WIND POWER | WEATHER & CLIMATE | AVIATION WEATHER | AIR QUALITY & INDUSTRIAL RISK

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Observing on the microscale the urban wind field impacting UAVs using Scanning Doppler Lidar

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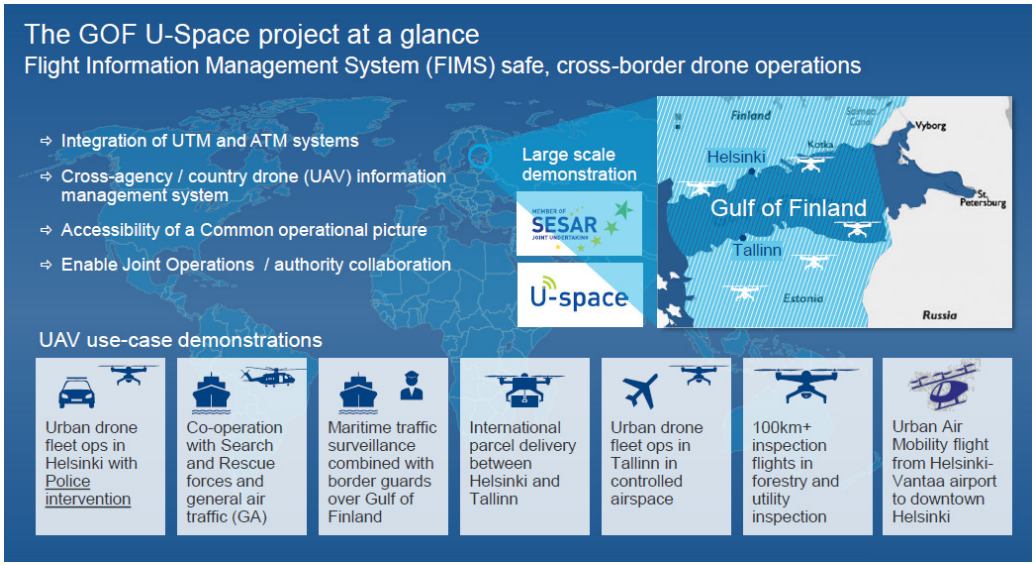
Gulf of Finland (GOF) UAV demonstration project

- Multiple UAV operators demonstrate simultaneous UAV operations in shared urban Airspace
- Need: real time measurement-based micro-scale weather data
- Providing support in form of weather information
- Scanning wind lidar (WLS 400S) was deployed to provide high-resolution wind information
- Radial wind speed data is readily available

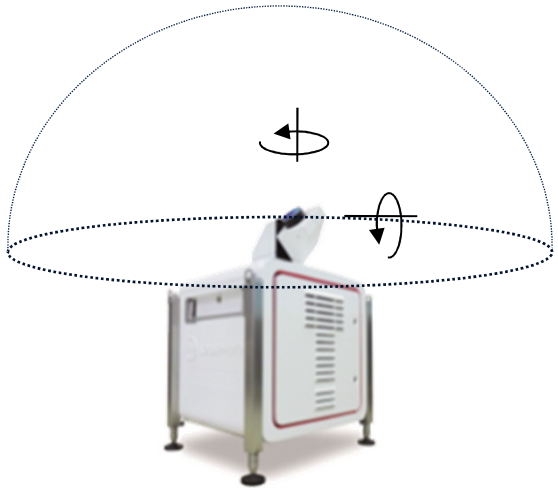


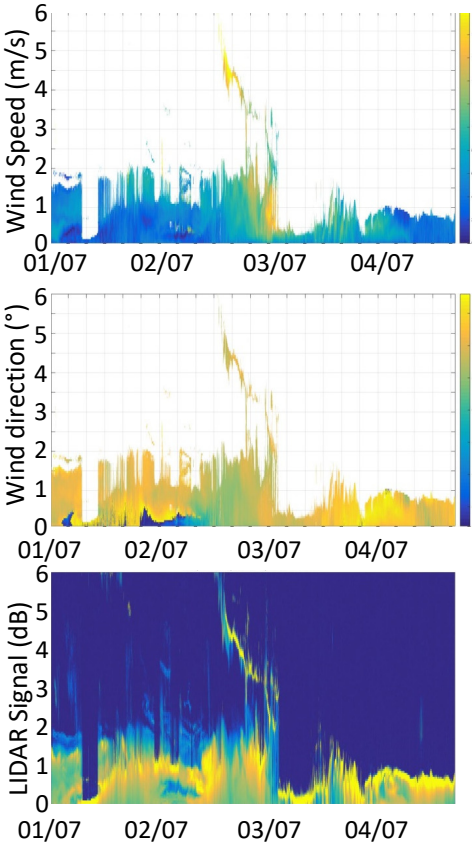
- New development: Volume Wind – a dense grid of wind information in a box of 12 x 12 x 0.3 km

Scanning WindCube capabilities

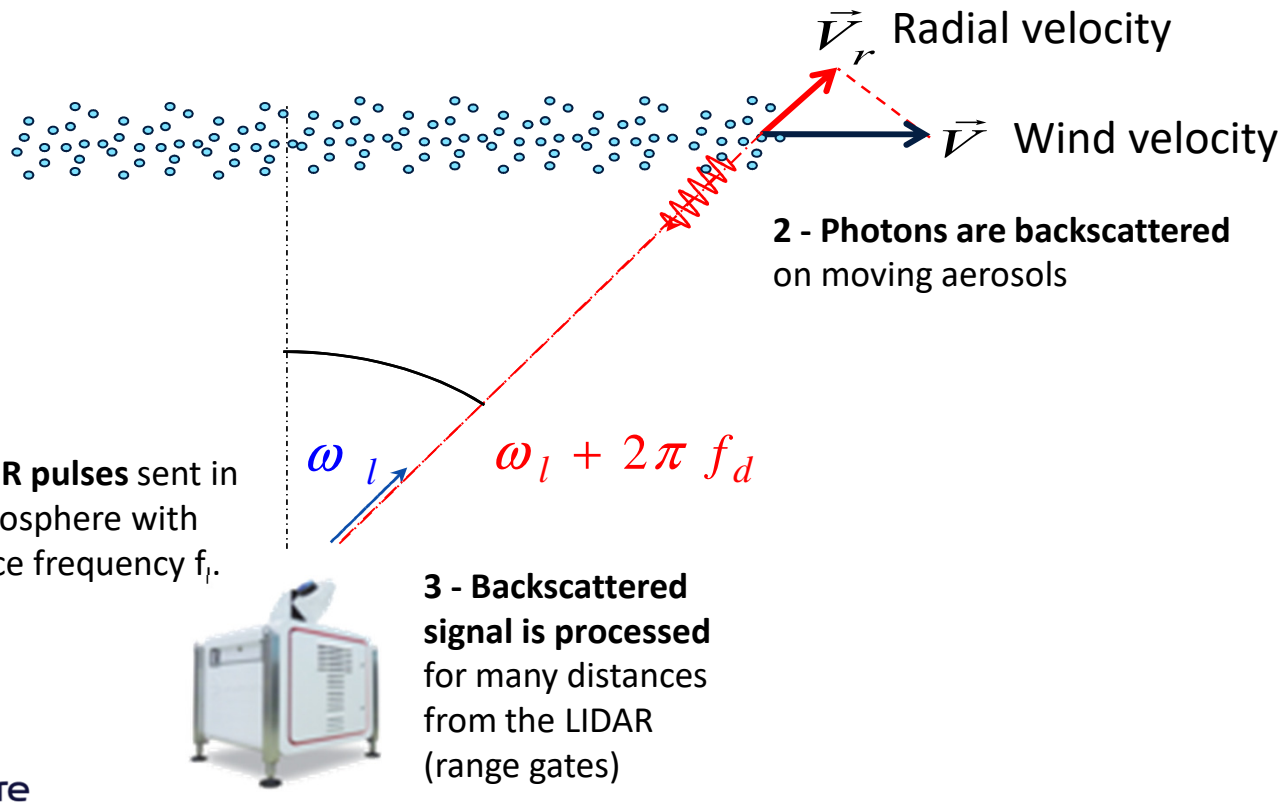
- Measures wind and aerosols/clouds with a resolution from 25m to 200m under clear air conditions

- Many different scenarios available: PPI / RHI / DBS

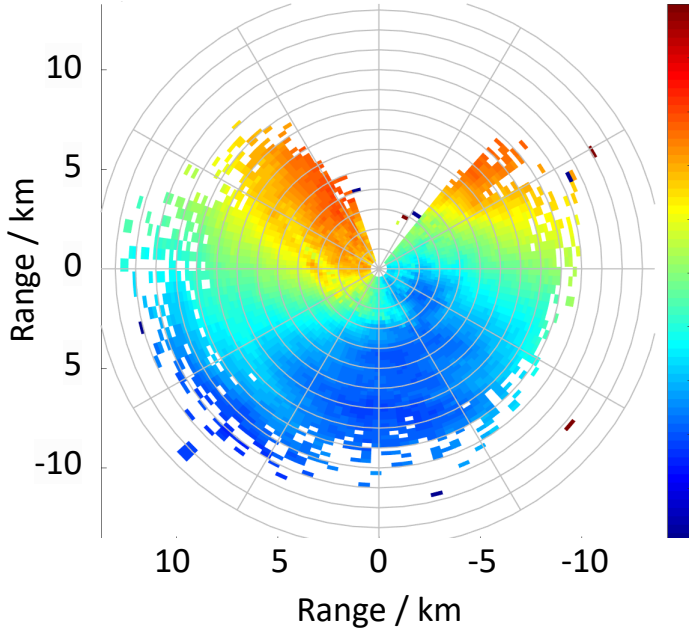




Methodology: Radial velocity

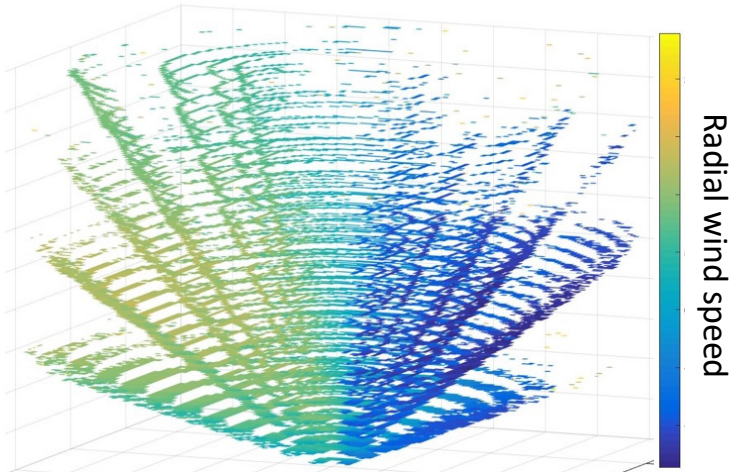


Volume Wind: Radial wind speed



Full conical scans at 19 different elevation angles

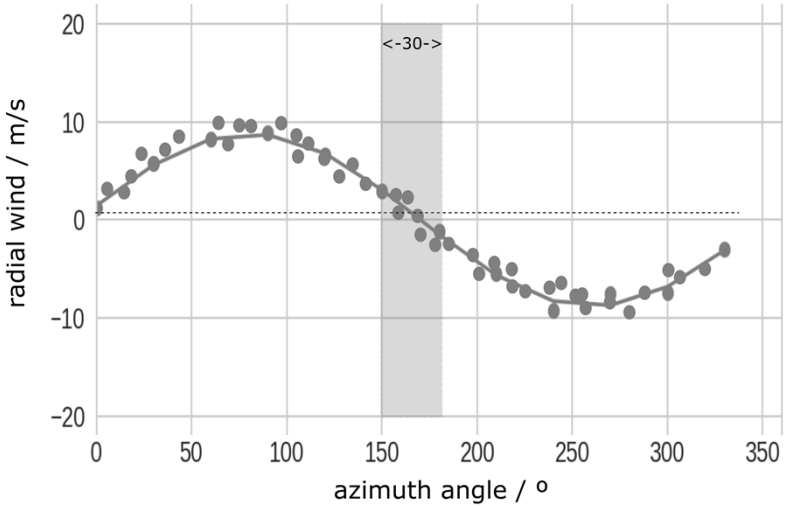
(7 shown for illustration purpose)



Volume Wind: Reconstructing the 3D wind vector

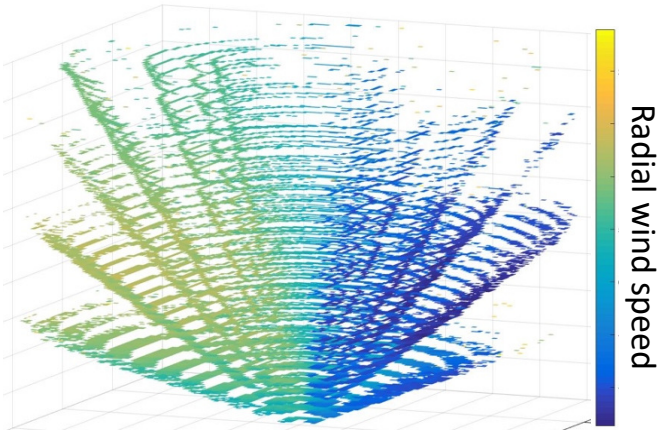
- Basic reconstruction

$$v_R = v_x \cos(\beta)\cos(\alpha) + v_y \sin(\beta)\cos(\alpha) + v_z \sin(\alpha)$$

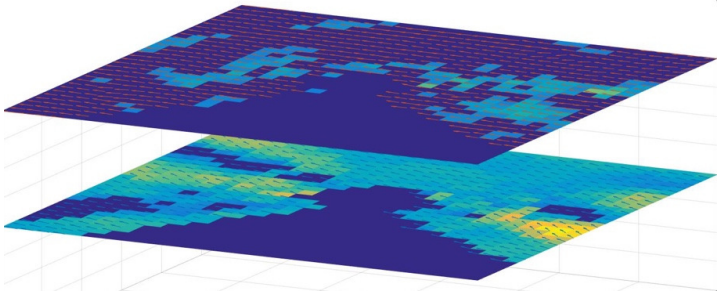


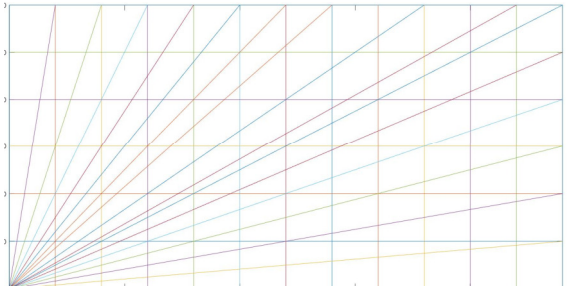
- With elevation angle α, and azimuth angle β
- 30 degree section of horizontal scan for each voxel

Volume Wind: Reconstructing the 3D wind vector



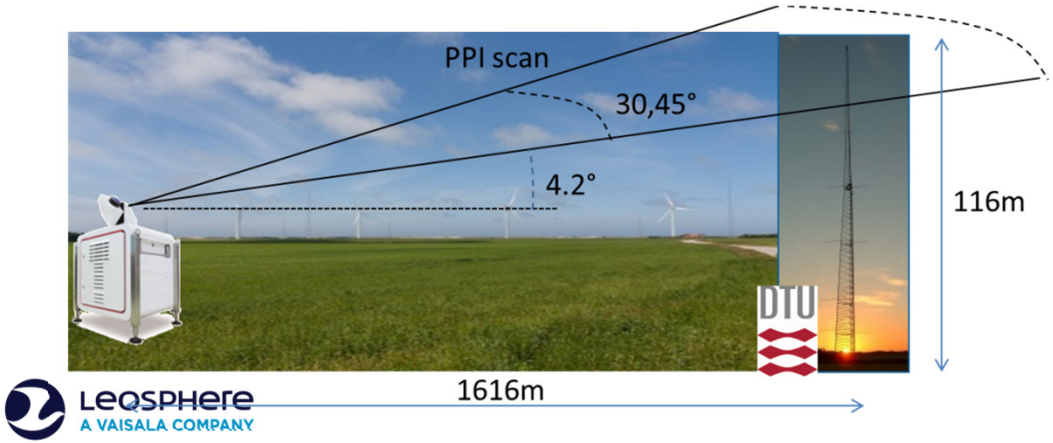
Reconstruction
with grid resolution
of 200x200x50 m

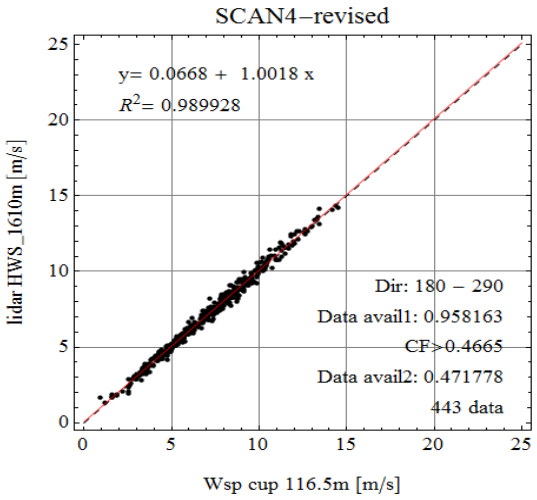




Reconstruction quality

- Scan scenario is tradeoff between accurate wind speed and direction retrieval vs temporal resolution
- Best current scanning scenario (45° sector scan at 3°/sec)
- Retrieval accuracy assessed with DTU Wind Energy at Hovsore Test Facility





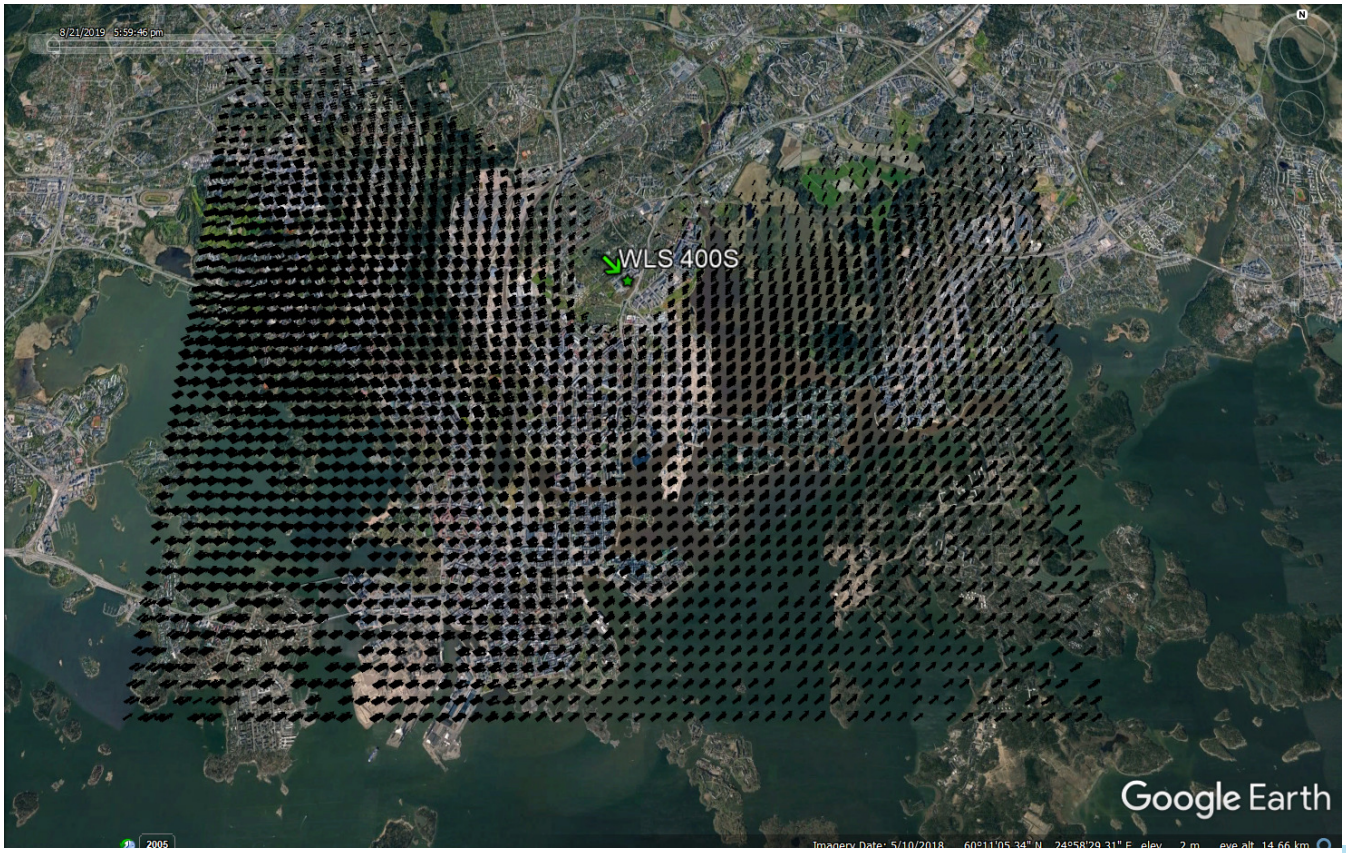
Bias and precision on retrieved horizontal wind speeds about 0.2 m/s and 0.5 m/s, respectively

Campaign: Helsinki, Finland

- Windcube 400S
- Located on roof of FMI building
- Duration: July and August 2019

Campaign: Helsinki, Finland

- Horizontal extend of 12 by 12 km
- Horizontal resolution of 200 by 200 m
- Radial wind speed of full horizontal grid



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Campaign: Helsinki, Finland

- Vertical extend from 50 to 300 m
- Vertical resolution of 50 m
- Radial wind speed at six levels

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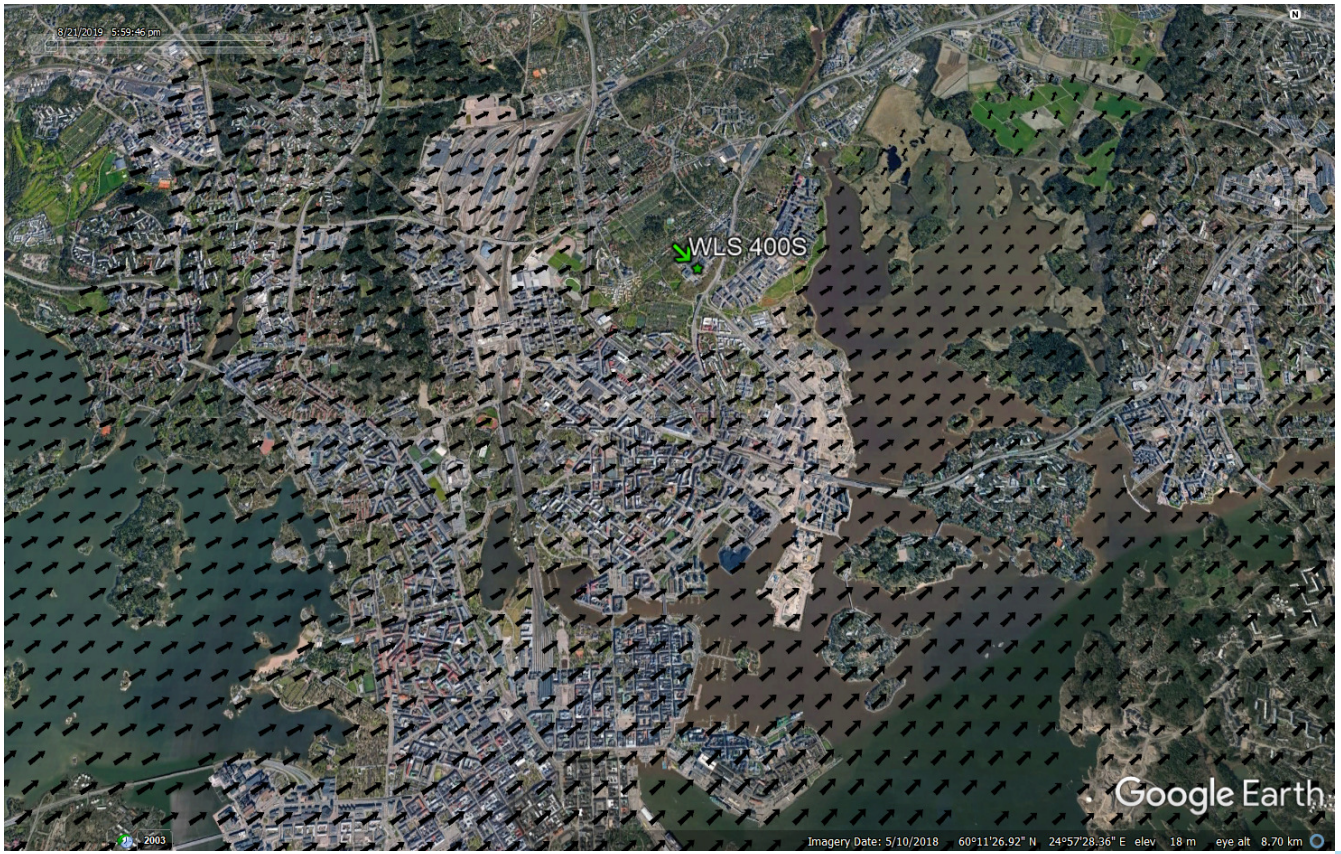
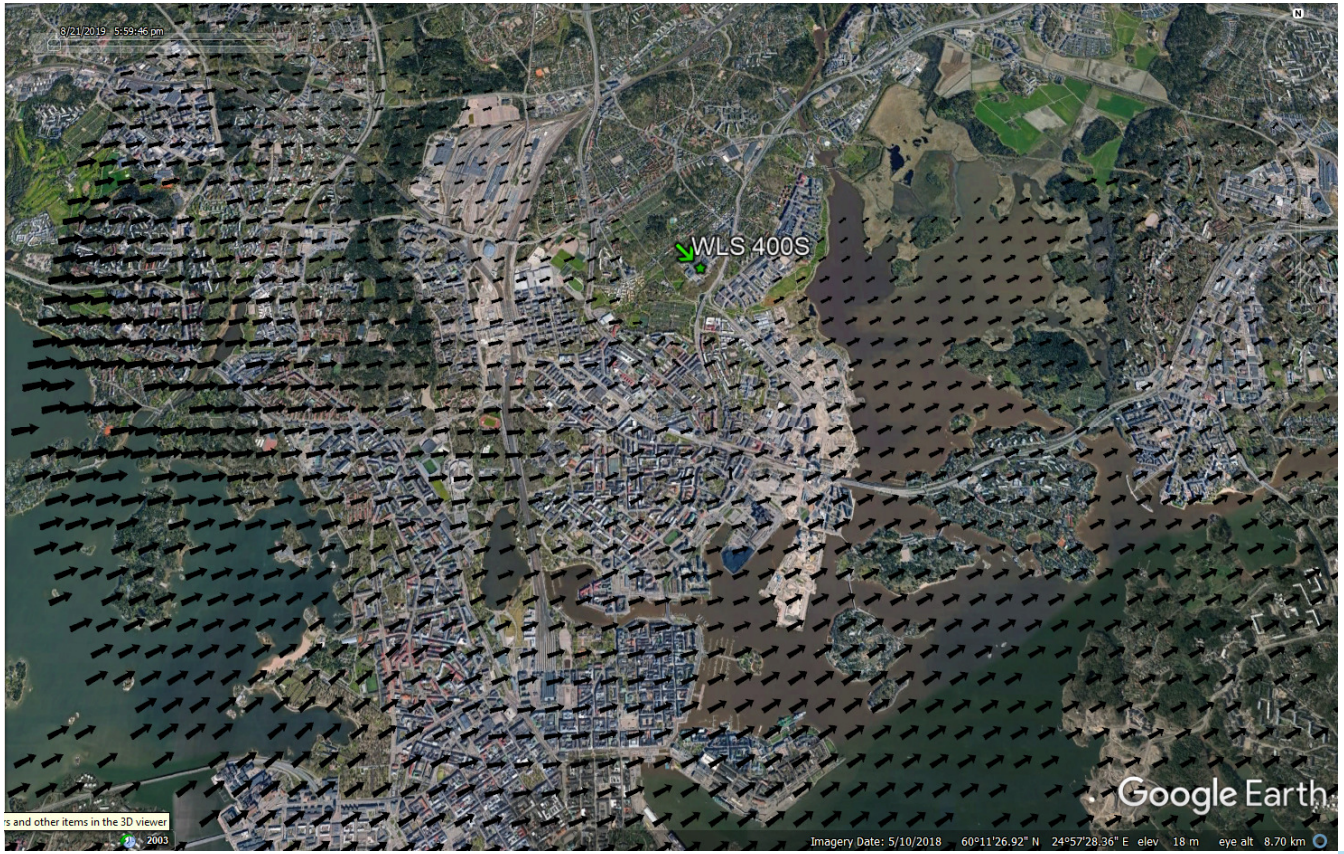
Campaign: Helsinki, Finland

- Radial wind speed at 250 m above lidar level
- General wind direction SW



Campaign: Helsinki, Finland

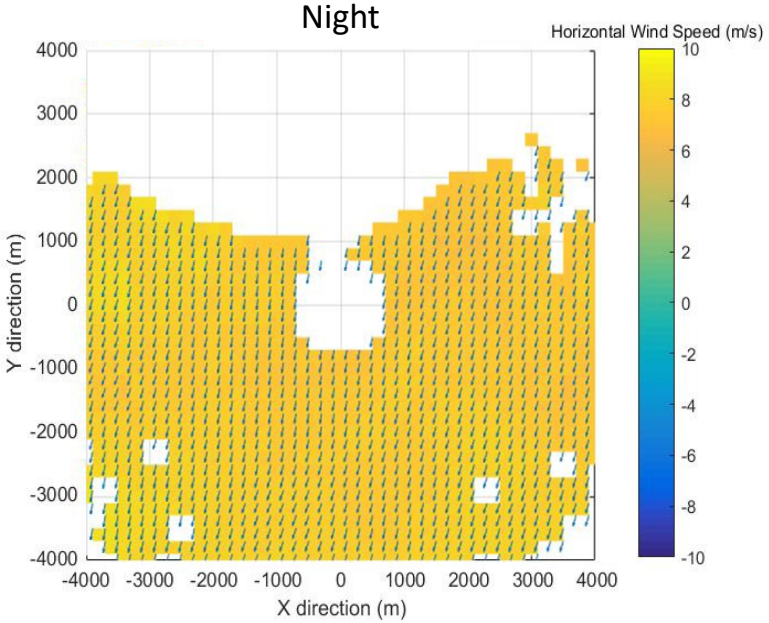
- Radial wind speed at 100 m above lidar level
- Generally lower wind speed
- Higher wind speed at lower altitude W of the city: low level jet
- Wind shear



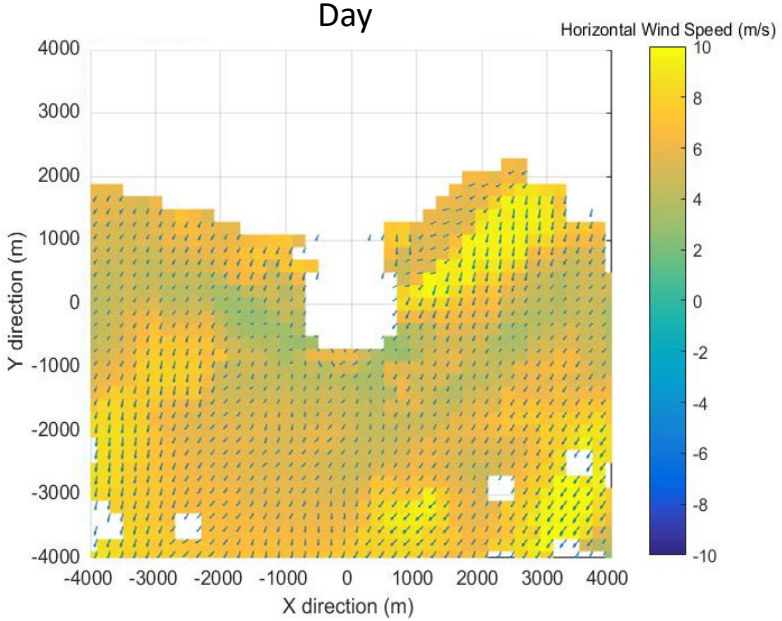
Campaign: Helsinki, Finland

- Horizontal wind speed at altitude 200 m, example day in August 2019

Night

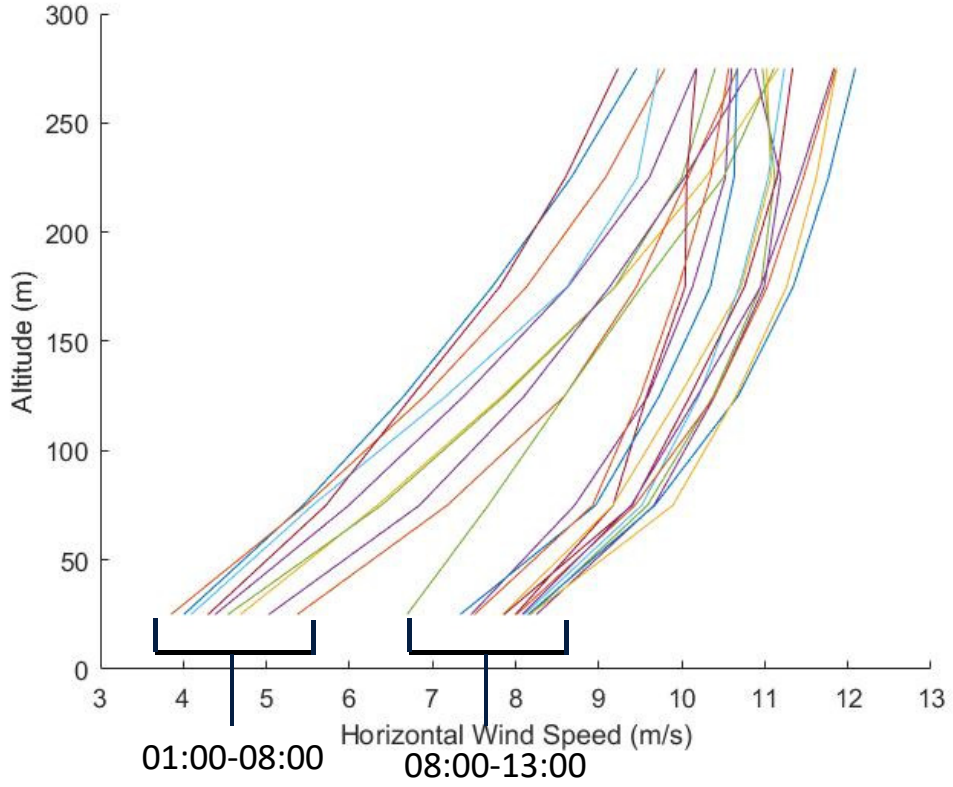


Day



Campaign: Helsinki, Finland

- Horizontal wind speed profiles, example day in August 2019
- Two regimes observed:
  - 01:00-08:00 LT: steep gradient
  - 08:00-13:00 LT: moderate gradient/inversion
- Higher turbulence could be accelerating vertical energy transfer during daytime.



Conclusions and outlook

- UAV Traffic Management requires highly resolved and precise meteorological observations especially wind
- Coherent Doppler Lidars based on fiber technology ensure reliability and cost effectiveness
- GOF U-SPACE trial shows the capability of scanning WindCube to provide relevant wind data for UTM flights with a resolution of 200 m over Helsinki city (area 12 km x 12 km)
- Data were transferred to UTM test operators
- Preliminary analysis showed local heterogeneities of the wind over the city both in horizontal and vertical directions
- More and more projects are on-going worldwide to develop LIDAR-based micro-weather observation systems including wind and turbulence data
- For some projects, Dual-Doppler solution used to maximize accuracy