

Review of the AMT manuscript: “Evaluating the use of Aeolus satellite observations in the regional NWP model Harmonie-Arome” by Hagelin et al.

General comments.

The manuscript describes the results of assimilating Aeolus Doppler wind lidar data in a regional high-resolution data assimilation system covering the Nordic region. It is an interesting and important study that complements a number of global NWP assimilation studies of Aeolus data by other scientists. Few, if any, similar studies have been performed, so it is certainly an area of research where publications are welcome in AMT and other journals. Before publication can be considered the manuscript needs to be tidied up and written with a more accurate use of data assimilation terminology. I have proposed a rather long list of related corrections below.

The conclusions are generally supported by the data. But the manuscript overstates the conclusions related to forecast and analysis impact evaluation from this study. The analysis increments and DFS are not good measures of forecast and even analysis impact, because they can be made artificially large by reducing the observation error. Too low observation error would give negative forecast impact. This would show up in forecast impact measures like 12-24-hour observation-minus-forecast statistics or FSOI (Forecast Sensitivity Observation Impact) statistics. The manuscript does include verification against radiosondes, that shows neutral results. So, due to the above the impact part of the conclusions has to be toned down.

It is a bit unclear what quality control has been applied to the data, both for the data assimilation process and for the diagnostics shown in Figs. 2-4. Are data in certain pressure ranges rejected? It is also unclear if observation errors have been inflated. Please improve the description of this in the manuscript.

In several places “model” is used where “data assimilation system” or “NWP system” is more appropriate. The data is not assimilated in the model. For example, I would prefer to replace “NWP model” with “NWP system” in the title. Please check and rewrite this throughout the manuscript. I have corrected some of the occurrences in my list of proposed corrections below.

The Aeolus data availability and usage within the region is a bit unclear: Is there only data available for the 03, 06, 15 and 18 UTC cycles? Why is the data limited to one orbit per assimilation cycle (line 136)?

If Aeolus data only is available for the 03, 06, 15 and 18 UTC cycles, it would be interesting to focus more on the statistics and impact for these cycles only. For Figure 5 it would very interesting to add the DFS statistics just for these four cycles, either in the form of a parallel set of bars or use of two colours to enable this in Figure 5.

It is useful to include Fig. 4, but it should be made clear in the text that $STDV(O-B)-STDV(O-A)$ is not a measure of impact. It just reflects the observation error settings. Overfitting data would “look good” but give degraded forecast impact.

It would be informative to add curves with mean statistics for specified observation error to Fig. 4.

Lines 195-225: Be careful not to overestimate the use of DFS as an impact measure. DFS is very sensitive to observation error specifications. DFS does not estimate forecast impact. Please tone down the text accordingly.

It is not always clear what data assimilation experiments were performed: Did you run separate assimilation cycles with Rayleigh data and Mie data, respectively? I don't think this is necessary in order to get DFS and Desroziers diagnostics (line 276). Also, did you only use 4D-Var for the single observation experiments?

Conclusions lines 336-346: I think the statements are too strong and not justified based on the results. Aeolus Mie data will be more accurate than Rayleigh data due to Rayleigh-Brillouin scattering (Gu and Ubachs (2014), J. Chem. Phys.), but Mie data will have limited availability (only where there is clouds or aerosols). So, it is not so simple to determine if Mie or Rayleigh data is more useful for assimilation in regional km-scale models. Departures for Rayleigh data could be computed using model values averaged over several point to improve departure computations. This also relates to my comment above about the limitations in using increments and DFS to evaluate forecast impact. Basically, I don't think you can justify making such clear and definite statements about Mie versus Rayleigh data. So please tone down the text and remove unsubstantiated impact claims.

More detailed comments.

Line 14: A better data assimilation related reference would be: *"Some aspects of the improvement in skill of numerical weather prediction. A. J. Simmons and A. Hollingsworth (2002) QJRMMS <https://doi.org/10.1256/003590002321042135>"*

Line 20: I suggest to update to a newer WMO reference. This one would be better: *"Fifth WMO Workshop on the Impact of Various Observing Systems on NWP (Sedona, Arizona, USA, 22 - 25 May 2012) - Workshop Report (Edited by: Erik Andersson and Yoshiaki Sato)"*

Line 23-24: Note, AMVs are also available from tracing moisture features. Please include radiosonde wind profiles in the list here.

Line 78: "applying ECMWF global EDA forecasts as lateral boundary conditions." Do you mean EDA (Isaksen et al. 2010) or EPS (Buizza et al. 2007)?

Line 78: "Ensemble Data Assimilation experiments (EDA)" → "Ensemble of Data Assimilations experiments (EDA, Isaksen et al 2010)" That is if you meant EDA and not EPS.

The reference is Isaksen et al. (2010) ECMWF RD TM 636.

Line 84: Are you averaging model fields along the 86 km BRC for Rayleigh data or using one model value for departure calculations?

Line 91-92: I find it easier to understand the equation in the form:

$$(H(x)-y)^2/(\sigma_b^2+\sigma_o^2) > L$$

But you decide that.

Figure 2 and 3: Fig. 2 shows surprisingly low STDV(O-B) for Mie in Sep-Oct 2018. The values look smaller than for the similar data shown in Fig. 3 (left panel). Has it to do with using different quality control settings? Please check this.

Line 164: As noted just above, I'm surprised to see STDV(O-B) for Mie as low as 2 m/s for Sep-Oct 2018. Please check. The surprisingly large increase between first and second period for Mie departures is partly to reduced effective laser performance, as you mention, but also due to the change in accumulation length from 86 km to 12 km for Mie. I suggest to mention this in the manuscript.

Line 192: Based on my general comments, I suggest to rewrite "The Mie data has a larger impact within the data assimilation when estimating the initial state than the Rayleigh data" → "The Mie data, with its smaller observation errors, adjust the initial state more than the Rayleigh data"

Line 228 and 230: "only some of the forecasts which are analysed" and "we verify the forecasts after 6 hours, so that some of the forecasts will have used Aeolus data in the data assimilation"
It is unclear to me what you mean. Aeolus data is used in the appropriate 3-hour data assimilation cycle and not in the forecast. Please rewrite.

Figure 6: It would be most more useful to plot the difference between each experiment and the control experiment. This can either be in m/s or relative difference. Please consider to do this.

Line 250: Desroziers (2005) diagnostics is useful, but it provides an estimate with limitations. E.g., it assumes background error and observations error covariances are correctly specified. Please make this clear in the text.

Lines 270-275: It is unclear to me what you have done and why. Please improve the explanation.

Lines 280-285: It is difficult to understand what you have done. Please rewrite the text.

Line 307: The assigned observation error of 0.7 m/s seems very low. Please check and explain.

Figure 8 and the associated text lines 310-315: Please be consistent and either use pressure or altitude to describe level 15 and level 32.

Lines 326-329: It is useful to include Fig. 9 and the related text. But I believe it is an overstatement that the idealized single observation study demonstrated clear benefit of flow dependent 4D-Var versus 3D-Var. I believe it could well be true, but it cannot be concluded from these experiments. So, please tone down the text.

Minor comments and proposed corrections.

Line 31: Remove "most impacted by winds in"

Line 33: "used in clear" → "made in clear"

Line 43: It is "European Centre for Medium-Range Weather Forecasts"

Line 46: "models" → "NWP systems"

Line 48-49: Move LAM acronym from line 49 to line 48.

Line 54: “modelling” → “data assimilation”

Line 55: “observation and by model” → “observations and by the model”

Line 56: Remove “in some aspects”

Line 58: “observations.” → “observations, respectively.”

Lines 64 and 68: “3 h” → “3-hour” ; “1 h” → “1-hour”

Line 67: “Fig. ??” → “Fig. 1”

Line 74: “MetOp1 and 2” → “MetOp-A and MetOp-B” (If this is what you mean)

Line 75: Remove “so called” and “ideas of”

Line 94: Remove “so called”

Line 101-102: I suggest to remove the sentence “The Aladin ... quite good.”

Line 103: “On a later stage in the mission” → “In June 2019”

Line 103: “to improve the data quality and we” → “because the laser A had degraded in data quality. We ...”

Line 105: “with correction for the M1 mirror temperature bias (Martin et al, 2020).” → “with M1 temperature based bias correction (Rennie and Isaksen 2020).”

Line 106: “available and the data should have” → “available, so the data had”

Line 107: “is” → “was”

Line 116: “experiment run the model every three hours with 3D-Var” → “experiments used three-hourly 3D-Var”

Line 117: “catch-up runs of with a” → “only a”

Line 121: “models” → “systems”

Line 123: “80” → “86”

Line 125: “10 km after ...” → “12 km. This was implemented ...”

Line 125: “avoid the systematic error” → “account for Rayleigh-Brillouin scattering”

Line 131: Remove “orbital”

Line 131: “Martin et al. 2020” → “Rennie and Isaksen, 2020”

Line 134-135: “added upper limits to the size of the observation error that was acceptable to the data assimilation system. These were ...” → “rejected poor quality data with large observation errors. These limits were ...”

Lines 138- 142: “Between ... Rayleigh data).” Repetition of text above. Please remove.

Line 143: “observation” → “observation errors”

Lines 147-149: “Also ... runs.” Repetition of text above. Please remove.

Line 150: “1” → “Fig. 1”

Line 152: “particularly for the Mie” → “due to the data sampling reduced from 86 km to 12 km for Mie”

Figs. 1-4 and 6: Please add the experiment periods to the legend is all these plots.

Line 160: “Likely caused” → “caused”

Line 160: After “hot pixel” add reference to (Fig. 8 in Rennie and Isaksen, 2020; Weiler et al., 2020).
Weiler, F., Kanitz, T., Wernham, D., Rennie, M., Huber, D., Schillinger, M., Saint-Pe, O., Bell, R., Parrinello, T., and Reitebuch, O.: Characterization of dark current signal measurements of the ACCDs used on-board the Aeolus satellite, Atmos. Meas. Tech. Discuss. [preprint], <https://doi.org/10.5194/amt-2020-458>, in review, 2020.

Line 184: “depending on the direction of travel of Aeolus” → “for ascending and descending orbits”

Fig. 3: Please add a note in the legend that the bottom right panel is using different scaling.

Line 193: I suggest to remove: “, despite there being overall fewer Mie observations available.”

Fig.4: It would be very useful to add curves with mean observation error as function of altitude for Mie and Rayleigh to the two panels.

Line 199: I suggest to remove: “as compared to O-B and O-A departure statistics”

Line 200-202: Please remove repeated text: “The O-B and O-A departure ... per observation.”

Line 202: Remove “on the other hand”

Line 208: “SYNOP” → “screen-level winds”

Fig. 5: Please improve figure: Same plot title is used on all panels in each row. This is not informative. Either remove or specify Absolute/Relative “All, Mie, Rayleigh DFS”, as appropriate.

Line 216: “Furthermore, for the Mie only experiments, the” → “The”

Line 217: “The Rayleigh data on its own also have a larger relative than absolute impact in the DFS values,” I don’t understand what you mean.

Line 220: I would like you to, in Figure 5, also present the statistics just for the cycles with Aeolus data. I mentioned that above.

Line 236: I suggest to remove “in the verification”

Line 243: “used by the background forecast” Do you mean “used by the analysis”?

Line 246: It would make sense to perform the investigation both for the laser A and the laser B experiment, and combining the statistics to ensure more reliable results. Please consider to do this.

Line 252: “wind speed values given by the model are given more weight than the wind speed values from Aeolus, since there is a smaller error assumed for the model values.” → “wind speed background errors (red solid lines) are smaller than wind speed observation errors for Aeolus (black solid lines).” The original text is confusing.

Line 254: “model values” → “background”

Line 259: “model” → “background”

Line 264: “performance of the model” → “forecast skill”

Line 264: “Figure 7” → “Fig. 7”

Line 271: “using both Mie and Rayleigh data”

Was that not the case for the case for the experiments above. Please clarify.

Figure 7 legend: “model” → “data assimilation system” two times!

Line 283: “recommend” → “recommended”

Line 300: “launched” → “produced”

Line 301: “produced” → “computed”

Line 303: “initial states” → “analyses”

Line 315: “Figure 9” → “Fig. 9”

Line 327: “demonstrated” → “indicated”

Figure 9: Add to legend “Note, different colour scales used for the two panels”

Line 333: “model” → “assimilation system”

Line 335: “model” → “NWP system”

Line 339: Please mention the reduction of averaging length scale from 86 km to 12 km for Mie as a partly explanation for this.

Line 352: "a more refined assimilation techniques in this case 4D-Var" → "a 4D-Var assimilation technique"

Line 352: "as the" → "as using the"

Lines 354-358: I don't think the manuscript has shown what is written about LBC and positive forecast impact. I suggest to remove "We have also ... O-A, O-B statistics."

Line 360: "have a look at" → "use"

Line 371: "by by" → "by"

Line 394: Write out the list of coauthors.

Line 403: "and K., M." - Please update reference

Line 412: Improve Pourret reference and add doi-link

Line 430: "Quartely" → "Quarterly" !!