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DEVELOPMENT OF DATA SCREENING METHOD FOR WIND LIDAR UNDER LOW S/N ENVIRONMENT

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1. INTRODUCTION

One of wind measuring methods, VAD (Velocity Azimuth Display)(Browning and Wexler 1968) is widely used by wind lidar (Kameyama et al. 2007). In VAD technique, under the assumption of uniform wind field in observation atmosphere, since LOS (line-of-sight) or radial wind velocity form a sinusoidal curve, the curve is detected by sine curve fitting based on the least squares method. But in low S/N (Signal-to-Noise ratio) conditions such as heavy rain, fog and low density of atmospheric aerosol particles, accuracy of wind velocity and wind direction is degraded. That is, some or all of these three parameters are not estimated correctly. It is due to degradation of each LOS velocity. So degraded LOS velocity must be eliminated properly before VAD processing. This paper propose a data screening algorithm to estimate wind velocity and direction accurately under low S/N environment.

2. SCREENING METHOD

An amplitude of the sinusoidal curve is corresponding to the horizontal wind velocity, an initial phase is corresponding to the horizontal wind direction, and an offset is corresponding to the vertical wind velocity respectively. Screening algorithm is shown in Fig.1. The proposed method derive appropriate threshold to remove unnecessary (degraded) LOS velocity component utilizing the characteristics of a sinusoidal curve.

The radial velocity measured at range n can be written as eq.(1) with azimuth angle θ, fixed elevation angle ϕ, vector velocity component (u_n, v_n, w_n).

$$\begin{aligned} V_{n,\theta} &= u_n \cos\phi \cos\theta + v_n \cos\phi \sin\theta + w_n \sin\phi \\ &= A_n \sin(\theta + B_n) + C_n \end{aligned} \quad (1)$$

where

$$A_n = \sqrt{u_n^2 + v_n^2} \cos\phi, \quad B_n = sin^{-1} \frac{u_n}{\sqrt{u_n^2 v_n^2}},$$

$$C_n = w_n \sin\phi$$

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It is difficult to estimate these parameters at the same time with sine curve fitting under los S/N condition, but one parameter C_n can be estimated as eq.(2)

$$mean \left(\sum_{r=n-m}^{n+m} \sum_{\theta=0}^{2\pi} V_{r,\theta} \rightarrow \overline{C_n} \right) \quad (2)$$

After that, setting the appropriate threshold value and removing outliers from LOS component, (conventional) VAD processing will work well.

The threshold is determined as follows. The average of all LOS velocity asymptotic to offset value of sinusoidal curve, that is, the vertical wind velocity component. Next, the amplitude corresponding to the horizontal component is restricted because the horizontal wind velocity range is within at most 30 m/s. Then the threshold is defined as the offset value plus or minus the horizontal velocity range. Invalid LOS velocity is excluded by the threshold, it becomes easier to estimate the remaining two parameters (the amplitude and the initial phase). Under low S/N environment, which is considered the accuracy of LOS velocity itself is deteriorated, the offset value cannot be calculated correctly. But wind lidar has a high range resolution, and variance of vertical wind in a small area is relatively small in general, therefore LOS velocity of adjacent ranges can be utilized to calculate the offset value. In addition, the threshold is derived from the information of a plurality of ranges, it does not deteriorate the original range resolution.

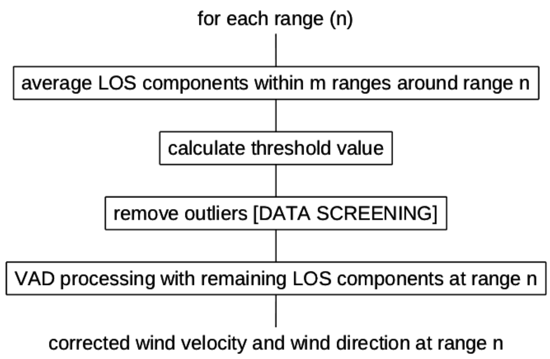


Fig. 1. Flow Diagram of data screening

3. SCREENING RESULTS

We have confirmed the effectiveness of the proposed data screening method applied to simulation data and real data. Table.1 show the parameters of simulation and Fig.2 and Fig.3 shows the simulation results of wind velocity and wind direction estimation.

In Fig.2 and Fig.3, horizontal axis indicates set value of wind velocity and wind direction and vertical axis shows estimated value. Fig.2(a) and (b) represent the results before applying the proposed screening method and Fig.3(a) and (b) represent the results after applying the screening method, respectively.

Before applying the screening method, estimated wind velocity and wind direction vary widely, that is, estimation accuracy is poor. On the other hand, after applying the proposed screening method estimated value agree well with set value. These results show effectivity of the proposed screening method.

TABLE 1. Simulation conditions

parameter	value
wind velocity	5, 10, 15, 20, 25, 30 m/s
wind direction	60, 120, 180, 240, 300 deg
number of LOS	30
number of ranges	20
ratio of degradation of LOS	50 % (15 LOS)
number of trials	100 times

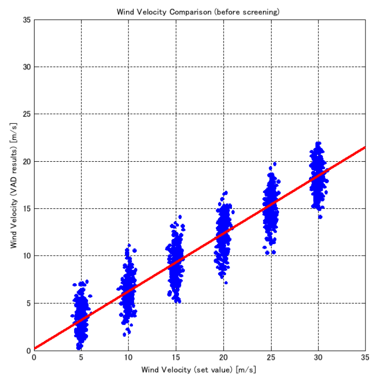
4. CONCLUSIONS

Data Screening Method to estimate wind velocity and wind direction accurately under low S/N environment have been developed. The results of computer simulation show the effectiveness of the proposed method. This method is able to be applied to Doppler radars and Doppler sodars. Develop algorithm to work in non-uniform and complex wind field is needed for future work.

5. REFERENCES

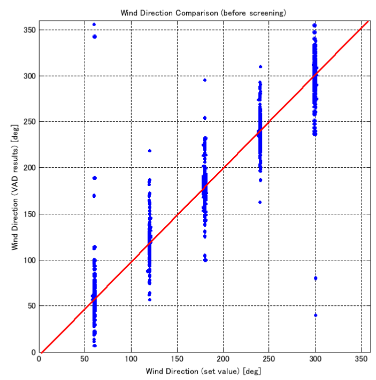
Browning, K. A., and R. Wexler, 1968: The determination of kinematic properties of a wind field using Doppler radar, J. Appl. Meteor., 7, 105–113.

Kameyama, S., T. Ando, K. Asaka, et al., 2007: Compact all-fiber pulsed coherent Doppler lidar system for wind sensing, Appl. Opt., 46, 1953–1962.



$$y = 0.592x + 0.472, \quad (R^2 = 0.908)$$

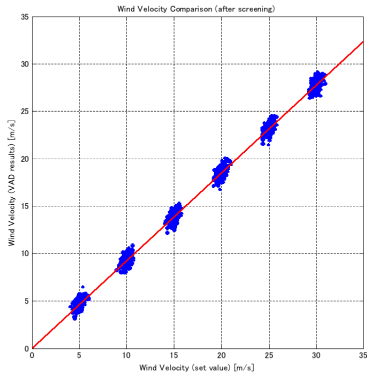
(a) wind velocity



$$y = 0.986x + 2.242, \quad (R^2 = 0.944)$$

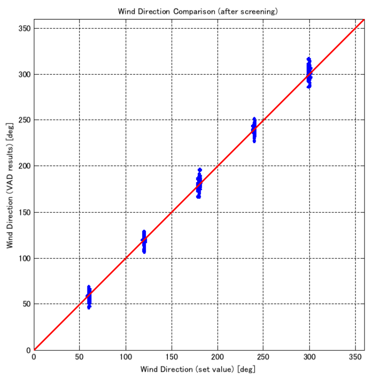
(b) wind direction

Fig. 2. Results of estimation (before screening)



$$y = 0.923x + 0.058, \quad (R^2 = 0.997)$$

(a) wind velocity



$$y = 1.000x - 0.364, \quad (R^2 = 0.999)$$

(b) wind direction

Fig. 3. Results of estimation (after screening)