Performance of Backscatter Visibility Lidar at UYN Airport

Tai Hongda[1,4], Kang Xiaohua[2], Zhuang Zibo[3] and Sun Dongsong[4*]

1 College of Air Traffic Management, Civil Aviation University of China, Tianjin 300300, China

2 Airport Weather Station, Yulin Yuyang Airport, Yulin 719000, China

3 College of Flight Technology, Civil Aviation University of China, Tianjin 300300, China

4 School of Earth and Space Sciences, University of Science and Technology of China, Hefei 230026, China

ABSTRACT

Backscatter visibility lidar has been installed at Yuyang (UYN) airport for precise measurements of visibility. The present study conducted the first experiments to compare visibility results of different measurement instruments involving backscatter visibility lidar. The present study introduced the system structure of the backscatter visibility lidar, and then compared the visibility data under different weather conditions viz., haze-fog, snow, dust and rain. The results of the backscatter visibility lidar are superior to the forward scatter meter in all kinds of weather conditions. The measurement results of the backscatter type visibility meter had little deviation from the transmissometer and the manual visual measurement under haze-fog weather. Under the rain and dust weather conditions, the deviation of the results measured by backscatter visibility lidar were larger than transmissometer and the manual observed, but the deviation was still less than the forward scatter visibility meter. The result should be confirmed by more experiments under different weather conditions.

Keywords: Lidar; Visibility; Backward scatter; Forward scatter; Transmissometer

1 INTRODUCTION

Visibility meters are mandatory equipment to be installed at all runways as per International Civil Aviation Organization (ICAO) and World Meteorological Organization (WMO) to aid pilots in landing and takeoff operations[1, 2]. Transmissometer and forward scatter visibility meter are most commonly used visibility instruments. In 1988, WMO organized the first large-scale visibility measurement intercomparison to compare the measurement performance of several sets of transmissometers and forward scatter visibility meters. However, only one set of backscatter visibility lidar was involved in the comparison, and the weather conditions processing algorithms were not used. As a result, the measurement results could not exhibit the measurement performance of the backscatter visibility lidar[3]. There are also some other experiments to evaluate the performance of the visibility equipments. Ming Hu et al. [4] compared forward scatter visibility meter and transmissometer in Xi'an Xianyang international airport from January 2013 to August 2014. He Chi [5] compared forward scatter visibility meters and transmissometer in GuiYang airport. Zhang Huichan et al.[6] and Yang Yuxia et al.[7] compared visibility results of instrument measurement and manual visual observation. So far, there has not been a long time comparison test at the airport specifically involving the backscatter visibility meters.

The backscatter visibility lidar (hereinafter referred to as lidar) can not only measure the horizontal visibility (generally referred to as visibility), but also measure the slant visibility and the vertical visibility, which are more practically valuable for aviation. It can be seen as a generalized backscatter laser echo signal receiver that can receive the laser echo

* Email: sds@ustc.edu.cn

signal from more than 100 meters far away emitted from the laser source. The extinction coefficient of the atmosphere can be inversed from the echo signal through the computer analysis, and thereby the visibility can be calculated. The lidar uses the micro-focal-level kilohertz frequency laser, which can effectively improve the measurement accuracy and also can guarantee the safety of the human eyes. An iterative algorithm based on detection probability is used to obtain the visibility information of the detection path accurately. The algorithm can effectively deal with data from low visibility weather conditions such as fog, cloudy conditions, and so on.

2 MEASURING PRINCIPLE AND SYSTEM STRUCTURE

2.1 Measuring principle

The measurement of visibility by lidar mainly includes four processes: The laser is projected into the atmosphere through the optical maser. The laser attenuated because of the scattering and absorption of the atmosphere. The telescope received the echo signal of the laser, and finally, the embedded computer processes the echo signal. Correspondingly, the lidar equation is composed of four parts, that is,

$$P(R) = K \cdot G(R) \cdot \beta(R) \cdot T(R) \tag{1}$$

where $K = P_0 \cdot {c\tau}/{2} \cdot A \cdot \eta$, used for characterization of the lidar performance; $G(R) = {Y(R)}/{R^2}$, describing the distance resolution of measuring geometric relationships; $\beta(R)$ represents the backscatter coefficient of the molecules and aerosols along the laser path, $T(R)$ represents the atmospheric transmittance along the laser path. The atmospheric extinction coefficient can be calculated from $T(R)$, in the meanwhile, the visibility of the atmosphere can be obtained by Koschmieder law.

2.2 System structure

The visibility lidar consists of three parts: laser emitting unit, optical receiving unit and signal acquisition and control unit. The system is small, light and compact. The structure of the system is depicted in Fig.1. Engineering prototype of the visibility lidar is shown in Fig.2. Fig.3 shows the control process diagram of the system.

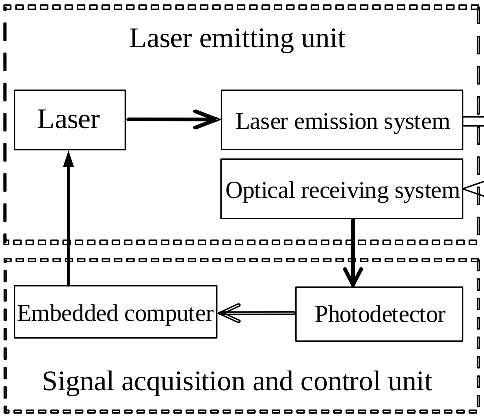

Fig.1 System structure


Fig.2 Engineering prototype

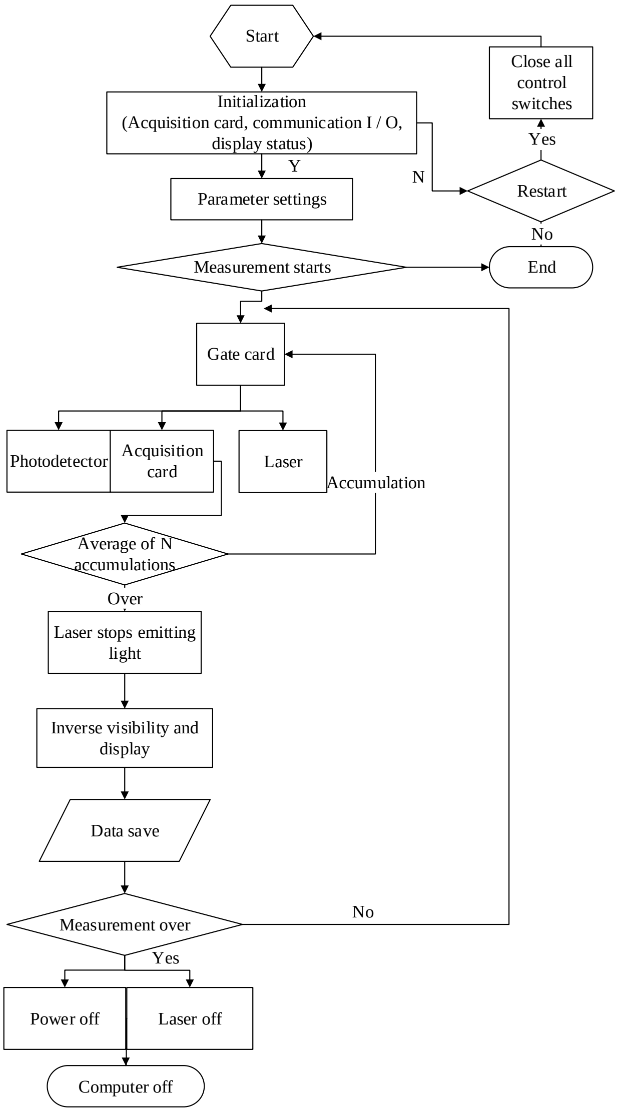

Fig.3 System control process diagram

Table 1 Technical parameters of the visibility lidar

Name	Technical parameters
Laser unit	
Laser model	Nd:YAG
Laser wavelength	1064
Beam divergence(mrad)	2
Pulse width(ns)	5
Repetition frequency	1~10kHz
Receiving optical unit	
Telescope model	Newtonian
Diameter	100

Field of view	0.5
Signal detection and acquisition unit	
APD photo-counting detector	400~1060
Single photon acquisition card	＞50Mc/s

3 DESIGN OF THE COMPARATIVE EXPERIMENTS

The visibility lidar was installed at UYN airport in May, 2014. Data comparison experiments were carried out with transmissometer, forward scatter visibility meter, manual observation and visibility lidar. Fig. 4 shows the comparative experiments. The instruments in the Fig.4 are, from left to right: the visibility lidar, the forward scatter meter and the transmissometer.

Fig.4 Comparative experiment

During the tests, the integration time of the visibility lidar was set to 10s ~ 20s. The data were averaged every 10 minutes for convenient comparison. The visibility data under 10km, which were of greater concern to civil aviation systems, were statistically compared on a monthly basis.

4 DATA UNDER DIFFERENT ATMOSPERHIC CONDITIONS

Visibility data were recorded from visibility lidar during haze-fog, snow, dust and rain conditions at 2016. The data from the transmissometer, one forward scatter meter, two lidars and manual were compared.

4.1 Haze-fog condition

4.1.1 January 1, 2016

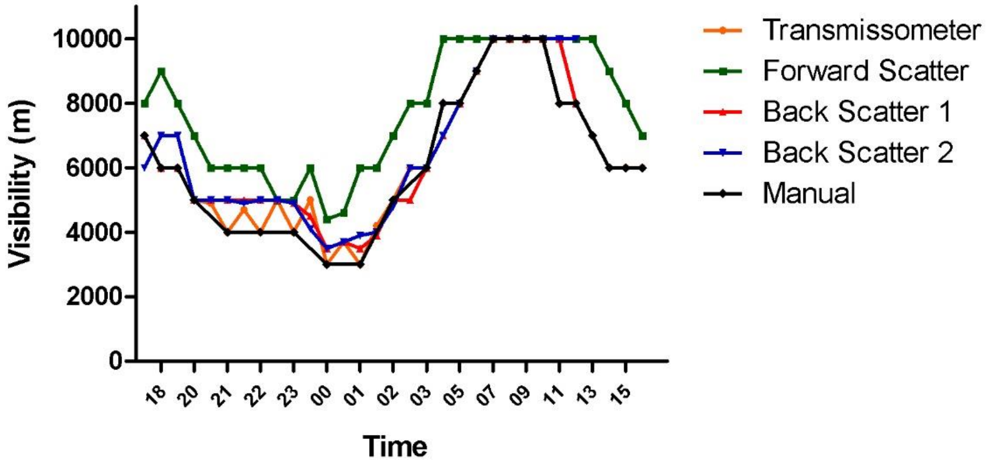

Fig.5 January 1, 2016

Fig. 5 gives the comparison data of visibility lidar and other visibility meters in a low visibility haze-fog event on January 1, 2016 at UYN airport. It was clearly observed that the visibility of the forward scatter visibility meter was higher than that of the transmissometer, the back scatter visibility lidar and manual observation. At the same time, two visibility lidars showed good consistency, and the measurement results were consistent with that of the transmissometer.

4.1.2 February 11, 2016

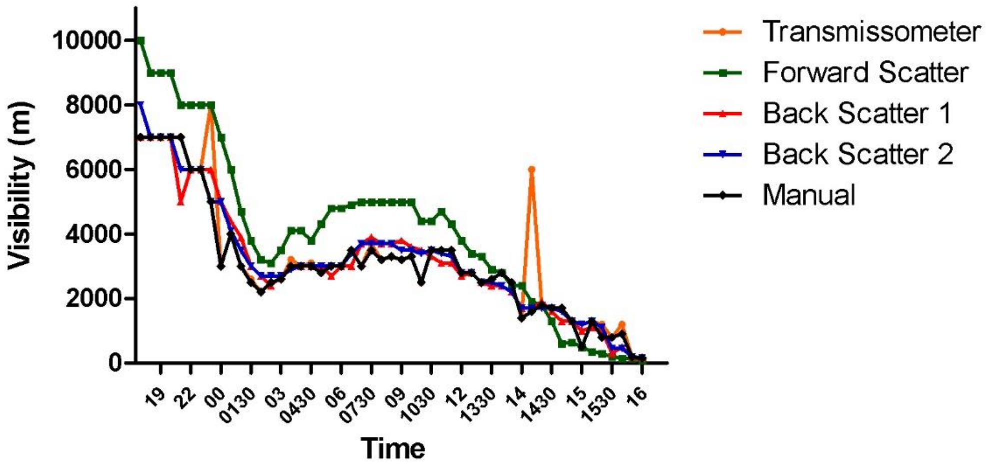

Fig.6 February 11, 2016

Fig. 6 depicts the visibility in another haze-fog event at UYN airport on 10 and 11 February, 2016. During the two days, there were haze between 17:00 and 01:30, mist between 02:00 and 03:30, haze between 04:00 and 10:00, mist between 10:30 and 14:30, broken fog between 14:40 and 15:50, and freezing fog at 16:00. It could reach the following conclusions that:

(1) The transmissometer, back scatter visibility lidars and the visibility observed by manual method had well

agreement. At the same time, the visibility observed by the forward scatter visibility meter are obviously higher than that of other visibility meters, especially when the visibility is above 2000m. On the other hand, when the visibility is under 2000m, the data of the forward scatter visibility meter was obviously lower than others.

(2) The data of the transmissometer had two obviously jump data, which were not consistent with the manual visibility during the two days.

(3) The data of two back scatter visibility lidar were very close and stable in the haze-fog events.

4.1.3 March 16, 2016

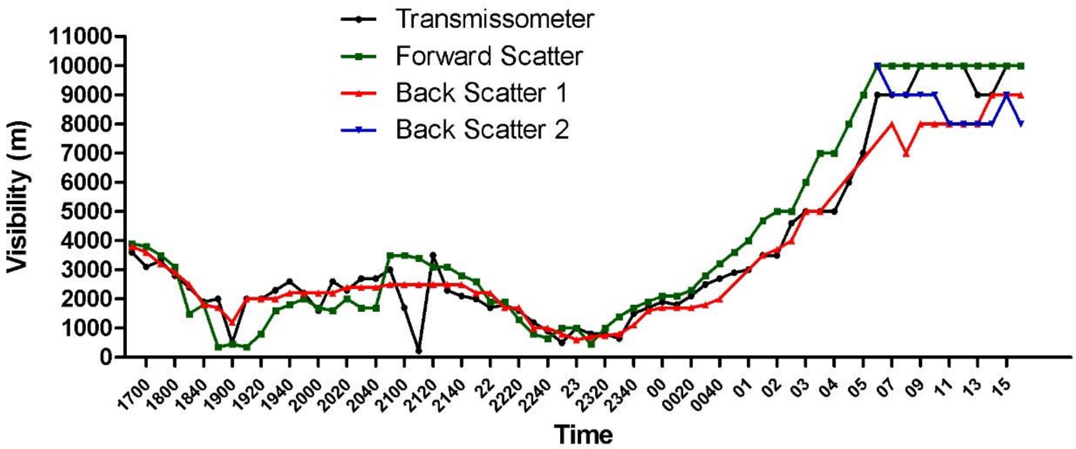

Fig.7 March 16, 2016

Fig. 7 gives the comparison data of several visibility meters during the haze-fog event at UYN airport on March 16, 2016. Since the measuring results of transmissometer were very close to the manual results, the manual results were not shown in the above figures for better visualization. We can see from fig. 7 that the measuring result of backscatter visibility meter is closer with the transmissometer than that of forward scatter visibility meter.

4.2 Snow condition

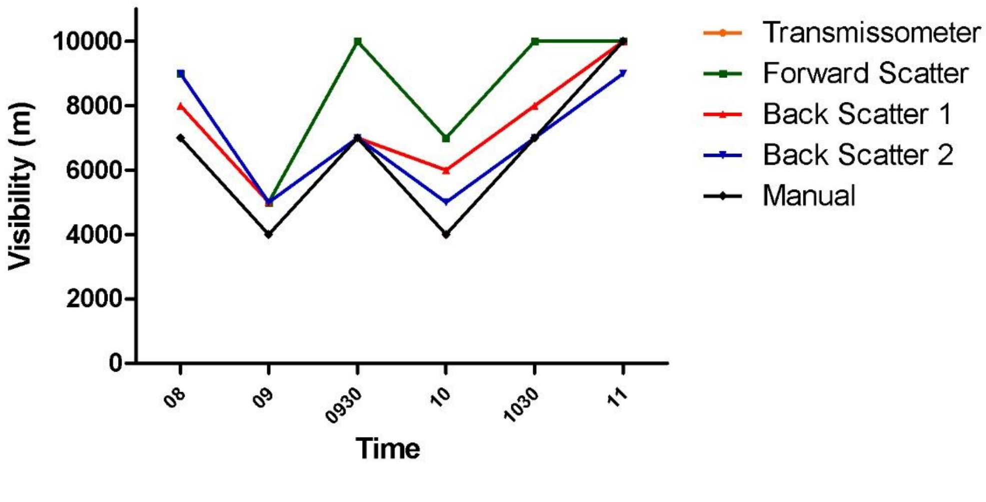

Fig.8 January 21, 2016

Fig. 8 depicts the light snow data of transmissometer, forward scatter visibility meter, two back scatter visibility lidars and the visual result. On this day, the visual data is exactly the same as the measurement data of the transmissometer. At the same time, the measurement results of backscatter visibility meters were closer with the results of transmissometer and visual measurement than that of forward scatter visibility meter measurement.

4.3 Dust condition

4.3.1 March 4, 2016

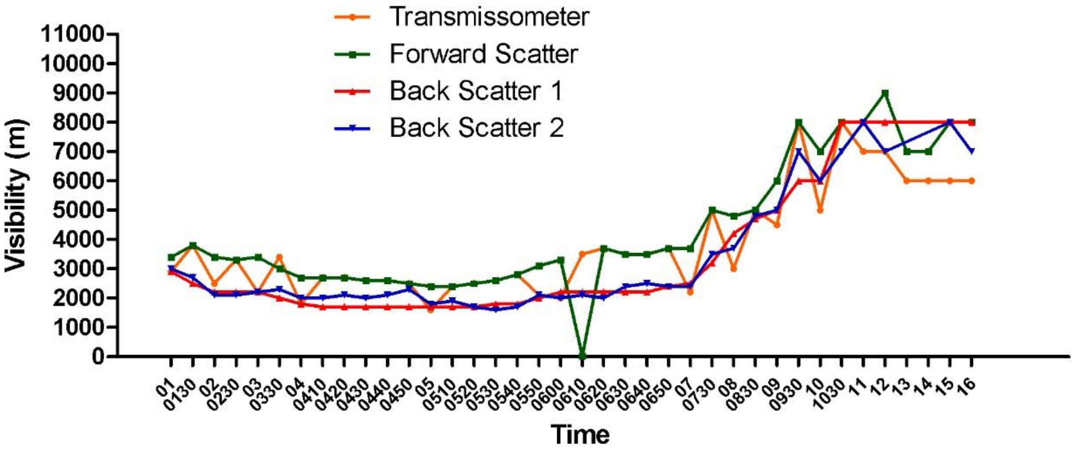

Fig.9 March 4, 2016

Fig. 9 depicts the sand event at UYN airport on March 4, 2016. From the comparison graph it is very clear that the measurement of both two back scatter visibility lidar are obviously stable and consistent. The measurement of transmissometer jumped several times between the forward scatter visibility meter and the back scatter visibility lidars. However, after 07:00, the measurement of the transmissometer was more consistent with the backscatter visibility meters.

4.3.2 May 11, 2016

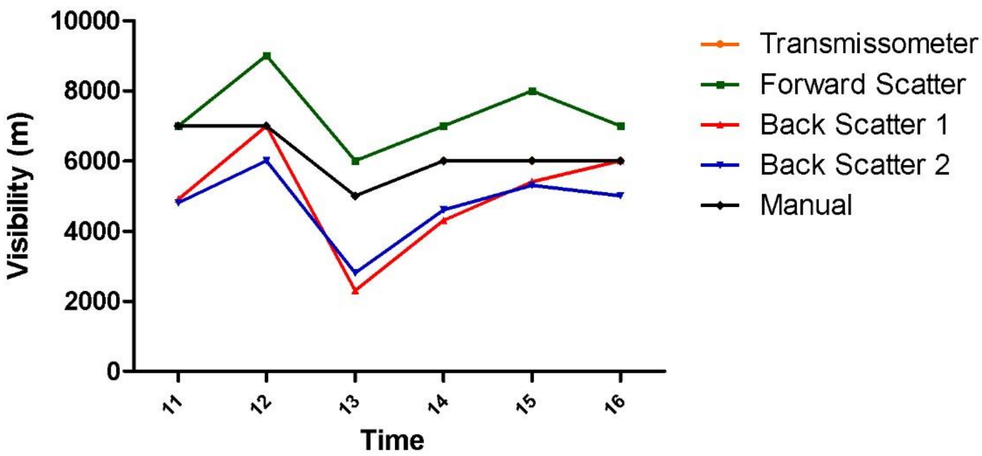

Fig.10 May 11, 2016

Fig. 10 depicts the blown sand event occured at UYN airport on May 11, 2016. The visual results of visibility are in good agreement with the measurement results of transmissometer. The results of the back scatter visibility lidar are lower than that of transmissometer. The results of forward scatter visibility meter are generally higher than that of transmissometer.

4.4 Rain condition

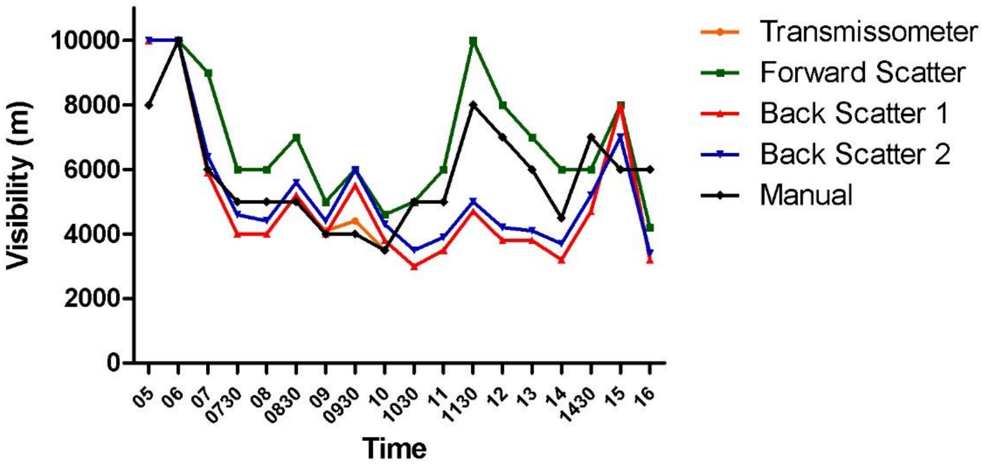

Fig.11 May 13, 2016

Fig. 11 depicts visibility data of the rain condition at UYN airport observed on May 13, 2016. It can be seen from the figure that the atmospheric transmittance measurement results and the artificial visual results are mostly coinciding. Before 10:00, the results of backscatter visibility lidars are closer with the result of manual observation, and after 10:00, the results of forward scatter type visibility meter are closer with the result of visual inspection. The measurement results of several sets of visibility measuring instruments show the same trend, and the two sets of backscatter type visibility instruments have good consistency.

5 CONCLUSIONS

The results of the backscatter visibility meter are superior to the forward scatter meter in all kinds of weather conditions, especially in the fog and haze weather conditions. The visibility lidar showed good agreement with the other three visibility measurement instruments.

In the haze weather, the measurement results of the backscatter type visibility meter have little deviation from the transmissometer and the manual visual measurement. In the rain and dust weather conditions, the deviation of the results measured by backscatter visibility meter are larger than transmissometer and the artificial visual measurement, but the deviation is still less than the forward scatter type visibility meter. The result should be confirmed by more experiments under different weather conditions.

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