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Atmospheric Measurement Techniques Discussions

Interactive comment on "Total Column Water Vapour Retrieval from S-5P/TROPOMI in the Visible Blue Spectral Range" *by* C. Borger et al.

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The paper by Borger et al., on total column water vapour retrievals from Sentinel-5P (S5P) is demonstrating the large potential of water vapour retrievals in the blue and visible spectral range to yield an accurate estimate of the total water vapour column (TWVC) largely independent from model data and capable to cover all surfaces. This type of TWVC product from instrumentation like GOME-1/2, SCIAMACHY, OMI and TropOMI, therefore serves as an important product for the evaluation of (re-)analysis NWP model data output.

The paper by Borger et al. is overall well written and structured and apart from presenting the very first results of this type of TWVC product from the S5p mission the

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Discussion paper

paper also presents an interesting and novel approach of employing sub-column water vapour profile information to TWVC retrievals, via a parameterization of the water vapour atmospheric scale-height for various conditions, like surface type and different observation geometries. The strong gradient of water vapour in the atmosphere, always required an implicit knowledge of its vertical distribution often “hidden” in the way the conversion from slant to vertical column densities (SCD to VCD) via the calculation or estimation of the air-mass factor (AMF) has been approached.

The paper is an important contribution to this problem, since it approaches this issue for the first time explicitly, and shows convincing improvements, especially when retrieving TWVC in the vicinity of clouds, or evaluating, and improving the performance for various surface reflectance conditions. However the exact relation between cloud coverage, cloud height and retrieval performance remains to this reviewer still - at least to some extent – obscure and while I can highly recommend the paper for publication, I would like the authors to address this and a few other issues before.

1. Scale-height parameterization

The paper goes in depth on a specific parametrising of the a priori (better “first guess”) water vapour profile using a parameterization of the water vapour scale height. While the motivation to introduce knowledge on the water vapour profile is in principle clear to any reader familiar with TWVC DOAS-like approaches, for the non-expert reader, the relation to cloud screening and surface sensitivity is not apparent. The simplest solution to use a “first-guess” water vapour profile from NWP re-analysis data is simply excluded with a reference to Wang. Then GPS climatologies are used to derive a scale-height parametrization. However, it is not made explicit or clear that the rational to use a scale-height (instead of the probably already quite realistic NWP full profile) is probably the simple need to regularize, and therefore constrain the retrieval problem. Since instruments measuring in the UV-visible range, will not be able to retrieve water vapour with significantly more than 1 to 2 independent pieces of information in the vertical. Adjusting VCD sub-columns by changing a single parameter, ie. scale height,

therefor serves the need to constrain the problem. Since otherwise using re-analysis data as a-priori or first guess (depending on the inversion approach) and adjusting multiple layers in the retrieval would clearly have been the better approach. Such a parameterization using a scaled full profile, then however, also has the tendency (or advantage) to compensate for missing information (e.g. below the cloud), which is essentially missing in the measurements. To which extend this happens here is not very clear, and leads to the next issues concerning the treatment of cloud-coverage.

2. Treatment of clouds

The treatment of partially (or fully) cloudy scenes (as observed and expressed in geometrical cloud coverage (cloud fraction CF) with the use of collocated imager data) is critical for TWVC retrievals, since clouds may shield or amplify (through scattering) the true total column value. Up to the validation section, (Section 2 to 5), the paper discusses the conversion of SCD to VCD for any level of cloud fractions, using the independent pixel approximation. The AMF error analysis however seems to be carried out for a CF of up to 50%. The impressive results shown in Figure 13, present the results for CF<20% and for all-sky (CF up to 100%), arguing for the usage of the presented scale-height method. These results seem to indicate that the method even works for CF>20%. In the introduction to the validation section (Section 6) it is then however stated that the validation is carried out for CF of up to 20% ("clear-sky") only and the paper validates the results with SSMI in dependence of CTH in Figure 21. It is assumed that this evaluation is also for CF<20%. Otherwise, the reader would expect significant underestimations of the results for large CF with high CTH. So Figure A10 to 13 adds to the confusion since, the results presented there seem to indicated the opposite: high cloud fractions for high cloud top levels lead to overestimations with respect to SSMI. How is this result interpreted with respect to the used combination of independent pixel approach, WV profile scale-height parameterization method, and the evaluation of the AMF and its error? What is eventually seen by the authors as the final product and at which CF? The CF threshold has been key to all previously

published retrieval methods from the UV/visible to NIR spectrometers. Therefore one would expect a clear statement even up-front in the introduction and for sure in the conclusions, if the product, with its novel scale-height approach, wants to target a specific cloud-coverage threshold or is proposing one for final use.

Minor comments:

l.57 p.2: Is the wavelength alignment carried out for all solar measurements provided by S5p, or only once for all retrievals.

l.73, p3: Are ISRF changes in width found with the WV retrieval over the orbit for S5p?

l. 84, p.3: the difference between ground and spectral pixel should be made clear to avoid confusion.

l.101, p.4: In this equation “beta” is not defined and it is not clear how I0 from the solar irradiance is used here.

Eq4, p.5: Is the refractivity equation relevant here? I guess the important point to be made is the use of COSMIC water vapour climatologies in contrast to the already smoothed model data. It is still very puzzling why the former should be better for this purpose than using actual reanalysis data. Since GPS (and hyper-spectral TIR) profile data is meanwhile an essential component in NWP data, and the model helps in reducing the vertical information content towards the one from S5p.

p. 4: The VCD equation on page 4 is not numbered and the usage of I is confusing here, since I guess it refers to the iteration step instead of the previously used sub-column layer number. Otherwise some clearer explanation would be needed.

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