Volume Wind: from radial wind speed to 2D wind using a single Doppler Wind Lidar

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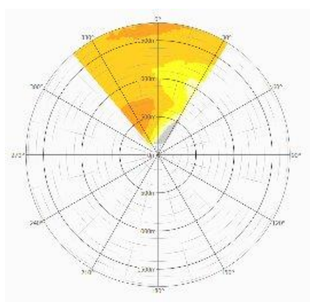
Wind Field Reconstruction

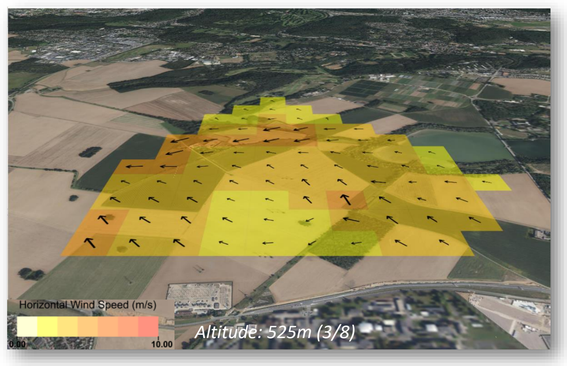
Doppler Wind Lidars measure the wind speed in the direction of the lidar beam: the **radial wind speed**.

For many applications, it is desirable to have access to the wind speed & direction: UAV operations, event detection, comparison with numerical models, calculations of the mass flux of particles ...

Wind Field Reconstruction is already used in DBS & VAD mode, which require specific scan patterns.

Volume Wind generalizes Wind Field Reconstruction for PPI & Volume Scans, allowing the mapping of the wind field across large distances.





Velocity Volume Processing

The **2D wind** is reconstructed from the Radial Wind Speed at several azimuths. An azimuthal sector between 30° and 60° is recommended.

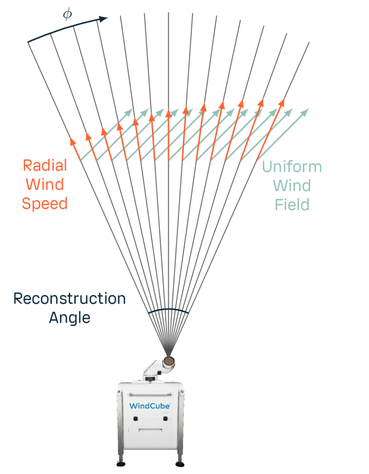
Two assumptions are made:

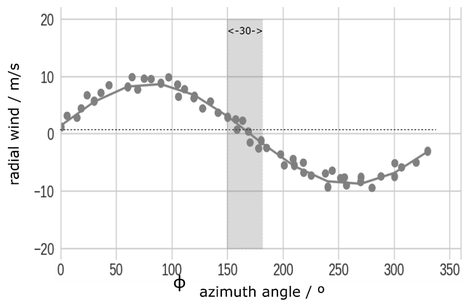
- **negligible vertical wind**,
- **homogeneous** wind in time & space within the azimuthal sector.

$$V_r = U\cos(\theta)\sin(\phi) + V\cos(\theta)\sin(\phi)$$

$$\begin{pmatrix} \sum \sin^2(\phi) & \sum \cos(\phi)\sin(\phi) \\ \sum \cos(\phi)\sin(\phi) & \sum \cos^2(\phi) \end{pmatrix} \begin{pmatrix} U \\ V \end{pmatrix} = \begin{pmatrix} \sum V_r \sin(\theta) \\ \sum V_r \cos(\theta) \end{pmatrix}$$

Solving this equation yields U & V, the two horizontal components of the wind. The **Horizontal Wind Speed** & **Wind direction** can then be computed.





Algorithm validation

An experimental campaign was performed in a DNVGL site with **flat terrain**. A WindCube Scan 400S was put 1.9km from a reference mast.

PPI scans are performed every 20s so that the beam intersects the mast at the location of a reference cup anemometer & wind vane. An azimuthal sector of **45°** was used for the reconstruction.

In each 10-minutes period, **26 scans** are performed. The accuracy of the reconstructed wind field is examined versus the measurement of wind speed and wind direction from the anemometer.

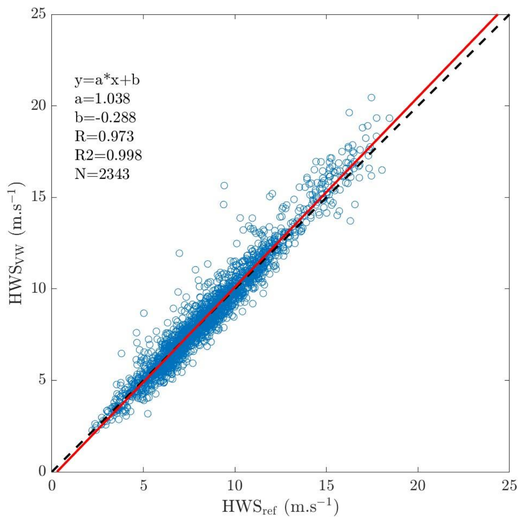
Data was acquired between Oct-01 2020 and Nov-03 2020, for a total of **4696 10-minutes** period.

Type	Azi (°)	Ele (°)	Range gate length (m)	Acc. Time (s)
PPI	240 - 300	2.82	100	1

Data is filtered using standard QC filters for the WindCube Scan. Then, data with low wind speed (<2 m/s) and from wind sectors where the wake of obstacles might be present is removed.

A total of **2343 10-minutes averages** are compared to the mast.

The reconstruction algorithm shows **good accuracy** versus the mast for both Horizontal Wind Speed and Wind direction.

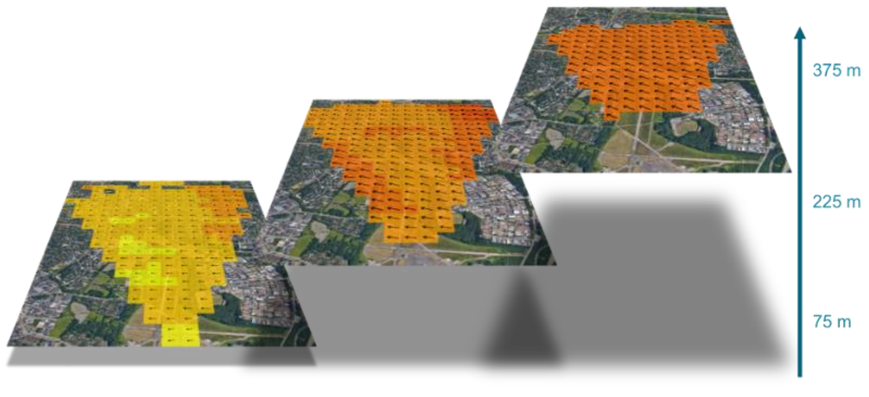


HWS_{VW}-HWS_{ref} (m/s)		$\lvert HWS_{VW}$-$HWS_{ref}\rvert$ (m/s)		Dir_{VW}-Dir_{ref} (°)	
Mean	Std	Mean	Std	Mean	Std
-0.035	0.677	0.467	0.491	-3.94	3.77

Use cases

By performing a series of scans with **different elevation angles**, it is possible to compute the 2D wind for several horizontal slices. The Wind Field is reconstructed, then interpolated on a 3D cartesian grid.

Example: PPI scans at 1°, 6° and 17° are used to map the 2D wind for 3 different altitudes.



Event detection: having access to the 2D wind field makes it easier to detect events in the wind field.

Example: 3° elevation PPI showcasing strong variations in the wind speed and wind direction. This change is easy to identify and quantify when having access to the **2D wind field**.