Comment on amt-2021-61
Anonymous Referee #1

General Comments

The authors have implemented a total ozone algorithm for the Ozone Mapping and Profiler Suite (OMPS) Nadir Mapper (NM) based on a technique they call the Weighting Function Fitting Approach (WFFA). The purpose of the algorithm is to estimate total ozone from OMPS NM coincident with OMPS LP stratospheric column ozone, and compute the tropospheric column by taking their difference. As such, the algorithm has been applied only near nadir and in cloud free conditions. The authors explain the WFDOAS approach is not the optimal to retrieve total ozone (TO) from OMPS NM due to the relatively low spectral resolution of the instrument which negatively impacts analysis of the differential spectrum. In the WFFA method the primary algorithmic changes increase the width of the fitting window and reduce the low order polynomial to a constant term. With these modifications, the WFFA method fits the spectral slope of the ozone absorption in addition to higher order structure. The first half of the paper describes the algorithm. The second half details validation of the total ozone retrievals using other datasets that are well known in the field. The total ozone results presented in the second half of the paper look quite good and therefore I feel this algorithm is very promising. However I have some questions about the algorithm and how it has been presented. I recommend the authors address the following to significantly strengthen the paper.

We appreciate your revision and comments.

After investigations of the spatial patterns of the limb-nadir matching for retrieving tropospheric ozone, we extended the total ozone retrieval to cover FOVs ranging from 10 to 22. Therefore, the following figures have changed: Figs. 5-7, 9 and 10. The added FOVs do not change the main conclusions in the manuscript.

All your technical comments have been addressed and will be included in the revised manuscript. With respect to the major comments, we detail the following points:

Specific Comments

1. The authors have made an unusual accommodation to get good results from their OMPS NM retrievals - they have achieved their results using only alternating pixels in the OMPS NM spectra. Oddly, this works when odd-numbered pixels are used in the retrieval. When even-numbered or all pixels are used, the results are unstable from one retrieval to the next and a bias is observed. I think it is important in this paper to provide further information on this instability. The issue raises questions about the performance of the algorithm, the instrument, or both. Do the authors have an idea why the WFFA method gives reasonable results in the one specific case? Perhaps the fitting of the spectral slope to determine TO is affected by end-point sensitivity of the fit? The authors use a fitting window of 316-336 nm in their algorithm. Does an adjustment of this window to include/exclude 1-2 spectral points at the window edges produce a more stable retrieval when all spectral pixels are used? Are there any particular spectral features at the edges of the fitting window that complicate a reliable spectral slope determination that might

show as a noticeable pattern in fitting residuals?

The nature of the problem using WFDOAS on OMPS-NM data is the instability of the retrieval resulting in unrealistic behavior of the results across the instrument FOV. We illustrate this effect in the appendix of the revised manuscript. The WFFA algorithm avoids this obstacle by reducing the weight of the differential absorption structure of ozone in the retrieval and by increasing the weight of the broad-band spectral signature of ozone. This is done by extending the spectral range to 316 to 336 nm and subtracting a lower order polynomial (constant) instead of the cubic one in WFDOAS. As a result, most of the instabilities has been eliminated, but some of them still remained. Subsequently, we further analyzed the retrieval results obtained using only selected spectral points from the retrieval spectral window.   The spectral sample with every second spectral point was found to have much weaker dependence on the temperature, which made the WFFA retrieval more stable. New plots providing more details on this topic are added to the revised manuscript (Figure A2). We could not identify any particular spectral point or range responsible for the observed behaviour. For the finally selected spectral window and sampling, skipping/adding points at the window's boundaries does not produce any significant differences.

If the authors think the issue is related to quality of OMPS NM spectra, this should be stated. It is worth nothing that colleagues at BIRA have successfully retrieved total ozone from OMPS NM with the GODIFT v4 algorithm to produce data consistent with the GTO-ECV record. I am aware of no similar issues with processing OMPS NM data.

We do not think it is an instrumental issue. The issue is rather related to the correlation between the spectral signatures of the main fitting parameters, namely, weighting functions of ozone and temperature as well as the Ring spectrum. GODFIT also had issues using the smaller fitting windows. In their final data product, the FOV dependent striping effects have been corrected a-posteriori (C. Lerot, personal communication).

2. The explanation of the insensitivity of the WFFA algorithm to absorbing aerosols and other broadband contributions should be explained better. The WFFA approach fits the spectral slope to estimate the ozone absorption signal, but several other geophysical effects may also affect spectral slope. The authors assume an aerosol-free atmosphere in their forward model and retrieve an effective scene albedo at 377 nm using the LER approach, so albedo wavelength is 40 - 60 nm from the edges of the fitting window region. Absorbing aerosols can produce several percent in spectral dependence in the radiance signal in this spectral region. The authors state the aerosol effect is largely accounted by the effective scene albedo, but I feel given the nature of the algorithm this may be an oversimplication. How can we be better assured of this? It is true that results shown later there are no significant ozone anomalies in regions of high aerosol load. But I cannot explain why. The WFFA algorithm may well be as insensitive as authors claim, but it would be useful for the reader to know the reason(s), and clarify circumstances where residual error may grow to be significant. Absorbing aerosols are common in the tropical regions and these are regions where tropospheric ozone is of particular interest. Since tropospheric column is a relatively small fraction of the total column, small errors for TO can be non-negligible for tropospheric ozone determination.

In Coldewey-Egbers et al. (2003), “WF-DOAS Algorithm Theoretical Basis Document” (DOI: 10.26092/elib/381), it is shown that: “the effective albedo by the Lambertian Equivalent Reflectivity

(LER) approach near 377 nm represents a first-order correction for non-absorbing aerosols (...) total ozone might be underestimated by 1% if visibility is reduced to 2 km by absorbing aerosols". We repeated this analysis for WFFA algorithm for different boundary layer aerosol types assuming a strong aerosol load (visibility of 2 km) and in addition for an extreme volcanic aerosol load in the stratosphere. We found that the WFFA TOC retrieval errors are highly dependent on the solar zenith angle. For small SZAs (about 30 deg), the TOC might be overestimated by about 3 %, in a presence of weakly absorbing aerosols in the boundary layer. For strongly absorbing (urban) boundary layer aerosols, an overestimation of TOC by about 1 % is found. In the case of an extreme volcanic loading in the stratosphere, the overestimation might reach about 8 %. For high SZAs (about 60 deg), the error is below 0.5 % for weakly absorbing boundary layer aerosols and increasing to about 1% for strongly absorbing boundary layer aerosols and extreme volcanic aerosol loading in the stratosphere.
The details of this analysis are presented in the Appendix A3 of the revised manuscript.

3. The sensitivity of the algorithm to tropospheric ozone is not discussed in the paper. This should be addressed in some fashion given the goal of the algorithm.

To investigate this issue, we scaled the lower part of the climatological ozone profiles (below 12 km) by factors 2 and 5 and repeated the retrieval. No significant differences in the resulting total ozone value were identified. This is discussed in Appendix A4 of the revised manuscript.

4. Some discussion of algorithm uncertainty and sources of error would strengthen the paper considerably.

A full analysis of uncertainty and errors of WFDOAS was presented in Coldewey-Egbers et al. (2003), "WF-DOAS Algorithm Theoretical Basis Document" (DOI: 10.26092/elib/381). In addition, we re-evaluated the major sources of errors that could be specific for the WFFA retrieval. As a result, we include in the main text of the revised manuscript a table with uncertainty estimates from enhanced aerosol loading, the use of BDM (Malicet) vs Serdyuchenko cross-sections, and tropospheric ozone profile shape (Table 1).

5. It is unclear why S5P/TROPOMI results from different satellite algorithms are compared. How do these comparisons relate to the OMPS-NM WFFA TO algorithm in the present manuscript?

As the WFDOAS algorithm was the basis of WFFA it was worthwhile to include its results for TROPOMI in the comparisons. On the other hand, OFFL/RPRO is the official TROPOMI product and we could not ignore it.

6. The title is very general. A more specific title will help readers distinguish this work from that of others.

The title has been changed.
The new title reads: "Total ozone column from OMPS-NM measurements using the broadband Weighting Function Fitting Approach (WFFA)"

Techincal comments:
Line 2: its -> the
Done
14: delete "characterizes the stratosphere. In turn,"

Done
15: remove "On the other hand,"
Done
19: remove "Among others,"
Done
20: "1970's, have provided"
Done
23: specify Suomi NPP OMPS
Done
22: change 1994 to 2005
Done
24: named -> known
Done
24: (all) -> (all instruments)
Done
29: giving -> which is useful to establish
Done
32: this -> that
Done
57: sensor (no s)
Done
58: radiation instead of radiances?
Done
64: 150 km wide swath
Done
95: "linearly"
Done
101: remove comma
Done
Eqn. 1: is this C or C_i?
It is C. Changed
113, 137: same comment as for Eqn. 1
Done
118: please revise statement in light specific comments above
A detailed discussion of the algorithm evolution from WFDOAS to WFFA and reasons for selecting the wavelength sample are included in the revised version of the manuscript, see Appendix A1
127,128: readouts -> pixels:
In the revised manuscript we avoid using the term "readouts", talking about spectral points instead. (Now lines 128-133)
140: define RTM:
It is defined in L138 of the revised manuscript.
149: this first sentence seems out of place; can safely remove.
We do not understand why this sentence is out of place. It defines the initial guess of total ozone. This value determines the initial guess ozone profile used for the radiative transfer calculations. (Now line 153)
174: may be V8.6:
The OMPS Nadir Mapper level 2 Description cited. It indicates that the version is V8.5
203: "from the" -> "reported with"
Done

212: Is this the IGACO3 recommendation?
No, it is not an IGACO3 recommendation. The line is changed as follows:
Original line: “The S5P-WFDOAS product is retrieved using the recommended Serdyuchenko et al. (2014) cross-sections”.
Now line 222: “The S5P-WFDOAS product is retrieved using the Serdyuchenko et al. (2014) ozone absorption cross-sections”
221: Fig. 5 shows ozone lower over Antarctica than tropics during SON.
The line is changed as follows:
Original line: The total ozone reaches its minimum in the tropical region in all seasons increasing polewards.
Now line 231-232: “The total ozone generally shows a minimum in the tropical region in all seasons.”
250: "OMPS-L2" does not indicate a specific product. Please clarify which product.
The product version has been specified: OMPS-NM L2 v2.1
284-286: cloud contaminated scenes would generally have low bias, not high
We believe that the reviewer means the bias in the total ozone. The statement refers, however, to the differences between WFFA and OMPS_L2 algorithms. The algorithms might react very differently on the residual cloud contamination. It is, however, impossible to predict if the difference is expected to be positive or negative.
291: define TOCS
Have been changed for TOC along the text.
305: th -> the
Done
327-328: more should be said to justify this statement. What are requirements for retrieving tropospheric ozone from the limb-nadir matching technique?
The lines have been deleted
Fig. 5: striping in these TO maps seems large for a 150 km wide swath.
With only cloud-free pixels processed and limited to four FOVs there are not enough data to remove the striping. The new data set includes 12 FOVs (instead of 4 before) covering approximately 600 km across-track. The striping is now strongly reduced.

Fig. 10: cannot find a reference to this figure in the text. Please define what the shaded areas represent. What is the difference between the grey and the very light green shaded areas?
The shadings indicate the standard deviation of each time series. In the revised manuscript, this is mentioned in the figure caption. The standard deviation of the operational product of OMPS-NM is light green, which turns to grey-green when it overlaps with the WFFA standard deviation shown in grey.

* Minor editing note: the use of plural nouns is not needed in a number of places
All that we could find have been changed.