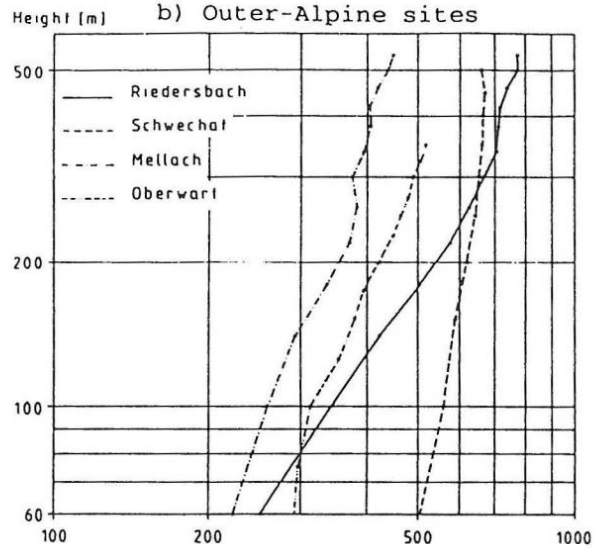
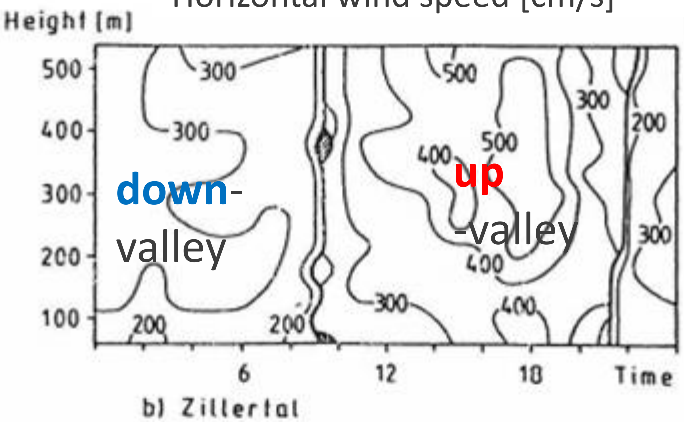
Inner-Alpine sites

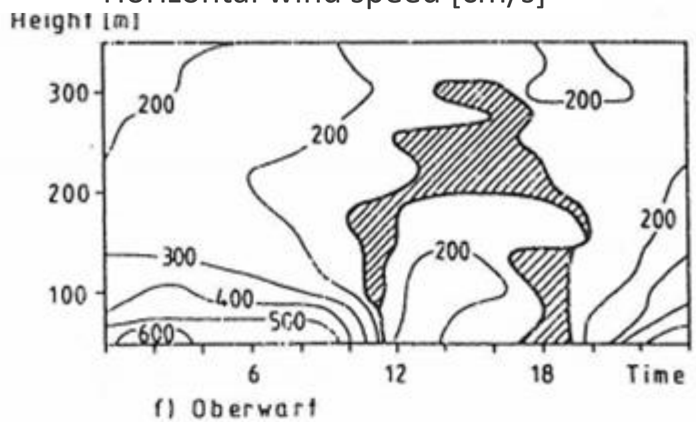


Outer-Alpine sites



Horizontal wind speed [cm/s] Horizontal wind speed [cm/s]





Frequency of along-valley winds [1/10 %] Frequency of along-valley winds [1/10 %]

source: Piringer (1992) WMO: Instruments and Observing Methods, Report Nr. 49

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RASS - Combination of RADAR and SODAR

RASS = **R**adio-**A**coustic **S**ounding **S**ystem

RASS measures the speed of the acoustic wave which is dependent upon temperature.

1290 MHz boundary layer wind profile radar (RASS LAP 3000)

left: acoustic antenna right: electromagnetic antenna at Lindenberg, Germany 1993

source: Neisser and Steinhagen (2005) promet 31, 2-4

METEK PCS 2000-64 with 2 RASS antenna

Sound frequency: 1,5 – 3 kHz

Electromagnetic frequency: 1290 MHz

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RASS at ridge site (wind energy assessment study)

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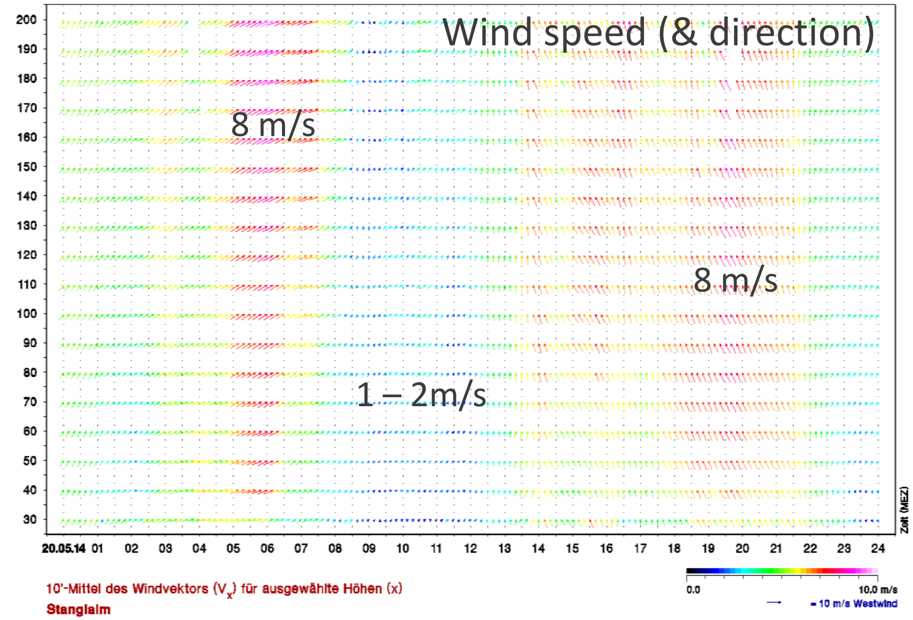
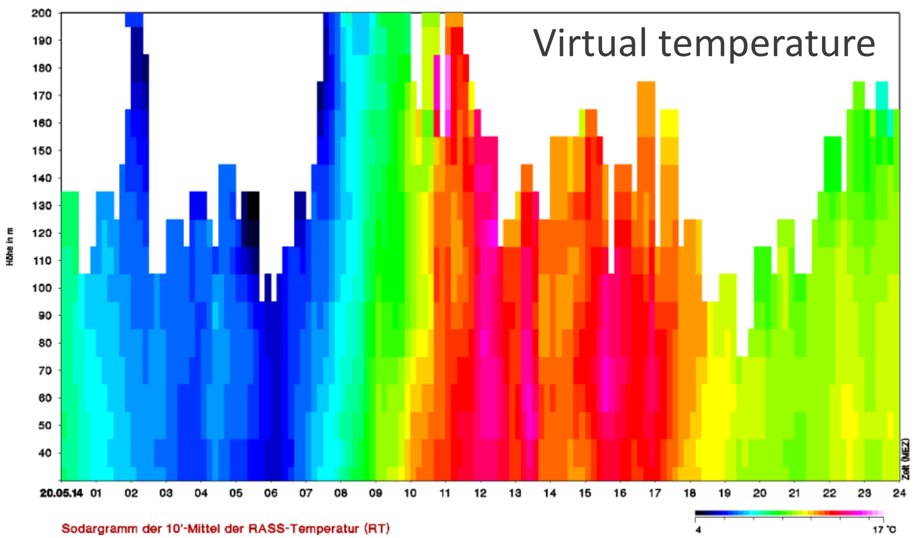
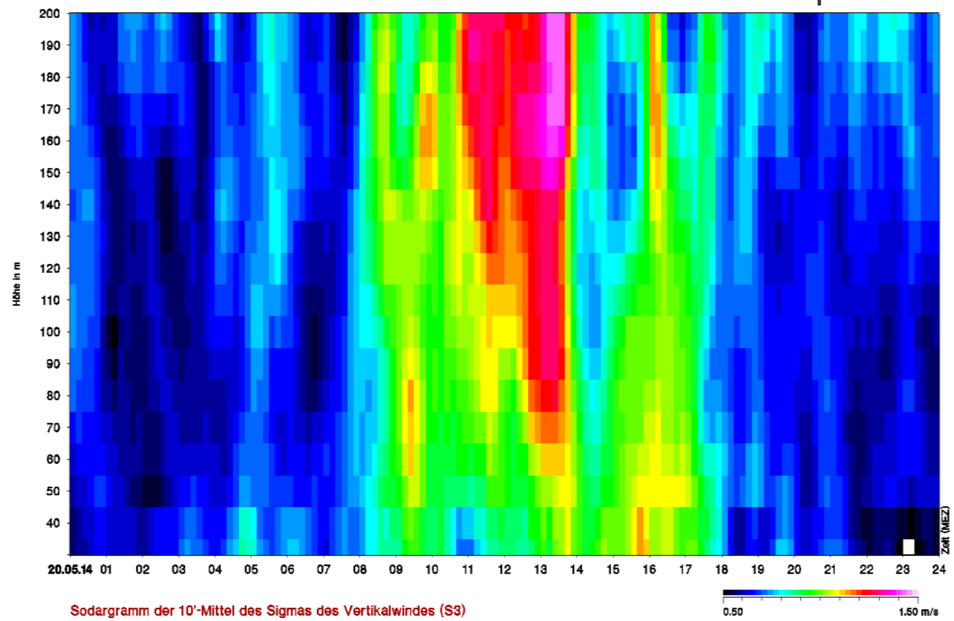
01.03.2022

20th May 2014 at Stanglalm, Austria





Standard deviation of vertical wind component



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RASS at ridge site (wind energy assessment study)

Wind distribution from one year time series at different heights

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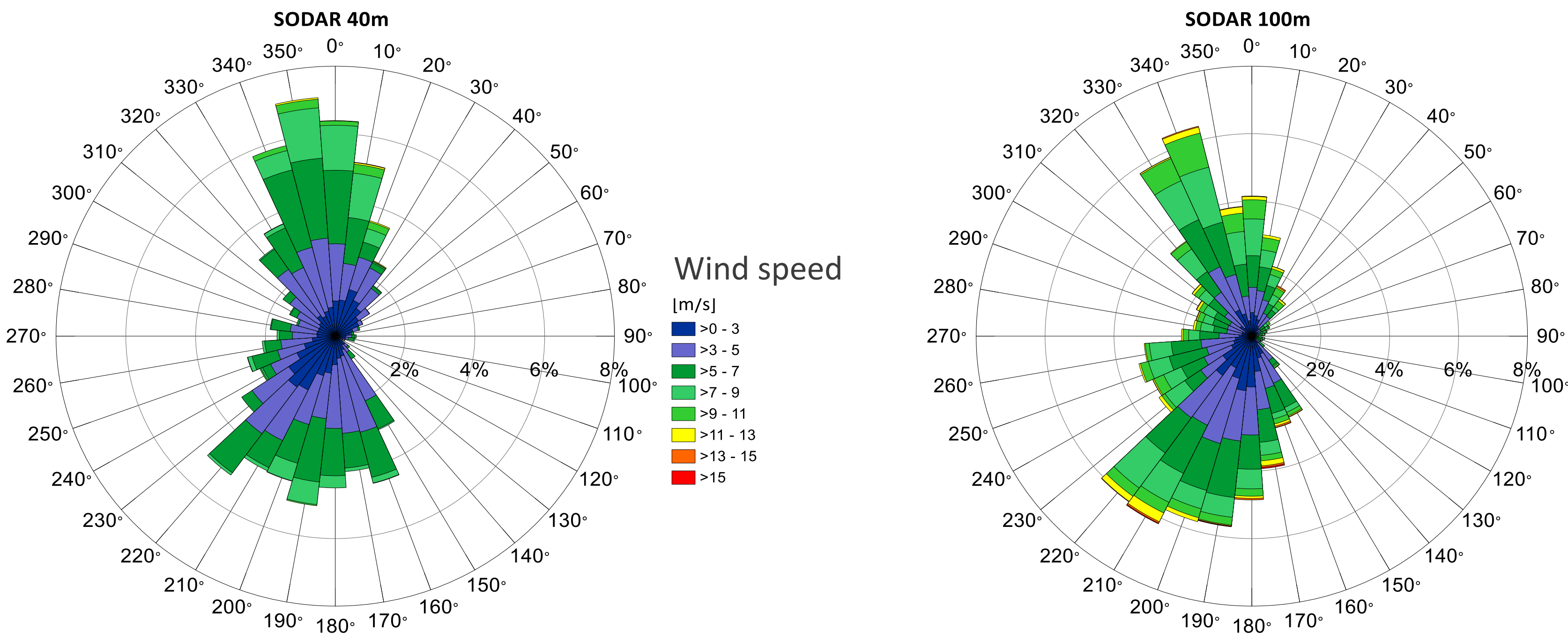

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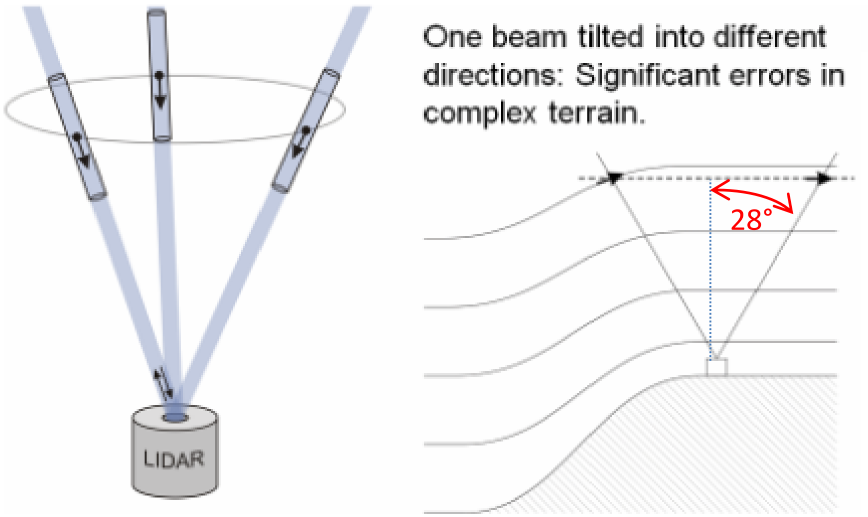
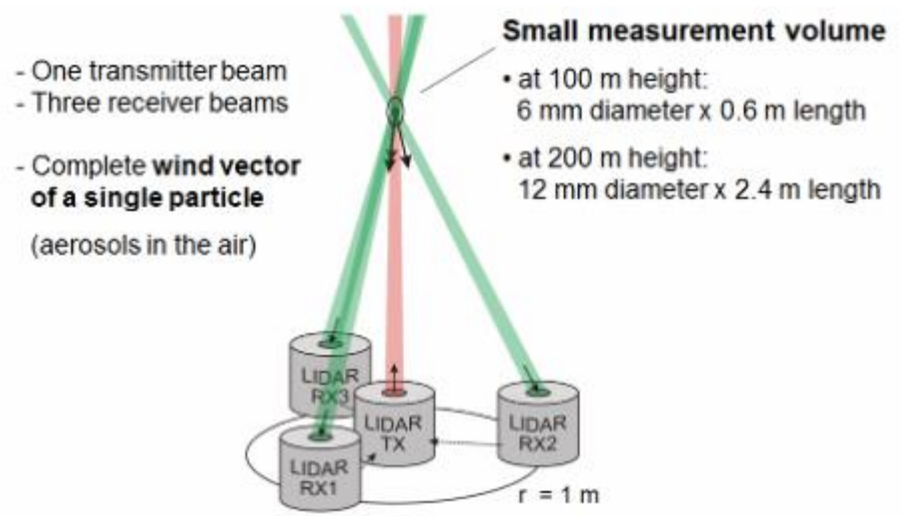
Probing horizontally inhomogeneous wind fields

LIDAR: correction with CFD modelling or special measurement techniques

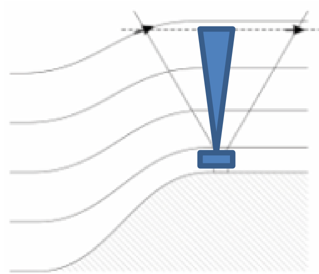
- bistatic
- continuous lidar with telescope lense focusing on selected heights



©www.windguard.de

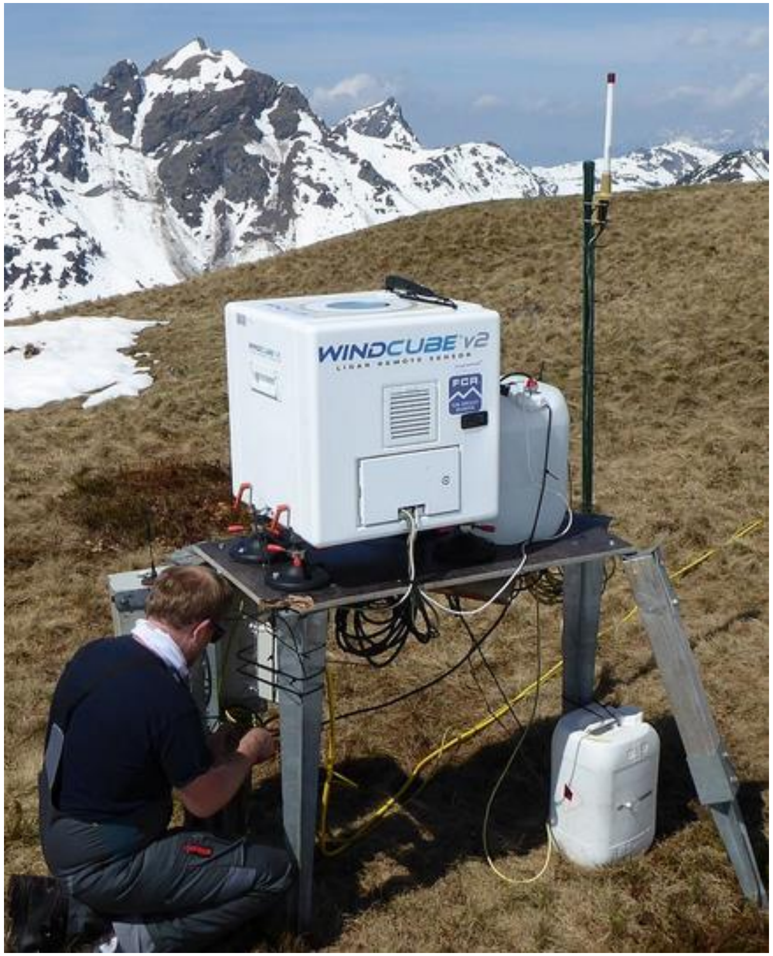


SODAR: angle << LIDARs



WIND LIDAR

Wind Ranger (METEK) near air quality station ©ZAMG



Wind Cube ©Energiewerkstatt V.

Current campaign at Linz, Austria
https://portale.zamg.ac.at/umweltprofile

Example: Ceilometer & LIDAR

https://portale.zamg.ac.at/umweltprofile

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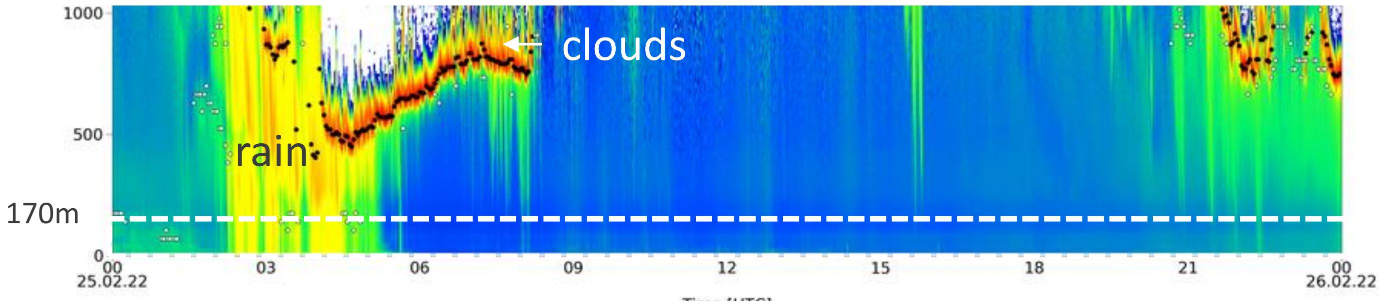
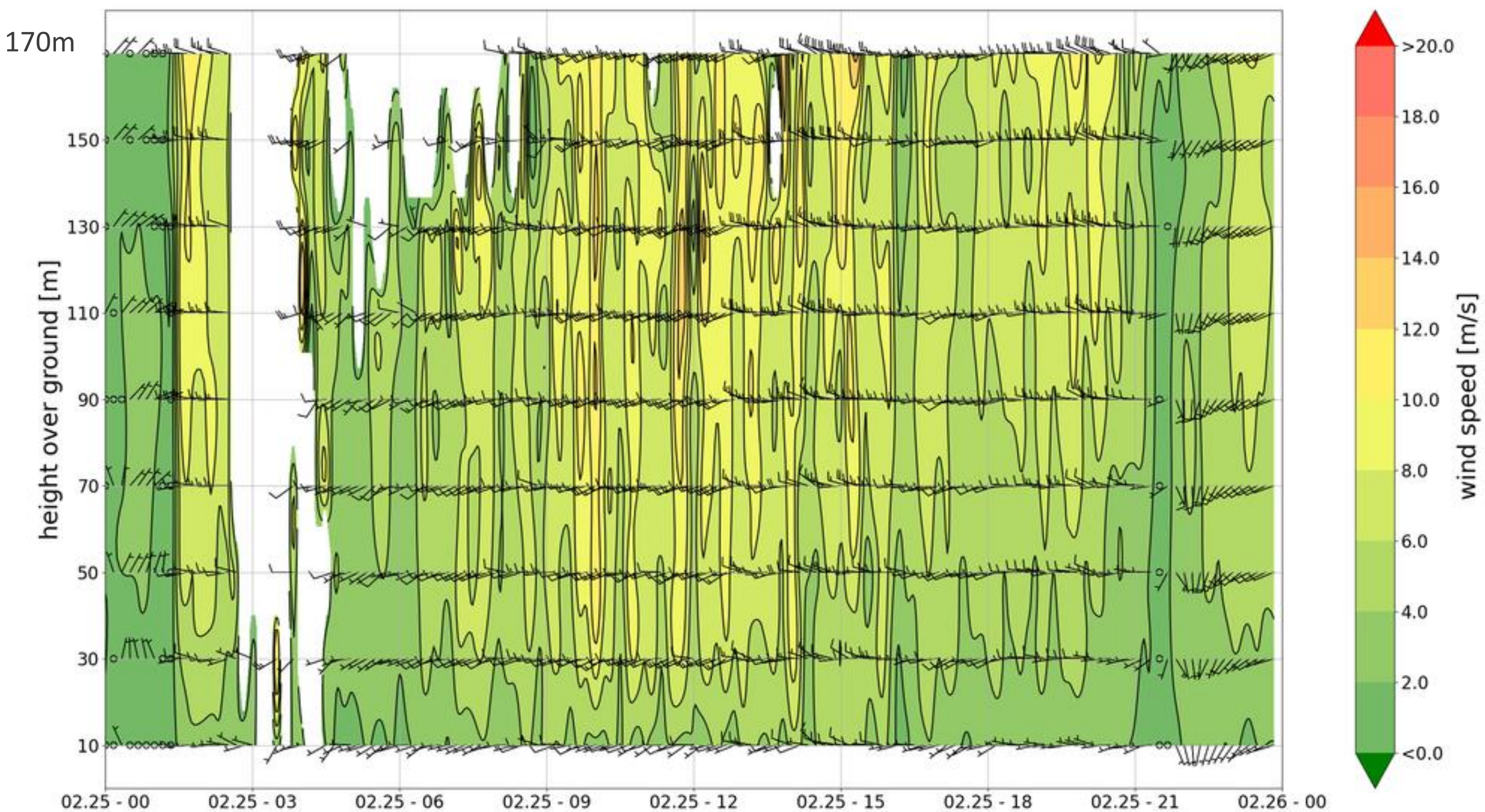


25.2.2022
Linz, Austria



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Example: Ceilometer & LIDAR

https://portale.zamg.ac.at/umweltprofile

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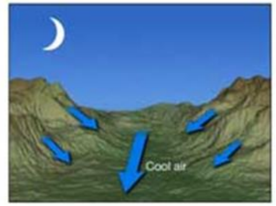
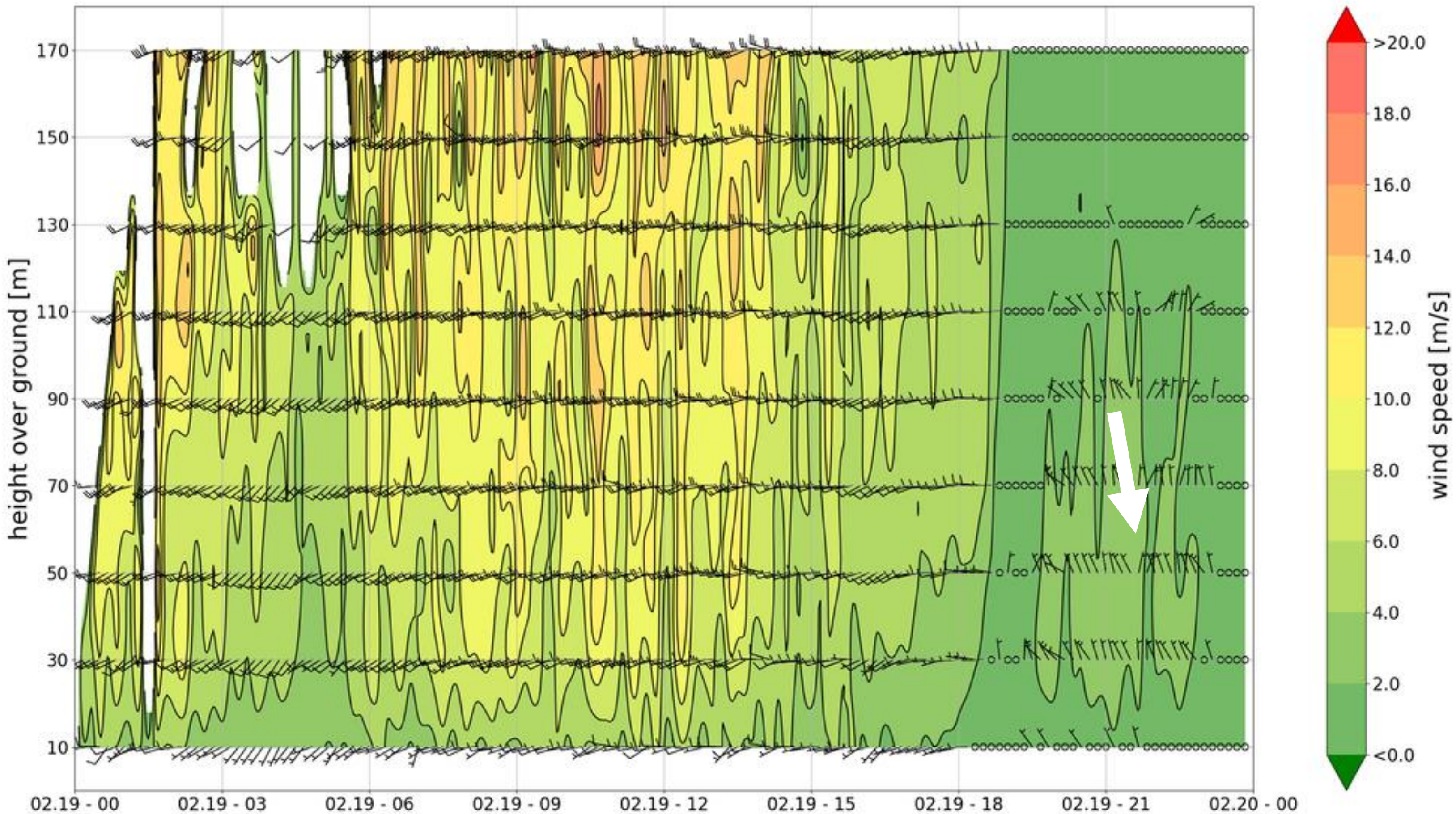


down valley
wind system

19.2.2022
Linz, Austria



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