Two-component vector wind fields by scanning aerosol lidar

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Research Objective: To determine the ability of a quasi-horizontally **scanning eye-safe aerosol lidar** to estimate the **two-component vector wind field** above the reach of traditional meteorological towers.

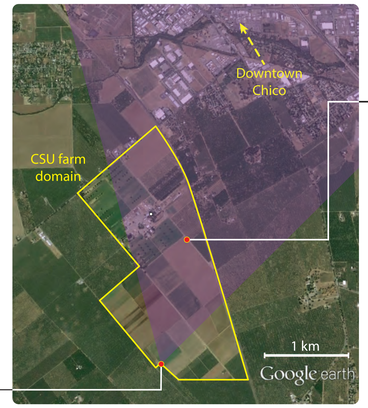
Phase 1: Temporal Validation

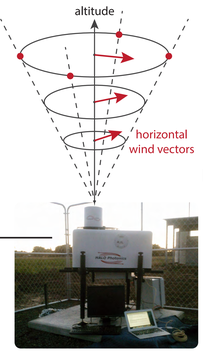
July 1, 2013 to November 25, 2013

During this phase of the experiment, **the Doppler lidar was located 1.52 km from the REAL** in order to provide a time-series of horizontal wind vectors for one point in the REAL scan area (purple shaded region at right). This data enables us to **compare the temporal evolution of the wind at a single point in space**.

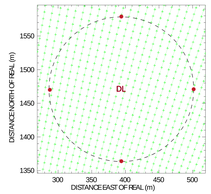
The **REAL** is an analog direct-detection elastic **backscatter lidar** at 1.54 µm. It has no Doppler capability. **Wind fields** are determined by application of **motion estimation** algorithms to aerosol backscatter images available every 17 s.

first generation — second generation



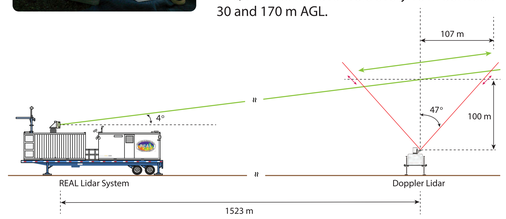


Top-down view of lidar samples at 100 m AGL above the Doppler lidar:
green + REAL backscatter
red ● Doppler pulse volume



HALO Phototonics Streamline (UK)
Doppler lidar for validation

The heterodyne Doppler lidar also operates at 1.5 µm wavelength.
From this location, the Doppler lidar observed **vertical profiles of horizontal wind vectors** by using a Doppler beam swinging technique. Horizontal wind profiles were updated every 17 s, with vectors available every 10 m between 30 and 170 m AGL.

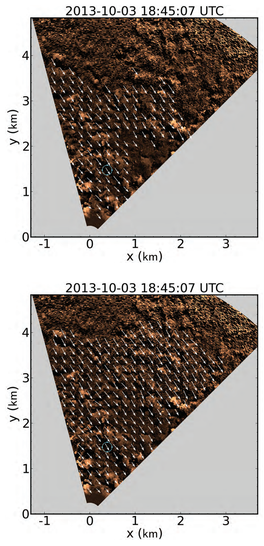


2 motion estimation algorithms

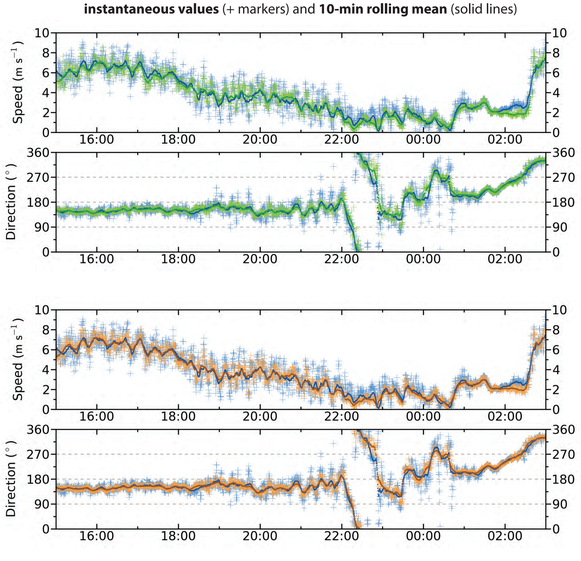
Cross Correlations

Wavelet-based Optical Flow

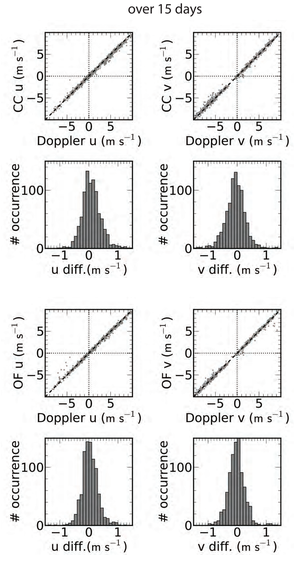
Example of **aerosol backscatter** and **estimated wind field**



Example of **time-series of wind speed and direction at 100 m AGL**, Doppler (blue), cross-correlations (green), optical flow (orange), **instantaneous values** (+ markers) and **10-min rolling mean** (solid lines)



Scatter plot and differences for the **10-min means** over 15 days



Statistics computed from the **10-min means w.r.t. Doppler reference values** for components u, v over 15 days during Phase 1

u	R^2	lin. reg. slope	lin. reg. offset (m/s)	Nb. points	% recovery
Cross-correl.	0.993	0.974	-0.050	891	99.0
Optic flow	0.993	0.980	0.007	892	99.1

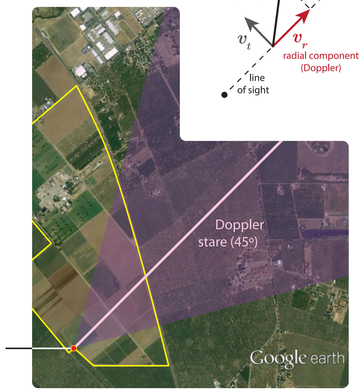
v	R^2	lin. reg. slope	lin. reg. offset (m/s)	Nb. points	% recovery
Cross-correl.	0.995	0.992	0.061	891	99.0
Optic flow	0.996	0.995	0.010	892	99.1

Phase 2: Spatial Validation

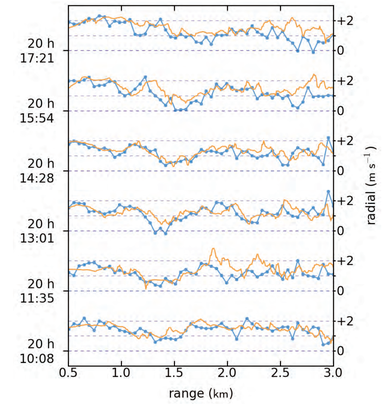
November 26, 2013 to January 15, 2014

During this phase of the experiment, the **Doppler lidar was installed on the roof of the REAL** container and operated in a **staring mode, horizontally,** at 45° azimuth. As such, it measured the **radial component of wind velocity only**.

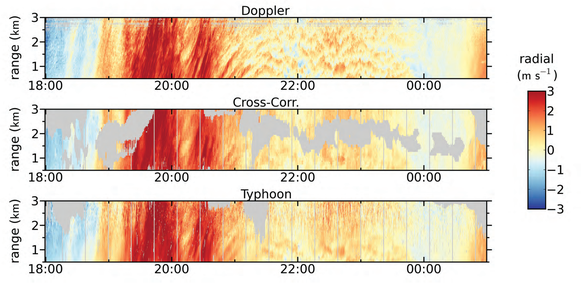
The corresponding radial component is derived from the 2-component wind fields estimated by the REAL for validation. This is the first time such a comparison is attempted.



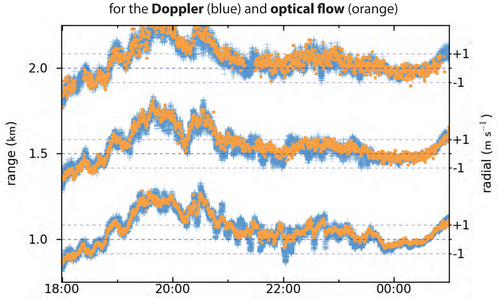
Radial velocity along the range
at different times
for the **Doppler** (blue) and **optical flow** (orange)



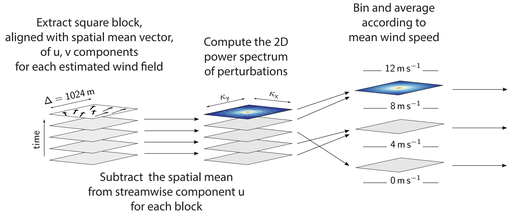
Series of radial velocity
as a function of time (horizontal) and range (vertical axis)



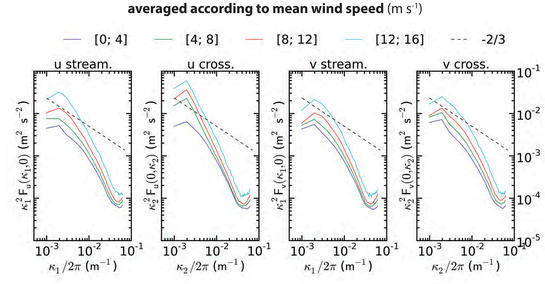
Time-series of radial velocity at different ranges
for the **Doppler** (blue) and **optical flow** (orange)



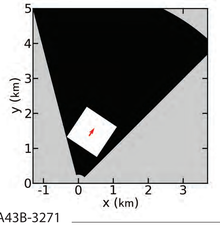
Spatial Power Spectra



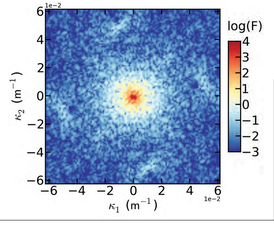
Slices of the 2d spectra
in k_2=0 (streamwise) and k_1=0 (crosswise)
for components u (streamwise) and v (crosswise)
averaged according to mean wind speed (m s⁻¹)



Location of the ~1x1 km block
(128x128 pixels at 8m/pixel)
rotating aroung (382, 1474) m



Example of **2D power spectrum** of spatial perturbations



A total of 30 092 wind fields were used, of which 36%, 34%, 28% and 2% contribute to each of the above wind speed bins, respectively.

References

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