Response to reviewer's (Viktor Banakh) comments on the manuscript "A six-beam method to measure turbulence statistics using ground-based wind lidars"

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First of all we would like to thank the reviewer for taking the time to review our manuscript. Three questions have been raised, to which we have the following responses:

Question The variance of the radial velocity measured by lidar is a sum of the radial velocity variance and the random error variance. Therefore, in the right part of Eq. (5) it is necessary to subtract the random error variance and then instead of 6 unknowns one has 7 (6 components of the Reynolds stress tensor plus the variance of lidar estimate of the radial velocity, if this variance is the same for any beam). The authors neglect the variance of lidar estimate of the radial velocity. It is quite possible that for the distances between the lidar and the sensing volume of 89 m (vertical beam) and 126 m (elevation 45 deg) the error of lidar estimate of the radial velocity is very small, but for large distances (when SNR is rather small) and weak turbulence the variance of random error of radial velocity measured by lidar can be comparable with the wind velocity variance. What limitations of the proposed method there are?

Author Response Let us denote the variance of lidar estimate of the radial velocity as ϵ, and assume that it is the same for any beam. Then $\mathbf{\Sigma} = \mathbf{M}^{-1}(\mathbf{S}+\mathbf{\Upsilon})$, where $\mathbf{\Upsilon}$ is a 6×1 matrix of ϵ. Thus one of the limitations of neglecting $\mathbf{\Upsilon}$ is that $\mathbf{\Sigma}$ will be systematically larger (for the diagonal components of $\mathbf{\Sigma}$), and smaller (at least in case of $\langle u'w'\rangle$, since it is usually negative). We agree with the reviewer that we have neglected $\mathbf{\Upsilon}$, because (as the reviewer also pointed out) this contribution is negligible at small distances of 89 and 126 m.

Including $\mathbf{\Upsilon}$ can also influence derivation of the optimum scanning configuration. Thus instead of Eq. (9), we will get $\langle\delta\mathbf{\Sigma}^{\mathrm{T}}\delta\mathbf{\Sigma}\rangle = \mathrm{Tr}(\mathbf{M}^{-1}\mathbf{M}^{-1\mathrm{T}})\langle\epsilon_{\mathrm{s}}^2\rangle + 2\langle\mathbf{\Upsilon}^T\delta\mathbf{S}\rangle(\mathbf{M}^{-1\mathrm{T}}\mathbf{M}^{-1}) + \mathrm{Tr}(\mathbf{M}^{-1}\mathbf{M}^{-1\mathrm{T}})\epsilon$. If we assume that $\langle\mathbf{\Upsilon}^T\delta\mathbf{S}\rangle \approx 0$ then instead of Eq. (9), we get $\langle\delta\mathbf{\Sigma}^{\mathrm{T}}\delta\mathbf{\Sigma}\rangle = \mathrm{Tr}(\mathbf{M}^{-1}\mathbf{M}^{-1\mathrm{T}})\langle\epsilon_{\mathrm{s}}^2\rangle + \mathrm{Tr}(\mathbf{M}^{-1}\mathbf{M}^{-1\mathrm{T}})\epsilon$. The same arguments can be made for the coordinate system rotated in the mean wind direction. Thus another limitation is that by neglecting $\mathbf{\Upsilon}$, we may not have obtained the optimum configuration that minimize the sum of the error variance of the wind field components.

For the particular lidar used here the uncorrelated noise in the velocity estimation is exceedingly small and will not have any effect for the analysis presented in this paper. The very low noise level can be seen from plots of spectra in Figs. 2, 5, and 7 of Sathe and Mann [2012].

Question The radial velocity is estimated from measured Doppler spectrum. If it is estimated as a centroid (first spectral moment), the weighting function in Eq. (3) is known. For

WindScanner lidar, as a rule, the radial velocity is estimated as a point of Doppler spectrum maximum. In this case correct accounting of the probe volume averaging effect is a complex problem (see Figure 2.1 in [1]). Do the authors plan to solve this problem in their future studies?

Author Response For the WindScanner lidar used in this study, the radial velocity is not estimated as a point of the Doppler spectrum maximum. The maximum likelihood method is used instead. The basic method is presented in the thesis of Valla [2005], but the final implementation is well-guarded secret of the company producing the lidar, Leosphere.

Question How it can be done?

Author Response We interpret this question as "How can the problem of probe volume averaging be tackled in pulsed lidars?". We have made a statement regarding this in the last paragraph of the Conclusions section, page 10345 of the discussion paper. We think that the framework provided by Smalikho et al. [2005] is promising and would be tested in our future studies.

References

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