

FIELD PERFORMANCE OF ALL-FIBER PULSED COHERENT DOPPLER LIDAR

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ABSTRACT

Coherent Doppler lidar (CDL) has been a powerful instrument to measure atmospheric wind velocity. In this work, an 1.5 μm all-fiber pulsed CDL has been developed and deployed to measure wind profiles in campaign experiment in 2018. The CDL has 0.1-5 km detection range with range resolution of 30 m, temporal resolution of 16 s at Velocity-Azimuth-Display (VAD) mode. Field experiments were implemented and the wind vector profiles were retrieved. As compared with sounding balloon, the discrepancy of wind speed and direction are nearly 0.7 m/s and 5 degrees, respectively. It shows that the CDL is a powerful tool for wind speeds measurement in lower atmospheric troposphere.

1. INTRODUCTION

1.5 μm all-fiber pulsed CDL has attracted much attentions due to its eye safety, compact size, flexible deployment and mature fiber components technology from telecommunication industry.[1] Mitsubishi Electric Corporation has developed an airborne 1.5 μm pulsed CDL which can detect as far as 9.3 km with changeable range resolution of 30, 75 and 150 m.[2] Leosphere displays a long range lidar (Windcube 200S) which can measure 3D wind profiles up to 7 km with 70 m range resolution, 0.5 m/s velocity resolution and 1 s time resolution.[3] Prasad et al. have presented a 1.54 μm all-fiber pulsed CDL which can measure wind velocity greater than 120 m/s over ranges greater than 10 km and its range resolution is less than 15 m.[4] Wu et al. have designed a 1.5 μm pulsed CDL with high updating rate of 4 Hz and variable physical spatial resolution from 15-60 m.[5] In

this study, an all-fiber single mode laser with pulse energy of 300 μJ, pulse width of 400 ns and repetition rate of 10 kHz is used to measure wind velocity in range of 0.1-5 km. The CDL shows good stability and reliability in field campaign.

2. METHODOLOGY

2.1 The lidar system

The pulsed CDL for wind velocity measurement is operated by transmitting high energy narrow bandwidth laser beam into the atmosphere, which can acquire LOS velocity by analyzing the Doppler shift between objective backscattered signal and local oscillator. The key technologies are composed by: High-power single-frequency pulsed laser technology, optical antenna system, high sensitivity heterodyne detection technology, signal acquisition and real-time processing technology, as is shown in Fig. 1.

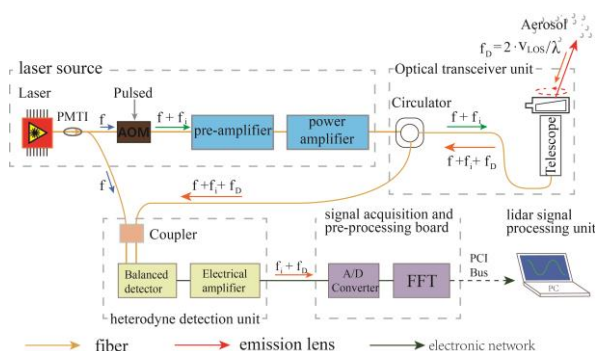


Figure 1. System diagram of the ground-based lidar.

The main system parameters are shown in Tab. 1.

Table 1. Main parameters of the pulsed coherent Doppler lidar system.

Component	Qualification	Specification
Transmitter	Operating wavelength	1540nm
	Pulse energy	300 μ J
	Pulse repetition rate	10 kHz
	Pulse width	400 ns
Transceiver	telescope diameter	100 mm
	scan mode	Conical
	zenith angle	20 $^{\circ}$
	azimuth	8
	scanning time	16 s
Data-Acquisition	sampling frequency	1 GHz
	sampling length	40 μ s
	range resolution	30 m

2.2 Comparison of CDL and sounding balloon

Sounding balloon detects wind speed through calculating its azimuth angle and elevation angle in unit time. The dataset from sounding balloon record 30 s average wind speed, updating time of 1 s, vertical range resolution of near 5 m. Horizontal space range between sounding balloon and CDL is near 50 m. The comparison scheme is given based on the quality of sounding balloon and CDL.

Table 1: comparison scheme between sounding balloon and CDL.

	Temporal resolution	Dataset updating time	Range resolution
Sounding balloon	30 s	1 s	5 m
CDL	16 s	2 s	30 m
Comparison	30 s	\sim 1 s	30 m

3. RESULTS

3.1 Continuous measurement of CDL

On Aug. 10th ,2018, the comparison experiments are implemented in Jingbian city, Shanxi province, China, with local altitude of 1332 m. The ground-

based CDL obtained a continuous 3D wind field dataset, as shown in Fig. 2.

There is a frontal surface (the interface between cold and warm wind) in range of 1500 to 2000 m. The continuous wind-profiles measurement displays the detailed characteristic wind zone which is meaningful in wind field monitoring.

Another point is that CDL signal shows the change of cloud base height from 22:00 to 23:00. The cloud base is higher than 5000 m (Altitude value) in that time. This feature captured by CDL can express its operational capacity below the boundary layer.

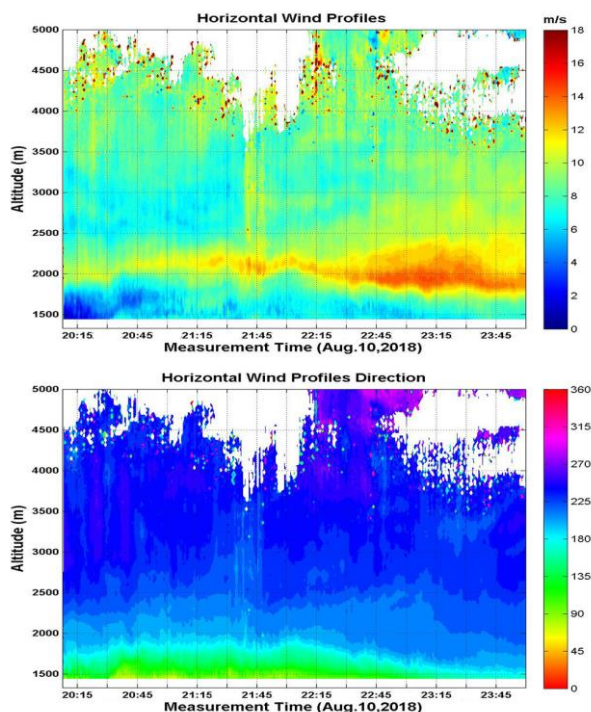


Figure 2: Horizontal wind profiles measured by CDL on Aug. 10th, 2018.

3.2 CDL and sounding balloon measurement

Measurements experiment of CDL and sounding balloon almost on the same time is implemented in August, 2018. Relative position of the two instruments are marked in Fig. 3. The horizontal space distance between CDL and sounding balloon on the ground is less than 50 m.

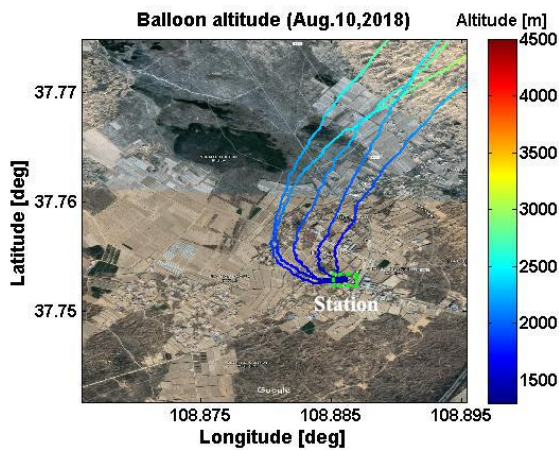


Figure 3: Relative position of sounding balloon and CDL. The color lines show tracks of the altitude of sounding balloon.

Samples of the comparison of wind speed are shown on the left side below. Wind speed of two instruments shows similar tendency. There are differences in 30 s average wind speed in range of 1~2 m/s, this discrepancy might become decrease after longer temporal average. On the right side, comparison of wind direction shows accordance in most situations.

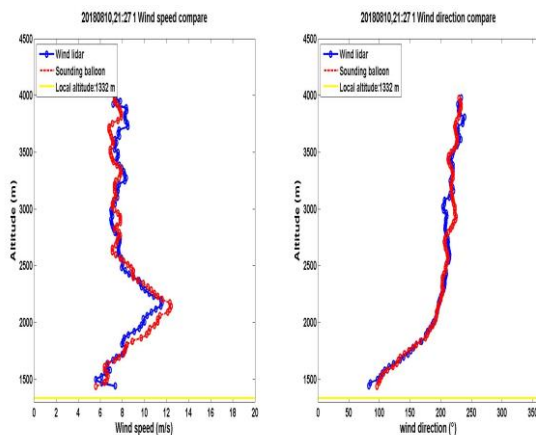


Figure 4: Comparison of wind speed and wind direction measured by CDL and sounding balloon.

Numerous analysis of the differences is shown on Fig. 5. Take the dataset on Aug. 10th, 2018 as an example, the discrepancy of wind speed and wind direction is less than 1 m/s and 5 degrees between CDL and sounding balloon, respectively. It shows good agreement of wind detection in two different methods, which prove the accuracy of CDL.

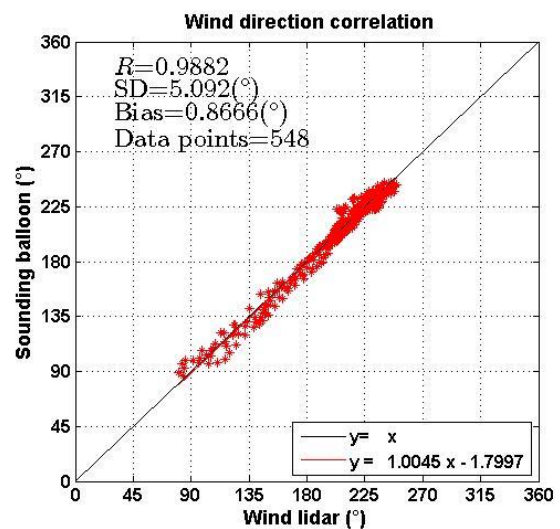
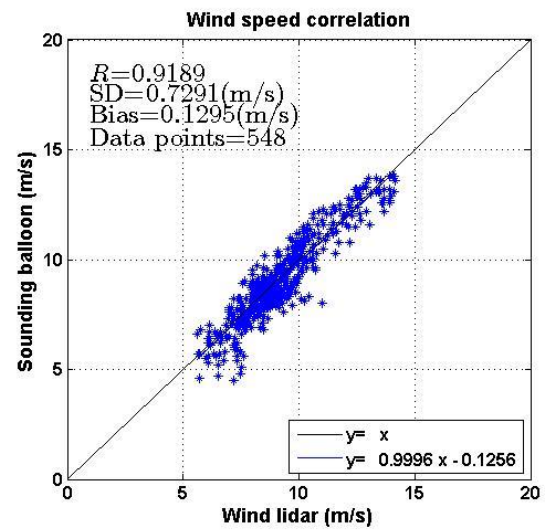


Figure 5: Linear correlation of wind speed and wind direction detected by CDL and sounding balloon.

The 1.5 μm all-fiber pulsed CDL is used to measure wind profiles in the campaign experiments in Aug. 2018. The practical detection altitude is more than 4 km in hazy weather. The comparison with sounding balloon shows good agreement. This 1.5 μm all-fiber pulsed CDL shows good performance in field experiments and potential application on ground-based or airborne platform in future.

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