Temporal Evolution of Wavelength and Orientation of Atmospheric Canopy Waves

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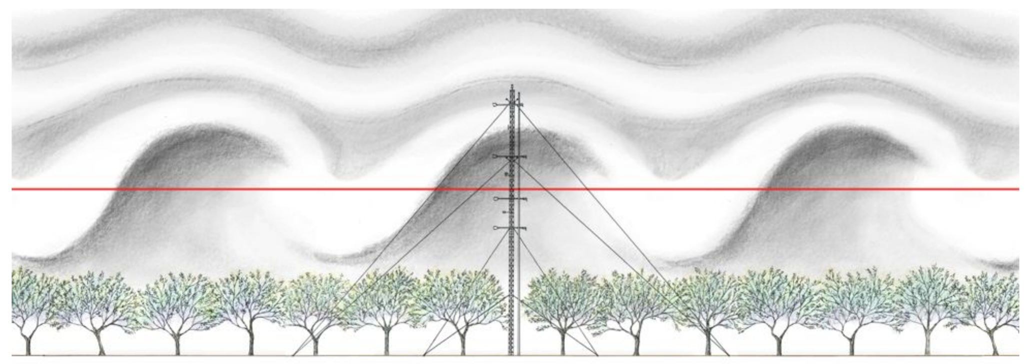
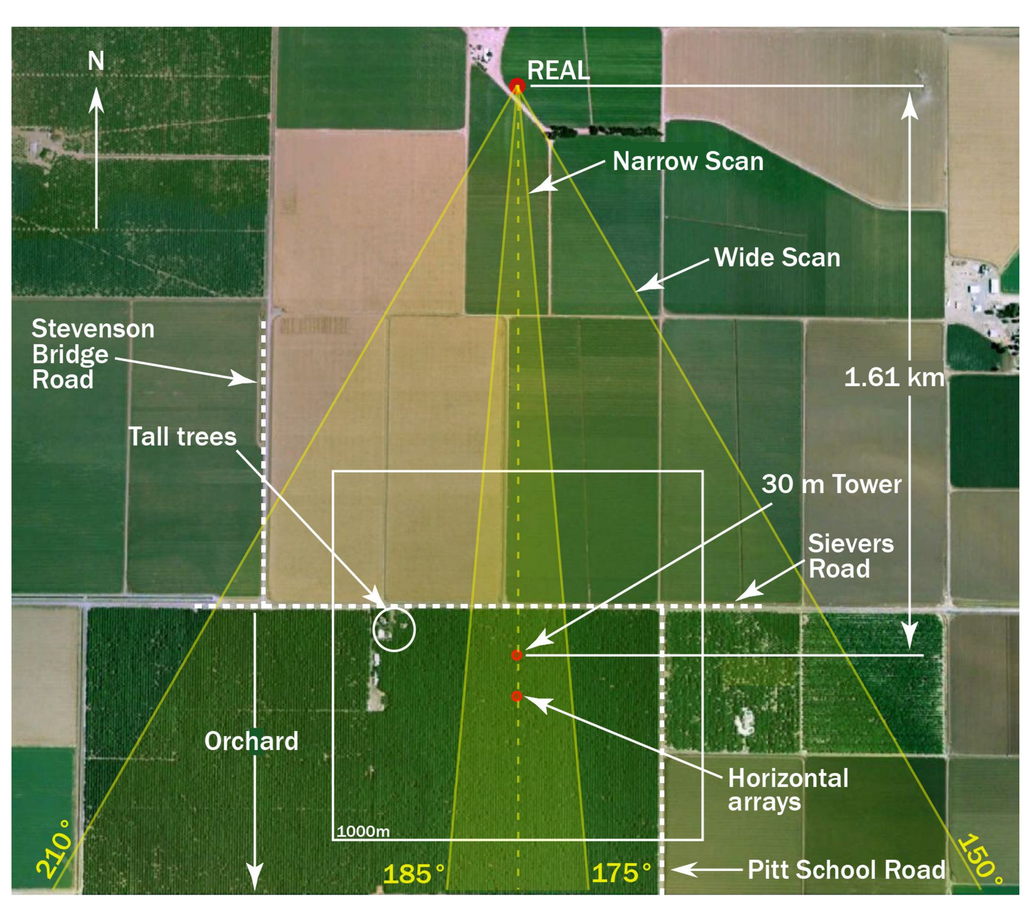
CANOPY WAVES: Atmospheric canopy waves are small-scale vertical oscillations of the stable boundary layer that occur near the top of forest canopies due to the drag exerted by the trees. They are the result of shear-induced inflection point instability and result in Kelvin-Helmholtz waves and billows (Mayor, 2017).
(Below: Artist's rendition of a vertical cross-section of the waves.)



LIDAR: A horizontally scanning aerosol lidar was used to make horizontal cross-sectional images of the canopy waves just above the trees.

OBSERVATIONS: Data was collected in Dixon, California, in the spring of 2007 in the Canopy Horizontal Array Turbulence Study (CHATS). Lidar images and in-situ data (wind velocity, temperature, humidity, pressure, etc.) were collected continuously over 3 months. In total, 53 episodes of canopy waves were observed.

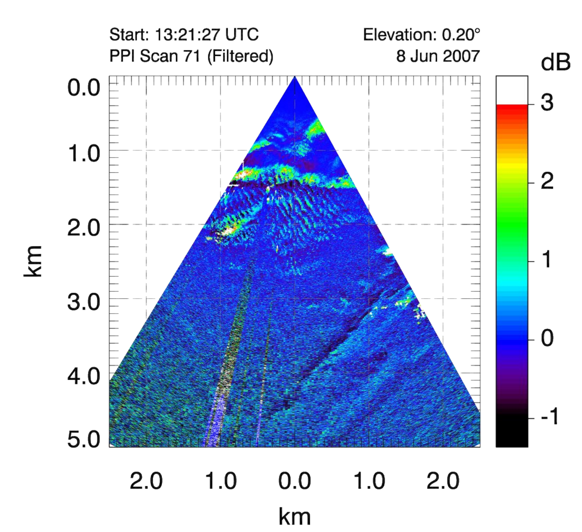


Above: Map of experimental area near Dixon, CA. All of the canopy wave episodes occurred at night when the atmosphere was stably stratified and winds were light.

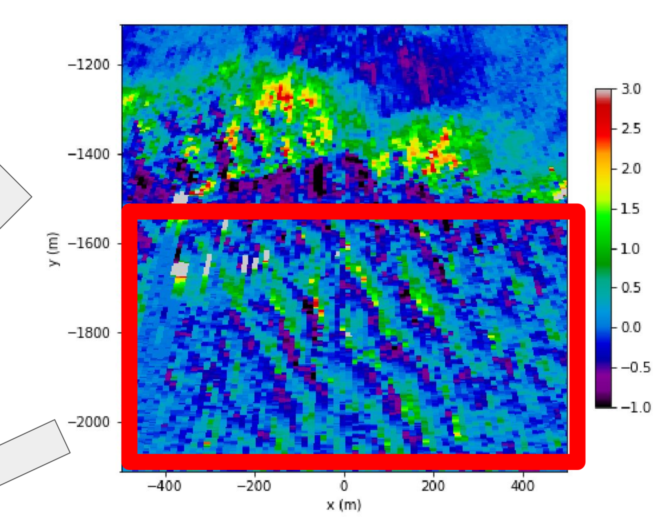
ALGORITHM: An algorithm developed by Dr. Pierre Dérian computes an autocorrelation function (ACF) in a rectangular subset of pixels from a lidar scan. It can be used to determine a single salient wavelength and wave crest orientation in each frame (Mifsud et al, 2021). We found that the algorithm is distracted by various factors such as multiple wave trains and aerosol plumes. We customized the algorithm's region of interest (ROI) (red box below) to avoid non-wave features in some episodes.

In the following images, we show the steps of how we applied the algorithm to each lidar scan to determine a single wavelength and orientation for that time.

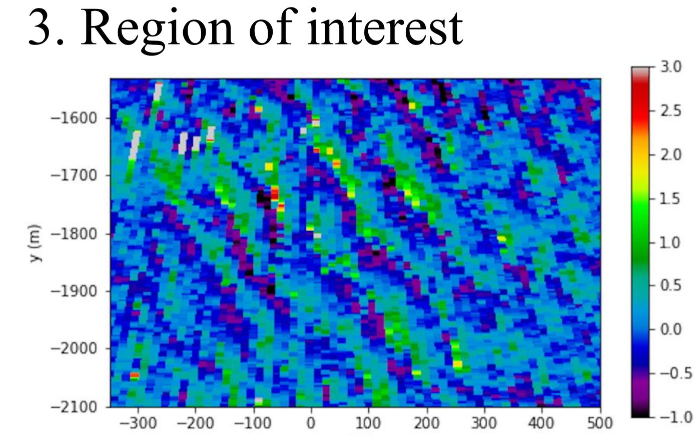
1. Full lidar image



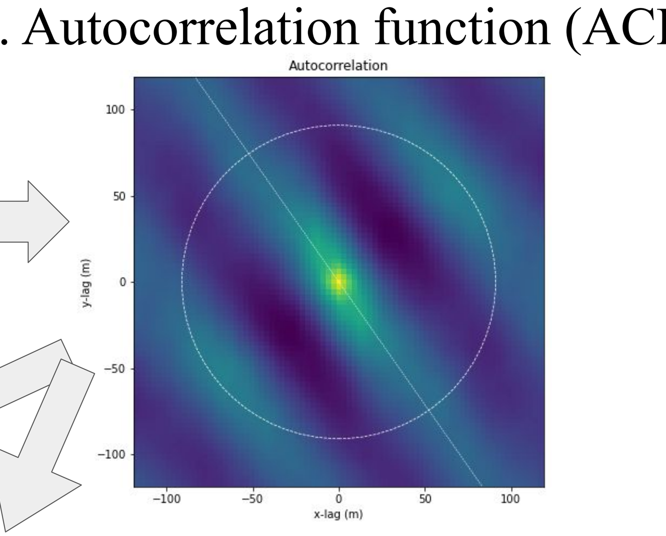
2. Zoomed in to 1 km^2 around tower



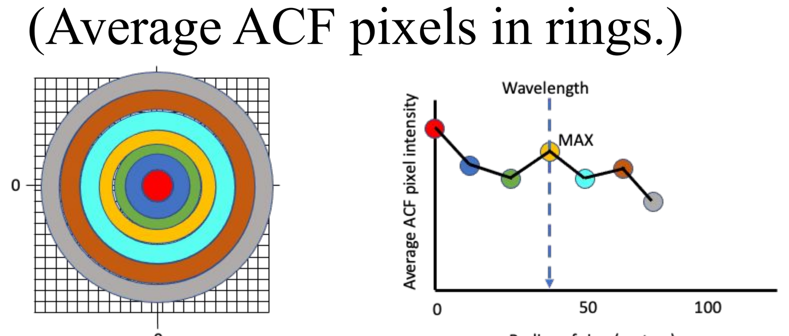
3. Region of interest



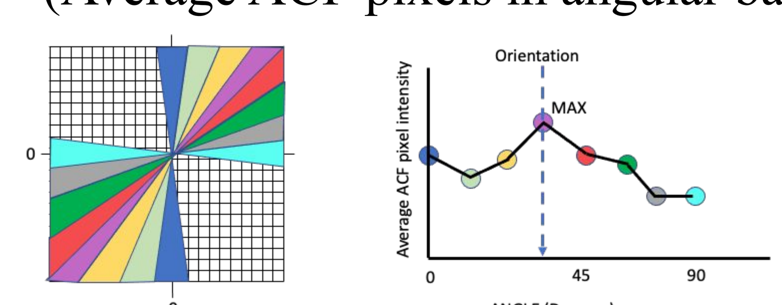
4. Autocorrelation function (ACF)



Determine wavelength from ACF (Average ACF pixels in rings.)



Determine orientation from ACF (Average ACF pixels in angular bands.)



Our new contribution to this ongoing research program was to apply the algorithm to all frames of every episode. By doing so, we have the first opportunity to examine natural variability and trends in wavelength and orientation. A long term goal of this work is to determine the factors that control canopy wave formation and their dissipation or transition to turbulence.

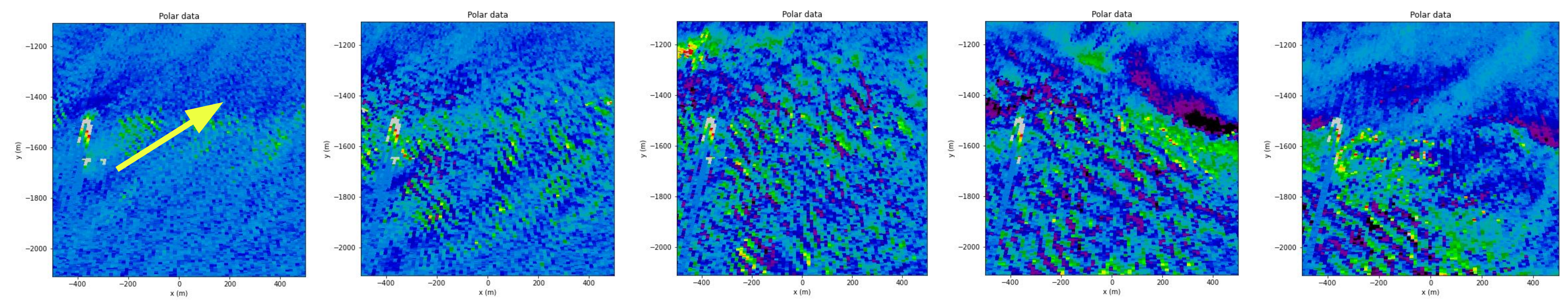
REFERENCES:

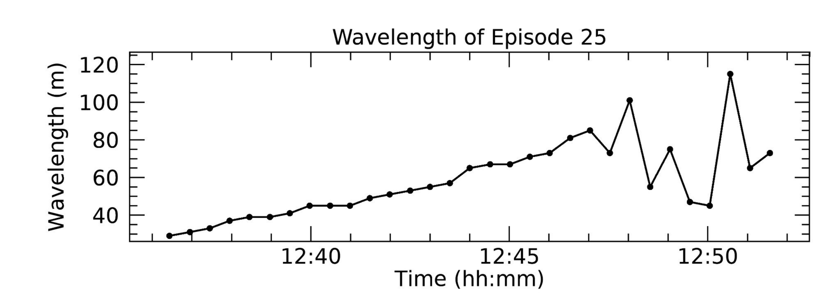
Mayor, S. D., 2017: Observations of microscale internal gravity waves in very stable atmospheric boundary layers over an orchard canopy. *Agric. For. Meteorol.* 244-245, 136-150.

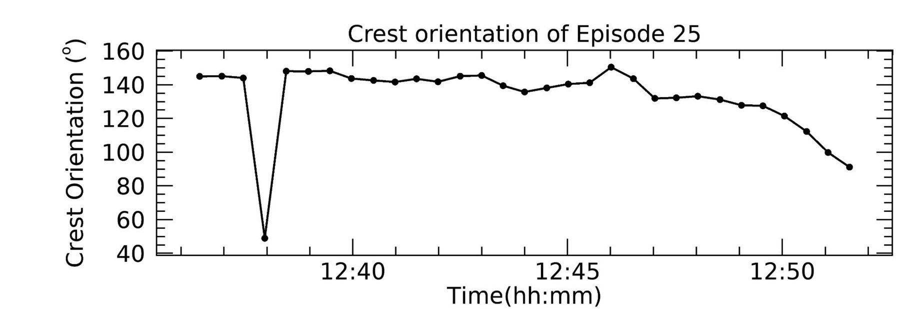
Mifsud, K. E., M. Iqbal, P. Dérian, S. D. Mayor, 2021: Objective determination of wavelength and orientation of atmospheric canopy waves. Poster A45C-1867 at Fall meeting of the American Geophysical Union, 16 December, New Orleans, LA.

RESULTS: Due to the large amount of natural variability from case to case, we have yet to find a good way to display and summarize the results of all 53 episodes. So far, a common trend is not apparent. In this section, we present three episodes.

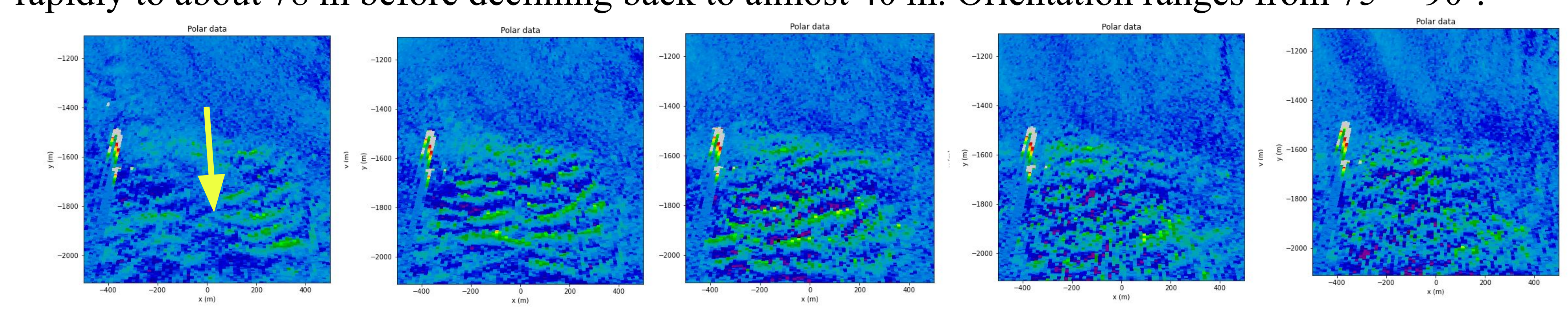
Episode #25: Here we show the ability of the algorithm to track natural variability in the wave characteristics. In the beginning of this case, the wavelengths are small and increase linearly throughout the episode. The erratic results at the end are the result of the cessation of the episode.

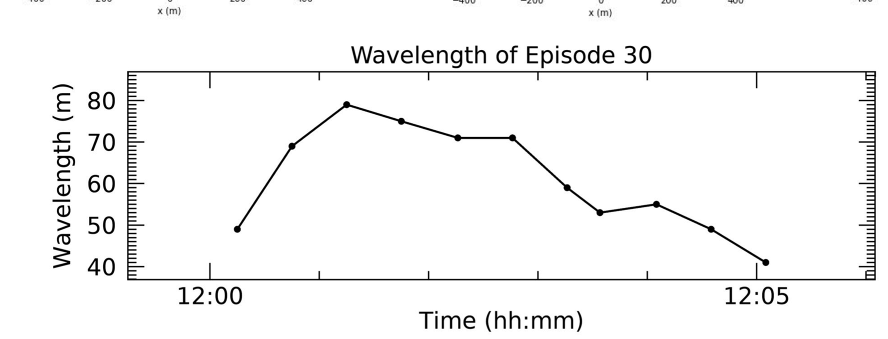


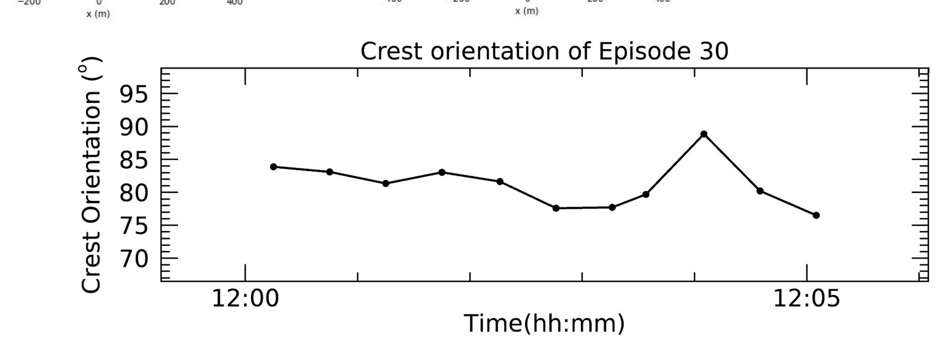




Episode #30: In this shorter episode, the wind direction is from the north. Wavelength increases rapidly to about 78 m before declining back to almost 40 m. Orientation ranges from 75º - 90º.







Episode #12: In this episode, the wind direction is from the northwest and the waves develop over a very short distance from the leading edge of the canopy. The erratic orientation results at the beginning are probably due to non-wave aerosol features dominating the ACF.