Fine-scale atmospheric gravity waves in the nocturnal boundary layer above an orchard canopy

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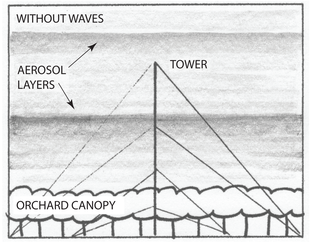
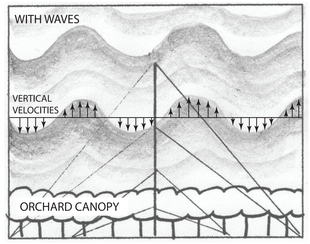
Hypotheses:

#1. The lidar is capable of revealing canopy gravity waves due to the modulation of the aerosol strata by the vertical velocity (w).

#2. The lidar images can reveal wavelength and phase speed. This is a unique strength of the lidar data.





Experiment: CHATS, 15 March - 16 June 2007, Dixon, CA.

Sonic anemometers on the tower (left) sample 3-component wind velocities at 60 Hz. The lidar (right) scans over the orchard and through the tower at about 18 m altitude. Time-series data from the anemometers can be used to determine the period of the waves. Lidar scan images can be used to determine the wavelength of the waves. If the lidar scan images are collected rapidly enough, phase velocity can also be measured.

References:

Mayor, S. D., et al., 2007: Polarization lidar at 1.54-microns and observations of plumes from aerosol generators, *Opt. Eng.*, **46**, DOI: 10.1117/12.781902.

Lee, X., 1997: Gravity waves in a forest: a linear analysis, *J. Atmos. Sci.*, **54**,2574-2585.

Patton, E. G., et al,. 2011: The Canopy Horizontal Array Turbulence Study (CHATS), *Bull. Amer. Meterol. Soc.*, **92**, 593-611.

Acknowledgments:

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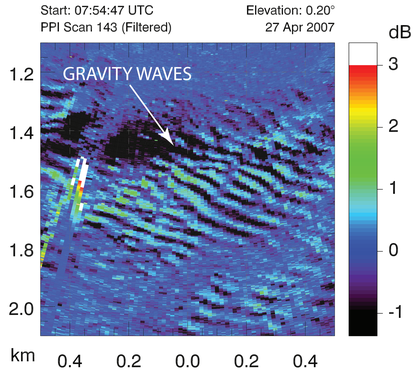
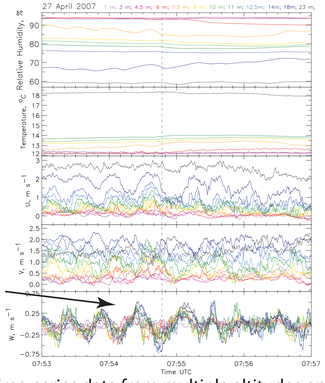
Observations and preliminary analysis

Case 1: 27 April 2007

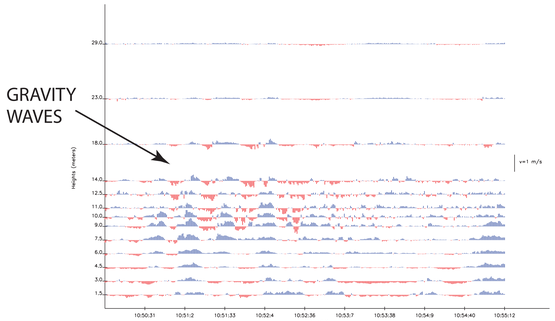


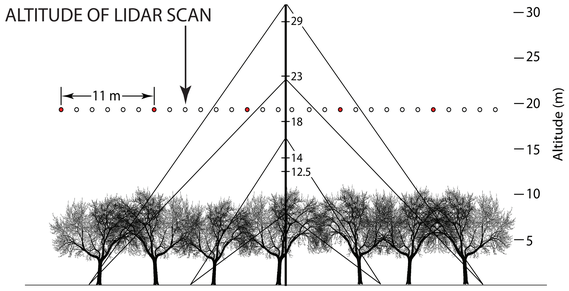
Above: Horizontal cross-section through the waves as observed by the lidar. The tower is located in the middle of the image. The lidar image shows the wavelength of the gravity waves, in this case $\lambda_L \approx 70$m.



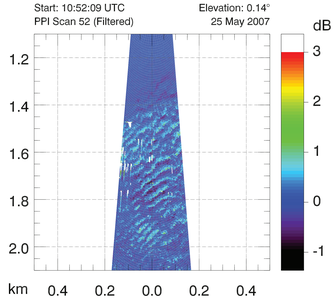
Above: Time-series data from multiple altitudes on the tower. The vertical velocity (bottom trace) shows the period of the waves in this case to be $T_T \approx 38$ s. By combining lidar wavelength and tower period we determine that the phase speed of the waves in this case $v = \lambda/T \approx 1.8$ m/s.

Case 2: 25 May 2007





Above: (left) Vertical velocity from multiple altitudes on the tower (right). Upward velocities are in blue and downward are in red. This plot reveals the vertical coherence of the waves and their vertical extent.



Left: Narrow scans can be collected more frequently and therefore enable us to track wave crests and troughs and observe the phase speed without the need for tower data.

Lidar data alone
$v = \lambda_L/T_L \approx 1.1$m/s

Lidar and tower data
$v = \lambda_L/T_T \approx 1.0$ m/s

The consistency of these values shows that the lidar is capable of measuring both the wavelength and period without the need for tower data.

Measurable quantities

	Tower	Tower +Lidar	Lidar
λ		X	X
T	X	X	X*
v		X	X*

*Given a fast enough scan rate

Future research:

With this data, we plan to investigate the following aspects of the gravity waves: the linkage between lidar backscatter and sign of vertical velocity; vertical coherence; kinematics of the air motion; supporting environmental conditions; and the phase and group velocity relative to the mean air motion.

Conclusion:

The horizontally scanning eye-safe elastic backscatter lidar can identify and confirm the presence of fine-scale gravity waves over forest canopies. The lidar images contain quantitative spatial information such as wavelength that is not available from in situ time-series data. A key requirement for such lidar measurements is high spatial resolution images and sensitivity to small changes in aerosol backscatter. We note the spacing of backscatter data points in the radial direction of the REAL data is 1.5 m. This enables the instrument to resolve these wave structures that occur on scales of tens of meters.