

DOPPLER LIDAR STUDIES OF ATMOSPHERIC WIND FIELD DYNAMICS

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INTRODUCTION

For the past 5 years the Wave Propagation Laboratory has operated a pulsed CO₂ Doppler lidar system to evaluate coherent laser radar technology and to investigate applications of the technique in atmospheric research. The capability of the system to provide measurements of atmospheric winds, backscatter, and water vapor has been extensively studied over this period. Because Doppler lidar can measure atmospheric wind structure in the clear air without degradation by terrain features, it offers a unique capability as a research tool for studies of many transient or local-scale atmospheric events. This capability was demonstrated in recent field experiments near Boulder, Colo. and Midland, Tex., in which the lidar clearly depicted the wind field structure associated with several types of phenomena, including thunderstorm microbursts, valley drainage flow, and passage of a dryline front.

Until recently, the lidar operated with an output energy of 100 mJ per pulse, providing maximum ranges of 12-20 km in the boundary layer or lower troposphere, and 8-12 km when pointed vertically. Although adequate for most lower tropospheric applications, this pulse energy was insufficient for consistent measurement of winds throughout the troposphere and into the lower stratosphere. To improve sensitivity during the periods of low aerosol backscatter, the system has recently been upgraded with new transmitter/receiver hardware. The upgraded system, which transmits 2 J per pulse of output energy at a rate of 50 Hz and incorporates computer control for automated operation, underwent calibration testing during the spring of 1986.

MICROBURST AND DOWNBURST STUDIES

Because of their potentially hazardous effects on aircraft safety, thunderstorm-generated microbursts have received considerable attention in recent years (see e.g., Fujita, 1980). Microbursts are characterized by severe downdrafts that occur beneath convective clouds over scales of about 3 km or less. When the downdraft nears the surface, it spreads into a diverging horizontal wind. An aircraft flying through a microburst on approach or takeoff encounters a rapid change in

airspeed, which in the worst case produces an unexpected loss of altitude that can result in a crash.

Doppler radar is useful for detecting and tracking downbursts in precipitating environments. Under clear-air conditions, however, radar measurements near the surface can be severely limited by ground clutter. Because Doppler lidar operates in clear air with no sidelobe effects, it is useful for research into microbursts in the low radar-reflectivity environment.

The NOAA lidar has been used to track and observe gust fronts and outflows spawned by microbursts on several occasions. In at least one instance, an apparent microburst was observed. During a routine data-gathering session near Boulder, Colo., a member of the crew noticed a region of blowing dust beneath a virga-producing convective cloud. Horizontal scans of the disturbance revealed a region of strong divergence in the horizontal wind field just above the surface 6 km from the lidar. Maximum wind shift measured by the lidar in the region of the microburst was 11 m s^{-1} over a distance of 1.5 km, and 27 m s^{-1} across 3 km.

The disturbance spawned a well-defined gust front whose leading edge was clearly seen by the lidar as a strong shear in the velocity field and a line of enhanced backscatter (due to the dust cloud) in the intensity field. The progress and spread of the gust front from the point of the original disturbance was mapped over 10 km.

VALLEY DRAINAGE FLOW MAPPING

The WPL lidar was employed in a recent experiment sponsored by the Department of Energy to study drainage flow in a mountain valley near Parachute, Colo. (Post and Neff, 1986). The instrument was positioned in the middle of the valley, with line-of-sight views exceeding 10 km towards both the head and foot of the valley. By scanning the lidar beam first toward the head, then toward the foot of the valley in a raster-like scan, we were able to map out cross sections of the along-valley flow field at 300 m intervals along a 20 km segment.

In this experiment, the Doppler lidar provided data that were unobtainable by other means. It was able to scan within meters of the terrain at the sides of the valley, showing the effects of friction on the drainage flow. On seven occasions during a 1 month period a complete 3-dimensional map of the valley flow was obtained at half-hour intervals between 2200 and 1000 local time. From these maps, the formation and subsequent behavior of a compact jet core in the drainage flow field was observed. The jet core was seen to wander from one side of the valley to the other as the night progressed. From

the 300-m-long cross sections of along-valley wind, the contribution to the drainage flow at various points along the length of the valley was estimated by computation of the mass flux. Increase in flow due to the effects of side canyons was clearly seen as an increase in the mass flux below the entrance of each side canyon. Lidar results also permitted observation of the breakup and reversal of the drainage flow during the morning hours due to solar heating of the valley walls.

DRYLINE AND FRONTAL PASSAGE DYNAMICS

The capability of Doppler lidar to resolve the transverse fine structure of the wind fields in clear air makes it a valuable tool for studying wind field dynamics along frontal boundaries. During spring 1985, the instrument was used in an experiment to observe frontal hydraulics at the leading edges of cold fronts near Midland, Tex.. It has been postulated that vertical motion can occur over very short length scales along frontal boundaries, with sufficient intensity to trigger convective outbreaks in otherwise stable air (Shapiro et al., 1985). The lidar was employed in the experiment to map the small-scale wind field features vertically and along the frontal boundary during the period of frontal passage, and to monitor the tropospheric wind field with velocity-azimuth-display (VAD) wind profiling before and after the frontal passage.

Midland was selected as the site for the experiment because during April it is climatologically located west of the line of demarcation, often referred to as the dryline, that separates the moist Gulf of Mexico air over the southeastern states from the drier continental air to the west. A site located within the dry air but near the dryline was desirable for lidar operation, so as to reduce the likelihood that the vertical motion associated with the front would produce clouds that could limit measurement capability.

While at Midland, we observed several weak frontal passages with the lidar. We also were able to examine wind field structure along the edge of the moist air boundary as the dryline moved past Midland to the west. The well-defined leading edge of the dryline was detected by a vertically pointing radiometer, which showed a rise in precipitable water vapor from 1.3 to 2.5 cm over a 10 min interval.

Wind structure behind the leading edge of the moist air was seen to be similar to that produced by density currents such as cold fronts. Range-height-indicator (RHI) displays of radial winds indicated a sharp interface in the wind field sloping away from the direction of motion. Winds behind the boundary appeared to move toward the interface at the surface, then curl up and away from the interface at a height of about

2-3 km. Some evidence of Kelvin-Helmholz waves was observed in the region of strong shear at the top of the moist air surge. In general, the appearance of the wind field structure was quite similar to results obtained by Droegemeier (1985) in numerical simulations of density currents.

LIDAR UPGRADE

To improve the capability of the lidar for long range measurements of atmospheric parameters, especially in the upper stratosphere and lower stratosphere, a new, more powerful transmitter was incorporated into the system following the 1985 Texas experiment. The new transmitter employs an injection-locked, unstable resonator configuration to obtain 2 J per pulse of frequency-coherent energy at 50 Hz. Computer control of many functions makes the new system much easier to use than the previous 100 mJ system in field experiments.

The lidar underwent testing and calibration during spring 1986. It is scheduled for use in field experiments this summer to study the effects of terrain-induced, mesoscale convergence near Denver on convective activity, and to further study microburst occurrence and characteristics. Preliminary results from the summer experiments should be available for presentation at the meeting.

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