Atmospheric Chemistry and Physics Discussions

Atmos. Chem. Phys. Discuss., referee comment RC1
https://doi.org/10.5194/acp-2022-732-RC1, 2022

Comment on acp-2022-732

Anonymous Referee #1

Referee comment on "Validation activities of Aeolus wind products on the southeastern Iberian Peninsula" by Jesús Abril-Gago et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2022-732-RC1, 2022

General comments about the preprint:

This paper describes the validation of wind profile products from ESA's Aeolus Doppler Wind Lidar at a ground based station in Spain over a time period of two years. Two Aeolus wind products are compared to collocated observations by a ground-based Doppler wind lidar providing winds in the lowest 3 km of the atmosphere and radiosondes.

The work and presented results definitely add to the overall validation of the Aeolus instrument, which has already been done in a similar way by other teams operating Doppler lidars and releasing radiosondes at other locations in Europe and around the world. Comparisons with ground based data at this geographical site is new. The topic is very relevant to AMT, addressing instrument comparisons and data analysis. The method applied is valid, although the statistical sample is on the low side with only one ground-based locations and not that many collocations.

However, the language is not well phrased, which makes the analysis and results very difficult to understand. A large portion of the text therefore needs to be rewritten to be more precise and clear. Also, some further analysis is needed to strengthen the scientific analysis and interpretation of the results. The reviewer therefore recommends that the paper is only accepted upon revisions, according to the comments provided here.

Specific comments:

The manuscript has many acronyms and Aeolus specific abbreviations and expressions are used early in the paper (including in the abstract) without being fully explained or spelled out. This makes in particular the abstract but also the early sections difficult to read. This would need to be revised and improved.

Due to the lack of detail in how the data collocations were calculated, it is not possible to judge whether the 100 km collocation criteria was applied to (i) the horizontal distance between the compared observations or (ii) the distance between the satellite ground track and the ground-based station. If the latter is the case, the collocation criteria has not been applied correctly since the Aeolus wind observations are done at a slant angle of 35 degrees with respect to the satellite nadir direction, and hence the distance between the measurement track and the ground track cannot be ignored especially at the lower altitude levels. The look direction is also different for ascending and descending orbits, which means that the measurement track will be either East or West to the satellite ground track. The authors must therefore describe how this has been done and confirm that the measurement distance of 100 km has been applied in the statistical comparison.

There is some confusions created due to an incorrect use of the Aeolus terminology measurement, observations and bin in several places. Throughout the paper, the word "bin" should be replaced with "observation" for the Aeolus wind data. An Aeolus (vertical) bin refers to an altitude level along the instrument line of sight over which the received atmospheric backscatter has been integrated. The altitude of a bin with a given number varies according to the vertical sampling scenario applied to the instrument for different latitudinal regions, and is also not the same for the Rayleigh and Mie winds. This is illustrated in several of the references Aeolus papers.

In several places in the paper it is written that the Aeolus wind data have a larger or smaller error, based on the statistical comparison with the ground-based or radiosonde data which are defined as the truth. However, this should be rephrased to state that the Aeolus observations differ to a larger or smaller extent with the ground based data, and that this can be due to 1) errors in the Aeolus observations, 2) errors due to different horizontal representativity of the Aeolus (observation data representing ~87 km horizontally integrated measurements and 1 to 2 km vertically integrated signals) and ground-based or radiosonde (point observations) datasets, 3) horizontal variability in the wind field between the location of the Aeolus observations and the location of the ground-based observations (up 10 100 km). This mut be clarified throughout the manuscript. The authors refer to the errors of the ground-based lidar data and radiosondes in the text, but it would be better to also include the information in the figure capture where the datasets have been compared. As it is now, only the estimated errors of the Aeolus data are reported in the figures.

A lot of statistical analysis is done, mentioning the inhomogeneity of the wind field, and especially in the atmospheric boundary layer (ABL) due to terrain, local temperature gradients and ABL stability. However, no examples of the typical variability of the wind field in the study area is show. This should be done for some examples, e.g. by plotting wind fields at 1 km, 3 km, 5 km and 10 km altitude from a regional weather forecast model (e.g. 1-2 km horizontal measurement resolution) or the ECMWF model forecast field (about 10 km horizontal measurement resolution). This could be done for a

homogeneous and highly inhomogeneous case and for timesteps representative of the ground-based and Aeolus data or Aeolus and radiosonde data. This would support the discussion about horizontal variabilities to be expected in the region.

Technical corrections:

Page 1, Abstract:

- Start the abstract with a short explanation of what Aeolus is: An ESA mission carrying the first Doppler Wind Lidar in space, which is providing profiles of wind observations in the troposphere and lower stratosphere globally. Explain that it provides wind profiles from the lower stratosphere down to thick clouds or to the surface in cloud free conditions. Several wind profile products a are stored in the so-called level 2B product.
- Spell out and explain L2B wind product or drop L2B and write wind profile products.
- Line 12: Instead of writing that the data are from the period between the Aeolus public data release (i.e. May 2019 and not the reprocessed data releases which are taking place every 6-12 months) and the time of the orbit shift, write the exact time period (dates).
- Line 13: Propose to rephrase to "Aeolus data from two different on-ground data processing software baselines were validated, using a 100 km horizontal and 30 minutes temporal collocation criteria. This resulted in 109 collocations."
- Line 14: What do you mean with "mean bin distance"? The authors probably mean the distance between the ground based or radiosonde wind observations and the Aeolus wind observations that were compared. Please rephrase.
- Line 15: Explain HLOS wind speed and Rayleigh clear and Mie cloudy.
- Line 15: "… and equal over and underestimation of Aeolus wind speed" is not understandable. It does not precisely describe the main conclusions of your results. Do the authors mean that no constant or wind-speed dependent biases were found? Or do the authors mean that the results were not the same for different time periods, or for different collocation criteria?
- Line 16: Refrain from using "lowermost bins" in the abstract and write instead Aeolus observations close to the surface of just above the surface.
- Line 16: The sentence "However, the reliability of the results was constrained to …, due to the limited vertical coverage" This is not understandable and not correct English. I assume that the authors mean that the ground-based lidar observations were limited to the lowest 3 km of the atmosphere, which is only a fraction of the vertical extent and valid wind observations from Aeolus. Also, the Aeolus observation resolution is quite coarse in the lowest 3 km, and the horizontal and vertical variability of the wind field is large, which makes the comparison difficult. Rephrase to make that clear.
- Line 17: What do the authors mean with spin-off analysis? This is not clear. Explain what the authors mean by that, and if possible choose a more precise expression to make it clear.
- Line 18: "… varying the maximum distance to consider an Aeolus bin into the comparison and the average of the ground-based lidar measurements, …" It is not understandable what the authors mean here. Do the authors mean that the authors

performed an analysis to find the optimum collocation criteria to be used for the statistical analysis?

- Line 19-20: Be explicit of the start and end date of the second dataset that is studies with yet another Aeolus data product baseline. Explain that the analysis was done separately because the collocation with the ground station changed because the ground-track of Aeolus was moved. Another reason is that the data from this period was processed with yet another on-ground data processing software baseline.
- Line 23-34: What do the authors mean by "an approximately equal overestimation and underestimation."? Equal to what, and over and underestimation compared to what? This needs rephrasing to make it clear what the authors mean.
- Line 25: Again, refrain from using spin-off analysis. Be clear about how this analysis differs from the other analysis done.

Line 28: The authors motivate the study with the need of winds to study aerosols and clouds. This is a valid point, but is not at the core of this paper. It is also not the main objective of Aeolus. Therefore, this sentence can be move to the end of this paragraph.

Line 166: Please add that the recommended collocation criterion of 100 km is valid for large-scale wind field comparisons. For comparisons in areas where the wind variability is large, on scales lower than 100 km, more stringent criteria should be applied. This is especially true when comparing observations in the ABL and close to the surface where the wind field is strongly modulated by the local and regional terrain. This will also be investigated in this paper.

Line 169: Figure 1: From the description here, it is not clear whether the authors pick the observation collocations as a function of distance between the instrument ground track and the measurement station, of the measurement track on ground and the station, or the difference between the observations at the respective observation altitude. It is important that the authors pick one of the latter options, especially since the instrument looks to the east of the ground track on ascending orbits, and to the west on descending orbits. Please plot also the measurement track on ground in Figure 1 to illustrate this and mention that the distance to the ground track position decreases with the measurement altitude. Specify in all places throughout the document whether the distance between the Aeolus measurement track and the station, or the orbit ground track has been used.

Line 196: Please discuss that the Aeolus laser output energy was high at the start of the laser B operation in July 2019, and then steadily decreased over time, with the exception of the regular periods where the laser output energy was increased. This led to the random noise of the L2B wind product to steadily increase with time, for then to increase again a little bit when the laser output energy was adjusted upwards. This will influence the wind statistics w.r.t. random errors (the bias mainly changed when a new processor version was used). This is described in the papers by Michael Rennie. Please take this information into account for this analysis and discuss here how this is impacting the results for the data series which spanned 2-3 years. This has also been discussed by

several authors who have submitted papers to the Aeolus special issues in AMT and the Q.J.R. Met. Soc.

Line 221: What do the authors mean with ”Both variable profiles presented the same variable vertical resolution …”? Do the authors mean that the Mie cloudy and Rayleigh clear wind profile products were sampled with the same vertical resolution? Make it clear that the Mie channel sampling differs from the Rayleigh sampling, and both may not have been the same for the whole period of the observations at all altitudes. This could impact the statistics. Please check and verify.

Line 233-243: It is difficult to follow your explanation on how you have averaged the two datasets to compare them in vertical in steps of 0.5 km or 2 km. From the plots later in the paper, it shows that you have used the vertical averaging of 0.5 km in the ABL when comparing with the ground-based lidar, and 2 km when comparing with the radiosonde. Please specify that here, and explain what the vertical sampling of the Rayleigh observations were in the ABL, at higher atmospheric altitudes, and whether it remained the same. If it was larger than 0.5km, explain what that means for the statistical comparison done on 0.5 km scale.

Line 237: The authors write that the Aeolus wind speed is over or underestimated. As mentioned above, this is not necessarily correct, since the difference between the two collocated datasets can be either due to the individual observation errors, spatial or temporal representativity errors. Especially, for comparisons in the ABL, differences could be expected to be dominated by spatial and temporal variability effects. Please clarify this here.

Line 262-265: It is not understood which statistics the authors are presenting here as mean HLOS wind speed values. Is this the average of all observations over all altitudes throughout the whole time period? If yes, what is the purpose and physical meaning? Please clarify or remove.

Line 273: Why do you think that a maximum wind speed of 77 m/s is not realistic? At which altitude was the wind detected? Please comment.

Line 275: Discuss why the Mie error estimates are generally smaller than the Rayleigh ones, and refer to discussions provided in the cited papers by M. Rennie.

Line 290: with “equally significant”, do you mean statistically representative? Please explain.

Line 300-307: From Figure 3, it looks like the intercept for the Mie wind comparison was negative and not positive. Please check and correct if needed. Discuss that from both the comparisons to the Mie and Rayleigh winds, there seems to be possible wind-speed dependent biases which you report are statistically significant. Discuss whether this could be related to local wind condition effects. Note here that the other studies were performed at other geographical locations.

Line 311: Contrary to what you write, the Mie cloudy HLOS wind speed bias is not 0 m/s as reported by von Bismack. Also, the results from Wu and Iwai differ. As explained in the papers by M. Rennie et al., the Aeolus telescope temperature bias correction method is tuned to minimize the Aeolus wind bias globally. This means that local biases can still be present in the data product. Please check this in the papers by Rennie et al, and discuss this accordingly.

Line 315: Please add here some examples figures of typical wind variabilities at a few altitude levels for the study region, for two typical prevailing weather conditions. You can use for this either ECMWF model weather maps, or regional weather maps. Discuss the example weather maps and how the local topography impacts the wind variability in the study area at different altitudes and for different conditions. Discuss this as part of your analysis of the comparisons between Aeolus and the ground-based lidar. This should also be used for the discussion about the wind differences as a function of altitude in Figure 4. An alternative way could be to make a statistical comparison of the wind direction reported in the Aeolus L2C product (ECMWF model data at the location of the Aeolus observations) and the wind direction from your ground-based lidar. This would indicate whether the wind conditions are generally very different at the location of the Aeolus measurement track and the ground station.

Line 334: As mentioned before, it is not possible to conclude whether the differences in wind speeds between the Aeolus and ground-based lidar observations are due to measurement errors only, or also due to different representativeness errors. Please add this here.

Line 335: The large RMSE for the Rayleigh winds at 0.5 km altitude are probably due to the low number of observations compared, the large horizontal averaging of the Rayleigh observations (87 km along-track averaging), and the large variability in the wind field close to the surface also within the 100 km radius (large representativeness errors). Furthermore, possibly imperfect removal of ground return contamination in the lowest Aeolus observation bins play a role. Please discuss this here. This is less of an issue for the Mie winds which are sampled at smaller horizontal and vertical scale.

Line 352: Again, discuss the difference in Rayleigh wind representativity compared to Mie winds here while interpreting these results.

Line 365: Add here that your conclusion, that a 100 km collocation criteria is the best

choice, is based on your dataset analysis for this station. Therefore, it would not necessarily be applicable to all geographical locations and local (weather) conditions for weather station across the world.

Line 382. Add here that another possible reason for the less good results for the ANX2 case is the constant decrease in the Aeolus lidar performance. The Aeolus wind errors were significantly larger in 2021 and 2022 than in 2019 and 2020. Also Aeolus biases may have changed slightly.

Line 423-424: It is not the differences in the cloud conditions at the location of the radiosonde and the Aeolus observations that matters the most, but the local variability of the wind field. Please compare the difference in the wind speed and direction reported in the Aeolus L2C product (ECMWF model forecast) compared to the radiosonde.

Line 441: Other reasons for the disagreement for the Rayleigh and radiosonde winds between 0 and 2 km altitude could be the variability of the wind within the 87 km Aeolus observations, and possible ground contamination of the lowest altitudes. Please add this.

Line 468: A time difference of 12 hours can lead to a very large difference in the local wind regime, especially in costal and mountainous terrain and when a front is passing. Please add this to the discussion below why the comparison results got worse.

Line 493: Also in the conclusions, please explain ANX4.5 and the product versions again since it has a similar function as the paper abstract.

Line 495: In stead of writing only “minor disagreement”, please report the number for the magnitude here.

Line 498: Specify that the vertical coverage limitation refers to the ground-based lidar.

Line 511: Remove “and to the fact that cloud properties may vary significantly”, which is not relevant here. Rather, the horizontal and vertical wind variability is important.

Editorial corrections:

Throughout the whole manuscript, replace “bins” with “observations”

Line 17: spell out asl, above sea level

Line 30: “However, there is a current lack of accurate worldwide near-real-time atmospheric dynamics tracking in the Global Observing Systems (GOS), which affects the reliability of Numerical Weather Prediction (NWP) models” This sentence is difficult to understand. Proposed rephrase: “Numerical Weather Prediction (NWP) models need accurate wind profile observations in order to produce accurate weather forecasts. This is currently limited by the lack of globally distributed wind profiles in the World Meteorological Organization (WMO) Global Observing System (GOS).”

Line 31: “For this aim” replaced with “Therefore”

Line 35: “…a single meteorological instrument, …” I propose to delete meteorological

Line 37: “into” to be changed to “to”. “non-stop” to be removed. It is not clear what you mean with non-stop. The authors mean continuously over several years?

Line 40: Propose to update “… Aeolus processing chain changed and product versioning has been updated, with subsequent improvements and fixings …” to: “… the Aeolus on-ground data processing is being continuously improved, resulting in processor updates about every 6 months and hence new product versions. The updated processors contain both improved calibration routines, bug fixes and retrieval algorithm improvements”.

Line 43: Propose to replace “… fields after being processed under NWP models” with “fields where Aeolus L2B winds have been assimilated in the weather forecast model of the European Centre for Medium Range Weather Forecasting (ECMWF), and the 3D wind field from the model has been stored at the location of the Aeolus observations.”

Line 44: Propose to rephrase “…, Aeolus provides L2A optical information about the atmospheric components” to “Aeolus also provides profiles of atmospheric backscatter and extinction coefficients along its line of sight, which are stored in the Aeolus Level 2A product. All data products contain metadata, observation geolocation and other supporting variables” [RD-XX]. Add here references to the papers by Flament et al.

Line 46: Add that operational monitoring of the Aeolus wind profile product quality was set up with the European Centre for Medium Range Weather Forecast (ECMWF), providing information of the wind quality within 3 hours of sensing.

Line 52: Add here the publication by Ehlers et al 2022, https://doi.org/10.5194/amt-15-185-2022

Line 58: The Aeolus wind products were not developed at Granada, rephrase this sentence to clarify this.

Line 67: This sentence repeats the launch date repeated in the previous section. Proposed rephrase: "The Aeolus satellite orbit is sun-synchronous, with an orbit altitude of 320 km, an inclination of ~97°, and an orbit repeat cycle of 7 days."

Line 70-71: The description of the dual Fabry-Pérot interferometer channel, which is used to measure the Doppler shift from the atmospheric backscatter by molecules, and the Fizeau interferometer channel, which is used to measures the Doppler shift of the atmospheric backscatter from particles, is not very clear. The channels measure the Doppler shift of the backscattered light, caused by the movement of the molecules or particles along the instrument LOS. From this, the wind speed is derived by comparing the measured frequencies with the laser emit frequency. It is also a repeat of what is written in the section before. Rewrite and remove duplications in the manuscript where possible.

Line 76: Not Aeolus, but the on-ground data processing performs the horizontal projects the LOS winds measured by Aeolus. Rephrase.

Line 77: what do you mean by "… which is a variable able to sufficiently characterize the wind field"? Mention that the wind direction is not measured by Aeolus, and also not the vertical wind component, which is assumed to be 0 in the data processing from LOS to HLOS. Mention that the winds need to be assimilated in a weather model to yield the full 3D wind vector.

Line 80: Mention that the vertical resolution of the Aeolus wind observation profiles are not fixed, that they differ for the two Aeolus wind channels, as a function of latitude (i.e. along the orbit) and for different time periods through the mission. This is explained in the CAL/VAL plan, in papers by Rennie et al. etc.

Line 86: The Level 2B data processing is performed by ECMWF under ESA contract, as part of the Aeolus ground segment.

Line 88: The authors again mention the Level 2A product. I propose to only explain it in line 45, and also put the references to details on this product there.

Line 91-97: Also here the text is not clear. As explained in Rennie, the first step in the data processing from measurement to observation scale is to sort the measurements into two categories called clear and cloudy. The clear category contain measurements from molecular backscatter, and the cloudy category from particle backscatter. The classification is done by using a threshold for the measurement scattering ratio. The clear measurements are then averaged over about 87 km along the satellite track for the clear measurements to yield wind observations called Rayleigh clear winds. Cloudy measurements are averaged over about 13 km along the satellite track for the clear measurements to yield wind observations called Mie cloudy winds. Please rephrase to make this clear. The authors can mention the further Rayleigh cloudy and Mie clear products briefly, but explain that these are generally of less good quality and are quite sparse and are therefore not analysed here.

Line 99: The main reason why issues with the Aeolus instrument alignment and detector quality could be detected quite fast and mitigated though improved instrument calibration and on-ground data processing corrections was that the L2B wind product is operationally monitored at ECMWF. ECMWF compares the Aeolus winds arriving within 3 hours of sensing (e.g. in near-real-time) directly with the short-range forecasts fields and produces error statistics. The Aeolus CAL/VAL activities were able to confirm the errors detected by the ECMWF model monitoring and provide further information. This allowed for the Aeolus data processing to be quickly improved. Please rephrase accordingly.

Line 105: This is a repeat of what is written earlier in the paper on the on-ground data processing baseline versions. Please harmonize and rephrase, to write that the processor updates are done approximately every 6 months, allowing for bug fixes, improved data calibration and data processing, and thereby improving the product quality. About once a year, the datasets are reprocessed with one processor baseline in order to produce long datasets with the same data quality.

Line 110: The text is not clear hear, mentioning malfunctioning periods and “rarely interrupted” in one sentence. Please rephrase. With “malfunctioning periods” I guess you mean the periods where the instrument switched itself off automatically, which means that it took several weeks to switch it on and realign it again. Mention that these spontaneous switch-off events have been rear.

Line 111: For a non-expert, it is not possible to understand what ANX4.5 means. This is the longitude of the reference ascending note of the orbit used for the longitudinal placing of the 7 day repeat cycle. I propose that you explain this and refer to Figure 1 to illustrate how the weekly overpasses close to Granada shifted in June 2021.

Line 135: rephrase the explanation of the system measures the frequency shift of the

backscattered signal, caused by the movement of particles along the instrument LOS. From the frequency shifts, the movement of the atmosphere along the LOS, and hence the wind in this direction, can be obtained. The system measures along 3 LOSs or it is scanning, yielding the 3D wind field.

Line 136: Rephrase to say that the system can only measure the backscatter from particles due to the wavelengths used (1500 nm) which is compatible with Mie scattering. The signal strength is important for the instrument range.

Line 140: explain "agl". Explain that the telescope overlap means that winds cannot be measured below this altitude.

Line 165: Like for line 11, explain ANX2.0.

Line 174: The authors have mentioned before that you compare two of the four wind products in the Aeolus L2B data. I propose to refrain from mentioning this again and simply say that the Aeolus Rayleigh clear and Mie cloudy products will be analysed.

Line 177: What is meant with " … where the configuration could provide several wind estimates even for the same bin height, …" Do you mean that Rayleigh clear and Mie cloudy winds sometimes occur at the same geolocation ad altitude? Please clarify.

Line 178: I do not understand this sentence: "… presenting a vertical coverage limited to the clous extension …) . Please rephrase and be more precise what you mean here and which data product you refer to. The whole sentence to too long with too many parenthesis and commas. Mention that Aeolus provides good quality winds on top of water clouds in the ABL.

Line 184: Rewrite to say "Aeolus observations where the quality flag was set to valid was used." Write observations and not bins also in the further parts.

Line 194: Specify whether you have used data from January to June 2020, and if yes which processor version these have been processed with (B11?)

Line 201, 213: Specify again what you mean with a spin-off comparison.

Line 245: Replace “On the other hand” with “Furthermore” or something similar. To be checked by a native speaker.

Line 254: You have not explained B11 before, and for this data period it was used. B11 and the period it was covering should be introduced earlier in the manuscript.

Line 254-255: The language is not clear here and needs to be checked. “were B10” etc is not clear.

Line 255: Mention here that earlier studies have found that the Aeolus winds have orbit phase dependent biases. Refer to the papers describing this, e.g. Rennie et al. Mention that this motivates you to check also orbit phase dependent statistics in the later analysis.

Lines 258-260: Again, it is difficult to understand what is written. Language needs to be checked and refined.

Line 357-358: This sentence is difficult to understand. Please rephrase to make it clearer what you mean and see from the data analysis.

Line 399: replace “values” with “observations”

Line 410: Mention the geographical location of the wind comparisons done by Baars et al (2020), and discuss why the result could be different.

Line 443: The phrase “Aeolus did not present a particular performance …” is not understandable and should be changed, e.g. to “The Aeolus and radiosonde wind observations agreed well …”

Line 445: “The RMSE presented a similar value between 4 and 18 km …”? Similar to what?

Line 498: Change “emphasize” to “increase”

Line 500: “The limitation is softened …” This is not understandable, please rephrase.

Line 502: Rephrase to: “The 100 km collocation criteria proposed by ESA was shown to be suitable for this study.”

Line 514: replace “handicap” with “drawback”, and “Additionally” with “However”