Atmospheric Measurement Techniques Discussions

Atmos. Meas. Tech. Discuss., author comment AC1
https://doi.org/10.5194/amt-2021-381-AC1, 2022
© Author(s) 2022. This work is distributed under
the Creative Commons Attribution 4.0 License.

Reply on RC1

Isabell Krisch et al.

Author comment on "On the derivation of zonal and meridional wind components from Aeolus horizontal line-of-sight wind" by Isabell Krisch et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2021-381-AC1, 2022

Dear Anonymous Referee #1,

Thank you very much for reviewing our manuscript and for your helpful comments. We added a section to discuss the impact of our methods on possible future Doppler-Wind-Lidar scenarios and applied some minor changes to the manuscript. Please find detailed answers on all your comments below.

Sincerely,

Isabell Krisch on behalf of all Co-Authors

- **Eq. 11 is expressed in a slightly different way as Eq. 10 in the first line. It's better to rewrite the Eq.11 for consistency.**

  Both equations (10 & 11) were slightly amended for consistency, as also proposed by Anonymous Referee #2:

$$\begin{aligned} u_3^* &= -0.5 \cdot \left(\frac{w_{HLOS,asc}}{\sin\theta_{asc}} + \frac{w_{HLOS,dsc}}{\sin\theta_{dsc}}\right) \\ &= -0.5 \cdot \left(\frac{-u_{asc}\sin\theta_{asc} - v_{asc}\cos\theta_{asc}}{\sin\theta_{asc}} + \frac{-u_{dsc}\sin\theta_{dsc} - v_{dsc}\cos\theta_{dsc}}{\sin\theta_{dsc}}\right) \\ &= 0.5 \cdot (u_{asc} + v_{asc}\cot\theta_{asc} + u_{dsc} + v_{dsc}\cot\theta_{dsc}) \\ &= 0.5 \cdot (u_{asc} + u_{dsc}) + 0.5 \cdot \cot\theta_{asc} \cdot (v_{asc} - v_{dsc}), \end{aligned} \tag{10}$$

$$\begin{aligned} v_3^* &= -0.5 \cdot \left(\frac{w_{HLOS,asc}}{\cos\theta_{asc}} + \frac{w_{HLOS,dsc}}{\cos\theta_{dsc}}\right) \\ &= -0.5 \cdot \left(\frac{-u_{asc}\sin\theta_{asc} - v_{asc}\cos\theta_{asc}}{\cos\theta_{asc}} + \frac{-u_{dsc}\sin\theta_{dsc} - v_{dsc}\cos\theta_{dsc}}{\cos\theta_{dsc}}\right) \\ &= 0.5 \cdot (u_{asc}\tan\theta_{asc} + v_{asc} + u_{dsc}\tan\theta_{dsc} + v_{dsc}) \\ &= 0.5 \cdot \tan\theta_{asc} \cdot (u_{asc} - u_{dsc}) + 0.5 \cdot (v_{asc} + v_{dsc}). \end{aligned} \tag{11}$$

- **All three methods produce reliable zonal wind estimates between 70° S and 70° N with absolute errors typically below 5 ms^{-1}. Method 3 is the only method**

able to produce reliable meridional winds at all latitudes. It's straightforward that the error of Method 1 and Method 2 depends on how well the zonal and meridional wind components is projected onto Aeolus Line-of-sight measurement. It's a latitude related error different from the equator to the poles. Method 3 is based on the combination of two measurements in the collocated analysis region, the error of which relies on temporal and spatial interpolation. This method can be analogous to the velocity-azimuth processing technique, so called VAP method for single weather radar and wind lidar. The colocation analysis would be instructive for future Aeolus follow-on mission, for instance the two-satellite constellation to provide two independent measurements for zonal and meridional wind components. It would be great if authors can comment on that two points above.

Yes, method 3 is inspired by the VAP or more commonly VAD (velocity azimuth display) method. A note on this has been added to the manuscript:
The third method is inspired by the velocity–azimuth display (VAD) technique for single ground-based or airborne radar or lidar instruments (e.g. Browning and Wexler, 1968; Reitebuch et al. 2001; Witschas et al., 2017): The laser or radar beam is actively stirred in different azimuth directions to retrieve a horizontal wind vector by combining different LOS measurements. Aeolus cannot stir its LOS, but we can use the geometrical differences between ascending and descending orbits and combines measurements from both to more accurately estimate the true zonal and meridional wind over a specific region.

Regarding possible Aeolus follow-on scenarios and additional section has been added to the manuscript briefly touching this issue:
Impact of possible future Doppler-Wind-Lidar scenarios on the accuracy of Method 3
Although a detailed discussion of possible future Doppler-Wind-Lidar (DWL) scenarios (e.g. Marseille et al., 2008; Baker et al., 2014) is beyond the scope of this paper, we would like to briefly comment here on the impact of dual-perspective and multiple satellite constellation scenarios on the accuracy of derived winds from our Method 3.
A dual-perspective DWL would provide two LOS wind measurements under different azimuth angles from one satellite (e.g. Baker et al., 2014, their Fig. 12). This would be ideal, because the time difference and spatial distance between these two wind measurements would be negligible and the systematic errors of our Method 3 would become very small.
Another scenario discussed for a future DWL mission is a multi-satellite constellation. In this scenario, the accuracy of our Method 3 strongly depends on two key characteristics of such a constellation: how far apart in time and space are the two (or more) satellites, and do the different instruments have the same LOS with respect to flight-direction?
In a constellation with two identical satellites that both have the same LOS direction in the same orbit plane and only a small shift in time and space (e.g. Tandem-Aeolus scenario of Marseille et al., 2008), errors in our Method 3 would only be slightly reduced compared to a single satellite constellation. This is because although the spatial distance between the nearest neighbours would decrease by a factor of two (or more, for more satellites) in such a constellation due to the shift in orbit, the time difference would remain large.
However, if the tandem constellation described above was amended such that one of the satellites had a different LOS viewing direction, errors in our derived winds would be strongly reduced and their reliability greatly increased. This is because, in addition to the close spatial separation of the different LOS measurements, there would only be a small time difference.

Thus, for deriving the zonal and meridional winds from spaceborne DWL measurements, a dual-perspective DWL would perform best, followed by a multiple satellite constellation with differing LOS. A multiple satellite constellation with similar LOS for all satellites is expected to only slightly improve the derivation of zonal and meridional wind components compared to Aeolus.

Baker, W. E., Atlas, R., Cardinali, C., Clement, A., Emmitt, G. D., Gentry, B. M., Hardesty, R. M., Källén, E., Kavaya, M. J., Langland, R., Ma, Z., Masutani, M., McCarty, W., Pierce, R. B., Pu, Z., Riishojgaard, L. P., Ryan, J., Tucker, S., Weissmann, M., and Yoe, J. G.: Lidar-Measured Wind Profiles: The Missing Link in the Global Observing System, Bulletin of the American Meteorological Society, 95(4), 543-564, https://doi.org/10.1175/BAMS-D-12-00164.1, 2014.

Browning, K., and Wexler, R.: The determination of kinematic properties of a wind field using Doppler radar. J. Appl. Meteor., 7, 105–113, https://doi.org/10.1175/1520-0450(1968)007<0105:TDOKPO>2.0.CO;2, 1968.

Marseille, G.-J., Stoffelen, and A., Barkmeijer, J.: Impact assessment of prospective spaceborne Doppler wind lidar observation scenarios, Tellus A: Dynamic Meteorology and Oceanography, 60:2, 234-248, https://doi.org/10.1111/j.1600-0870.2007.00289.x, 2008.

Reitebuch, O., Werner, Ch., Leike, I., Delville, P., Flamant, P. H., Cress, A., and Engelbart, D.: Experimental Validation of Wind Profiling Performed by the Airborne 10-μm Heterodyne Doppler Lidar WIND. J. Atmos. Ocean. Tech. 18, 1331-1344, https://doi.org/10.1175/1520-0426(2001)018%3C1331:EVOWPP%3E2.0.CO;2, 2001.

Witschas, B., Rahm, S., Dörnbrack, A., Wagner, J., and Rapp, M.: Airborne Wind Lidar Measurements of Vertical and Horizontal Winds for the Investigation of Orographically Induced Gravity Waves, Journal of Atmospheric and Oceanic Technology, 34(6), 1371-1386, https://doi.org/10.1175/JTECH-D-17-0021.1, 2017.