amt-2016-304

An intercalibrated dataset of Total Column Water Vapour and Wet Tropospheric Correction based on MWR on board ERS-1, ERS-2 and Envisat

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Response to Reviewer 1

We thank the reviewer for his constructive comments. Below please find a detailed response on all reviewer comments.

Section 2.1 needs to include a more detailed satellite description: launch dates, termination dates, type of orbits, etc. It also needs to include more details on the microwave radiometers (MWR): location of the channels, width, footprint size, are the channels exactly the same for the three instruments?

We have added this information now at the beginning of Section 2.1 and have also added a new Table 1 that summarizes key information about the instruments.

Error characterization for the channels (expected error in brightness temperature),

We have added this information in Appendix B and toward the end of Section 3.1

lat lon coverage in an average day, numbers of measurements per day, etc.

We have added this information now at the beginning of Section 2.1 and have also added a new Table 1 that summarizes key information about the instrument.

Section 2.3.1 needs to be expanded to include details on the forward model, spectroscopy used, do you use the Liebe model or something similar? mention the gases absorbing in this region? mention why you need the surface air temperature, surface specific humidity and the wind speed? which model do you use for sea surface roughness?

We have added a statement and two references. We are using the RTTOV forward modelling package, which is being used routinely by a huge number of operational and research users. All the information requested by the referee can be found in the RTTOV documentation.

Are you sure that the LWP from ERA-interim is accurate?

We are not using the ERA-Interim LWP at all. We only use the profile of LWP to distribute liquid vertically. (The only alternative would be to just select a height range in which to put liquid clouds, which to us appears even worse).

Once the vertical profile of liquid is established, we initialize the retrieval with a first guess LWP of 30 g/m^2 and then let the retrieval take over. As pointed out in the sensitivity studies, we are virtually independent of the first guess (as we should be).

How many iterations are needed for convergence?

On average the algorithm converges after less than five iterations.

Which apriori errors are assumed in Sb, is So assumed to be diagonal?

This is discussed in Appendix B, where we refer to the appropriate reference. We have now included a statement in the main text referring to that.

Which cost function value is used as convergence criteria?

At level 2 we do not screen according to cost function. When aggregating up to gridded data, we use a cost function value of five. This is addressed in Section 2.4.

Section 3.1: Please explain how you select the 4% of the observations, could there be a sampling bias? Are they distributed through out the globe?

This was just a compromise between having enough data for meaningful statistics and computational efficiency. We have added a statement to that extent.

Section 4. Please include a comparison against ERA-Interim vs the GNSS stations as well as versus the ERS1, ERS2 and ENVISAT data. The purpose of this comparison is to see if the new dataset posses more information than ERA-Interim (i.e., hopefully the comparison of the new datasets vs the GNSS stations is going to be better than the ERA-Interim / GNSS comparison)

This is an excellent suggestion and we have included the requested information in the new Table 2. The results indeed show an improvement in terms of a reduced RMS-Error.

Further, LWP has not been validated. Comments on its usefulness are needed.

We have added some discussion on LWP and expected uncertainties in Section 3.1, where we discuss the cloud-free LWP histograms. Beyond this, we do not see any way of 'validating' LWP as there is no reference available for such a validation. Comparisons with visible/near infrared estimates of LWP could be performed but have their own caveats and are typically only meaningful, if the two observations are on the sample platform, such as AMSR and MODIS. For the three satellites discussed here, that option does not exit. For more details on general LWP comparisons see e.g.:

- **Seethala, C., and Horváth, Á.: Global assessment of AMSR-E and MODIS cloud liquid water path retrievals in warm oceanic clouds, Journal of Geophysical Research, 115, 10.1029/2009jd012662, 2010.**
- **Greenwald, T. J.: A 2 year comparison of AMSR-E and MODIS cloud liquid water path observations, Geophys Res Lett, 36, 10.1029/2009gl040394, 2009.**
- **Borg, L. A., and Bennartz, R.: Vertical structure of stratiform marine boundary layer clouds and its impact on cloud albedo, Geophys Res Lett, 34, DOI: 10.1029/2006GL028713, 2007.**

Appendix B The sensitivity study needs to be expanded further. No information is given on the impact of the surface wind speed and sea surface temperature.

It is unclear to us, what such a sensitivity study would achieve since those parameters are fixed parameters that are not retrieved. In general, there are various studies already out there that address the sensitivity of MW retrievals w.r.t. wind speed and sea surface temperature. For the two frequencies under consideration, see e.g.:

> **Ellison, W. J., English, S. J., Lamkaouchi, K., Balana, A., Obligis, E., Deblonde, G., Hewison, T. J., Bauer, P., Kelly, G., and Eymard, L.: A comparison of ocean emissivity models using the Advanced Microwave Sounding Unit, the Special Sensor Microwave Imager, the TRMM Microwave Imager, and airborne radiometer observations, J Geophys Res-Atmos, 108, 10.1029/2002jd003213, 2003.**

The statement "as long as the actual TCWV is less than maybe 5-10..." needs to be proved (change the background by 5 -10 km/m2 randomly through-out the vertical profile and do the scatter plots).

Figure 8 and the corresponding table actually show exactly this. For a FIXED background of 28 kg/m2 all retrievals with an actual TCWV between about 20 and 40 kg/m2 do converge. We have rephrased the sentence slightly to make clearer what we actually meant.

What is the impact of the temperature being off by 3, 5, 10K.

If the reviewer asks for the general sensitivity of retrieved parameters to changes in Tbs, those can be read off Figure 2 and are discussed also toward the end of Section 3.1. We have added some more discussion there, that also justifies our choice for the magnitude of the observation error covariance matrix.

Good rule of thumb:

dTCWV/dTb23 ~ 1 kg/((m^2K))

dLWP/dTB36 ~ 25 (g/(m^2K))

Again, prove the statement: the choice of background is uncritical as long as it represents the general conditions for the geographical region and season.

See our discussion of the your earlier comment: Figure 8 and the corresponding table actually show exactly this. For a FIXED background of 28 kg/m2 all retrievals with an actual TCWV between about 20 and 40 kg/m2 do converge. We have rephrased the sentence slightly to make clearer what we actually meant.

Specific Comments

P2 L2: Define ERS

Fixed

P3 L3: Define GNSS (it was defined in the abstract but it needs to be defined again in the text)

Fixed

P3 L12: Define CLS (currently, only defined in the affiliations)

Fixed

P3 L13 please explain the anomaly and if know, the cause of the anomaly.

Fixed.

P3 L22: Define GNSS in P3 L3 not here.

Fixed

P4 L2: Should this section be called TCWV and LWP?

Agreed. Fixed.

P4 L8: Could you please explain if this retrieval is exactly the same as optimal estimation (it looks like it) or if there is any difference could you mention those.

Yes. We added a sentence to that extent.

P4 L10: Please give some basic details about ERA-Interim or at least provide a reference.

We added the reference recommended by ECMWF Dee et al. (2011).

P4 L13: Mention that the channel at 23 is close a line emission center and that the channel at 36 is a window channel.

We added this information.

P5 L11: Appendix B seems to indicate that the retrieval is based on ln(q) which will make it impossible to get negative values for TCW please explain why TCWV>0 is possible.

The retrieval only returns negative values (-999) only to indicate the retrieval has failed. Any converged retrieval will be positive as stated by the reviewer. We have rephrased this sentence to make this clearer.

P5L12: Why such a big value of a cost function shouldn't this be close to 1?

No, the expectation value of the cost function equals the number of degrees of freedom in the dataset. In our case the number of degrees of freedom is two. For an idealized retrieval 66 % of the retrieved cost function values should be below the number of degrees of freedom in the dataset. By allowing the cost function to go up to 5, we exclude 2.5-sigma outliers.

P8 L13: Is this 3 a footnote? It needs to be a superscript. Also, which figure in this link is related to your statement. Please clarify further.

Yes. Footnote… Word formatting issue…We have now addressed the figure selection on the website better in the footnote.

P8L29: Delete extra dot.

Fixed

P9L4: Define MSL.

Fixed

P11L14: delete frequencies below 37 GHz and change to limited to two frequencies 23 and 36 GHz.

Fixed

P15L17: xb needs to be bold because it is a vector and the b needs to be a subscript.

Fixed

P15L18: Sb needs to be bold because it is a matrix and the b needs to be a subscript.

Fixed

Figure1 caption: Envisat was launch in 2002 so the date most be wrong or this is a different satellite, please check.

Fixed (It was January 2005)

Figure 2: There is redundant information on both panels please delete one. Also specify for which satellite/month this is.

We have added the satellite/month. We are not sure what the referee is referring to in terms of "redundant information". The two panels are complementary. Only the isolines appear in both panels to provide visual orientation to the reader where the 'zero-bias' isolines intercept each other.

Figure 5 top add number of co-locations to the color bar.

Fixed

Figure 5 bottom right: there is a clear bias in the time series not shown in the scatter plot above please fix.

We believe this is correct, as the y-axis of the lower plot is in relative units. We have added the following text in the revised manuscript:

> The lower panels in Figure 5 provide time series of average relative differences between MWR and GNSS. These were calculated by first computing the relative difference for each individual observation and then averaging these individual relative differences. Note that for the same absolute difference relative differences are larger if the absolute value is smaller, e.g. for an absolute value of 20 kg/m^2, an absolute difference of 2 kg/m^2 would correspond to a 10 % relative difference, whereas for an absolute difference value of 60 kg/m^2 that same absolute difference would only correspond to a 3.3 % relative error. Therefore relative biases can be different from absolute biases as can be observed in Figure 5. We provide the stability here in relative terms because the World Meteorological Organization's (WMO) Global Climate Observing System (GCOS) requirements for temporal stability of TCWV are formulated in relative term as well (GCOS-107, 2006).