Atmospheric Measurement Techniques Discussions

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Reply on CC2

Ryan Volz et al.

Author comment on "Four-dimensional mesospheric and lower thermospheric wind fields using Gaussian process regression on multistatic specular meteor radar observations" by Ryan Volz et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2021-40-AC3, 2021

There is a lot we agree about regarding the difficulties and pitfalls of the meteor wind measurement, but perhaps we're not quite speaking the same language. We'll try to clarify a few relevant points:

a) It is suitable to apply intuition from the monostatic case to the bistatic case, with minor adjustment to a notional equivalent monostatic system. For each meteor scattering, the bistatic scattering is equivalent to a monostatic geometry where the middle point of the bistatic link gives the virtual monostatic radar location, and the loci of zero velocity is an ellipse with foci at the tx and rx instead of a circle. The effective Bragg wavelength will depend on the geometry and will be greater than or equal to half the radar wavelength, and the "line-of-sight" direction is given by the difference between the scattering and incident wave vectors. The particulars of the bistatic case are discussed in more detail in Stober and Chau (2015) and Chau et al. (2019).

Stober, G., & Chau, J. L. (2015). A multistatic and multifrequency novel approach for specular meteor radars to improve wind measurements in the MLT region. Radio Science, 50(5), 431–442. https://doi.org/10.1002/2014RS005591

Chau, J. L., Urco, J. M., Vierinen, J. P., Volz, R. A., Clahsen, M., Pfeffer, N., & Trautner, J. (2019). Novel specular meteor radar systems using coherent MIMO techniques to study the mesosphere and lower thermosphere. Atmospheric Measurement Techniques, 12(4), 2113–2127. https://doi.org/10.5194/amt-12-2113-2019

b) Accounting for Earth curvature is an important consideration when working with measurements over an area of this scale. This shows up in differences between what would be seen as "vertical" or "horizontal" motion in the East-North-Up reference frame at the radar receiver versus the local vertical and horizontal directions in the E-N-U frame at the meteor location. There is a discussion of this and the coordinate conversion procedure that we use in Stober et al. (2018). Whenever we refer to vertical or horizontal winds, we mean with respect to the Earth's surface underneath that location taking into full account these coordinate conversions. Perhaps that addresses some of the concerns here.

Stober, G., Chau, J. L., Vierinen, J., Jacobi, C., & Wilhelm, S. (2018). Retrieving horizontally resolved wind fields using multi-static meteor radar observations. Atmospheric Measurement Techniques, 11(8), 4891–4907. https://doi.org/10.5194/amt-11-4891-2018

c) The LoS Doppler measurement indeed contains contributions of vertical velocity, and most works based on monostatic systems have ignored the vertical velocities because of sampling issues, inhomogeneous horizontal winds, etc. The assumption has been that horizontal winds are much larger than vertical winds, and the mean vertical wind is very small. The GPR technique is agnostic to the assumptions the user wants to impose about the horizontal winds, and one could force a zero vertical wind component or scale the variance of the vertical component relative to the horizontal to suitably affect the final estimated winds. There are important estimation decisions here that welcome further consideration, but we consider that to be beyond the scope for the introduction of the GPR technique as contained in this paper.

d) To that point, the Ph.D. student of one of the co-authors (JLC) is about to submit a paper dealing with the vertical velocity estimates using a virtual meteor radar system (i.e., geometry and realistic sampling) on a high resolution atmospheric model (Upper Atmosphere - ICON). Namely, the measured line of sight velocities are replaced by projected velocities using UA-ICON winds at each meteor detection point. One of the main conclusions is that a variability of ± 1-2 m/s is an apparent vertical wind variability due to horizontal wind inhomogeneities. So we agree, mean vertical wind estimates in monostatic and bistatic systems obtained over the whole area (a few hundred of kms diameter) present a large artificial variability.

e) In this work, our focus is in the wind estimates with much smaller horizontal scales than traditional meteor systems, taking advantage of more samples and different viewing angles (equivalent as having different monostatic systems with relatively close separations). That is contrary to previous works: we don’t do a global 3D wind fit on the illuminated area, but instead we effectively do it locally in smaller areas (controlled by the covariance length scale). We show that the reliable area of vertical velocities is narrower than the area for horizontal velocity estimates. These areas depend on the sampling geometry that in turns depend not only in the system geometry but also, as you mentioned, on the meteor population.

f) Although we don't highlight it, the GPR technique also provides the two-component covariance values as final estimation outputs in addition to the single-component posterior variances. These covariance entries allow one to quantify exactly one of the issues you mention: how perturbation/error in one wind component bleeds into the estimate of another wind component. This doesn't solve the problem of correlated errors, but it does let us be aware of it, quantify it, and potentially optimize meteor radar network geometries to minimize it. This is an important topic that begs for further investigation, and we think that the GPR outputs/analysis can help with that.