

## Replies to Reviewer #1's comments

First of all, the authors gratefully acknowledge the reviewer for his/her comments and suggestions. The reply to each reviewer's comment is given in blue below the comment.

**Interactive comment on “The Advanced Infra-Red WAter Vapour Estimator (AIRWAVE) version 2: algorithm evolution, dataset description and performance improvements” by E. Castelli et al.**

**Anonymous Referee #1**

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### General Comments

This paper outlines updates made to the AIRWAVE algorithm that exploit the dual view of the ATSR series of IR radiometers to retrieve TCWV using the split window technique. The authors present seasonal maps of TCWV and present results from inter-comparisons with an established SSM/I TCWV product and ARSA radiosondes. The general comments were written after completing the specific and technical comments. When reviewing the results section the reader is redirected to a previous paper by the same group from 2018 for comparison of results. After downloading Papandrea et al. (2018) it becomes immediately apparent that the 2 manuscripts are very similar in layout and appearance. The results from the earlier manuscript have practically identical figures, in the same order, with the only difference being Papandrea et al. (2018) validates the version 1 product whereas this study uses the new version 2 data. This study fails to show enough independence from the previously published work to warrant a new publication at this stage.

The main concern of the reviewer is related to the fact that the present paper seems not enough independent from Papandrea et al., 2018, that contains AIRWAVEv1 validation. He/she says that this is due to the fact that the lay-out of figures is the same in the two papers.

The reviewer is correct about the style of the figures regarding the validation. However, this is not true for the content of these figures! The use of the same figures layout is meant to produce a benefit for the reader, who can easily appreciate the differences between the two versions of the algorithm. Furthermore, the present paper contains the description of AIRWAVEv2 algorithm and a climatology of the dataset in addition to validation. We think that all these elements guarantee enough independency from previous work and that the improvements of version 2, are relevant and deserve publication.

In order to clarify the relevance of these improvements, also considering the other reviewer's comments, we add information on the comparisons between AIRWAVEv1 and AIRWAVEv2 (see specific comments below and reply to reviewer #2).

Also, missing from the analysis/discussion is a quantification of the improvements between version 1 and 2 of the algorithm.

In the revised version of the paper we report directly the comparison of performances of AIRWAVE version 1 and version2 adding in Table 2 the results of AIRWAVEv1 validation from Papandrea et al., 2018. This allow the direct comparison and the quantification of the improvements between the two version of the algorithm. The results of the comparisons and the improvements obtained with AIRWAVEv2 are also reported in session “Discussion and Conclusions”.

Overall the study is of value due to the legacy of the ATSR series, and the FCDR the radiances represent. I would recommend this for publication only after all the issues that I have highlighted are addressed.

### Specific Comments

1. Introduction lines 24-39: You mention microwave and near-infrared sensors, but what about water vapour from infrared sensors? TCWV estimates using the split window technique have been done with HIRS, AVHRR and MODIS to my knowledge. There is also no mention of chal-

allenges of ocean vs. land retrievals using IR window channels. What are the benefits of using the ATSR series?

To cover this point, in the revised version of the paper we add:

“TCWV retrievals from infrared spectral regions were performed from Advanced Very High Resolution Radiometer (AVHRR; Emery, 1992) measurements, using the split window technique, (Sobrino et al., 1991) and from MODIS (Seeman et al., 2003). TCWV retrievals from infrared channels over land suffer of the limited knowledge of the temperature and the emissivity of land surfaces (Lindstrot et al., 2014)”

before “The Along-Track Scanning Radiometer (ATSR, Delderfield et al. (1986)) instrument series had as main objective the accurate ...”

In line 37 we also add, following the reviewer’s suggestion “Due to the legacy of the ATSR series, and the fact that the radiances are a fundamental climate dataset record, the AIRWAVE dataset is an important resource for water vapor studies.”

Consequently, we add the following references:

Lindstrot, R. M. Stengel, M. Schröder, J. Fischer, R. Preusker, N. Schneider, T. Steenbergen, and B. R. Bojkov. “A global climatology of total columnar water vapour from SSM/I and MERIS”, *Earth Syst. Sci. Data*, 6, 221–233, 2014 [www.earth-syst-sci-data.net/6/221/2014/](http://www.earth-syst-sci-data.net/6/221/2014/) doi:10.5194/essd-6-221-2014

Seemann, S., J. Li, W. P. Menzel, and L. Gumley (2003), Operational retrieval of atmospheric temperature, moisture, and ozone from MODIS infrared radiances, *J. Appl. Meteorol.*, 42, 1072–1091.

Sobrino, J. A.; Coll, C.; Caselles, V. Atmospheric corrections for land surface temperature using AVHRR channel 4 and 5. *Remote Sens. Environ.* 1991, 38, 19-34.

2. Introduction line 42: Quantify ‘general good quality’ from previous assessment of version 1.

Done. we add “(average correlative bias of 0.72 kg/m<sup>2</sup> vs SSM/I and 0.80 kg/m<sup>2</sup> vs ARSA)” after “general good quality of AIRWAVEv1 dataset”.

3. Section 2.1: Equation 1 it is unclear how lambda 1 & 2 are being used here. Is it referring to the 10.8 and 12 micron channels? How is it being used in the superscript notation? What is being multiplied with the optical depths? Also what is F? Further clarity is needed here.

Yes, lambda 1 refers to the channel at 10.8 um, while lambda 2 is for the channel at 12 um. In the superscript it is the exponent of the term. The optical depths are multiplied by the values of the frequencies. F is now explicitly described and in the revised version of the paper we clarify all these points.

4. Section 2.1 Line 96: Can you state the accuracy? Has this already been shown with AIRWAVE-v1?

In Casadio et al., 2016 Appendix A we evaluate the accuracy of geometric correction to the AMF for the TIR channels of ATSR. In this paper we evaluate the accuracy of the whole retrieval procedure (not only the linear dependence between TCWV and optical depths).

5. Section 2.1 Line 136: Do the reported effects have an equal impact on retrieval precision for scan angles in the swath?

The estimates reported in the paper are given for along track configuration only. In the revised version of the paper we specify this in the text. However, we can also give an estimate of the improvement for extreme across track points: In worse cases, the precision has at maximum 1% higher value in the extreme across track of the swath with respect to the sub satellite points. We add this information at the end of Section 2.1.

6. Section 2.2 line 156: So what year do you use and why?

We use the 2010 (we added this information in the revised version of the paper). As stated in the text, the year to year variability has globally no impact on the spectra apart from some species whose impact has been assessed in the appendix.

7. Section 2.2 line 165: Why do you use ECMWF SSTs instead of the ARC/ESA CCI SST data products which are from the same instruments?

The SST used to calculate the retrieval parameter should be just representative of average conditions in a given season and latitude band. For this scope average SSTs obtained from the easily accessible ECMWF monthly means are suitable. ARC/ESA SSTs would have been suitable too.

8. Section 3 line 194: Do you also retrieve TCWV over lakes?

Yes, we clarify this in the revised version of the paper. We add “surfaces (sea and lakes)” after “over water”

9. Section 3 line 198: Are the uncertainties aggregated to the 0.25x0.25 grid? If so how are they propagated?

No, As specified in lines 199-200 the SSM/I group contains also the values of standard deviations for each 0.25x0.25 grid points. In the revised version of the paper we rephrase in order to clarify this point.

We replace :”The SSM/I group, in addition, contains the value of the standard deviation and the number of elements aggregated within the SSM/I grid cell. ”  
with

“The SSM/I group, in addition, contains the value of the number of elements aggregated within the SSM/I grid cell and the standard deviation of the TCWV value associated to each cell. ”

10. Figures 1-4: Too many sub-figures with replication of information. These should be combined into a single figure, removing either the 1b, 2b, 3b and 4b plots or the standard deviation maps to allow the reader to compare them side-by-side.

Following also the comments by Reviewer #2 we combine in one single figure figures 1,2,3 and 4 a and 1,2,3,4 c, now it is Figure 2.

Figures b) were moved in a separate figure, now it is Figure 3. We changed the text and the captions accordingly.

11. Section 3 line 223: Is this the RSS or HOAPS SSM/I product?

RSS as in Papandrea et al. 2018. This information has been added into the revised version of the paper where we describe with version of the SSM/I dataset was used for the comparison.

12. Section 3 line 234: Figure 7 is introduced before figure 6. Also you switch between Fig and Figure - please be consistent.

In the revised text we have switched the order of figures 5 and 6. We use Figure when it is at the beginning of a sentence and Fig. in all other cases as specified in AMT guidelines.

13. Figure 5: There is approximately 3 orders of magnitude more collocations with SSM/I than there are with ARSA. What impact does this have on the reported biases? Also the legends have different labels, the right-hand figure has bias while the left-hand figure says mean. Which is it? Ideally these should also be labelled a) and b).

About the different number of collocations: The reviewer is right when he says that the satellite has 3 orders of magnitude collocations than the radiosondes. However the number of collocations is very high (order of  $10^5$ ) and thus the impact on the bias is not related to that. However, the positions of the ARSA stations, that are not equally distributed worldwide as the satellite measurements (the majority of sites is based at mid-latitudes), may result in a small displacement of the TCWV values that are compared w.r.t. satellite (i.e. less relative amount of very high TCWV, characteristic of tropical conditions).

Done. We add a) and b) in figures and use "bias" in both panels (now it is Figure 5).

14. Figure 6: If using colour filled regions that sit on top of one another then the alpha value needs to be lowered to add transparency so that both regions can be seen. Alternatively replace one with error bars.

Done. In the revised version AIRWAVEv1 has blue error bars (now it is Figure 4).

15. Section 3 line 250: Do you require the reader to physically compare the table from Papandrea et al. 2018 with table 2 in this paper? From looking at the publication there is no table 2 but a table 1 and is this paper the validation of AIRWAVE-v1? This should be added to the discussion section if you want to make this comparison and discuss the improvements rather make the reader search them out.

Done. We added the values of bias and standard deviations of the differences between AIRWAVEv1 and SSM/I, ARSA extracted from Table 1 of Papandrea et al., 2018 in Table 2. We also change Table caption and text accordingly.

16. Section 4: This section seems very empty especially as results from what assume to be the AIRWAVE-v1 product were only published earlier this year. There is a lack of quantified improvements in the algorithm discussed or shown, especially as this is key to the title of the paper. Reads like a summary at best.

In the revised version of the paper we add here a quantification of the improvements obtained from version 1 to version 2.

We added:

As expected also from the analysis of synthetic retrievals, the most significant AIRWAVEv2 improvement is achieved at polar latitudes. In polar regions the bias versus SSM/I improves of 4.2 kg/m<sup>2</sup> and of 3.2 kg/m<sup>2</sup> versus ARSA. In both cases the standard deviations are reduced of about 1.6-1.9 kg/m<sup>2</sup>. However, improvements at mid-latitudes are also found. The average bias with respect to SSM/I improves of about 0.7 kg/m<sup>2</sup> and the standard deviation is reduced of about 1 kg/m<sup>2</sup>. In case of validation against radiosondes the bias in AIRWAVEv2 is reduced of about 0.6 kg/m<sup>2</sup> with respect to AIRWAVEv1 and the standard deviation is reduced of 1.6 kg/m<sup>2</sup>.

### Technical Comments

1. Abstract line 1: First sentence doesn't read well. Suggested change to: "Total Column Water Vapour (TCWV) is a key atmospheric variable which is generally evaluated at global scales through the use of satellite data."

Done.

2. Introduction line 19: Remove the word 'the' after 'Actually,'

Done.

3. Introduction line 20: Full stop after Allen et al (2014) reference, begin new sentence with 'For this reason, ...'

Done.

4. Introduction line 44: Incorrect spelling: 'theese' (1 to many 'e')

Done.

5. The AIRWAVE v2 line 55: Delete the 'general' from 'general high quality'

Done.

6. The AIRWAVE v2 lines 55-63: You switch between AIRWAVE-v1, AIRWAVEv1 and v1

In the revised version of the paper we use AIRWAVEv1 everywhere.

7. Section 2.1: Inconsistency in how AIRWAVE is referenced between v1 and v2 throughout section.

In the revised version of the paper we use AIRWAVEv1 everywhere.

8. Section 2.1 Lines 95-96: 'is envisaged' suggests an aspirational future outcome. If this was done in AIRWAVE-v1 then it should be known whether this is true. The 2 sentences don not read well as the second sentence states that the known linear dependence allows for accurate retrievals. This is a little confusing to read, needs rewording.

Done. In the revised version of the paper "is envisaged" is removed and the two sentences were rephrased: "This equation shows that a linear behavior exists between the water vapour optical depth and the TCWV.

The linear dependence is exploited to solve the AIRWAVE equation and to retrieve TCWV. "

9. Section 3 Line 192-193: Inconsistency in how AIRWAVE is referenced, here it is AIRWAVE V2 rather than AIRWAVE-v2 or V2. Need to settle on a single style.

In the revised version of the paper we use AIRWAVEv2 everywhere.

10. Section 3 line 201: Same as above but now you use AIRWAVEv2 11. Section 3 line 224: DMSP already defined in Introduction

In the revised version of the paper we use AIRWAVEv2 everywhere. DMSP Done.

12. Section 3 line 239: incorrect spelling: 'radiosoundes' (no 'u')

Done.

13. Introduction & section 3: Acronym SSMI should be SSM/I.

Done.