Development of Data Screening Method for Wind Lidar under Low S/N Environment

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1. Background / Objective

One of the wind measuring methods, VAD (Velocity Azimuth Display) is widely used in Doppler lidars and Doppler radars. 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 and wind velocity and wind direction are decided from derived sine parameters. 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 the sine 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. We propose data screening algorithm to estimate wind velocity and wind direction accurately under those low S/N environment.
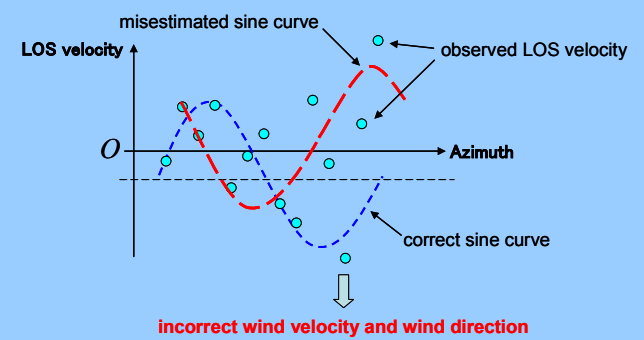

Fig. 1   wind estimation under Low S/N environment

2. Data Screening Algorithm

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) .

$$V_{n,\theta} = u_n \cos\phi \cos\theta + v_n \cos\phi \sin\theta + w_n \sin\phi = A_n \sin(\theta + B_n) + C_n \qquad (1)$$

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

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

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

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

for each range (n)

↓

average LOS components within m ranges around range n

↓

calculate threshold value

↓

remove outliers [DATA SCREENING]

↓

VAD processing with remaining LOS components at range n

↓

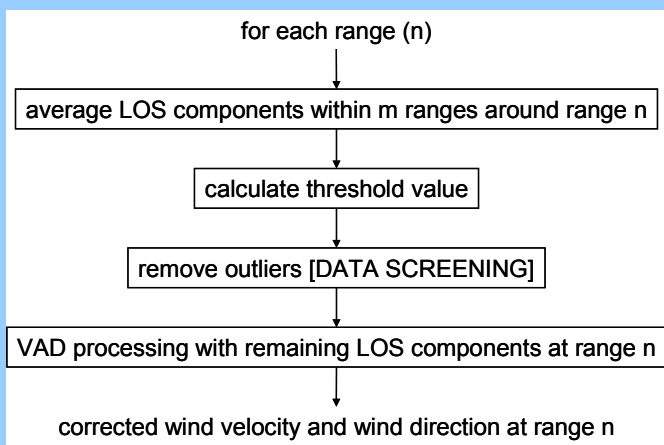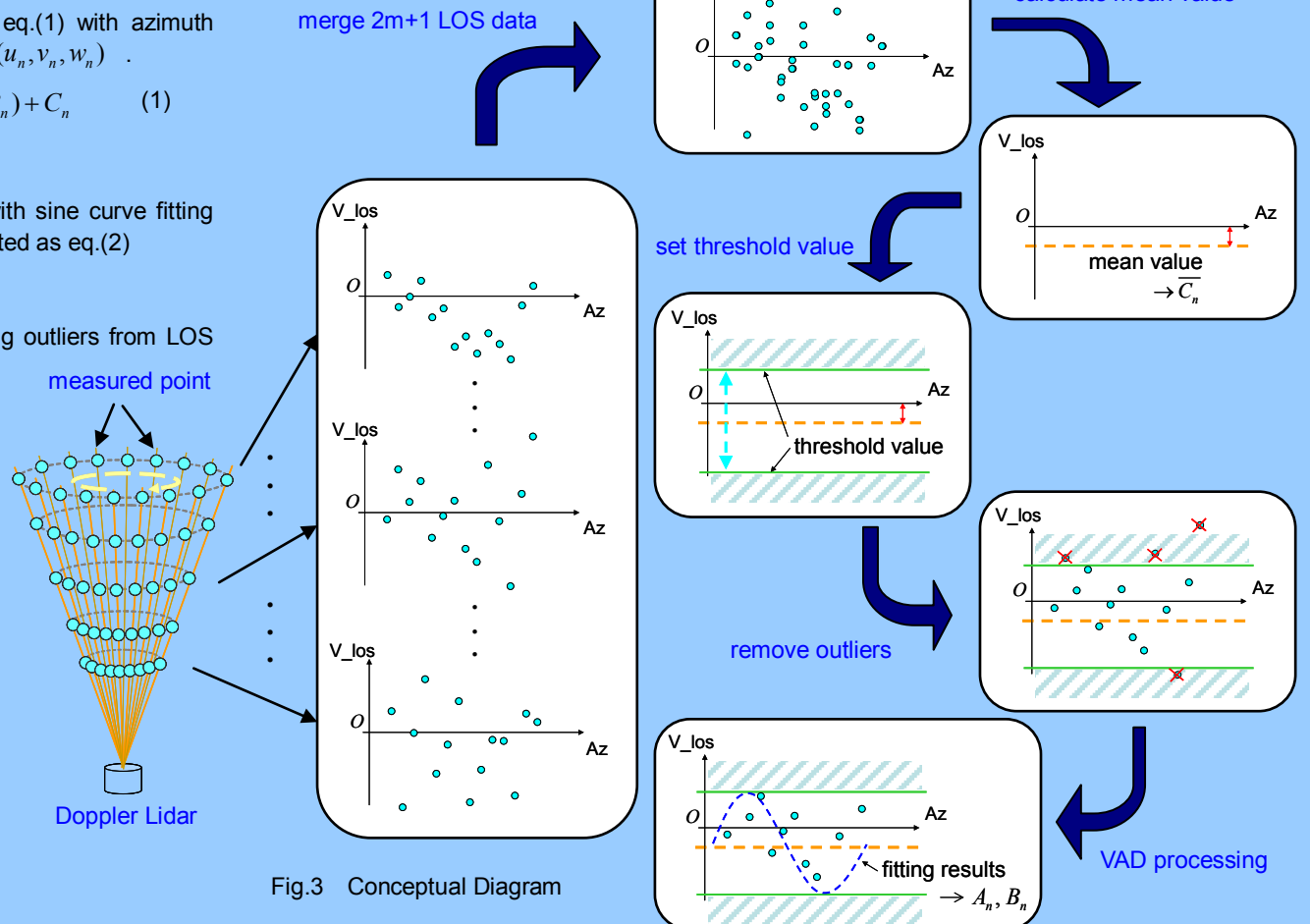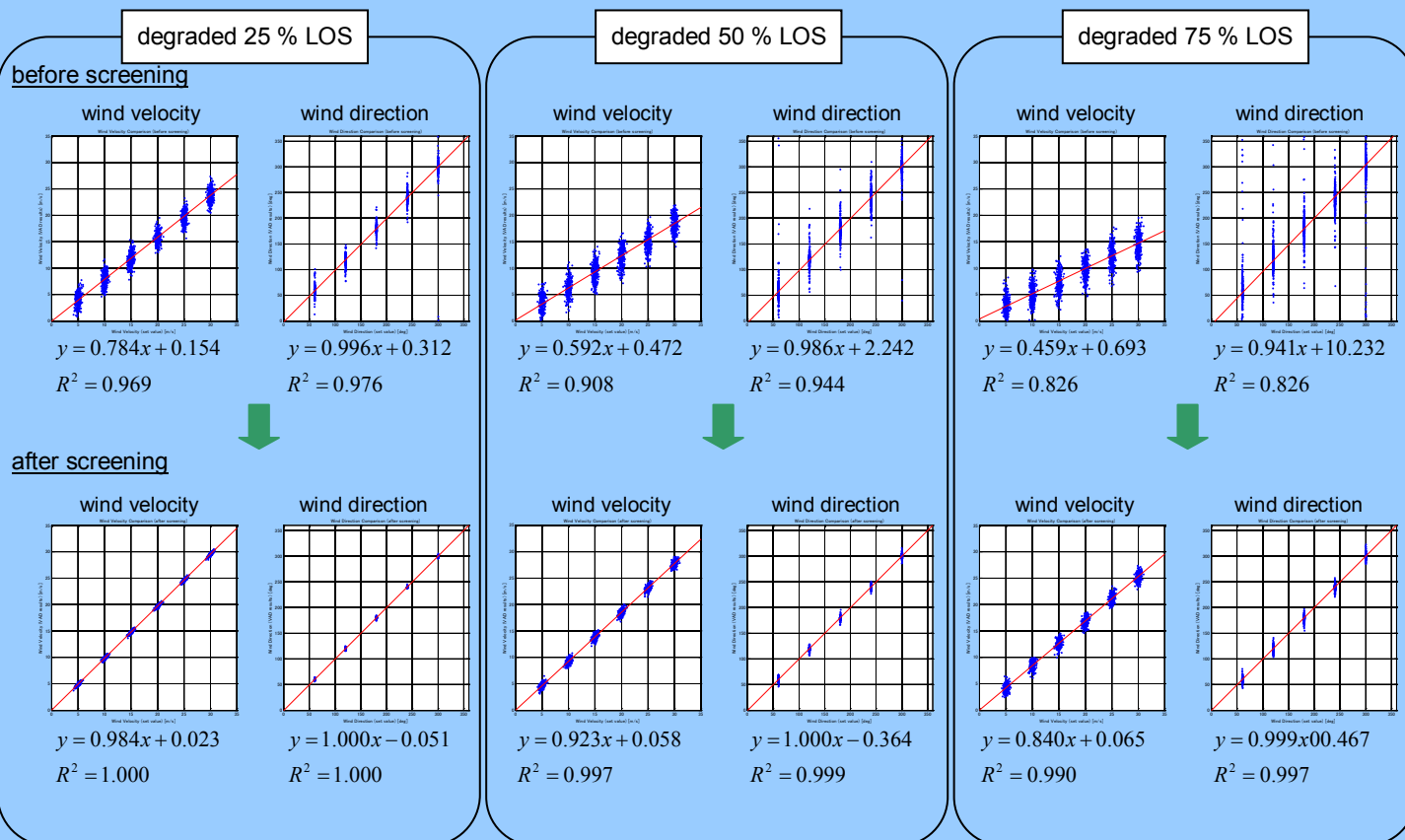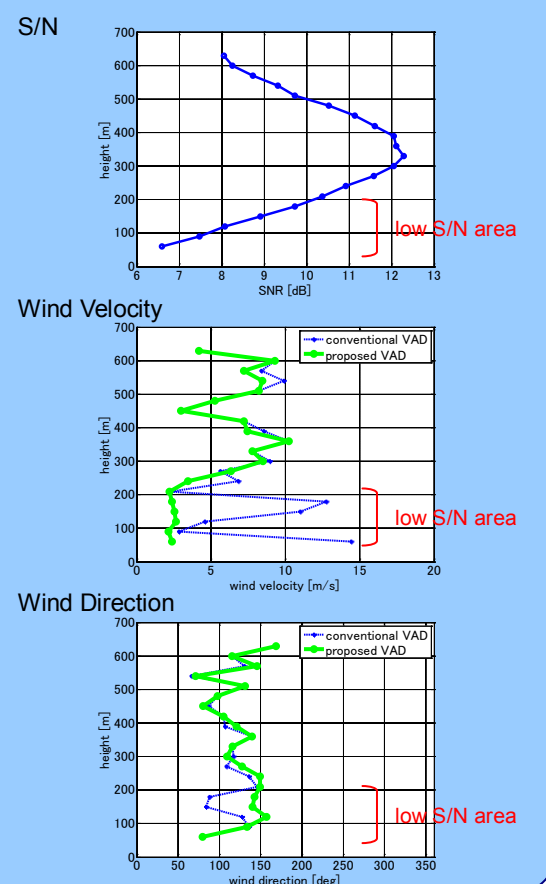corrected wind velocity and wind direction at range n

Fig.2   Flow Diagram

Fig.3   Conceptual Diagram

3. Results

3-1. Simulation data

degraded 25 % LOS

before screening

wind velocity
$y = 0.784x + 0.154$
$R^2 = 0.969$

wind direction
$y = 0.996x + 0.312$
$R^2 = 0.976$

degraded 50 % LOS

wind velocity
$y = 0.592x + 0.472$
$R^2 = 0.908$

wind direction
$y = 0.986x + 2.242$
$R^2 = 0.944$

degraded 75 % LOS

wind velocity
$y = 0.459x + 0.693$
$R^2 = 0.826$

wind direction
$y = 0.941x + 10.232$
$R^2 = 0.826$

after screening

wind velocity
$y = 0.984x + 0.023$
$R^2 = 1.000$

wind direction
$y = 1.000x - 0.051$
$R^2 = 1.000$

wind velocity
$y = 0.923x + 0.058$
$R^2 = 0.997$

wind direction
$y = 1.000x - 0.364$
$R^2 = 0.999$

wind velocity
$y = 0.840x + 0.065$
$R^2 = 0.990$

wind direction
$y = 0.999x00.467$
$R^2 = 0.997$

3-2. Real data

S/N

Wind Velocity

Wind Direction

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 and applied to the real data show the effectiveness of the proposed method.

5. Future Work

- Develop algorithm to work in non-uniform and complex wind field.
- Data collection and evaluation to improve the algorithm