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Atmospheric Measurement Techniques Discussions

Interactive comment on "Tomographic retrievals of ozone with the OMPS Limb Profiler: algorithm description and preliminary results" *by* Daniel J. Zawada et al.

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Referee report to "Tomographic retrievals of ozone with the OMPS Limb Profiler: algorithm description and preliminary results" by D. Zawada et al.

The manuscript presents a new 2-D algorithm to retrieve vertical distributions of ozone from OMPS-LP measurements. At vortex edge conditions with high meridional gradients of ozone, the algorithm is shown to perform better than a commonly used 1D retrieval. This fact makes the paper highly important for the scientific community. From the scientific and technical point of view the manuscript exhibit, however, several significant shortcomings related to the quality of the algorithm description, validity of the

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approach and the used data, and the extention of the validation and analysis. A detailed list of the issues is provided in my general comments below. To my opinion the manuscript will be suitable for publishing in AMT after a major revision considering all my comments.

General comments

- Authors use outdated versions of OMPS Level 1 data (v2.0-2.4) although the new data version v2.5 is available already since May 2017. As version 2.5 already includes the pointing correction described in Sect. 3 of the manuscript this section would not be necessary any more if new Level 1 data was used.
- Pointing accuracy is mentioned as the main error source and the corrections in the order of 200-300 m seem to be considered by authors as important, otherwise one would rather skip Sect. 3. On the other hand, the authors do not hesitate to neglect the field of view of 1.5 km without making any considerations about the impact of this decision. As the field of view illumination is vertically inhomogeneous, I assume the neglect of field of view integration should have a similar effect as a misspointing. In this regard it is not quite clear why a very good agreement with MLS is still achieved and if the entire verification results might be accepted as trustable. To my opinion the evaluation must be repeated taking into account the field of view of the instrument.
- As an improvement of the retrieval quality by using a 2D retrieval is a key topic of the manuscript, synthetic retrievals as done in Sect. 5.1 need to be presented for the whole orbit. This is necessary to assess if smoothing out the small latitudinal variations by 2D retrieval as seen around 50°S in Fig. 8 is a general drawback of this approach or just an insignificant outlier. Furthermore, a similar study should be performed for another season with a vortex edge in the northern hemisphere. This will allow the reader to assess how the viewing geometry affects the relative performance of the 1D and 2D retrievals. Another important question is how the

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retrieval results depend on the ozone distribution used to initialize the radiative transfer model. This question has not been addressed in the manuscript at all.

- The retrieval description is too much general with a lot of details hidden from the reader. For example, no or only insufficient quantitative information is provided about the latitudinal grid, reference tangent height and regularization parameters (γ in Eq. (2) and α in Eq. (3)). The authors state that the a priori state vector is set to zero but make no comments about the values used to initialize the radiative transfer model. Are they also zero at the first iteration? The valid altitude range of the retrieval in not clearly identified.

- The validation is not sufficient to demonstrate the overall performance of the algorithm. The monthly mean comparison plots similar to Fig. 10 must be provided for absolute values rather than for anomalies for several latitude bands (tropics, middle and high latitudes).

Detailed comments

- Page 2, line 24: "... $\gamma_i I$ might be included..." - please make a clear statement if this term is included in your retrieval or not, if yes, what is the starting value and a typical end value of γ_i?

- Sect. 2.2: State vector is described insufficiently. Both altitude and latitude grids must be specified exactly providing the upper and lower limits as well as the sampling.

- Page 3, line 13: "A consequence of the limb viewing geometry..." - this is not a general consequence of the limb viewing geometry as a scanning instrument can be operated to avoid this problem (e.g. SCIAMACHY). This is rather a consequence of the imaging technique (2D detector array) used in OMPS.

- Page 3, paragraph starting at line 16: this is an unnecessary general discussion which do not provide any useful information. It is highly questionable if the method described by authors is really that general as no references are provided. Furthermore, possible griding issues vary with the observation method. For example the issues are completely different if a combination of measurements along and across the flying direction is used. I recommend to remove the paragraph and focus on the detailed description of the setup used in the retrieval rather than discussing any "general" approaches.

- Page 4, Sect. 2.3, starting from line 16 till the end of the section: to my opinion this text does not provide any useful information as for the retrieval/modeling description it is absolutely irrelevant whether the model performs the internal transformation of the coordinates or not. If you think it is important you need to describe it in much more details to give the reader understanding what is performed, how and for what reason, and which implications it can cause. Otherwise the text must be deleted as in its current form it is just confusing.

- Page 5, lines 1-2: "The sparsity of the Jacobian matrix can be improved..., as is done in Livesey et al. (2006)" - there are a lot of things which "can be done". The essential information is, however, if it "is done" in your retrieval or not. Please provide the numbers if it is done or clear statement that it is not done otherwise.

- Page 5, lines 3-6: This text does not contain any useful information. The matrices to be stored and inverted are already known from Eq. (2), their dimensions are already discussed in the first paragraph of the section, the fact if you solve the linear equation system using a solver for sparse or dense matrices is an absolutely minor technical information and a calculation of a memory space needed to store a 10000×10000 matrix is a very simple arithmetical exercise which is not relevant for a scientific paper.

- Page 5, last paragraph: the paragraph is quite confusing. It not strictly defined

what you understand as a “forward model run”. In any case you have to simulate the radiance for every measured pixel, otherwise you just loose the information. Formally you can do just one “forward model run” and simulate everything. Thus, to understand this discussion, the reader has to know what is meant as a “run”. Normally the forward model is run for each internal grid point, this might coincide with the location of the image or not. Surely a reduction of grid points reduces the computation time. So, actually, you just need to provide the information on the latitudinal grid and skip the remaining discussion.

- Page 6, line 1: “10° cone” - commonly the term “cone” is used for a 3D object while you have a 2D approach. Please use a proper notation. Furthermore, it is unclear how this “cone” is defined, I suppose from the Earth’s center, but it should be clearly stated to avoid a confusion.
- Page 6, line 3: “Each image...” - do you mean that the solar zenith angle changes from image to image? It is actually obvious that the illumination and composition of the atmosphere changes from one location to anther. Why is it an issue?
- Page 6, line 4: “... internal atmosphere is specified as a plane” - I suppose you mean the meridional direction. It should be clearly stated to avoid a misinterpretation.
- Sect. 2.5: Actually I did not find anywhere a statement about the variable defining the along-orbit grid, is it latitude, solar zenith angle, of anything else?
- Sect. 2.5: The last paragraph does not contain any useful information as it is not discussed how the OSIRIS images are compiled and how the corresponding radiative transfer calculations are done. Surely the listed conditions are not an issue for 1D retrievals if each observation is processed independently. I recommend to remove the paragraph.

- Sect. 2.6: Remove the first two paragraphs of the section. These paragraphs pretend to provide an overview of the methods fail however to do that as the discussion is to sketchy. Furthermore, this information is not needed for the discussion below.
- Page 6, line 28: "For our retrieval ...": please bear in mind that $\gamma_i I$ also works as a regularization term. So, when using Levenberg-Marquardt approach it is incorrect to state that the retrieval is completely unregularized. By the way, it is still not clearly stated if you use the Levenberg-Marquardt term in you approach or not.
- Page 7, Eq. (3): Provide α value.
- Page 7, Eq. (3): The statement "**0** indicates a number of zeros equal to the number of altitude grid points" is wrong. It must be the number of altitude grid points minus one.
- Page 7, line 4: There are certainly some good reasons to use zero a priori state vector especially when employing smoothing constraints but the "simplicity" is not really the best one. It should be also mentioned that usage of zero a priori state vector often results in a low bias of the solution.
- Page 7, lines 9-10: I do not agree that the resolutions of the vertical and horizontal grids are strictly coupled. In principle any grid combinations can be used, this might require however a stronger regularization as the total amount of information remains obviously the same. The main challenge here is to identify the optimal set of grids and regularization parameters. This set might however depend on the targeted usage of the retrieval data.
- Page 7, lines 12-13: "The effect of a one dimensional retrieval on horizontal regularization...." - I guess you mean "horizontal resolution".

- Table 1: Please provide the reference tangent height for each interval.
- Sect. 2.7.1: What is the minimum retrieval altitude for ozone?
- Page 8, line 7: Here and further below in the text you are talking about the "atmospheric upwelling". I suppose you mean the upwelling radiation. However, this notation is commonly used in the scientific community to describe the dynamic processes and means the upward moving air masses rather than radiance. Please use another notation throughout the text to avoid a confusion.
- Page 8, lines 20-21: I guess Eq. (4) is valid for both triplets and doublets. "... for triplet k" in line 21 should be "... for triplet l".
- Page 9: "...any errors in the absolute calibration ..." - this is not completely true for an imaging instrument because the information for different tangent heights comes from different areas of the CCD and can have different calibration errors.
- Page 10, Eq, (6): It is not clear how the second term is employed in the retrieval as the modeled Rayleigh background needs to be subtracted in the same way from both measured and modeled radiances and thus is canceled out when calculating $y - F(x)$ in accordance with Eq. (2).
- Sect. 2.7.2: No information is provided about how the aerosol extinction coefficient is calculated for other wavelengths.
- Page 11, line 1: "... albedo is handled in a two-dimensional sense ..." - what is the second dimension for the albedo?
- Sect. 2.7.3: 40 km tangent height to retrieve the surface albedo is quite high. Have you checked a possible influence of the stray light at this tangent height?

- Sect. 2.7.3: The influence of the albedo spectral dependence must be discussed. For example, for a green vegetation the albedo obtained at 745 nm can be very different from that at 602 nm (red edge).
- Sect. 3: The section is unnecessary as all discussed corrections are already implemented in the Level 1 v2.5 dataset of NASA.
- Sect. 4: If Levenberg-Marquardt term is used in the retrieval it must be also included in the error analysis.
- Sect. 4: Is the signal to noise of 100 is used only in the error analysis or in the standard retrieval as well? Why was not the signal to noise data provided in Level 1 data set used? The latter would provide a realistic instead of maximum error estimation.
- Page 13, line 9: Only in the error analysis section the reader learn that the logarithm of the number density is the retrieval parameter rather than the number density itself. This must have been mentioned already in Sect. 2.2.
- Page 13, line 14: what does “but near where the tropopause lowers at mid-latitudes” refer to?
- Fig. 7: Suboptimal color scale. How is the sign of the distance from the retrieval location defined?
- Page 14, line 3: “Since the regularization term...” - once again, do not exclude the Levenberg-Marquardt term from the discussion.
- Fig. 7: The definition of the vertically/horizontally integrated averaging kernels is not quite clear. You have a set of averaging kernels for each vertical/horizontal grid point and each of them spans in both vertical and horizontal directions. Is the integration done over these directions? Is yes you seem to show one averaging

kernel at each altitude in each panel in Fig. 7? If it was true I would expect the plural in the beginning of line 8 as you show multiple averaging kernels for different altitudes in each panel of Fig. 7. If my understanding of the definition is correct, I would like you to explain why there is a clear maximum at 40 km in tropics and 45 km at mid-latitudes and how it can be interpreted in terms of the retrieval sensitivity.

- Page 14, line 9: “Only minor differences ...” - to my opinion the majority of differences occur around 40 km and they are not minor.
- Page 14, lines 11-12: “it was found that ...” - it is hard to believe as it is widely known that the averaging kernels for “relative” retrievals (i.e. retrieval of relative deviations from a priori or logarithms) depend on the atmospheric state. Please provide the averaging kernel plot for different season to justify you statement.
- Fig. 7: why does the tropics plot have a white area below 18 km, how is the lower boundary of the retrieval defined?
- Page 14, last paragraph: It is absolutely inappropriate to neglect the instrument field of view without any investigations as it might lead to a significant change in both the retrieval results and error analysis.
- Sect. 5.1: The results must be provided over the whole orbit as it is essential to estimate how the retrievals compare outside the vortex edge region. Another simulation for a different season with a vortex edge in the northern hemisphere needs to be provided to assess the influence of the viewing geometry.
- Page 15, line 25: “For limb scatter measurements ...” - please illustrate this by plotting the averaging kernel for about 65°S and 15.5 km in both horizontal and vertical directions using a proper color scale.

- Sect. 5.2: this section is not really informative and can be skipped. Details on the execution time suit better in the algorithm description section.
- Sect. 5.3: Not only the anomalies but also the monthly mean values themselves need to be compared. This needs to be done for different latitude bands (tropics, mid-latitudes, high latitudes).
- Fig. 10: Why the altitudes above 59 km are not shown? If I understand it correctly, the retrieval runs up to 59 km.
- Page 19, lines 1-3: "... with the horizontal along-track resolution being poorer.." - please provide the values of the resolution and sampling for both instruments.
- Page 19, lines 5-6: ".. has been degraded to the MLS pressure grid with a least square fit..." - please clarify what exactly was fitted and how you can degrade the vertical resolution using a least square fit. Here, a convolution with averaging kernels would be more suitable.
- Fig. 12: Provide the lower and upper altitude of the plotted range. Provide the same plot from 1D retrieval. Explain the lower limit of the retrieval.
- It would be also interesting to show some examples from NASA Level 2 data, especially in Fig. 14.

Technical corrections

- Page 2, Eq. (1) matrices have to be shown in bold face to match the corresponding notations in the text.
- Page 15, line 5: duplicated word "those"

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