Two-component vector wind fields by scanning aerosol lidar

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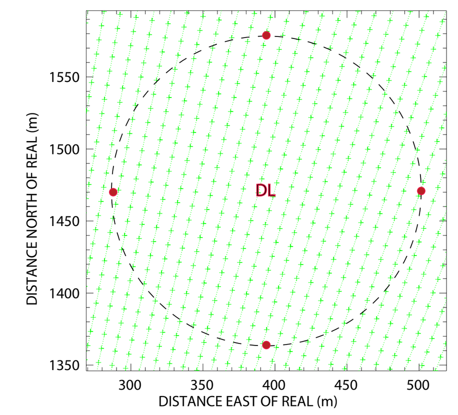
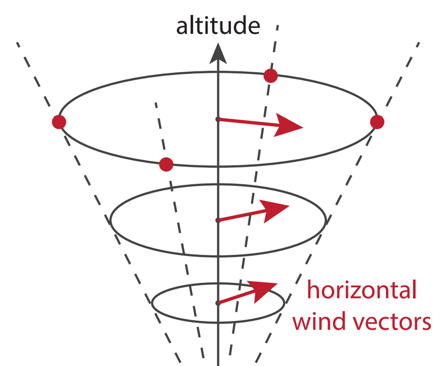
Research Objective: To determine the ability of a quasi-horizontally **scanning eye-safe aerosol lidar** to estimate the **two-component vector wind field** above the reach of traditional meteorological towers.

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





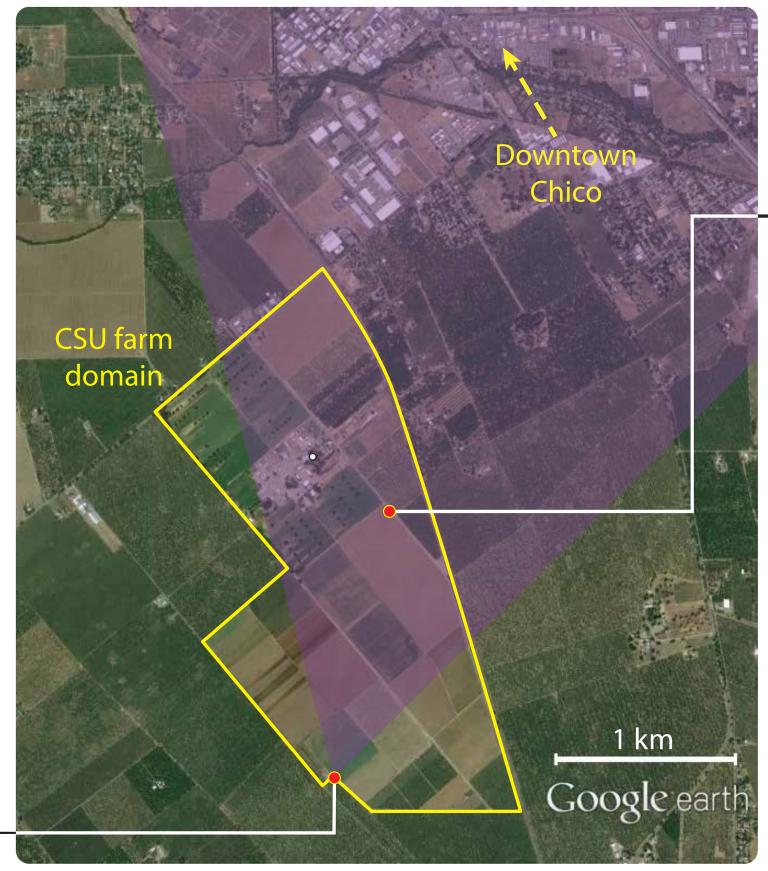
Phase 1: Temporal Validation

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.

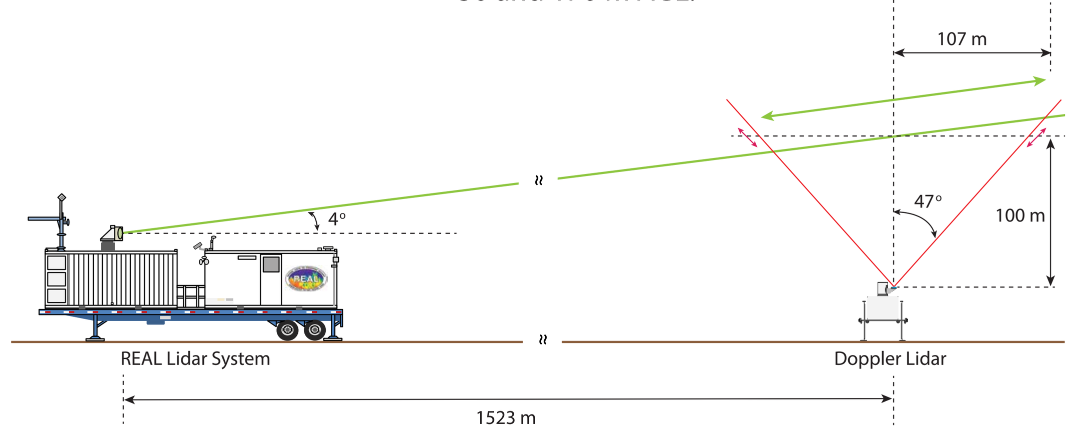
first generation second generation



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.

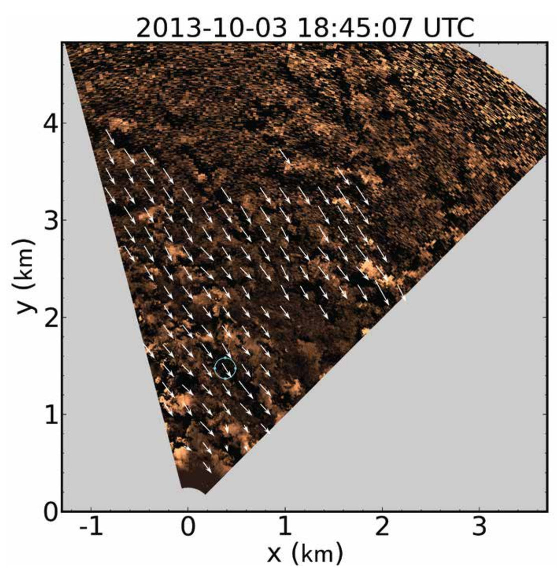


2 motion estimation algorithms

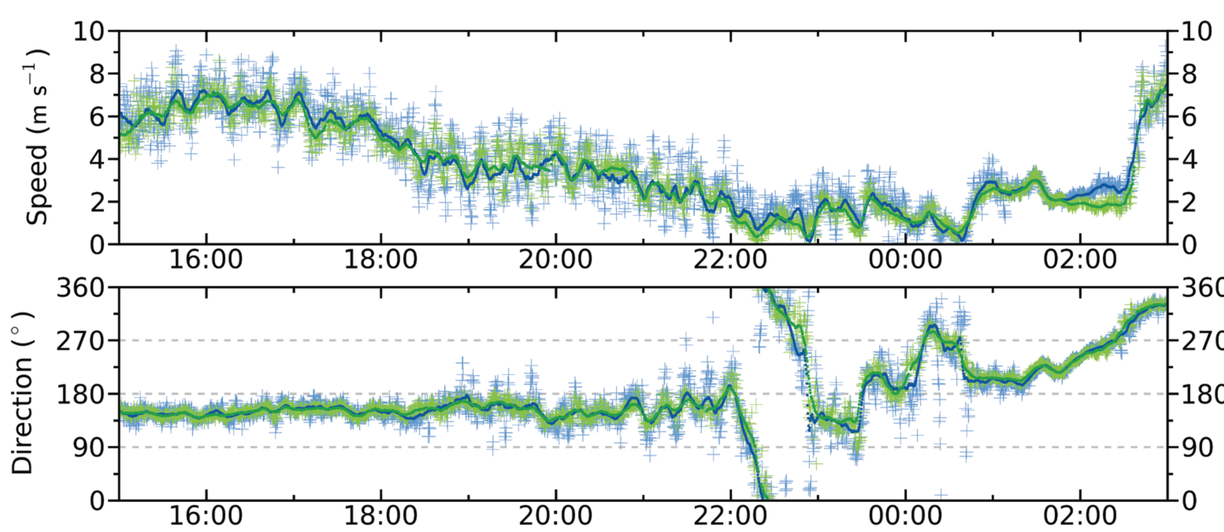
Cross Correlations

Wavelet-based Optical Flow

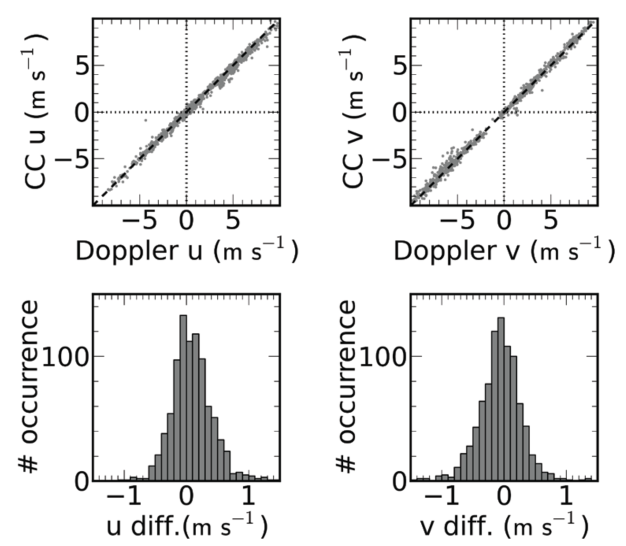
Example of **aerosol backscatter** and **estimated wind field**

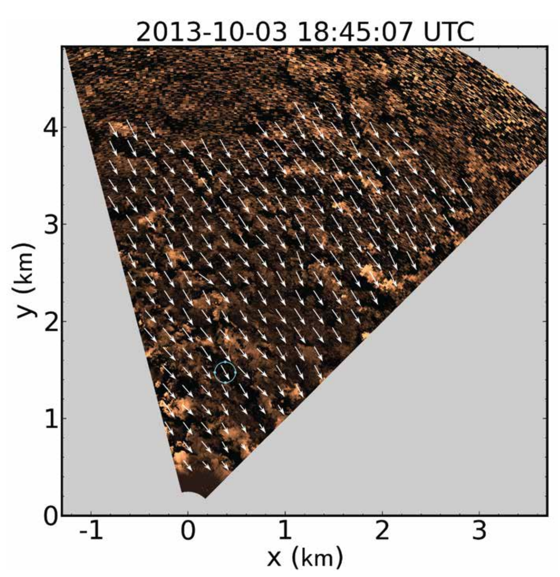


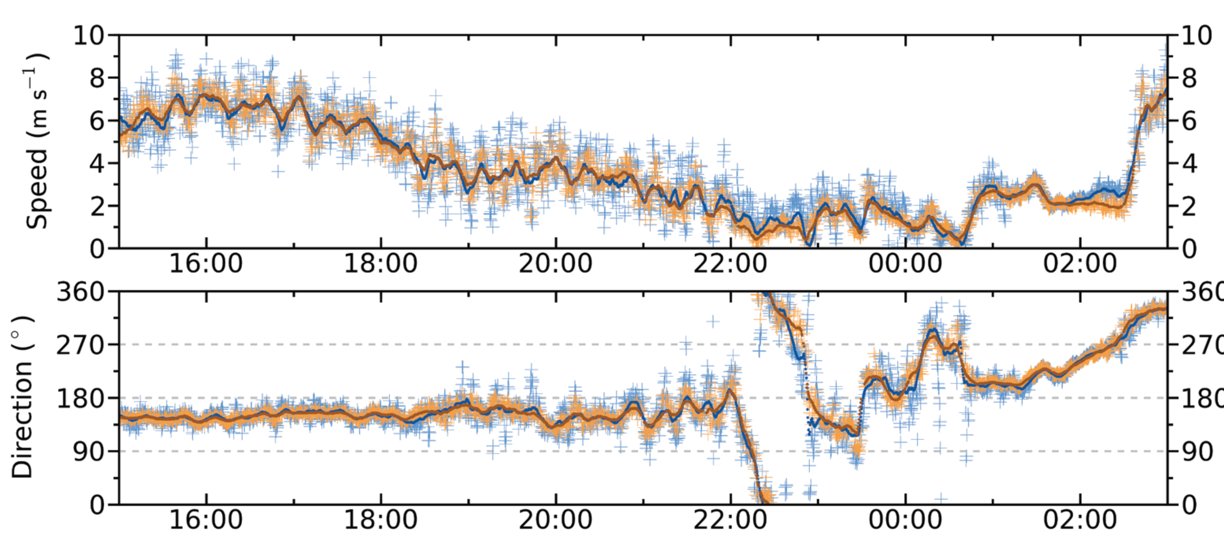
Example of **time-series of wind speed and direction at 100 m AGL**, Doppler (blue), cross-correlations (green), optical flow (orange), **instantaneous values** (+ markers) and **10-min rolling mean** (solid lines)

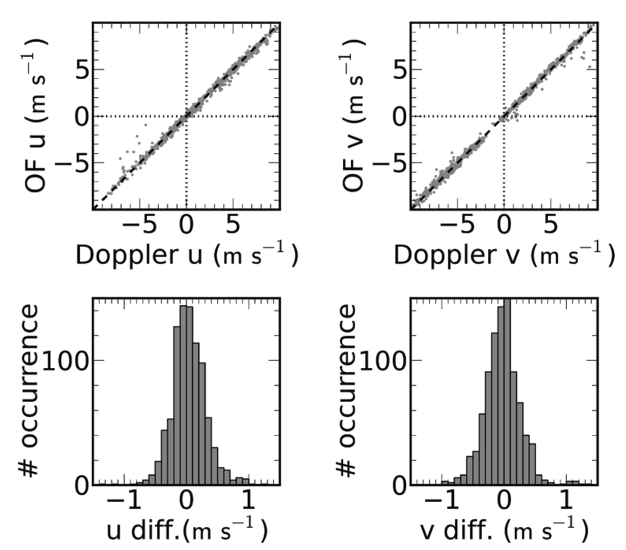


Scatter plot and differences for the **10-min means** over 15 days









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

References

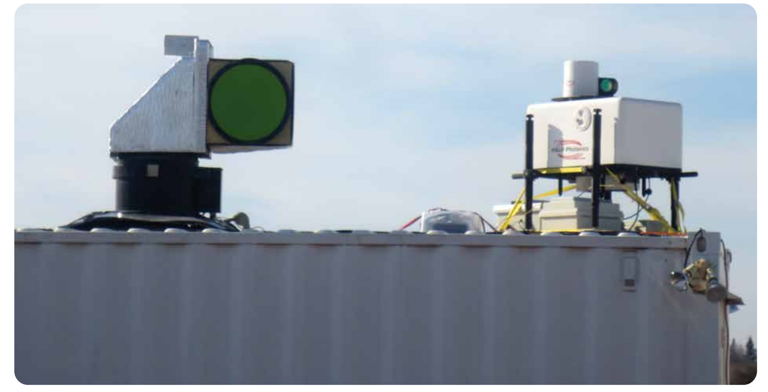
Dérian, P., P. Héas, C. Herzet and E. Mémin, 2013, Wavelets and Optical Flow Motion Estimation, *Numerical Mathematics: Theory, Methods and Applications*, **6**, 116-137.
Mayor, S. D., J. P. Lowe, and C. F. Mauzey, 2012: Two-component horizontal aerosol motion vectors in the atmospheric surface layer from a cross-correlation algorithm applied to elastic backscatter lidar data, *J. Atmos. Ocean. Technol.*, **29**, 1585-1602.
Schols, J. L. and E. W. Eloranta, 1992: The calculation of area-averaged vertical profiles of the horizontal wind velocity from volume-imaging lidar data, *J. Geophys. Res.*, **97**, 18 395–18 407.
Mauzey, C. F., P. Dérian, and S. D. Mayor, 2014: Wavelet-based optical flow for real-time wind estimation using CUDA, poster presentation, *GPU Technology Conference* (GTC), 24-27 March, San Jose, CA.

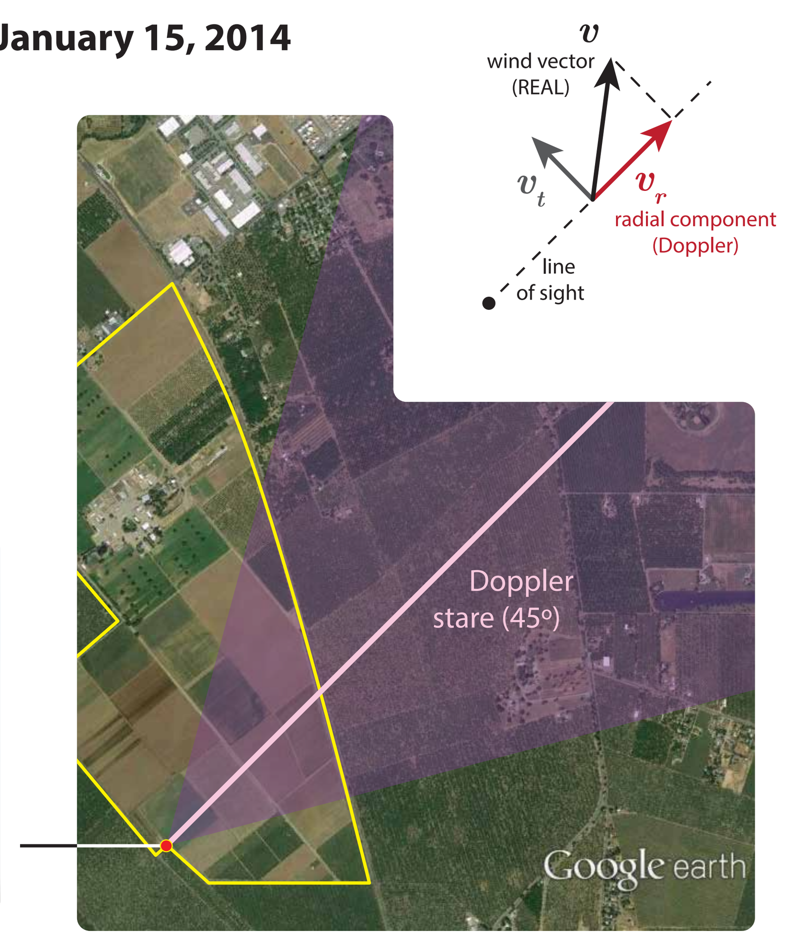
Phase 2: Spatial Validation

November 26, 2013 to January 15, 2014

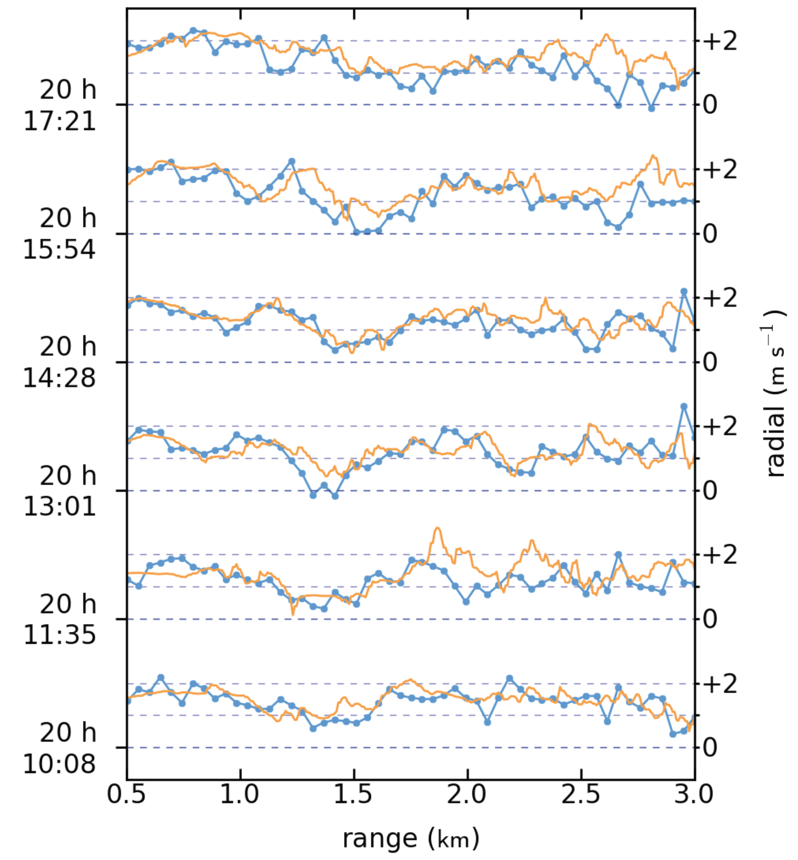
During this phase of the experiment, the **Doppler lidar was installed on the roof of the REAL** container and operated in a **staring mode, horizontally,** at 45° azimuth. As such, it measured the **radial component of wind velocity only**.

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.

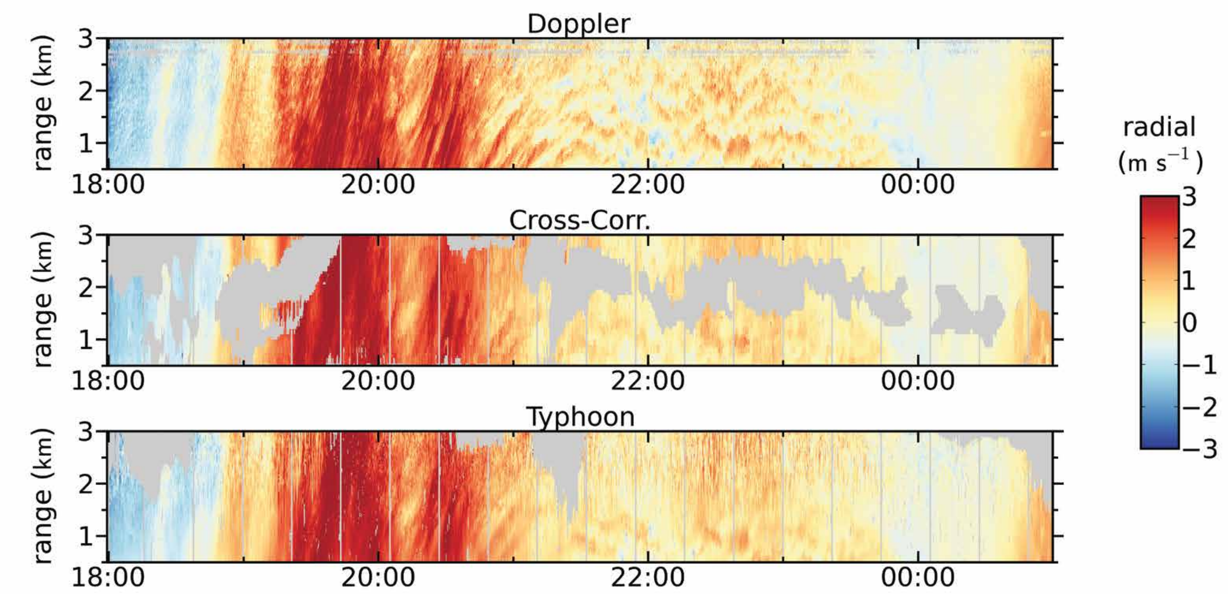




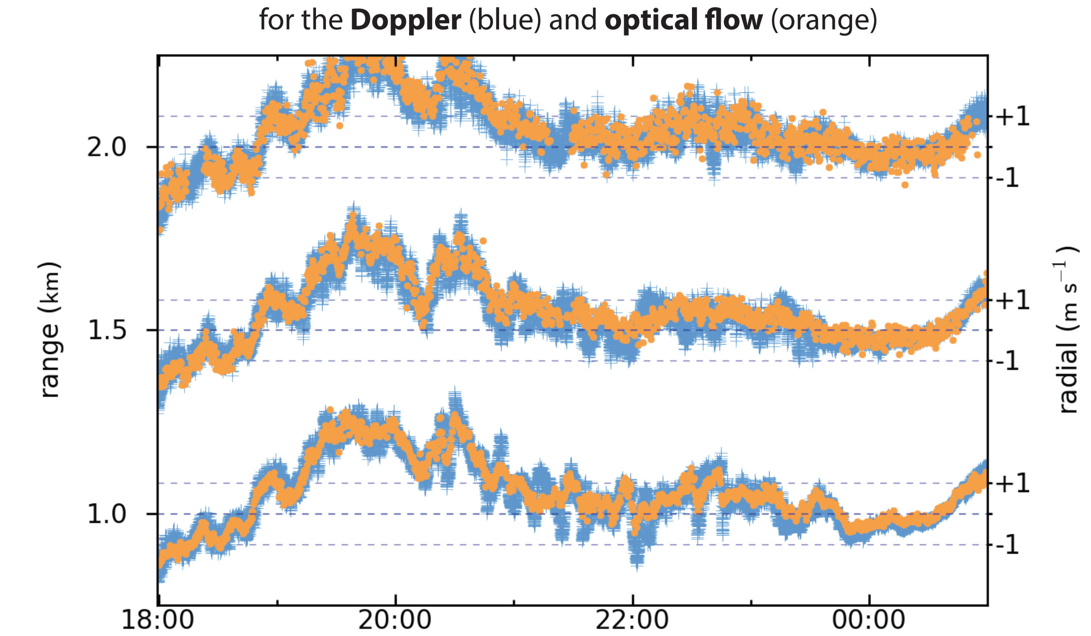
Radial velocity along the range at different times for the **Doppler** (blue) and **optical flow** (orange)



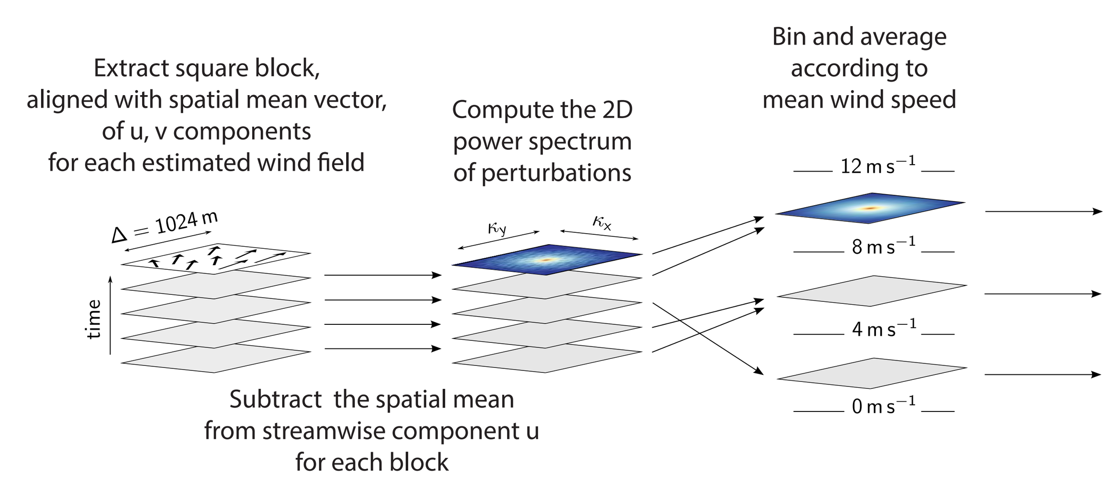
Series of radial velocity as a function of time (horizontal) and range (vertical axis)



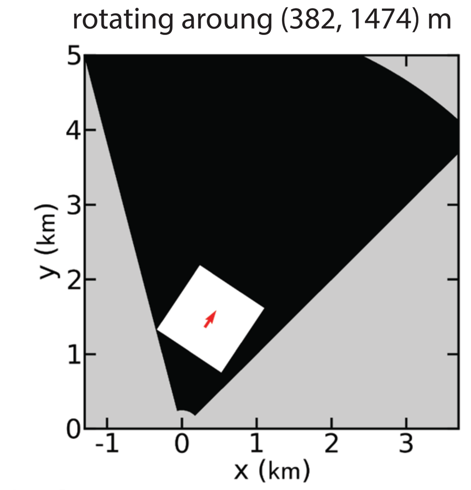
Time-series of radial velocity at different ranges for the **Doppler** (blue) and **optical flow** (orange)



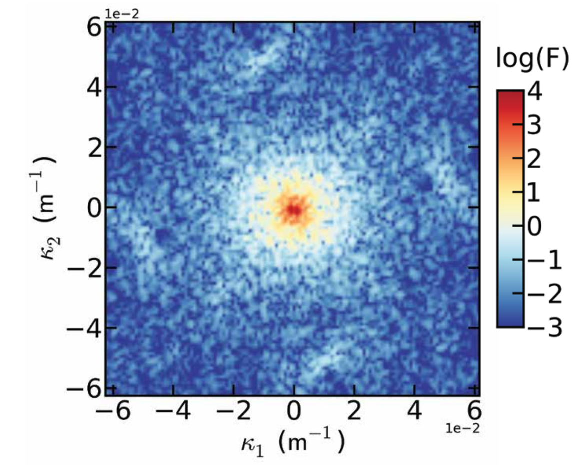
Spatial Power Spectra



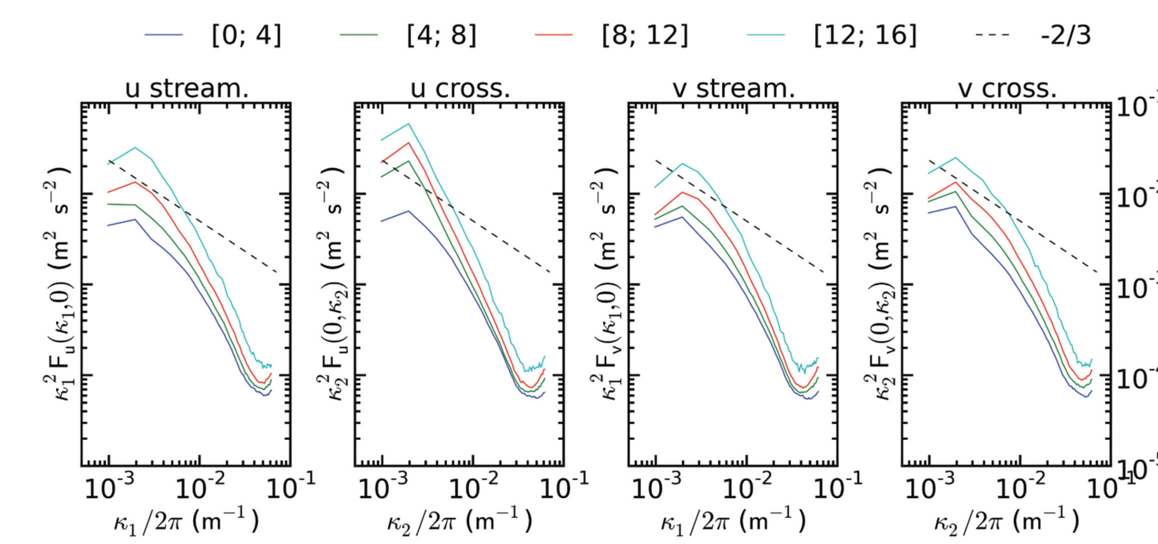
Location of the ~1x1 km block (128x128 pixels at 8m/pixel) rotating arournd (382, 1474) m



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



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)



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.

Acknowledgments

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