Ground-based Doppler Lidar Signal Processing in the Vicinity of Strong Backscatter and/or Wind Inhomogeneities Using a Progressive Context Method

G. D. Emmitt, S. A. Wood and D. Bai
Simpson Weather Associates, Inc.
Charlottesville, Va 22902

INTRODUCTION

Many of the expectations for the performance of a space-based Doppler lidar are based upon the experienced gained from ground-based lidar systems. To date, there have been no pulsed Doppler lidar wind measurements made with a space-based perspective on the atmosphere. In particular, the space-based Laser Atmospheric Wind Sounder (LAWS) concepts were derived from existing ground-based lidar programs (NASA and NOAA) with pulse-pair algorithms involving 3-50 shots per estimate. A space-based system will probably have a pulse repetition rate < 20 hz and each shot will be processed separately.

Until a pulsed, downward scanning airborne lidar is available for research, we are using ground-based lidars to collect single-shot samples using scanning geometries, pulse dimensions, and shot densities that are similar to those expected from space. Single shot in-phase and quadrature time series, as well as polypulse-pair estimates, have been obtained to investigate the vertical and horizontal velocity structures where there are strong gradients in the aerosol backscatter and/or horizontal wind components.

LIDAR SYSTEM CHARACTERIZATIONS

We receive polypulse-pair and single shot Doppler lidar data collected by the NASA/MSFC and NOAA/ETL Doppler lidar systems. The MSFC lidar system is a 10.6 um 10j pulsed Doppler lidar with a pulse to pulse frequency stability yielding a [sigma subv] ~0.1 m s-1. While this pulse energy is rather marginal for getting strong returns in the vicinity of very thin cirrus clouds, the stability makes it ideal for single shot vertical velocity measurements within clouds. Although the frequency stability of the NOAA/ETL 10.6 um laser is not suitable for single shot vertical velocity measurements, its 1 J energy/pulse permits velocity measurements above and below cirrus clouds. Conical scans with elevation angles >45 deg provide measurements of the horizontal wind flow near and within the clouds. Both lidars provide data within and particularly at the upper boundary of the continental PBL.

These Doppler lidar observations are taken to obtain single shot and polypulse-pair data that could be used for the following investigations:

* to simulate a space-based observing perspective and 10-50 km intershot spacing

* to examine the velocity and backscatter fields at cloud boundaries (especially at the lower boundary of cirrus clouds)

* to examine the velocity and backscatter fields in the lower PBL

* to examine single shot statistics in comparison to those derived from polypulse pair statistics.

PROGRESSIVE CONTEXT SIGNAL PROCESSING

Simpson Weather Associates (SWA) has developed and refined a series of computer tools that are designed to process and analyze NASA/MSFC and NOAA/ETL ground-based Doppler lidar polypulse-pair and single shot data (Wood et. al, 1993). Over the past few years, SWA has used these computer tools with ground-based Doppler lidar data to simulate what will be obtained from space-based systems (Emmitt, 1993; Emmitt et. al., 1993, Emmitt and Wood,1988). The ground-based lidar data processor segments the raw polypulse-pair and single shot data into either azimuth scanning or azimuth fixed files. Once the data is segmented, the single shot in-phase and quadrature data is passed to the Progressive Context Signal Processing Model to produce line-of-sight wind (LOS) velocities. An example of a first pass through single shot raw lidar data is shown in figure 1. Here the "strongest " weighted peak in the FFT produced spectrum is shown as a solid blue line as the 32 bit processing window is "slid" by 8 bits between FFTs. The dashed red line represents the 2nd highest peak in the spectra. It is clear that the correct choice of peaks when SNRs are marginal, relies upon, in part, knowledge of the answer from nearby range gates with stronger SNR.

For the azimuth scanning data, a Context Sine Fitting Model fits a sine wave to the LOS data by iterating on amplitude, phase and vertical offset. The LOS data is filtered by using SNR thresholds to improve the goodness of the sine fit. The goodness of fit is used to adjust each sine fit and to provide a first guess for the next range gate. The sine fits are then used to compute the vertical profile of horizontal winds. The PPI/UV Display couples the horizontal wind components with a Plan Position Indicator display of the line of sight wind velocities (or SNR).

CIRRUS CLOUD AND BACKSCATTER INHOMOGENEITIES

We processed NASA/MSFC single shot azimuth scanning data for July 17, 1992, 1623Z. Each data scan was noise filtered and least squares fit to a sine wave (example is shown in figure 2) to establish horizontal wind components . Figure 3 is a PPI/UV diagram of the filtered single shot data. At range gates 6-17 there were strong signals to make wind estimates, but after range gate 18, the single shot data showed loss of signal. However, at range gates 50 - 52 a thin cirrus cloud was present and there was strong SNR to make wind measurements. After examining a small set of VADS we found the lidar wind information from the cirrus clouds to be very variable. A longer time series of lidar data is needed to examine this closer.

We processed NOAA/ETL polypulse-pair azimuth scanning data for June 29, 1993, 1507Z shown in figures 4 and 5. The LOS PPI/UV diagram shows no strong varaibility in the vertical wind field. The SNR PPI/UV plot shows the existence of a two cloud layer structure that is not evident in the LOS diagram.

For our oral presentation we expect to show more current results of an ongoing study using single shot data from NOAA/ETL in areas where there are strong gradients in aerosol backscatter and/or horizontal wind components.