An Automated Wave Extraction and Identification Methodology for Atmospheric Lidar Observations Based on a 2D Wavelet Transform

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Lidars are unique and powerful observational tools for studies of atmospheric waves because of their capability to probe large altitude ranges at high resolutions for long durations of time. Atmospheric waves transport energy and momentum throughout the atmosphere and are a key component of the climate system on Earth. However, because these waves exist on a wide range of temporal and spatial scales and exhibit significant variability with geographic location, time, and altitude, the overall role of waves in the global atmosphere is still largely unknown. Most atmospheric models do not operate at resolutions sufficient to capture the majority of wave processes, so observational studies are critical for building a better understanding of the effects of atmospheric waves. Lidar observations are helping to fill in this knowledge gap and this work presents a sophisticated, new data analysis tool that will aid lidar researchers in the study of atmospheric waves.

We have developed an automated method which utilizes a two-dimensional Morlet wavelet transform to extract individual wave packets localized in time and altitude from lidar data, as well as to determine the spectral characteristics of wave packets as a function of altitude. The automated aspect of this methodology makes it suitable for application to large datasets and hence provides a means of performing systematic and statistical analyses of wave properties in a relatively easy and hands-off fashion. This automated wave extraction and identification methodology was developed and used to compile a statistical baseline of gravity wave properties in the mesosphere and lower thermosphere observed throughout the 10+ year McMurdo lidar campaign, led by Dr. Xinzhao Chu. While this was the initial application of this novel methodology, the procedure and associated MATLAB implementation are robust and can potentially be applied to any two-dimensional dataset to analyze periodic signals.

We believe this methodology will be a useful tool for the lidar community, particularly for the statistical analysis of atmospheric wave signals in large volumes of lidar data. This work will describe the automated wave extraction and identification methodology in detail, highlight its inherent limitations, and demonstrate its merit with statistical results of gravity wave properties derived from 10 years of resonance fluorescence lidar data collected at McMurdo Station, Antarctica. These types of studies are generating new insights into atmospheric wave processes and similar analyses of other lidar datasets will help form a more complete picture of the impacts of atmospheric waves on a global scale. Furthermore, such results will aid in the development of more accurate atmospheric models, which currently lack realistic representations of atmospheric wave activity.