Interactive comment on “A practical method to remove a priori information from lidar optimal estimation method retrievals” by Ali Jalali et al.

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This paper applies an elimination of a priori information for optimal estimation method (OEM) from lidars similar to the work of von Clarmann and Grabowski (2007). I have been enthusiastically following the progress and the application of different regularization methods but, the current paper has many flaws. In some cases, misleading statements and false claims have been presented as listed below. I sincerely hope that the authors would address these issues before the submission of the final version.

In page 3 line 4 it has been stated that “The retrieved profiles are calculated on the coarse grid by re-running the OEM in a way that the effect of the a priori constraint is minimized.” Later, in the Methodology, page 6 line 13, it is stated that “the first step is to run the OEM retrieval following the same procedures as in Sica and Haefele (2015) or Sica and Haefele (2016). This produces a temperature or water vapor retrieval along with their respective averaging kernel matrices and uncertainty budgets on the “fine grid” or first retrieval grid.” First, it is necessary to show the value of cost obtained in each iteration. Because the first iteration is usually the most critical iteration in which the cost significantly decreases between 2 to 3 orders of magnitude. Furthermore, quoting von Clarmann and Grabowski (2007) which has been referred for over ten times in this paper “While the usual approach to characterize retrievals which include a priori information by their averaging kernels and smoothing errors is, of course, still valid if done properly (which however, assumes availability of the climatological covariance information of the state variable under assessment), our re-regularization/resampling scheme is advantageous in less favourable conditions, i.e. if the required climatological covariance information is not available.” The statement gives the reader an idea that the advantage of the coarse grid method is for the time that there is no a priori or a priori covariance. But, if an a priori is already available and is used for the first iteration why should you use the re-regularization/resampling scheme and not use the already available a priori for the remaining iterations. Also, it cannot be claimed that the two a priori profiles used in this paper for temperature and water vapor retrievals are of poor quality and it made the use of resampling scheme necessary since they have already been used in Sica and Haefele 2015, 2016.

In page 9 line 7 it has been stated that: “The daytime case fine grid averaging kernels (Fig. 3a) quickly drop below 1 after 2 km due to a dry layer.” After that in page 9 line 22 it is stated that: “If we consider the last valid point to be 4.5 km with a statistical uncertainty of 27%, the a priori removal method extends the valid altitude range of the daytime OEM retrievals by 2 km.” However, in Sica and Haefele (2016) Fig. 11: the averaging kernel drops below 1 after 5.5 km not 2 km for another selected date. Further on, in page 20 line 12 it is claimed that: “Using this method helped to increase the altitude range of the daytime and nighttime water vapor retrievals by up to 2 km and
600 m, respectively.” A general claim cannot be made based on only one selected day. To make such a claim it is necessary to compare the results of at least several days of the resampling method with the daytime OEM retrievals especially the one used in Sica and Haefele (2016) which reads up to 5.5 km.

In Fig. 5, the statistical uncertainty of the coarse grid retrieval between 2.5 km to 4.5 km is much more than 27% on the right panel. Although the uncertainty at 4.5 km is about 27%, the uncertainty between 2.5 km to 3.5 km of the coarse grid is much larger than the fine grid. It is not clear how the cutoff altitude is defined. In the OEM, the cutoff is set at 0.8 or 0.9 which provides a quantitative cutoff, however, in the coarse grid method mentioned in this paper, it seems that one must look at the plots to decide the cutoff altitude which is a subjective matter. Also, it is not clear why the coarse grid method for water vapour has only been compared with the OEM at the cutoff of 0.9 and not 0.8. By putting the cutoff of the OEM at 0.8 higher altitudes will be gained and therefore, necessitates to compare the coarse grid method with the OEM when the OEM cutoff is set at 0.8. The results of the coarse grid method could be compared with the one done by Sica and Haefele (2016) where the cutoff is set at 0.8 to see if higher altitudes are really gained. As the OEM has considerable lower uncertainty if same altitudes are reached by putting the cutoff at 0.8 I then fail to see the advantage of the coarse grid method in retrieving a water vapour profile with a higher uncertainty of a about 30%.

In the caption of Fig. 6 it is stated that “The percent difference between the radiosonde and the InAne and coarse grid retrievals is plotted.” And, “However, the coarse grid retrieval is closer to the radiosonde above 2km and decreases the percent difference between the InAne grid and the radiosonde by up to 50% in regions where the a priori contributes to more than 10% to the InAne grid retrievals.” For this plot, it is necessary to also provide the error bars of the retrieval to be compared with the OEM.

In Page 13 line 1 it is stated that “We picked a sample night, 12 May 2012, from the Rayleigh temperature climatology in Jalali et al. (2018) to illustrate the a priori removal procedure for a Rayleigh temperature retrieval.” Again, it is not clear why the coarse grid method for temperature has only been compared with the OEM at the cutoff of 0.9 and not 0.8. Although it may be argued that the 0.9 cutoff has smaller a priori influence, Fig. 14 shows that the influence of using the a priori information is only about 2 K which is negligible. It seems from Fig. 13 that if you bring the cutoff at 0.8 for the OEM the height of the retrieval improves alongside with better uncertainty and vertical resolution. It is therefore necessary to compare the coarse grid method with the OEM when the OEM cutoff is set at 0.8. I suggest showing the results for the night of 24 May 2012 to be consistent with Sica and Haefele (2015) and Jalali et al. (2018).

In the following I have mentioned only a few of many statements in the paper that are either misleading or false or have not used appropriate scientific language. Page 10 last line: “The coarse grid method improves the retrieval in regions where the a priori has signifiAcant influence and performs as we would expect.” Page 13 line 10: “Fig. 11b shows that at the coarse grid points, the averaging kernel is completely sensitive to the measurements and therefore there is no a priori contribution.” Page 19 line 12: “The a priori removal technique is most useful when the SNR is low, particularly in dry layers. The method increased the retrieval altitude by roughly 2km which is highly beneiftAcial for meteorological studies that rely on accurate tropospheric measurements.” Page 20 line 17: “The a priori removal technique is most useful when the SNR is low, particularly in dry layers. The method increased the retrieval altitude by roughly 2 km which is highly beneiftAcial for meteorological studies that rely on accurate tropospheric measurements.” The above statements are false since, in higher altitudes the high averaging kernel value is artificial and is influenced by the noise of the instrument. The trace of the averaging kernel is also high which is artificial and is influenced by the presence of noise. Statements such as “that at the coarse grid points, the averaging kernel is completely sensitive to the measurements” and “The a priori removal tech-
nique is most useful when the SNR is low” are misleading and wrong. Specifically, the
fact that it is observed that the a priori removal technique works
better when the SNR is low and is not working so well when the SNR is high (as stated
in page 12 line 15). This clearly indicates that for the daytime the main reason to gain
higher altitudes is due to the influence of noise in the retrieval. Furthermore, in von
Clarmann and Grabowski (2007) when the coarse grid scheme was used the degree
of freedom of the retrieval became smaller. In the paper written by von Clarmann
and Grabowski (2007) it is stated that “the constrained retrieval has 9.7 degrees of
freedom. After application of the proposed transformation to a coarser information-
centered altitude grid, there are exactly 9 degrees of freedom left, and the averaging
kernel on the coarse grid is unity.” Therefore, removing a priori information does not
provide a higher degree of freedom and the retrieval height cannot be improved. If
otherwise is claimed, mathematical proofs should be provided which is missing in this
paper. Showing the results for a single day retrieval with large uncertainties above the
cutoff altitude of the OEM cannot be rendered as mathematical proof.

Page 20 line 21: “The systematic uncertainties after a priori removal increase roughly
by a factor of 2, but remain on the same order of magnitude as before the a priori
removal.” and “In all cases, the vertical resolution of the OEM retrieval decreases after
a priori removal.” These are two major disadvantages of the introduced method that
have been downplayed. In other words, the method provides a worse vertical resolution
and higher uncertainty.

Page 19 line 10: “The nighttime water vapor retrieval was provided for contrast to
illustrate how the a priori removal technique does not provide significantly more in-
fornation when the signal level falls off rapidly.” Page 9 last paragraph: “Using the a
priori removal technique for nighttime retrievals may be helpful when trying to improve
water vapour measurements of
the Upper Troposphere and Lower Stratosphere (UTLS) region. However, in this case,
because the nighttime measurements have large SNRs and a rapid change from high
to low signal values, we do not see as large of a difference between the coarse and
in\Ane grid retrievals as we do in the daytime retrievals.” The coarse grid method the
retrieval only improves for 600 m with a large uncertainty of 52% and the vertical res-
solution of few hundred meters. As shown in Fig. 9 the OEM at the same altitude has
the uncertainty of about 20% and not only the coarse method does not significantly
proceed with more information but also it performs much worse. Showing one night of
retrieval without comparing it with any other night(s), it is unclear how the method can
improve the UTLS measurements. Furthermore, the statements such as “signal level
falls off rapidly” and “large SNRs and a rapid change from high to low signal values”
are vague and do not contain any quantitative information. It is necessary to show both
daytime and nighttime measurements, and quantitatively state the difference between
the measurements for daytime and nighttime.

Page 9 line 22: “In this case, the fine grid averaging kernels are never exactly 1, there-
fore they have some a priori contribution which is why the vertical resolution is generally
higher in the coarse grid retrieval.” In Sica and Haefele (2016), Fig. 4, Fig. 14, and
Fig. 18 it is clearly shown that when the averaging kernel becomes smaller than 1, the
vertical resolution decreases. As can be seen from Fig. 4 of Sica and Haefele (2016),
in higher altitudes, the averaging kernel peaks become wider. Therefore, when the a
priori contributes in the fine grid the vertical resolution decreases. Therefore, the given
statement is wrong.

Page 16 line 6: “To illustrate that the a priori is in fact being removed, we compared
the temperature retrievals using two very different a priori temperature pro\Ailes, one
calculated by CIRA-86 and one calculated by the US Standard Model (Fig.14). The
difference between the two temperatures on the in\Ane grid retrieval is shown by the
black curve and is about 2K at the 0.9 cutoff line, within the statistical uncertainty. The
difference increases rapidly above that height. The same temperature difference after
the a priori is removed is shown in red and is on the order of zero at all altitudes.”
If $S^{-1}$ is set to zero, the final answer will be independent of your choice of a priori and it is not surprising that the plot of the temperature difference is close to zero. However, in the first step, an a priori information is already used to provide the first retrieval which highly influences your retrieval. The only reason that the effect is not seen in the final result is that in the next iterations $S^{-1}$ is set to zero.

Page 13 line 12: “The vertical resolution for both grids is similar up to 85 km altitude (Fig.12). Above this height the coarse grid incorporates more points from the ðñAñe grid, and thus, the vertical resolution increases.” This is a false statement, the vertical resolution decreases. In fact, when the SNR drops in higher altitudes, according to the proposed centered information approach, to have a layer with the degree of freedom of 1 more coarse points should incorporate, the peaks of the averaging kernel become wider and the vertical resolution decreases.

Page 19, line 12: “The a priori removal technique is most useful when the SNR is low, particularly in dry layers. The method increased the retrieval altitude by roughly 2km which is highly benéñAcial for meteorological studies that rely on accurate tropospheric measurements.”

The large uncertainty provided in the last 2 km of the retrieval is in contrast with your statement of providing accurate tropospheric measurements. The word dry layer is used several times in this work, but never is explained. It is unclear how the dry layers are defined and how one can identify dry layers.

Page 21 line 7: “Newcomers to the OEM may find this a priori removal technique helpful for checking their a priori’s influence on the retrieval and in determining the appropriate a priori.” How can removal of a priori information help one to determine the appropriate a priori?

Page 21 line 12: “Another advantage of this method is that the same coarse grid for a typical night can be used for multiple lidar retrievals. In some cases, the coarse grid will not be optimal but still reasonable.”

Reasonable is not a scientific statement. Besides, no such case (not optimal but reasonable) is discussed in the paper.