Observations of Canopy Waves Above an Orchard by a Horizontally-scanning Aerosol Lidar

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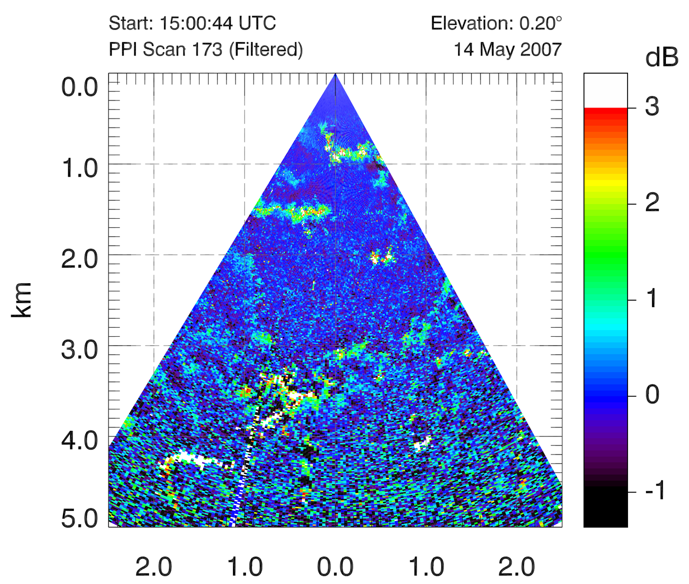
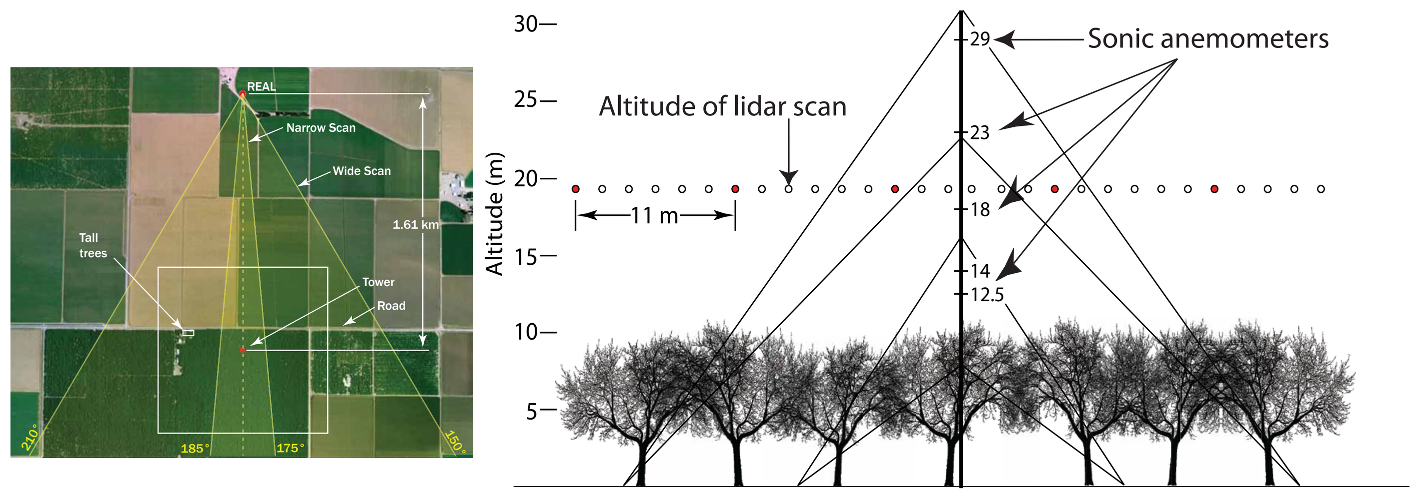
Background

Studies of canopy waves, internal atmospheric gravity waves immediately above forest canopies, to date have been primarily performed using in situ time-series data [1]. Previous research using high-power, gound-based, scanning elastic lidars has focused on turbulent structures [2]. Autocorrelation functions provide spatial information on eddy shape, size, and spacing [3]. Cross-correlation algorithms have been applied to elastic lidar imagery to deduce the velocity of coherent aerosol features and the wind [4].



Experiment

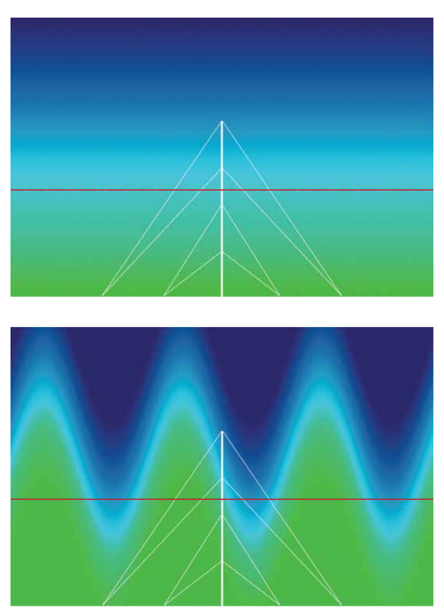
The Canopy Horizontal Array Turbulence Study (CHATS) took place in Dixon, California from 15 March through 11 June 2007 [5]. A 30-m vertical tower equipped with 13 three-component sonic anemometers was installed in the orchard. The REAL was located1.61 km north of the tower and collected data nearly continuously in the area surrounding the tower and orchard. It provided two-dimensional spatial images of aerosol backscatter intensity often revealing coherent structures such as plumes and waves.



Hypotheses

1. The REAL is able to detect canopy waves when vertical aerosol gradients are displaced by wave motion. Right: Artist's rendering of vertical cross sections of aerosol backscatter in quiescent (top) and wavy (bottom) conditions.

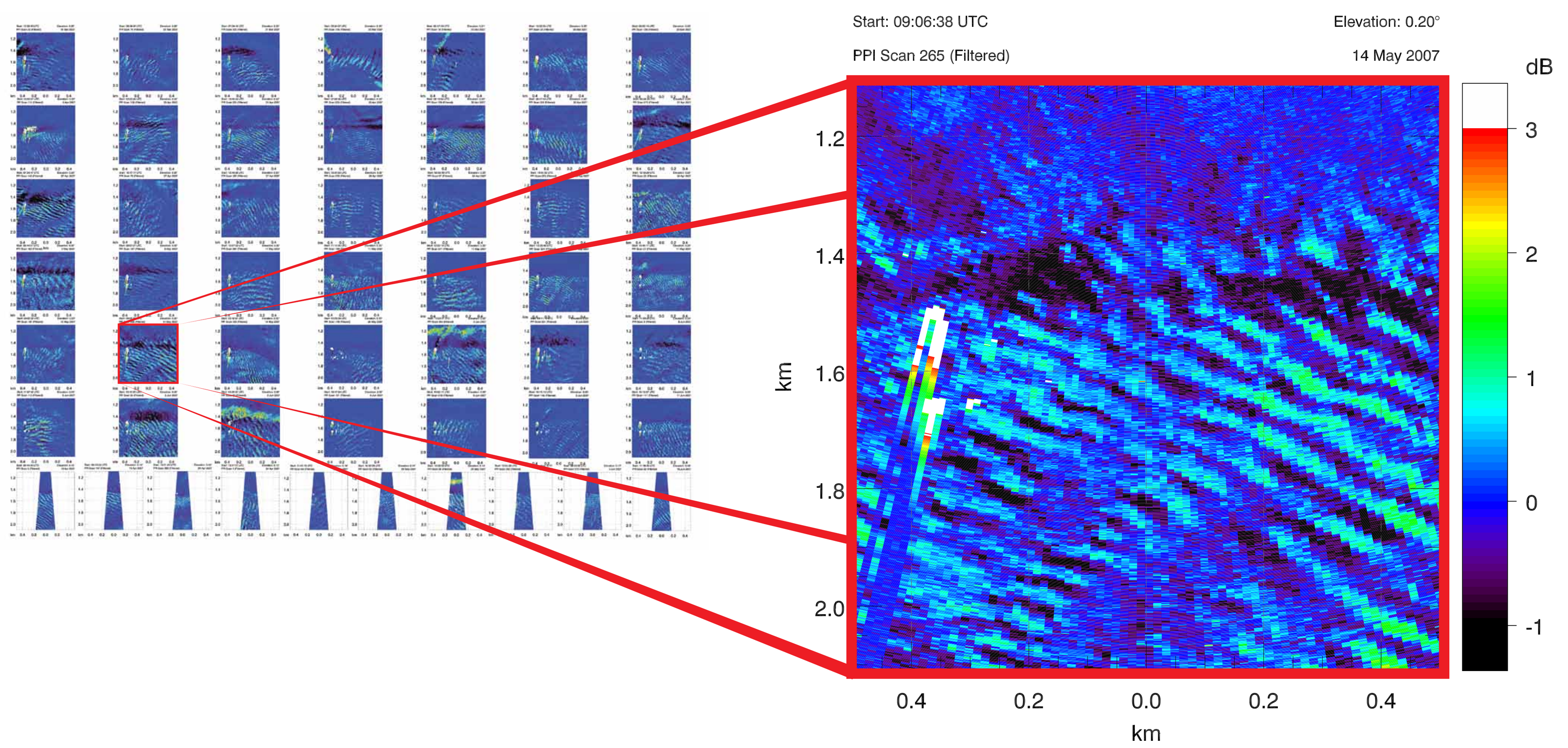
2. The wave properties can be determined objectively by computer algorithms by identifying the position of the crests of high-intensity backscatter as they propagate.



Observations

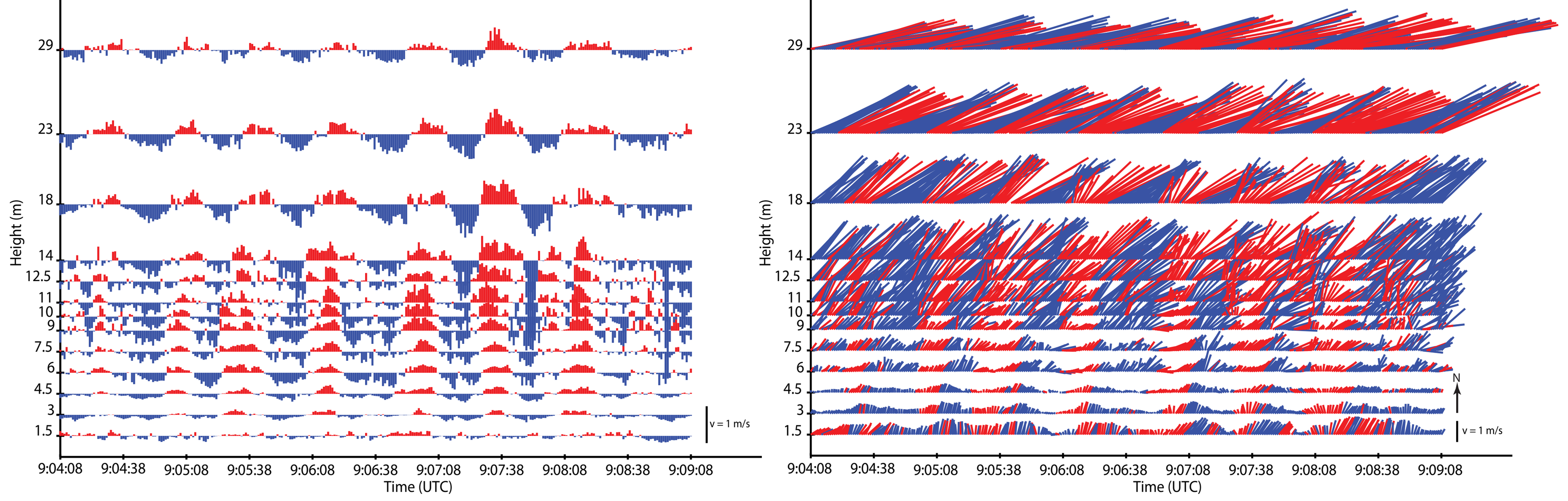
During CHATS, 52 episodes of canopy wave activity were detected in the horizontal scans. These include wide and narrow scans. For these episodes to be included in the study, they had to last longer than 1 minute and pass over the ISFF tower.

52 cases **1 example**

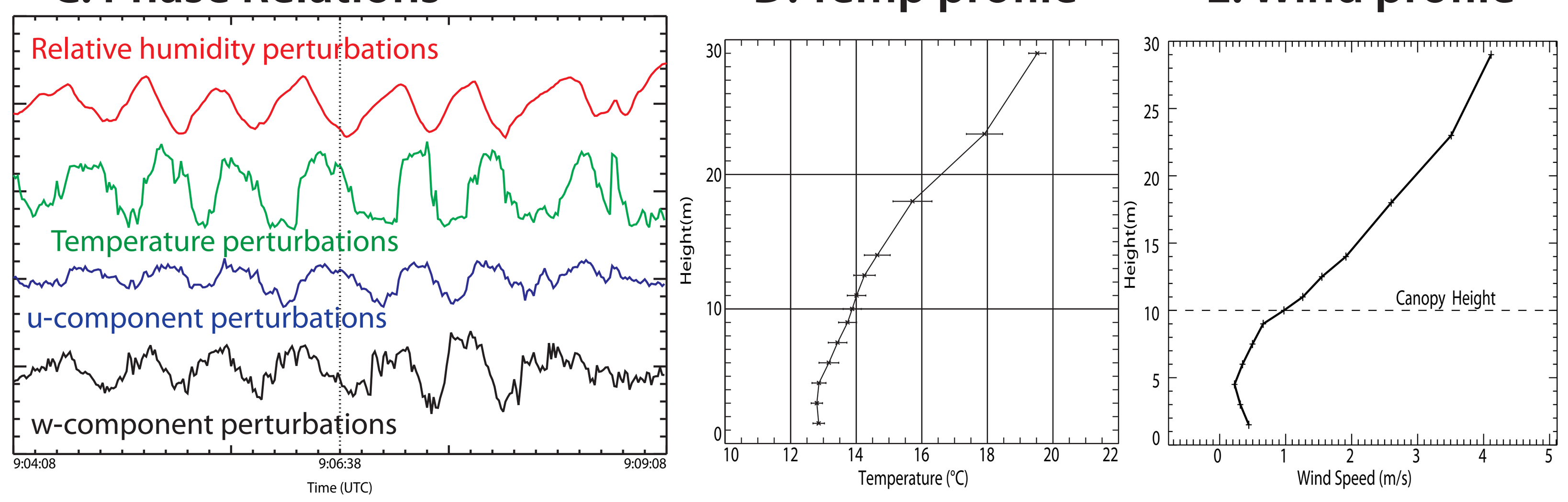


Once identified in the lidar data, the corresponding in situ data can be analyzed. Anemometer data shows that these waves have a dynamical cause. The waves exist as oscillations in time of the vertical [A] and horizontal [B] velocities, temperature, and sometimes relative humidity. The phase relations [C] indicate low heat and horizontal momentum in the vertical. The waves always occur with a stable temperature profile (dT/dz > 0) [D] and have vertical wind shear [E].

A: Sonic vertical velocities **B: Sonic horizontal velocities**



C: Phase Relations **D: Temp profile** **E: Wind profile**



Acknowledgments

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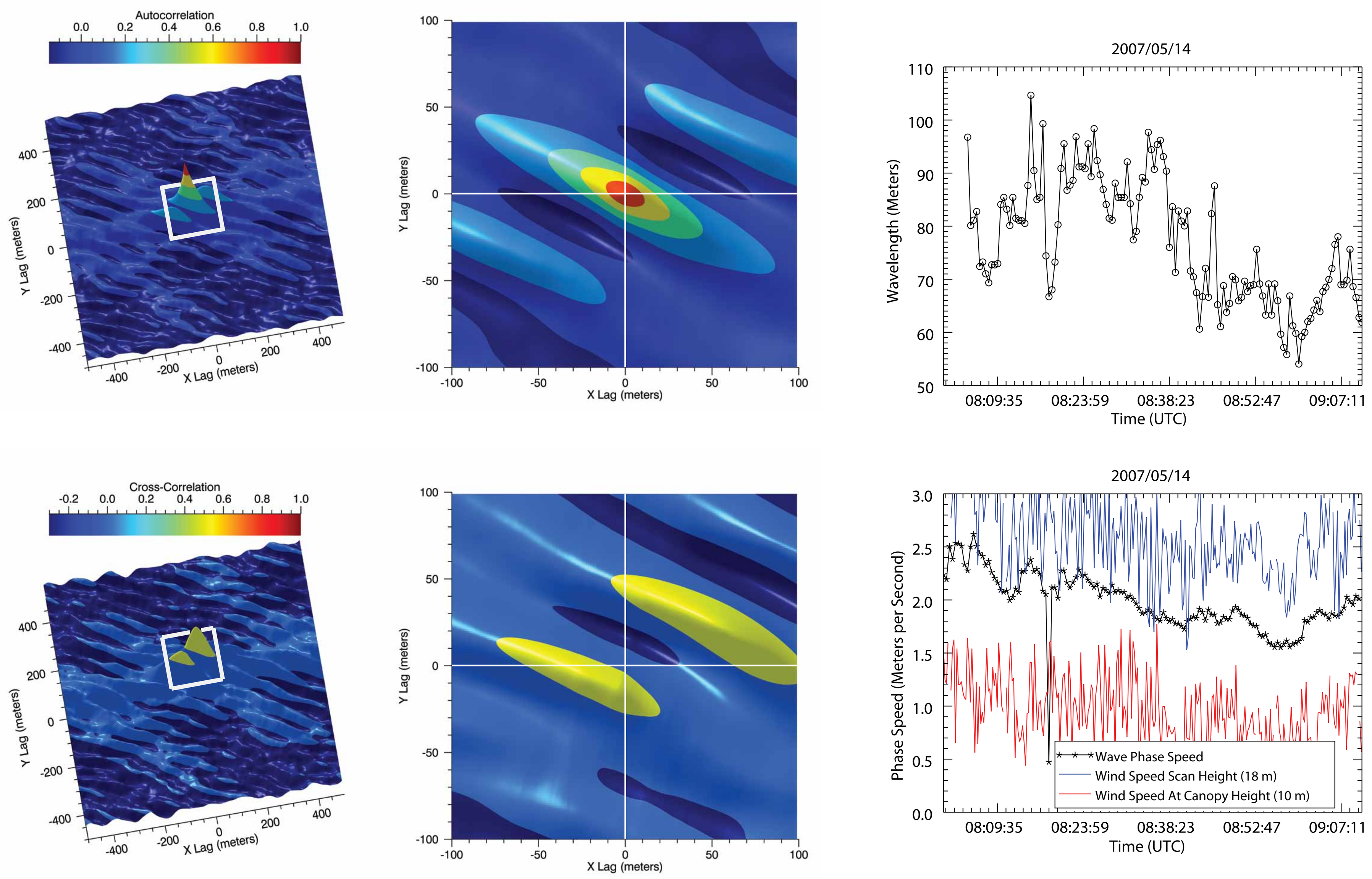
Analysis

Autocorrelation can reveal periodicity or scale in a time series or spatial data. When applied to turbulence data it can reveal length scales. Here it is applied to two-dimensional backscatter images from stable nocturnal surface layers showing fine-scale gravity waves. In an autocorrelation function, the distance between the origin and the second local maximum indicates the wavelength. In the example (left) shown, it is 78 m. Cross-correlation is similar to autocorrelation but uses the same area at two different times. Cross-correlation allows us to measure a displacement vector of coherent features such as plumes or the waves. For these waves , the displacement, indicated by the position of the global max, is 57 m over an interval of 30 s resulting in a phase velocity of 1.9 m/s 65° E of N. With velocity and wavelength, we can calculate the period. In this case, it is 41 s, in agreement with the period measured by the tower of approximately 40 s as seen in the in situ data.Both algorithms are applied to every scan in each episode to create time series. Phase speed can be compared with wind speed. We discovered the phase speed is always between the wind speed at canopy height (10 m) the height at which we scanned (18 m).



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