S8-1 Measurements with the University of Wisconsin Volume Imaging Lidar

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Boundary layer flow measurements have traditionally been acquired from instruments mounted on towers, aircraft and balloons. Although much has been learned from these observations, the measurements suffer from severe sampling problems. This occurs because boundary layer flows include coherent structures with a wide range of sizes and life times.
Temporal variations due to diurnal forcing and the movement of weather systems make flow statistics measured with tower based instruments non-stationary. Aircraft measurements yield more independent observations in a shorter time. This reduces problems with temporal variation. However, measurements must be performed over spatially uniform surfaces or the spatial statistics measured will also be non-stationary. It is also very difficult to derive the spatial structure and temporal evolution of coherent flow structures from tower or aircraft measurements. Ideal boundary layer measurements would provide the full 4-dimensional flow field. Active remote sensors such as radar and lidar offer the only hope of such comprehensive observations.

This paper describes measurements derived by mapping the spatial distribution of naturally occurring aerosols with the University of Wisconsin Volume Imaging Lidar (VIL). The paper provides an overview of VIL measurement capabilities with an emphasis on recent boundary layer measurements. Cirrus cloud observations with the VIL will also be discussed briefly.

The Volume Imaging Lidar (VIL) is an elastic backscatter lidar designed to image the 4-dimensional structure of the atmosphere. This system couples an energetic (400 mJ), relatively high pulse repetition rate (100 Hz) Nd-YAG laser with a large aperture receiver (0.5 m), and a fast computer controlled angular scanning system (up to 100 degrees/s). High bandwidth data acquisition is sustained during extended experiments by using a 7 gigabyte write once optical disk for data storage. Data acquisition and system control are performed using a Silicon Graphics Indigo 2 computer. Data analysis and real time control of the system are facilitated by 2-dimensional and 3-dimensional displays of data.

A typical 2-minute volume scan with the VIL provides approximately 10 million measurements of aerosol backscatter in a pie shaped sector of 40 to 60 degrees in azimuth, 20 degrees in elevation and 18 km in range. In a typical experiment, these scan patterns are continuously recorded for periods of many hours. Images derived from these data show boundary layer structures. Aerosol rich air is carried aloft by convective plumes while cleaner air from above the boundary layer is entrained into the boundary layer by downdrafts. Time-lapse video images created from this data show both the spatial organization of the convective elements and their temporal evolution. While the VIL does not have Doppler velocity measurement capability, cross-correlation of successive images provides precise area- and time-averaged vertical profiles of the horizontal wind speed and direction. It is difficult to determine the absolute accuracy of these measurements because of other sensors which can measure average winds over areas of approximately 100 square kilometers are not available. However, measures of internal consistency between independent estimates yield differences of less than 5 cm/sec in speed and 1 degree in direction for averages of 1 hour. Comparisons with aircraft, tower and balloon measurements all compare to within the expected statistical variations expected between the different sample volumes and averaging times implicit in these measurements.

Recently, the VIL has been used to observe the flow of cold wintertime air over warm water as part of a project to improve Large Eddy Simulation models of atmospheric flows. Time-lapse animations of lidar data collected in this experiment show a variety of boundary layer phenomena including: intense convection, a land-breeze case, intricate spatial patterns of falling snow and complex gravity wave patterns.

As part of this study, we applied our correlation wind algorithms to a single horizontal plane at 5 m above the water surface which was scanned at 12.5 second intervals. In this case, the scanned area was divided into 250 m square areas and wind speed and direction was computed in each square. Two data set have been analyzed at this point. In the first, a ~6 minute average provided 576 wind vectors in a 6 by 6 kilometer area. In second case, a ~40 minute average produced 960 wind vectors in a 6 by 10 km area. These wind fields show an acceleration of wind speed and veering of direction as the wind response to the decreased surface friction over the water. A plot of average speed and direction as a function of distance from the shore shows point to point fluctuations of less than 10 cm/sec in speed and less than 1 degree in direction. The wind fields also show variations in speed and direction downwind of shore features. The vector wind fields are sufficiently precise to allow calculation of divergence and velocity fields with a noise level of approximately 0.001 sec^{-1}; these fields show structure associated with shore features and longitudinal roll circulations.

Fast scanning and high sensitivity also allow the VIL to map cirrus cloud structure. Under favorable conditions, overhead scans obtained in less than 1 minute can image cirrus structure over a 120 km interval. The application of these data to verification of satellite cirrus cloud retrievals will be presented.