Lidar observations of fine-scale atmospheric gravity waves in the nocturnal boundary layer above an orchard canopy

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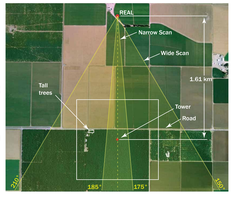
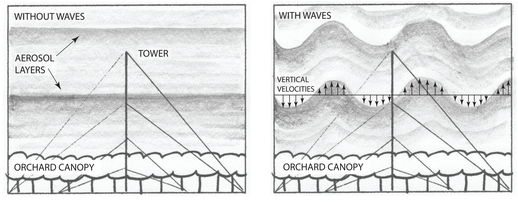
Part 1: Experiment - Canopy Horizontal Array Turbulence Study (CHATS)

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/e² 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



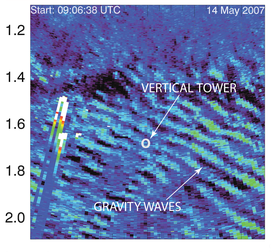
CHATS took place in Dixon, California from 15 March through 11 June 2007. A 30-m vertical tower equipped with 13 three-component sonic anemometers was installed in the orchard. The REAL was located 1.61 km north of the tower and collected data nearly continuously in the area surrounding the tower and orchard. It provided two-dimensional spatial images of aerosol backscatter intensity often revealing coherent structures such as plumes and waves.

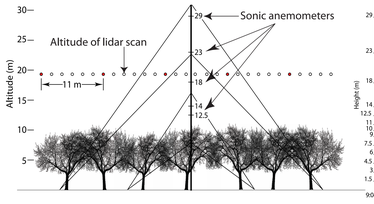
Part 2: Why can the REAL see these waves?



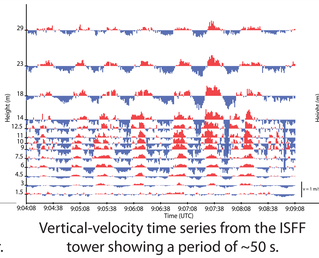
We hypothesize the REAL is able to detect internal atmospheric waves when aerosol strata are displaced vertically by the vertical air motion caused by the waves. In situ data confirm the presence of vertical air currents during the wave episodes.

Part 3: Example wave episode from 14 May 2007

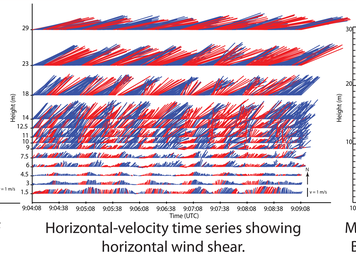




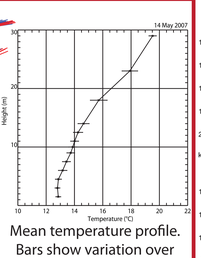
Arrangement of wind, temperature, and humidity sensors above the trees on the NCAR ISFF 30-m tower.



Vertical-velocity time series from the ISFF tower showing a period of ~50 s.
Red = Up, Blue = Down



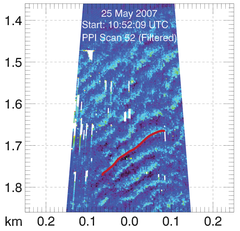
Horizontal-velocity time series showing horizontal wind shear.
Red = Up, Blue = Down

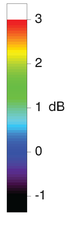


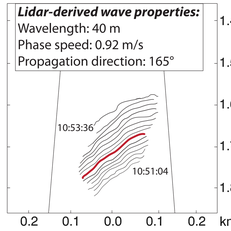
Mean temperature profile. Bars show variation over the episode.

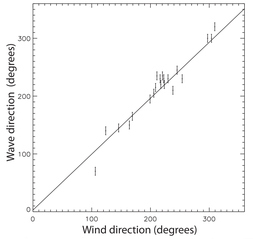
In this section, we present 1 of 52 wave episodes in the CHATS data set. Wave episodes were identified by subjective inspection of more than 1800 hours of time-lapse REAL data. For a wave episode to be included in our study, it must have a duration greater than 1 minute and passed over the CHATS vertical tower. The lidar image (above left) corresponds to the 1 km² area surrounding the tower. The scan intersected the tower between 18 and 20 m AGL. A high-pass median filter (500-m window) was applied to the range-corrected backscatter intensity data in the radial dimension. The color (see scale below) indicates the relative intensity of backscatter caused by particulate matter. The in situ data show that the waves in the lidar images are the result of oscillations in vertical velocity. The wave periods range between 20 and 60 s for all cases. The horizontal velocity data frequently exhibit shear and periodicity. All of the temperature profiles (above right) during wave episodes show the atmosphere is statically stable.

Part 4: Using REAL data to study wave propagation









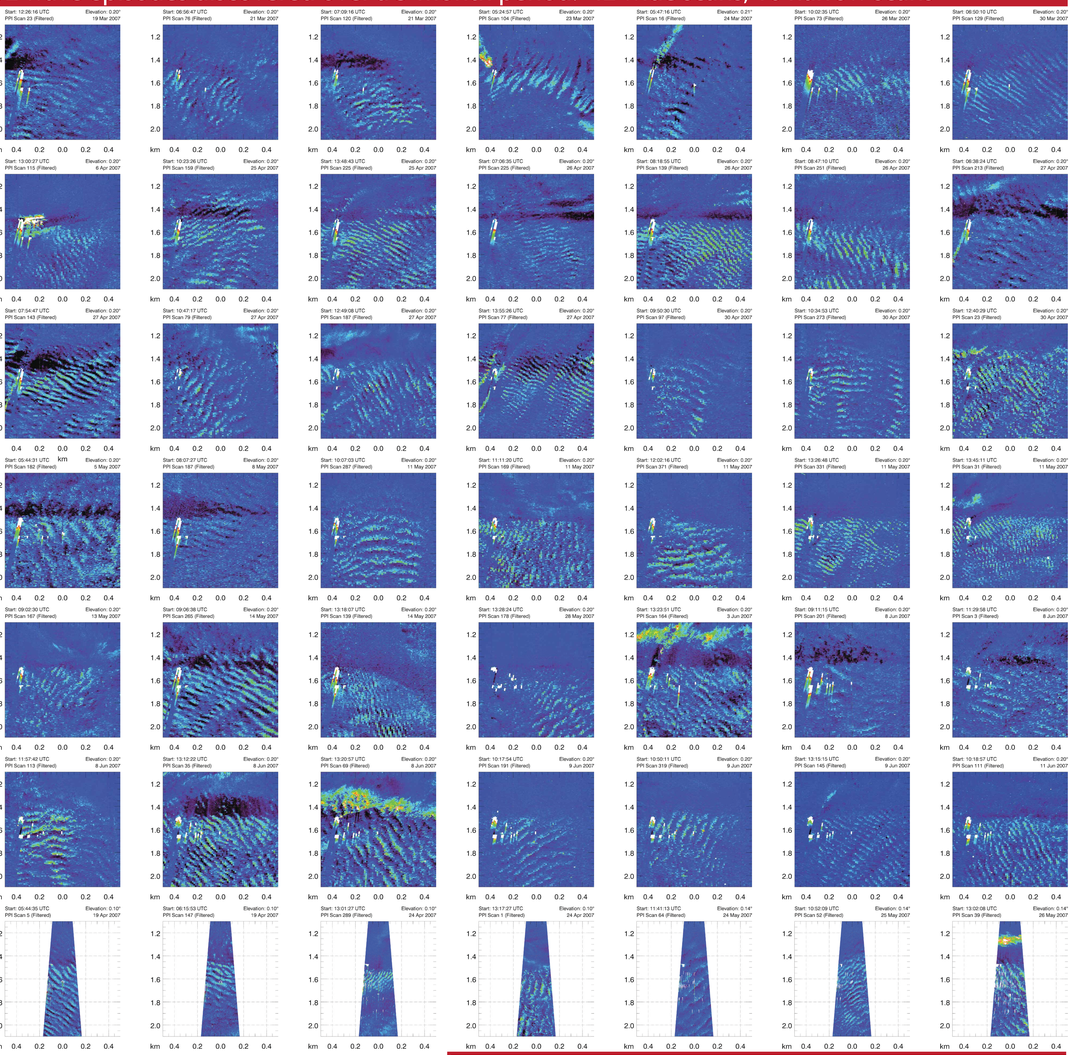
Wavelength of the gravity waves can be obtained from the wide and narrow scans. Phase speed and direction can be determined from the scans with short update intervals (≤17 s). In the above case, subjective tracking of wave-fronts from 15 consecutive narrow scans at 11 s intervals reveals wave propagation. The plot (above right) shows wave propagation direction for 22 cases observed with fast frame-rates versus the wind direction from the tower data. We conclude that the waves travel in the direction of the wind.

Summary

This poster presents our initial discovery of 52 episodes of gravity waves in the two-dimensional spatial REAL data from CHATS. In situ data confirm that the waves present in the lidar images are the result of vertical air motion. Lidar images have been used to determine wavelength, phase speed, and propagation direction. Eye-safety, sensitivity to small changes in backscatter intensity, and high range-resolution were critical in order to make these lidar observations. By having both lidar and in situ data, we are able to explore the environmental conditions that support the formation of these waves and possibly the impact of the waves on the environment. We plan to continue our investigation by using the observations to verify theoretical explanations of the waves.

For more information, please visit our website:
http://physics.csuchico.edu/lidar

52 wave episodes discovered over a 3-month period: 42 wide scans; 10 narrow scans



Acknowledgments: This research was funded by Grant 0924407 from the US National Science Foundation's Physical and Dynamic Meteorology Program. NCAR EOL ISFF staff provided the in situ data.

References:

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