The paper by Hummel et al on the

“Total water vapour columns derived from Sentinel 5p using the AMC-DOAS method”

provides a detailed discussion of the results of total column water vapour (TCWV) retrievals from the Sentinel-5p TROPOMI instrument using the AMC-DOAS retrieval methods originally developed by Noel et al.

The results are compared in particular to the most recent ECMWF ERA5 reanalysis model data dominated by thermal infrared, GPS, and radiosonde water vapour profile data assimilation, as well as to other, model independent, retrieval results, in particular MPIC DOAS operating in the UV region, AMC-DOAS TCWV results from the GOME-2 instrument on Metop, and TCWV results from the SSMIS microwave sensor.

Additional corrections on the impact on surface albedo and elevation, as well as empirical corrections, potentially due to instrument artefacts, have been applied to the AMC-DOAS retrieval results from S5p.

The authors find good agreements between all data-sets with typical standard-deviations expected for any TCWV retrieval validation, due to differences in spatial scales and resolutions, as well as low mean biases, in particular also to the ERA5 model.

This is in contrast to previous studies where comparison to reanalysis model data revealed larger biases, typically also due to statistical effects of comparing “cloudy” model results with typically cloud free or low cloud) retrieval results. This fact points to significant improvements in the reanalysis data modelling of small-scale relative humidity and clouds, however not discussed by the authors. Also in this respect to the paper may serve as a good validation of the ERA5 re-analysis data, in particular in regions where assimilated data in the reanalysis fields is sparse, like in remote areas over land, and TCWV from thermal infrared missions biased because of lack of thermal contrast.

The impact of the additional corrections applied to S5P version of AMC-DOAS is significant, in particular with respect to surface elevation, albedo and clouds. While the elevation related effects on the TCWV are obvious and discussed when comparing to the “non-corrected” Metop-B AMC-DOAS results, the discussion on the additional albedo and cloud effects are less conclusive. But the authors expect that the same correction should be principally always applied, because they are basically instrument independent, and therefore would also apply for the GOME-2 data-set. This should indeed be followed up in future work.

The paper is well written and I can recommend it for publication in AMT.

The general introduction is however missing an overall conclusion with respect to the significance of the TCWV products derived from the UV-visible to NIR spectrum, in addition to the large amount of data-sets on TCWV and profile information existing and extensively used from the thermal infra-red and MW region. This is important in the context of a longer discussion on the application range of these data-sets, linking back to the discussion referred to above. The relevance of these visible data-sets is their coverage and (relatively) weaker dependence on surface type, as well as their sensitivity to the surface WV profile layers, ie. their accuracy w.r.t. the total column.

Being independent of model re-analysis data, they can be used for the validation of the latter. It would improve the motivation of why an operational WV product from S5p, as well as from S5 should be made available in the future.

Thank you for your recommendation for publication on AMT. We will include a short summary about the significance of the TCWV products:

„In general, water vapour products derived from the visible (VIS) to the near infrared (NIR) spectral range have the advantage that the measurements are sensitive to the surface. They have a relatively weaker dependence on surface type than products from other wavelength regions and usually cover both land and ocean. Specifically, the AMC-DOAS retrieval method does not rely on external datasets and therefore provides completely independent water vapour data. The independence of the VIS-NIR water vapour products of model re-analysis data makes them useful for the validation of the latter. “

Specific comments:

Section 3.4 on the empirical correction:

(Q1) There seems no indication (from experience from other retrievals?) of what causes the artefacts. Usually such across track features (which are frequently observed for such data, also in other VIS/NIR spectrometer missions) can be typically the result of an additive offset: i.e. stray-light, or a problem in the solar irradiance spectrum. What exactly is used for the latter? Experimenting with I0 (using artificial offsets or a very low TWVC (polar region) reference spectrum) potentially can reveal the origin.

(A1) For almost every day there is a irradiance measurement from S5P. When calculating TCWV from the S5P orbits we use the latest available irradiance measurement. If there is no irradiance measurement for one specific day we use that one from the day before.

Straylight in either the solar or the earthshine data might indeed be a potential reason for the artefacts which is worth further investigations. We will consider the reviewer‘s suggestions for a future product version.

(Q2) Can it be that the surface albedo correction already takes out a significant part of the feature over land? Since, if the artefact is not visible over land it can hardly be an instrumental feature.

(A2) The feature is not visible over land even before the albedo correction is done. The effect is mainly visible over ocean . This does not exclude an instrumental feature: For example, a straylight offset could have a larger effect over ocean where the surface albedo and therefore the signal is low. Other possible reasons for this effect could be aerosols, or angular dependence of the surface reflection which also might have different/larger impact over ocean. We will discuss this in the updated paper.

(Q3) Section 4.3, on the assessment of spatial features:

It should be generally not be surprising to find a feature related to vegetation in the AMC DOAS retrievals given is usage of measurements from the red-edge of the spectrum. The behaviour of MPIC DOAS in this respect is not surprisingly much different. Reducing albedo variations was in the end a large motivation I would assume (not only higher albedo over water as stated in the paper, and spectral regions covered by future instrumentation)

to move towards the blue. This specific sensitivity of a TCWV retrieval operation around 700 nm should be better highlighted and discussed in the paper.

(A3) We agree that the red edge causes some sensitivity of the retrieval to vegetation; however, since we use a very small fitting window most of this is handled via the polynomial fit. What we see is actually a second order effect. Note that the MPIC product also has some sensitivity on vegetation although it is based on the measurements in the blue spectral range. We will explain this in the updated paper. The following will be added to the conclusion section:

„This pattern reveals potential influences of vegetation either on the AMC-DOAS S5P TCWV or on the FRESCO product which is used as input for the correction.This could be related to the spectral variation of the surface albedo („red edge“) which is not fully captured by the polynomial fit.“

Editorials:

Introduction, l.21: Full stop missing.

Section 3.3.1, l9f: Sentence should be improved.

We will replace „This is the reason why we limit from present the scenes being studied to those having cloud fractions from 0 to 0.2“

to

„To reduce the impact of clouds we therefore filter out scenes with cloud fractions larger than 0.2 as a first step.“

Acknowledgments: Acknowledgment to EUMETSAT providing GOME-2B level-1 data missing.

We will address the issues mentioned above in the revised version.

Thank you very much for your constructive feedbacks and questions.