6.3 Comparison of GWOLF and VALIDAR Doppler Lidar Measurements

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1. Introduction

As seen elsewhere in these proceedings (Emmitt et al., 2005a; Emmitt et al., 2005b; Greco and Emmitt (2005)), the Navy's Center for Interdisciplinary Remotely-Piloted Aircraft Studies (CIRPAS) was funded jointly by the Navy and the Integrated Program Office (IPO) of NPOESS to install a coherent 2 micron Doppler lidar in a Navy Twin Otter aircraft. With Emmitt as the PI, this Twin Otter Doppler Wind Lidar (TODWL) was flown out of Monterey, CA during the springs of 2002 and 2003 in a series of missions dedicated to both wind lidar issues and characterizing the vertical wind and aerosol distributions in the lower levels of the atmosphere. After the 2003 series of flights, CIRPAS decided to upgrade the TODWL and install the current Doppler Wind Lidar (DWL) in a trailer for use between flight campaigns. This DWL is fully operational and has been operating as GWOLF (Groundbased Wind Observing Lidar Facility) at NASA/LaRC under funding from IPO.

There are several other ground-based coherent systems built and operated by NASA and NOAA. Recently, NASA/LaRC has established a Lidar Intercomparison Facility (LIF) (Kavaya, et al., 2004) with a coherent 2 micron system as its core DWL (Doppler Wind Lidar). The LIF was designed to provide a location for routine simultaneous operation of up to 4 DWLS; provide means to make parallel the beams of up to four lidars slanting up through the atmosphere and provide a clear path to the atmosphere in all directions.

The coherent 2 micron system, called VALIDAR (Koch et al., 2004), has been built using a high-energy (~ 100 mJ) laser. The Validar project was initiated to demonstrate a high pulse energy coherent Doppler lidar. Validar gets its name from the concept of "validation lidar," in that it can serve as a calibration and validation source for future airborne and space-borne lidar missions. Validar is housed within a mobile trailer for field measurements.

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Both VALIDAR and GWOLF have been stationed at the LIF in Langley,VA. Figure 1 shows the layout of the trailers containing the respective lidars.

2. GWOLF

As the ground-based version of TODWL, GWOLF can provide continuous 3D mapping of the atmospheric flow within 10-15km range (perhaps less in the vertical and more in the horizontal). The line-of-sight resolution is ~ 50 meters with accuracies ~ <10 cm/sec. In addition to wind speed along a single LOS, GWOLF provides an estimate of aerosol (or cloud) backscatter and turbulence for each 50 meter range gate. By combining angularly separated LOS's, we can provide complete vertical soundings of u, v, and w to compliment the microwave and GPS soundings. If desired, the lidar can be put in the profile mode and collect complete soundings (50 meter vertical resolution of winds, turbulence and aerosols) every 12 seconds.

While the bi-axial scanner of the airborne TODWL was mounted on the side door of the Twin Otter aircraft, the GWOLF version of the scanner was positioned on a sliding rail-car that could look up and slantwise in the vertical when outside the trailer.

A summary of some of the prominent features and characteristics of GWOLF are given below:

- Wavelength ~2 microns

- Energy per pulse ~ 2-3 mJ
- Pulse Repetition Frequency ~ 500 Hz
- 10 cm bi-axial scanner
- Range resolution of ~ 50 meters
- LOS measurement accuracy < .05 m/s
- Wind component accuracy < .1 m/s
- Aerosol backscatter threshold sensitivity ~ 10 -08 m sr -1 at 10 km

3. VALIDAR

A complete lidar system testbed has been built and integrated with a real-time signal processing and display computer. .

A partial list of VALIDAR specifications is given below:

- Hemispherical scanner with 20 cm effective aperture
- GPS Receiver
- 50-150mj, 5-10 HZ, Diode-pumped transmitters
- 10 cm COTS and 25 cm SPARCLE telescopes
- Real-time data processor and display

A sample wind measurement is shown in Figure 2. The wind data are acquired by pointing the lidar scanner in 3 different directions. The first 2 are orthogonal wind profile measurements at on elevation angle of 45 degrees, from which the horizontal wind profile is measured. Figure 2, shows an example of a wind profile up to an altitude of 8 km. In this profile the top of the atmospheric boundary layer can be seen at 2800 m and is marked by a sharp increase in the wind speed. The erratic results between 5600 m to 6500 m are due to the loss of signal resulting from very low aerosol levels. The signal returns above 6500 m as a result of encountering cloud cover.

4. Intercomparisons

An early comparison between GWOLF and Validar as shown in Figure 1 is presented in Figure 3. More recent data taken in Dec 2003 is just now being evaluated.

During the processing of the 2003 TODWL data, it was found that the vertical component of the wind could be reasonably measured during a conical scan. Given the 12 look angles used to obtain a sounding, the three components were, in principle, obtainable. However, since the expected magnitude of the vertical wind (w) was usually on the order of a few cm/s, there were no high expectations of resolving it. Although the observed TODWL w near the surface were large and variable, the fact that the aircraft moves ~1.5 km during a 12 point scan adds the complication of varying terrain and PBL depths around the cycloid. While we are still evaluating those data, it seems quite likely that we should be able to provide all three components if we change the scan pattern to a tight cycloid coupled with a nadir stare. Such a pattern was designed for GWOLF and tested. The results were very encouraging. The intent is to continue to use GWOLF to evaluate scanning and signal processing ideas and to use Validar to validate the resulting data products.

In addition to exploring the signal processing issues related to near surface returns (<500 meters), there was a related interest in returns from cloud tops (or bottoms) where the sharp discontinuity in backscatter demands special signal processing strategies. We have only begun to look at some data sets taken during the 11 February flights of TODWL. However, GWOLF provided an excellent opportunity to investigate this matter for a variety of cloud types and multi-cloud layer situations such as that shown in Figure 4.

5. References

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Figure 1. LaRC's VALIDAR next to CIRPAS/IPO's GWOLF lidar. Both are 2 micron coherent DWLs.

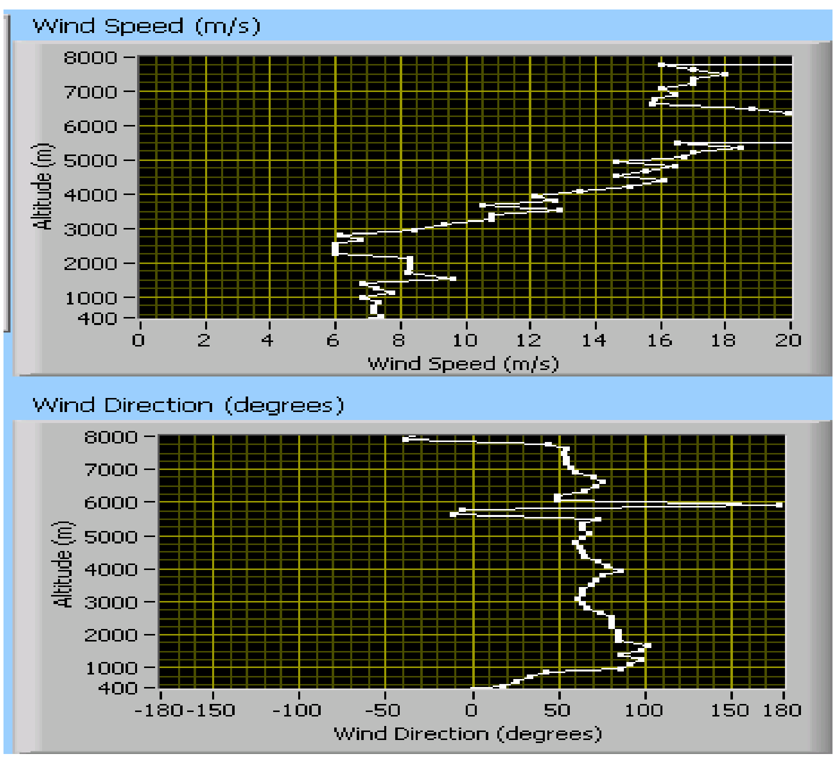

Figure 2: Wind speed and direction as a function of altitude as measured by NASA LaRC Validar high-energy coherent Doppler wind lidar.

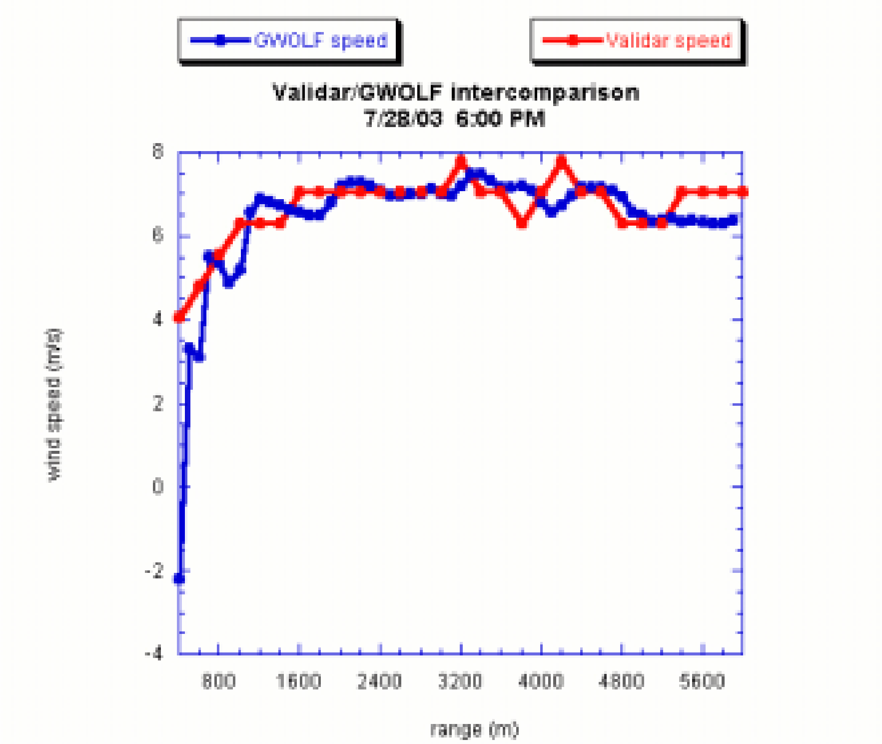

Figure 3. Preliminary comparison of VALIDAR and GWOLF returns from a common volume. A common volume is defined as 6000km long , 10 meters wide and 5 meters high.

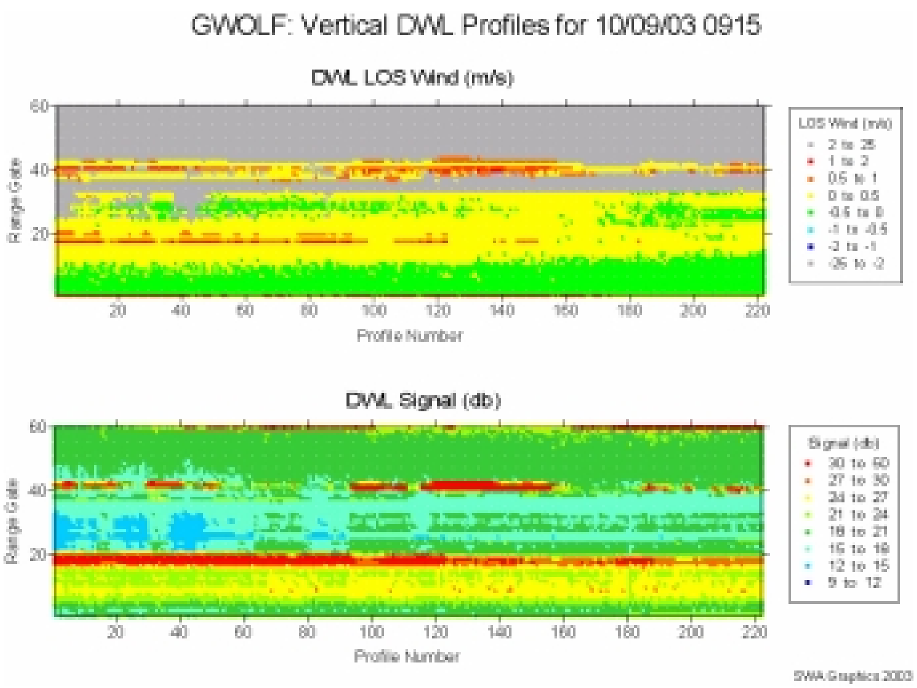

Figure 4. Example of multi-cloud layer over the LaRC's Lidar Comparison Facility. These data are being used in developing an algorithm for processing returns from regions of strong backscatter gradients.