Two-Component Wind Fields from Scanning Aerosol Lidar and Motion Estimation Algorithms

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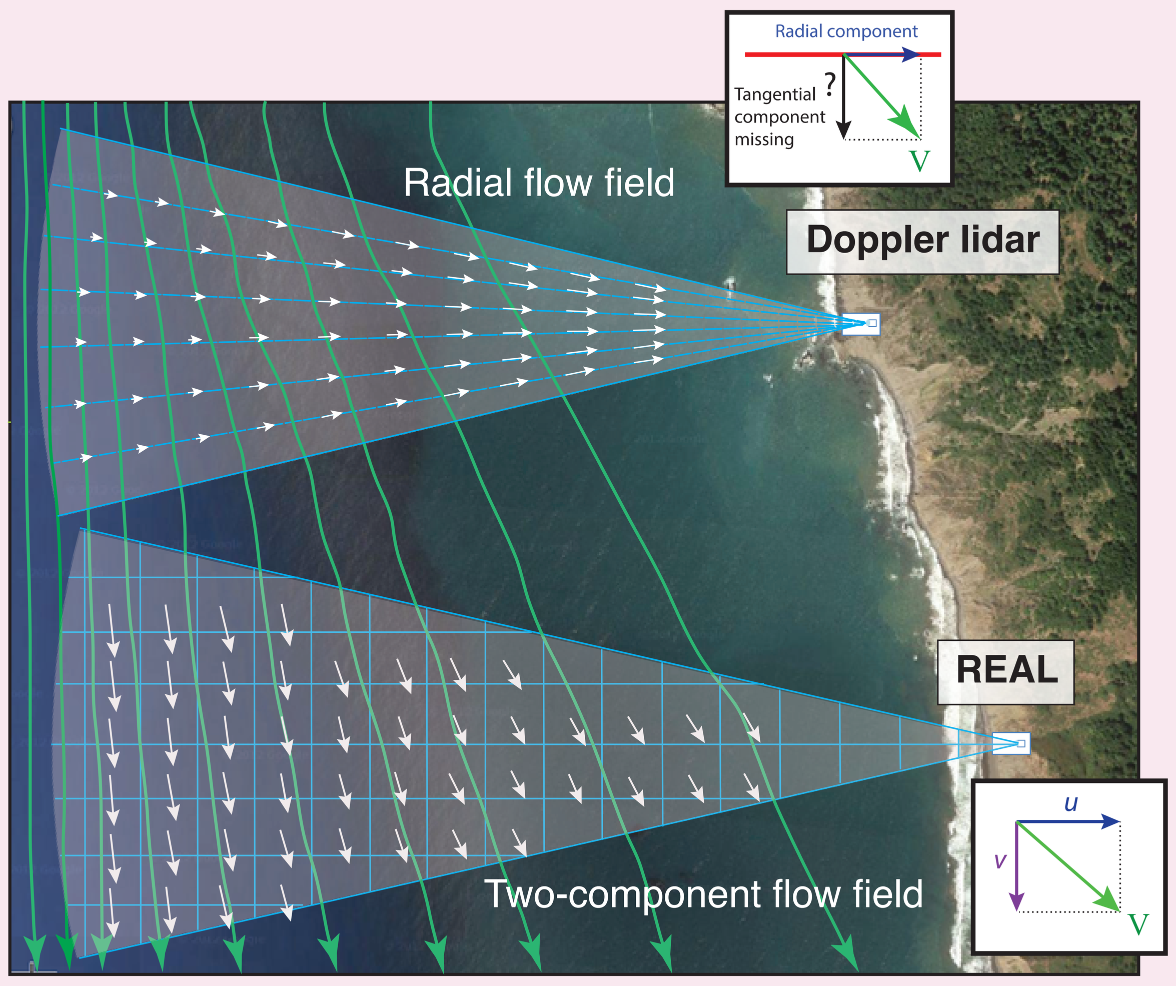
1. Concept

A single Doppler lidar is limited to direct measures of only one component of the wind (the radial component).

We are developing and testing techniques to remotely measure **two-component vector wind fields using a single aerosol lidar and motion estimation algorithms**.

The aerosol lidar produces a sequence of frames of aerosol backscatter intensity and motion estimation algorithms are applied to deduce the movement of aerosol features from frame to frame.



Two components are necessary to determine wind speed.

2. Instrument: the REAL

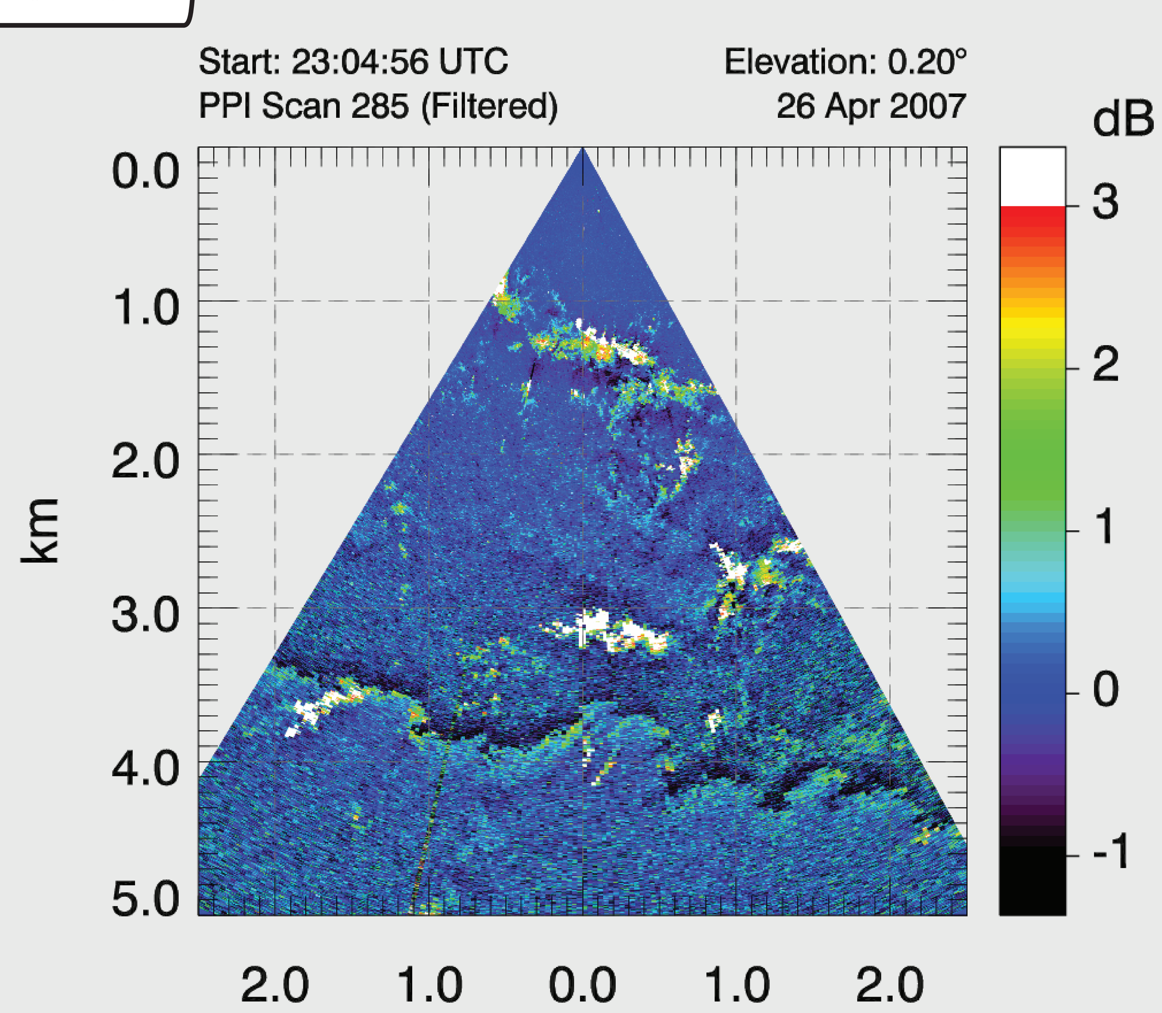
The **Raman-shifted Eye-safe Aerosol Lidars (REAL)** are **elastic backscatter lidars** making time-lapse **imagery of the clear atmosphere** through aerosol scattering (Mayor et al., 2007).

REAL System Specifications:
Wavelength: 1.543 µm
Pulse energy: 170 mJ
Pulse rate: 10 Hz
Pulse length: 6 ns
Beam diameter at lidar: 66 mm (1/e^2 points)
Beam divergence: 0.24 mrad (full angle)
Telescope diameter: 40 cm
Receiver field of view: 0.54 mrad (full angle)
Digitizer speed: 100 MSPS
Digitizer range: 14 bits
Detector type: 200-µm InGaAs APD

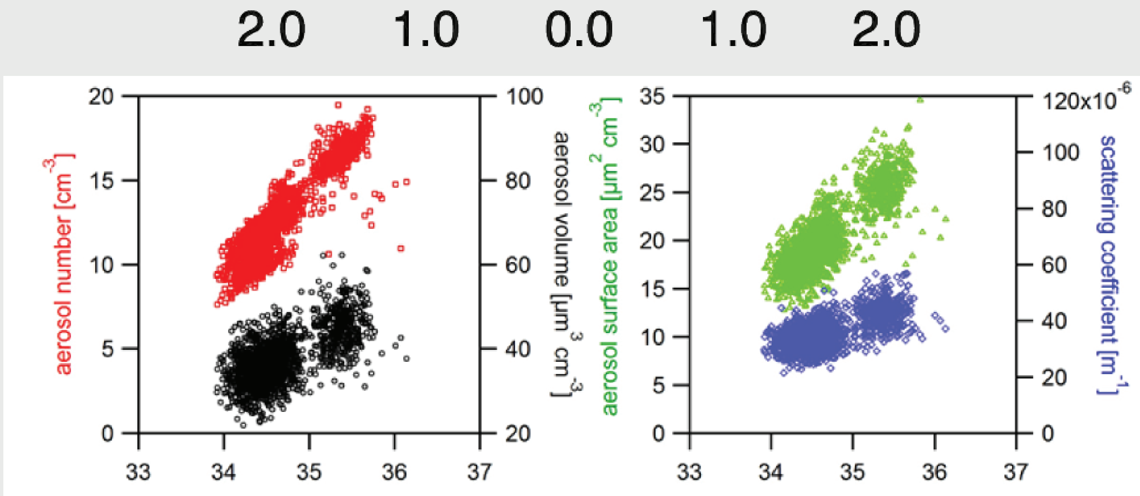
The REALs are not Doppler Lidars.
They produce high-resolution image sequences of aerosol backscatter intensity.

3. Backscatter Data

. REAL pulses at 10 Hz
. **A scan takes about 15s.**
. **No averaging** of backscatter data is necessary.
. Single pulse signal-to-noise ratio typically >10 **up to 5 km range**.
. High-pass median filter is applied to remove large-scale features and artifacts (e.g. attenuation).
. **Backscatter intensity** is approximately proportional to the **concentration of particles**, although the size and type of particles also have an influence.

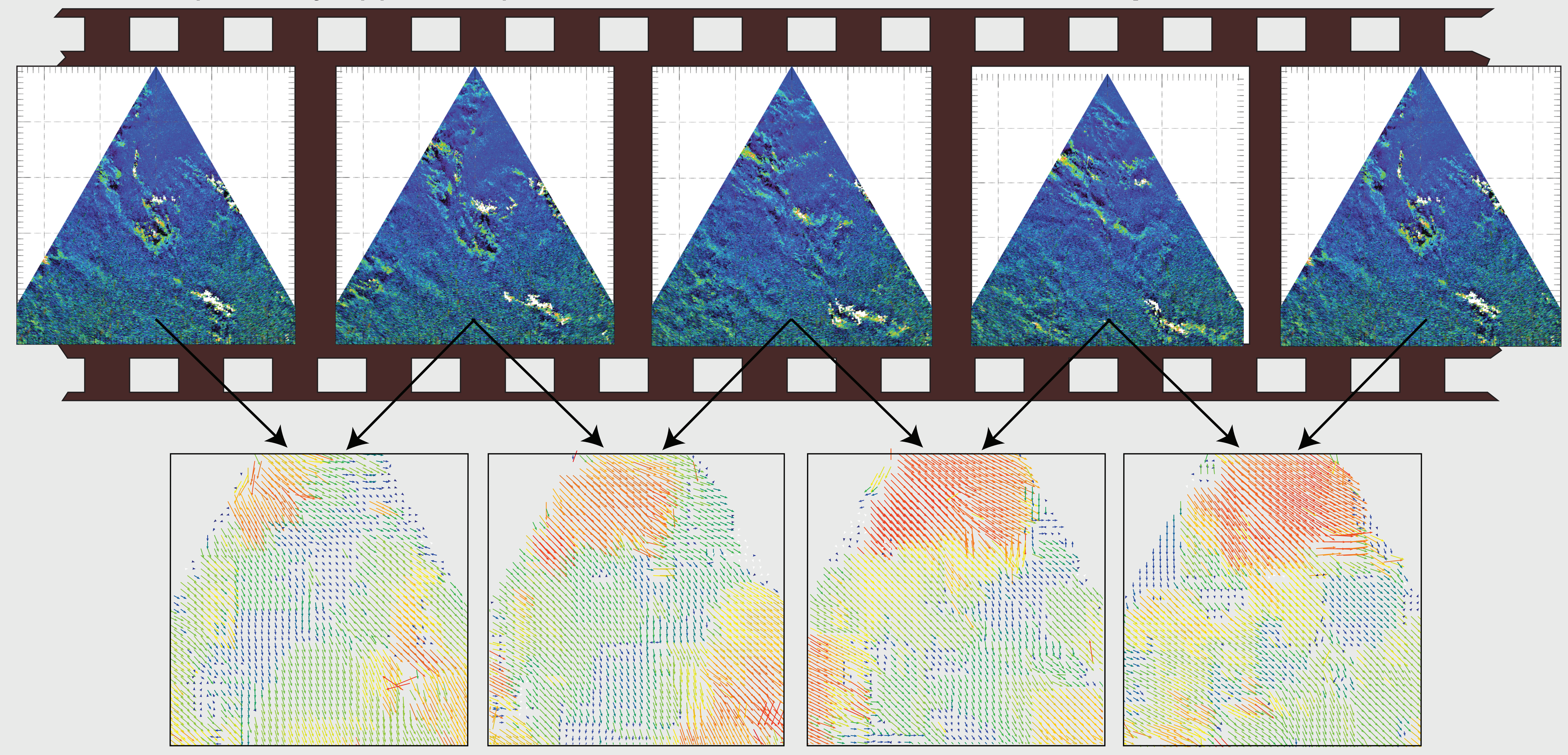


To determine the sensitivity of the REAL to small changes in aerosol particle concentration, an experiment was conducted. The lidar beam was held nearly horizontal and stationary and a particle counter was placed near the beam at 1 km range. The scatter plots to the right show the sensitivity of the lidar as a function of several measures of aerosol properties (Held et al., 2012).



4. Motion Estimation

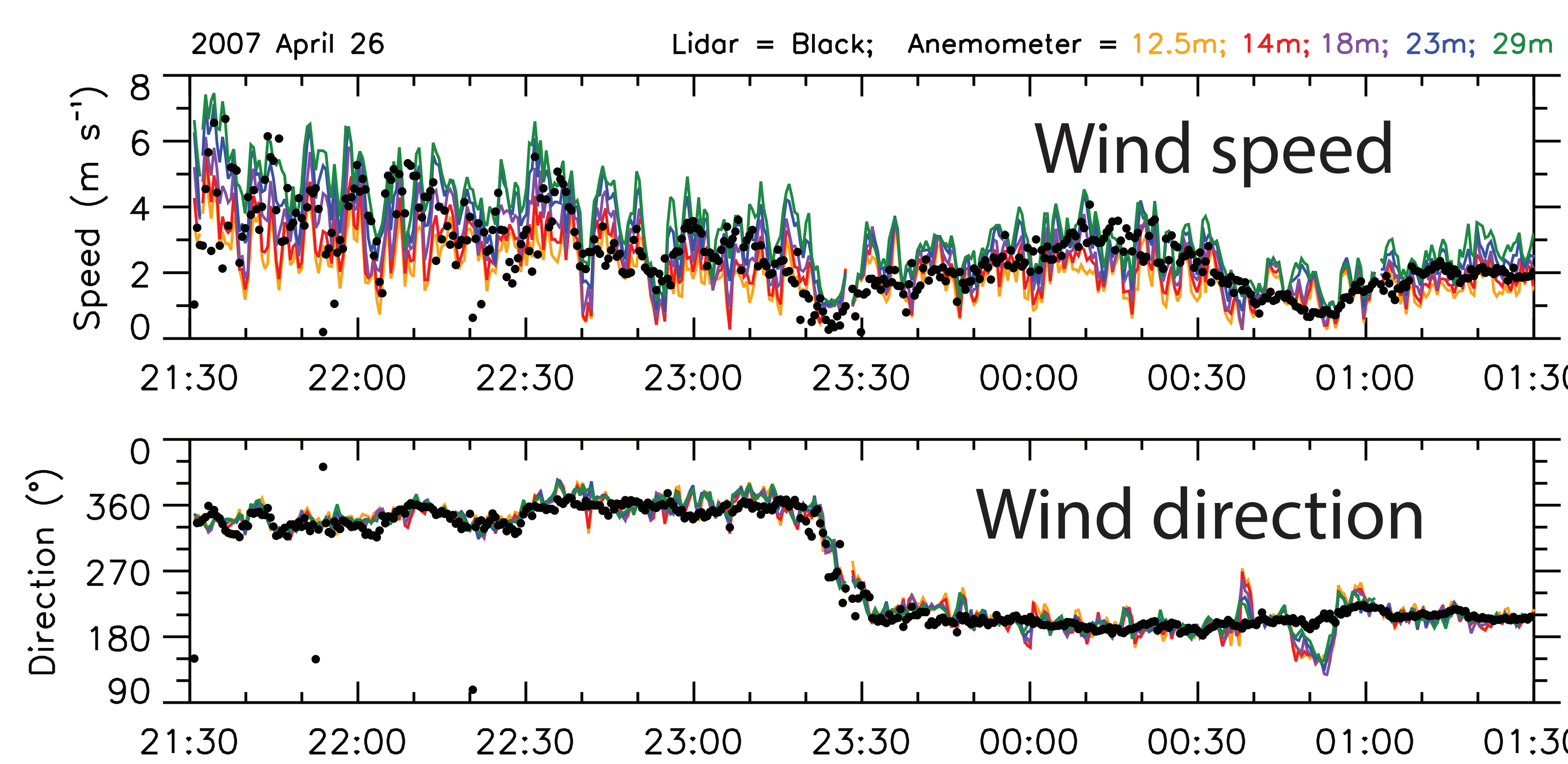
"**Computer vision**" methods extract **apparent 2D motion from image sequences**.They are commonly used in **experimental fluid dynamics** (e.g., particle image velocimetry). These methods rely on the observable motion of **passive tracers** to infer the underlying fluid motion. In our work, sequences of scans show **aerosol features** that serve as tracers of the wind. Motion estimation methods are sequentially applied to pairs of scans to determine the **two-component vector wind field**.



Above: a **series of frames** of aerosol backscatter intensity and a sequence of two-dimensional **vector flow fields** derived by application of a **cross-correlation algorithm**. The vectors are color-coded according to speed. Coherent structures can be observed evolving and moving from the northwest to the southeast.

5. Validation

Motion estimates given by a **cross-correlation algorithm** were compared with measures by tower-mounted **sonic anemometers** with good agreement (Mayor et al., 2012). Shown below is a time-series comparison from a 4 hour period when a density current front passed by.



6. Conclusions & Perspectives

Until recently, the leading (traditional?) approach to **determining 2-component wind vectors** from aerosol lidar image sequences has been **cross-correlation** (Schols and Eloranta, 1992). The algorithm requires the use of an interrogation window (subset of pixels in a block) to calculate each vector. This approach presumes uniform flow in the block area. Mayor et al. (2012) have shown that better **agreement with sonic anemometer** data occurs when larger blocks are used and when wind speeds and turbulent kinetic energy is lower. An entirely different approach to determining 2-component wind vectors is the use of ""**optical flow**". We have recently begun implementing a wavelet-based optical flow (Derian et al., 2013) for **real-time execution** and plan to test it this summer by **comparing with measurements from a Doppler lidar.**

7. References

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