A Wind Lidar Comparison Experiment at The Howard University Beltsville Atmospheric Observatory

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ABSTRACT

A wind lidar experiment was completed at the Howard University Beltsville Campus. Three lidars: the NASA/Goddard Laboratory for Observation of Winds (GLOW), the NASA/Langley Validation Lidar (VALIDAR), and a commercial lidar from Leosphere(WLS70). The lidars compared well with each other, with radiosonde data, a 915 MHz wind profiler and data from the Aircraft Communications Addressing and Reporting System (ACARS), as transmitted by NOAA's the Meteorological Assimilation Data Ingest System (MADIS) database. VALIDAR and GLOW are also used to demonstrate a combined profiling of wind from ground to 15km altitude.

1. INTRODUCTION

Wind profile information is one of the main meteorological variables that are crucial to accurate forecasting of weather. Yet, remote measurements of wind from satellite platforms have not been realized despite its importance. A substantial effort is currently underway to realize remote sensing of 3D wind profiling from space. One technique that has received a focused and intensive study is lidar-based Doppler wind profiling. Despite the importance of lidar profiling of winds, there exists very small data base of measurements from which to evaluate performance of future space instruments and algorithms.

We have been involved with evaluating and studying the errors associated with ground-based lidar profiling. In the following, we briefly highlight a wind-lidar intercomparison experiment that was hosted at the Howard University Beltsville Research Campus in February-March of 2009.

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2. THE EXPERIMENT LOCATION

The Howard University Beltsville Research Campus is located between the major metropolitan cities of Washington D.C. and Baltimore, Maryland at in Beltsville, at 39.054°N latitude, -76.877°E
The site contains a suite of remote sensing as well as other in-situ surface and profiling instrumentation. These include a 915 MHz wind profiler (operated by the Maryland Department of the Environment, MDE), a Vaisala CT25K ceilometer, and a 30 meter tower instrument with temperature, pressure, and relative humidity sensors, and a sonic anemometer. In addition, a continuous water vapor and temperature profiling microwave radiometer, NOAA and Suominet GPS sensors, a 2-channel radiometer and several passive long and short wave energy monitors, soil moisture and precipitation monitors are operational. The Howard University Raman Lidar (HURL) is also located at this site. The site also serves as a co-laboratory for many of the universities, private industry and federal agencies in the Mid-Atlantic United States region.

3. WIND LIDAR EXPERIMENT

Three wind profiling lidars were operated side by side in between February-March 2009 at the Howard University Beltsville Campus. These lidars include the NASA Goddard Laboratory for winds (GLOW), NASA Langley Validation Lidar (VALIDAR), and the Leosphere (www.leosphere.com) WLS 70 commercial lidar – a relatively new compact boundary layer wind profiler from Leosphere©, France. A brief statement on three of these lidars is given below, in the following sections.
In addition to the three wind lidars, a number of other "standard" sensors were also operated, including a 915 MHz wind profiler, several different types of radio sounding sensors (Vaisala RS92 radiosonde, the Sippican MARK IIA sonde

launched by the National Weather Service at Sterling, VA) and data from the Aircraft Communications Addressing and Reporting System (ACARS), as transmitted by NOAA's the Meteorological Assimilation Data Ingest System (MADIS) database.

3.1 GLOW

GLOW Doppler lidar is a field deployable system transmitting a very short (20 nsec) laser pulse into the atmosphere using a Nd:YAG 355nm laser and the light backscattered by molecules and aerosols in the atmosphere is collected by a telescope. The technique utilizes two high spectral resolution optical filters located symmetrically about the outgoing laser frequency to measure the Doppler shift. The design of the high spectral resolution Doppler receiver used to make the Doppler frequency shift measurement is based on the double edge technique (see Gentry, and Chen, 2000). The details of the double edge method have been reported for lidar systems measuring the Doppler shift from either the aerosol (Korb et al., 1998), Gentry et al., 1998)) or molecular (Flesia and Korb, 1999) backscattered signals. Although GLOW is designed for efficient operation in the clear air regions of the free troposphere and lower stratosphere, it can be adapted to operate in the boundary layer.

3.2 VALIDAR

The NASA/Langley lidar, called VALIDAR, uses a novel high-energy, 2-micron, Ho:Tm:LuLiF laser technology developed at NASA Langley and employed to study laser technology currently envisioned by NASA for future global coherent Doppler lidar winds measurement. The 250 mJ, 10 Hz laser was designed as an integral part of a compact lidar transceiver developed for future aircraft flight. This system is mainly sensitive to the aerosol and provides data in most of the lower troposphere. For details of VALIDAR and its aircraft-based recent operations see Singh et al., (this conference) and Koch et al., (2009).

3.3 LEOSPHERE WLS 70

The WindCube™ WLS70 is a new generation wind Lidar developed by LEOSPHERE© for meteorological applications. The Lidar is derived from the commercial WindCube widely used for autonomous measurements and modified to increase the range up to 4 km. The Lidar data has a time resolution of 30s per profile and a range resolution of 50m from (100m to 4000m), and a velocity resolution (0.2m/s).

4. VALIDAR-GLOW: *TOWARDS A HYBRID SYSTEM*

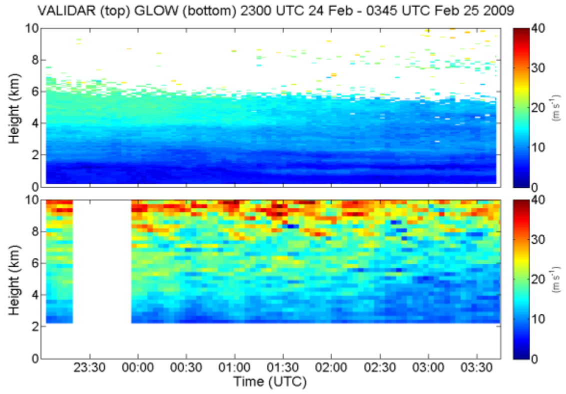

***Figure 1**: Wind Speed (m/s) profiles collected on 24 Feb 2009 by GLOW and VALIDAR.*

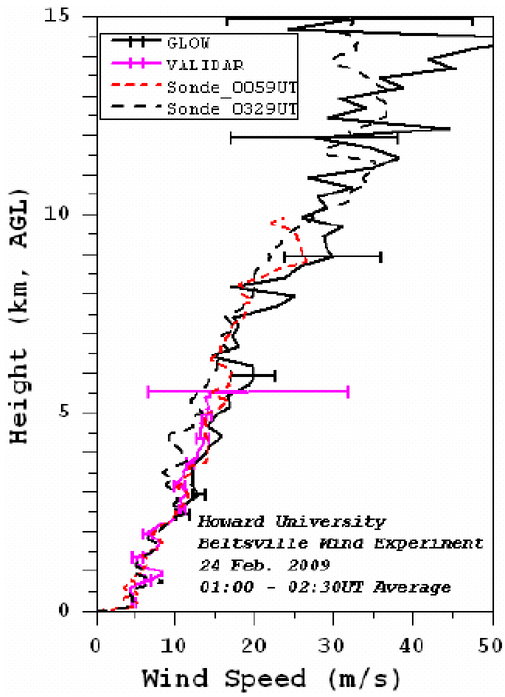

***Figure 2:** A comparison of GLOW, VALIDAR and two different sonde profiles (dash lines) made on 24 Feb 2009. Solid lines are averaged wind profile from the ground to 15 km using a combination of the direct detection method by GLOW and the Coherent technique by VALIDAR.*

A combination of these two lidar technique (the molecular-based direct detection for the upper troposphere and the coherent method for the lower aerosol laden boundary lidar) is a leading candidate for future NASA 3D wind lidar mission described in the NASA Decadal Survey. Thus, simultaneous ground operation and performance analysis of such systems is a pre-requisite for understanding limitations as well as usability of such data from future missions.

In Fig. 1, an example of a comparison of VALIDAR and GLOW performance with a Vaisala RS92 sonde launched at HUBC at 0329UT and a LMS Mark IIA (0059 UT) launched at Sterling, VA is plotted. All four independent wind measurement systems show very good correlation throughout the altitude ranges shown.

Differences of the standard deviation and correlation coefficient of wind speed measurements in a range between the altitudes of 2-7km, for all the profiles on that day, are shown. It reveals that the correlation coefficient between these two lidar systems has a maximum between the altitudes of 3.7 50 5km altitude. This may be explained by fact that the efficiency of the technique used by the aerosol sensitive systems (e.g. VALIDAR) decreases with altitude while that of the molecular-sensitive system (GLOW) increases with altitude. This is expected to lead to an overlapping optimum region for wind retrieval using the two techniques and a good region for data merge when creating a combined profile of wind properties.

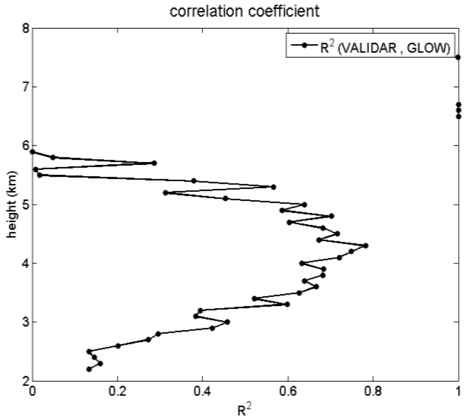

Figure 3*: A correlation coefficient versus altitude of the VALIDAR and GLOW data profiles on February 24, 2009.*

5. VALIDAR-WLS70

A comparison of the two aerosol-based lidar wind sensors shows a very good correlation. Note that WLS70 operates with a laser that is almost three orders of magnitude lower in power than VALIDAR and thus is limited in its reach in height. Nevertheless, the data from these two systems (Fig. 5) shows a very good agreement and has a correlation of 0.85 and intercept of 1.7m/s. Note however that the two systems have different variance/variability along the mean wind speed.

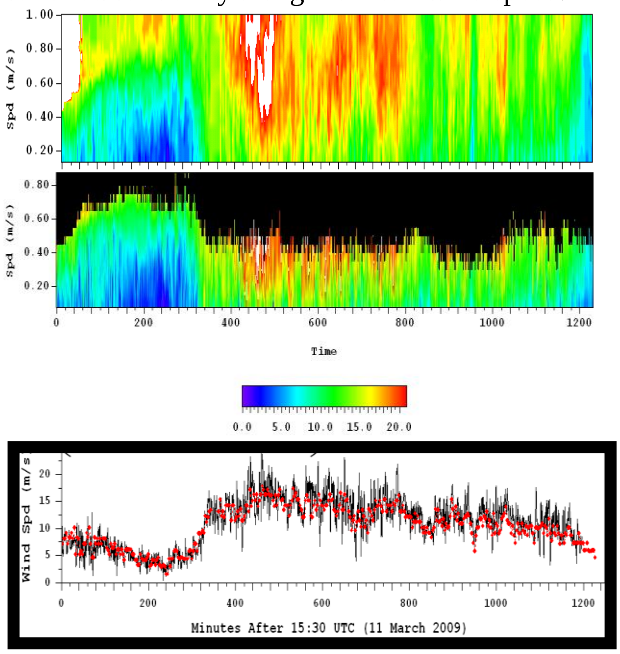

Figure 5: *A time-height pot of wind speed in the sub-km from VALIDAR (top), WLS70 (Middle) and a comparison of time series wind data taken from an altitude of 0.2km made by VALIDAR (red) and WLS70 (black).*

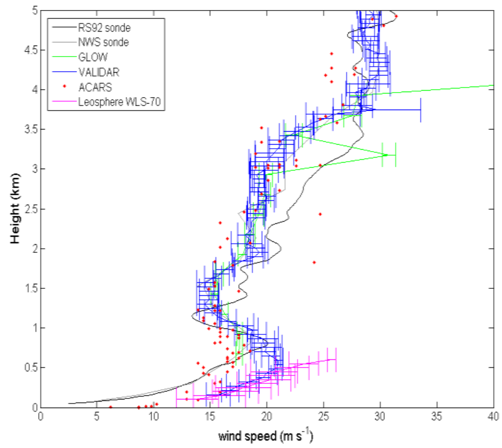

Figure 6*: A comparison of lidar (VALIDAR, GLOW, WLS70) plotted with 30-minute averaged ACARS and other "standard" wind measurements. Note that the ACARS (red dots) have the largest variability.*

6. COMPARISONS WITH ACARS

The ACARS wind is routinely being ingested and has contributed to quantifiable improvement in weather forecasts. WMO reports indicate a "3-hour wind forecast error was reduced by 40% with and an overall improvement of 11%", which is substantial.

(*[http://www.wmo.int/amdar/Publications/Final%20 Production%20AMDAR%20Flyer.pdf](http://www.wmo.int/amdar/Publications/Final%20Production%20AMDAR%20Flyer.pdf); Accessed on 03/13/2010*). A comparison of the lidar measured winds with ACARS measurements revealed that lidar winds have a smaller variability. Quantitative comparisons will be presented during the presentation.

7. LIDAR WIND IN THE CONTEXT OF CLIMATE

Lidar-based measurements of the wind need to be able to resolve long term trends. We plot here (Fig. 4) the monthly average wind speed at Sterling, VA. The plot indicates that wind speed and its variability increase with height, the location of the jet core altitude changes varies by about 2.5km or more, and the wind speed difference between June/July and Jan/Dec. at core altitude is about 25m/s. This indicates that a resolution of at least 250m (=2.5km*10%) and wind speed uncertainty of better than 2.5m/s is required to resolve any trends in the jet core, which is a major driver for weather. Lidar-based wind speed statistics so far suggests that this resolution and uncertainty is achievable.

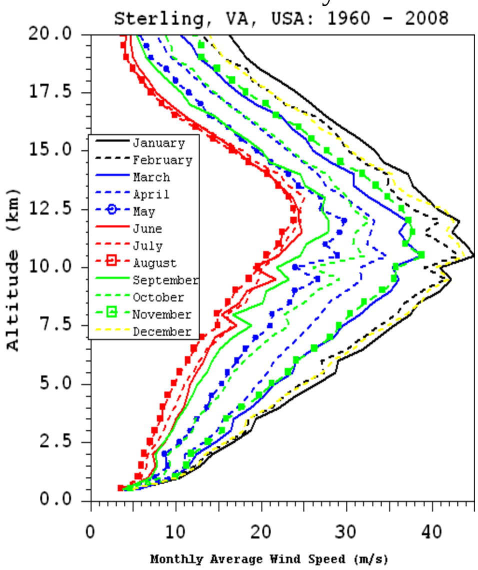

***Figure 4**: Monthly averaged wind speed (1960-2008) at Sterling, VA. Note that the jet core varies by about 2.5 km between summer and winter.*

8. SUMMARY

The NASA Decadal Survey explicitly states the need and plan for a lidar-based satellite 3D wind lidar measurements. Ground based performance of these candidate technologies demonstrates increased progress and maturation of the technology and algorithm needed for NASA's Future 3-D Winds Measurement from Space.

9. ACKNOWLEDGMENTS

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