Introduction

- Wind-energy in complex terrain is of great importance for the energy transition towards renewable energies, because it enables energy harvesting close to the consumer in many regions.
- Perdigão 2017 was a large field campaign jointly organized by international research groups to investigate the flow over two parallel mountain ridges and its interaction with a single Enercon E-82 wind energy converter (WEC) placed on one of the ridges (see map on the right).
- The DLR took part with three Leosphere Windcube 200S long-range lidar instruments, one RPG HATPRO-5G microwave radiometer (MWR) and acoustic sensors (microphones) to measure sound propagation of the WEC.

Coplanar RHI wake scans

- Lidar #1 and lidar #2 were both configured to measure vertical (RHI) scans at 237° azimuth, perpendicular to the ridge and towards the WEC.
- Typical RHI parameters for lidar #1 and #2 are:
  - Physical resolution: 25 m (100 ns pulse length, 64 point FFT)
  - Range gate separation: 10 m
  - Angular resolution: 0.5°
  - Accumulation time: 500 ms
  - Duration of one RHI: 1-2 minutes

- Horizontal and vertical wind of the flow in and over the valley can be calculated from the dual-Doppler radial wind speed measurements \( v_r \) by solving the geometric equation for the meteorological wind vector \( u \) and \( w \), where \( u \) is the horizontal wind in the scanning plane, and cross-winds are assumed to be small.

- From the coplanar scans of the wake, its propagation path in different atmospheric conditions can be studied (see Figures on the left).

- The wake center was tracked by fitting a superimposed Gaussian and logarithmic function to vertical profiles \( v(z) \) of wind speed downstream the WEC.

Adaptive multi-Doppler measurement

- Coplanar scans are only useful if the wind direction is aligned with the scanning plane.
- Placing multi-Doppler measurement points in the wake (see Figure on the right) is always possible, if the wind direction is known and scanning scenarios are adapted accordingly.
- In Perdigão 2017, case studies have been done with wind direction measurements by VAD scans of lidar #3 and real-time data of a sonic anemometer on a meteorological mast close to the turbine.
- Adaptation of scanning scenario was done every 30 minutes.
- The wind speed deficit downstream the WEC can be monitored over the whole measurement period.

- Rapid decay of wind speed deficit probably due to misalignment of the measurement points with the wake.
- Improvements could be achieved by using wind turbine yaw, or a real-time wake center estimation for scanning point control.

Conclusion

- Multiple long-range lidar systems are a powerful tool to measure wake dynamics.
- Adaptive scenarios can increase the availability of ground-based wake measurements significantly, but need good input data.
- Best scanning strategies depend on the scientific goal, the site and the experimental setup. Multi-Doppler measurements with the WindScanner software add significant benefit and a multitude of possibilities to full-scale field experiments in wind-energy research.