



EGUsphere, author comment AC2
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Reply on RC2

Gunter Stober et al.

Author comment on "Meteor radar vertical wind observation biases and mathematical debiasing strategies including the 3DVAR+DIV algorithm" by Gunter Stober et al., EGU sphere, <https://doi.org/10.5194/egusphere-2022-203-AC2>, 2022

Dear Chen Zhou,

Thank you for the feedback on our manuscript. We provide detailed replies to the raised points and will revise the manuscript accordingly.

General Comment:

This paper brings a thorough insight into the Meteor Radar vertical wind measurements and provides mathematical justification for the general assumption of zero vertical wind velocity in classical horizontal wind analysis. The intrinsic bias in the meteor radar system is analyzed in detail. The two debiasing algorithms presented in this paper show a significant improvement compared to the least-squares method. The 3DVAR+DIV algorithm can produce horizontal divergence and relative vorticity to identify coherent structures, which has good research potential.

The only problem is that the correctness of the vertical velocity retrieved by the algorithm can't be verified in an accurate and straightforward way. This is a difficult challenge for almost every observing method. Nevertheless, the author has tried several ways to indirectly prove the improvement in vertical velocity measurements. Moreover, some clarifications of equations and figures are not that clear in this paper. To avoid confusion and make the paper eminently readable, the author shall improve it in the revised version.

General reply:

Indeed, the validation of the monostatic retrievals involving the Tikhonov regularization and the Spatio-temporal Laplace filter are difficult to compare to other data. Due to the large observational volume, there are no other measurements available and only indirect comparisons are feasible. This is also the reason why we still keep the term 'apparent' vertical velocity and we make clear throughout the manuscript that we have no proof of their 'correctness' beyond the statistical moments concerning the ICON-UA model.

Major Comments:

Comment:

- In Figure 1, large vertical velocities up to 10 m/s are obtained using the synthetic data with zero vertical wind. Thus, the author concludes that only sampling biases might explain it, considering that exact radial velocities and interferometric locations are well determined. Before drawing a conclusion, is it possible to take a detailed look at those extreme values in vertical wind velocity histograms? Because velocities up to 10 m/s is far away from the zero vertical velocity setting. So checking these cases one by one might help you to rule out some other assumptions and provide more proof of your conclusion.

Reply:

The reviewer makes a good point. There is not that one reason why such high deviations from zero for the vertical velocities occur. The two main drivers are related to the random spatial and temporal sampling of small-scale atmospheric gravity waves within the beam volume and the poor geometric measurement response by low elevation meteors. The combination of both factors causes the deviations, but it is very difficult to make general statements for the monostatic systems. The 3DVAR+DIV retrieval already resolves some of the issues and, thus, provides the most reliable approach.

Comment:

- The huge difference in the zonal wind between monostatic MR and passive receiver is worth noting. Based on the geographic map, three stations have similar longitude, but there exists a 1° latitude difference between each station. Will it possibly account for the less affected meridional winds and discrepancy in zonal winds? What's more, the comparison of the radiant map is not that clear. Because the source radiant is small compared to the relatively large map.

Reply:

The CONDOR system with its alignment of the transmitter and passive receivers is more prone to zonal wind deviations compared to the meridional wind component. This needs to be further explored with other setups also including passive receivers with a more zonal alignment.

The radiant maps are there to prove that the Bragg vector is correctly located. Any systematic localization error that could result in a factor 2 magnitude offset would be associated with a wrong zenith(off-zenith) angle and, thus, the shower would appear at a different location (higher declination 15-30 degree) on the map. If the position determination is affected by random errors in the solver or the observations, the dispersion would lead to a vanishing source radiant and randomly occurring accumulation points in the radiant map would be visible. The angular probe size for the radiant mapping is about 4 degree to account for interferometric errors and the source radiant dispersion (Stober et al., 2013, Schult et al., 2018).

Comment:

- The usage of the Spatio-temporal Laplace filter is pretty good in debiasing the measurement of vertical winds. Histograms of vertical wind velocities in Figure 5 and Figure 6 show a huge improvement compared to the standard least-squares method. Zero vertical wind synthetic data are used to prove that the new algorithm effectively mitigates the overestimation of the least-squares method. But I have a question about

whether the newly debiasing algorithm is able to solve larger vertical wind velocity if the synthetic data is set with relatively large vertical wind velocity.

Reply:

The retrieval algorithm was already used in Gudadze et al., 2019 and doesn't contain a 'limitation' for a maximum vertical velocity, although we clearly have to state that the measurement response for the vertical wind for an HPLA radar is much different from a meteor radar. As the term 'large' vertical velocity is a bit unspecified, it is difficult to quantify. The more meteors we have in a time-altitude bin the more likely we can retrieve 'larger' vertical velocities. At the top and bottom of the meteor layer, the solver tends to stay close to the a priori. This is certainly a limitation. However, assuming a zero vertical wind might result in a smaller bias than computing a $w=10$ m/s with a least-squares when the likely true value is about 0.2 -1 m/s.

The most reliable solution is provided by the 3DVAR+DIV, where we found vertical winds up to 5 m/s values in some grid cells for 10 min temporal resolution data. There is no filtering done beyond the continuity equation or horizontal divergence.

Comment:

In Figure 6, a comparison of histograms of model results and retrieval algorithm might only illustrate that the distribution of vertical winds has similar statistical moments. Considering the comparison of individual observations is not feasible as the author has mentioned. If larger vertical wind velocity can be solved, it will provide much confidence in the correctness of this algorithm.

Reply:

We estimated the momentum flux to ensure that the gravity wave variability of the unresolved scales and resolved scales are well-reproduced (see Figures in the supplement material for Collm and TDF). The amplitude of the small-scale gravity waves changed with altitude by about 0.7 and 0.8 m/s per kilometer in altitude with opposite signs. The spatial and temporal sampling is kept, but the time averaging is done using 24 hours after subtraction of tides and planetary waves from each radial velocity using the adaptive spectral filter (Baumgarten and Stober, 2019 and Stober et al., 2020). The longer temporal averaging make a small mean vertical velocity even more likely and, thus, minimizes errors due to systematic offsets. Furthermore, the momentum flux retrieval indicates the small changes in the vertical velocity amplitudes of gravity waves with increasing altitude.

The 3DVAR+DIV retrieval resolves larger vertical velocities, although 'larger' cannot be quantified by a specific number. The monostatic solution depends on the total measurement statistics. The more meteors the better. Furthermore, the ability to observe higher vertical velocities is increased when using only meteors close to the zenith ($<10-15^\circ$). However, very often there are not enough meteors directly above the meteor radars for such a narrow angular region to compute hourly winds.

Minor comments:

Thank you very much for the language corrections. These will be implemented in the revised version.

Comment:

Line 395-397: The meaning of this sentence is not that clear to me. Since the debiasing algorithm has been applied to the data to obtain a more statistically accurate vertical velocity, it's not that appropriate to say your results are 'residual bias vertical velocity'. After all, we can't solve the vertical velocity 100 percent right.

Reply:

The presented methods for the monostatic meteor radar data analysis reduce the bias. A 100% correction would also mean that we know the 'true' value of the vertical velocity. The 3DVAR+DIV algorithm is more robust in that sense and at least the variability should be very accurate for the scales we are sensitive to. However, the absolute statistical mean still depends on the lower integral boundary.

Line 447: change 'associated due to' to 'associated with'

Comment:

Lines 495-496: Based on the assumption that the scattering center will change along the meteor trail, you have mentioned that forward scatter systems are more prone to this effect compared to monostatic systems. So why only monostatic meteor radars are faced with the additional challenge?

Reply:

Thanks for pointing out the remaining ambiguity in wording. Both techniques are affected and it is even more critical for forward scatter systems.

References:

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Please also note the supplement to this comment:

<https://egusphere.copernicus.org/preprints/2022/egusphere-2022-203/egusphere-2022-203-AC2-supplement.pdf>