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Atmospheric Measurement Techniques Discussions

Interactive comment on "Quantification of uncertainties of water vapour column retrievals using future instruments" *by* H. Diedrich et al.

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The remote sensing of water vapour (WV) is a challenging task because of its large variability in time and space, its large gradients in altitude (its profile decreases by three orders of magnitude up to the tropopause) and its complex and close obvious relation to clouds and precipitation - which however interferes with the measurements in the considered energy region in the case of clouds. Large variability in time and space requires frequent measurements at high spatial resolutions. Large gradients in altitude require very high spectral resolution over a wide spectral region and (in case of column retrievals) high sensitivity to the surface.

Up to today no single type of instrumentation is able to cover all the mentioned aspects

required for an accurate retrieval of the profile or even an accurate retrieval of the total column of water vapour. This will, as far as we currently can oversee, remain the case for the foreseeable future including the second generation of operational satellite instrumentation like FCI, OLCI and METimage on MTG, Sentinel-3 and EPS-SG respectively. The latest major step forward in terms of instrumentation was therefore the advent of the high spectral resolution thermal infra-red interferometers UV/vis spectrometers providing a significant improvement to our knowledge of the water vapour profile and column under specific circumstances.

For the imaging type of instrumentation operating in the near infrared their advantage clearly lies in their high spatial and, in case of FCI, temporal resolution per measurement, whereas their limitation remain in their sensitivity to the surface type, since the clear-sky ocean does reflect too little radiation above 800 nm, as well as in their sensitivity to clouds, which in basically all cases shield a significant part of the total column because of the nature of the underlying WV profile shape. The latter deficiency on the surface type is coupled with a limited knowledge of the instruments sensitivity to the profile shape even under clear-sky conditions.

In the thermal infra-red the sensitivity to the lower part of the atmosphere can be at times very poor depending on the thermal contrast and as a result the total columns may exhibit significant low biases, though there might still be a reasonably good knowledge of the profile, and therefore the partial columns, in the middle and upper troposphere. In the visible often only total columns are retrieved because of poor information content on the profile shape, however, the averaging kernels of these retrievals in most cases peak in the lower and middle troposphere, even over oceans, and therefore the total columns retrieved in cloud-free situations are usually very accurate when derived from the visible. The presented dis cussion paper is an important contribution to the optimisation of the forthcoming second generation of missions in operational total column water vapour (TCWV) imaging. The overall subject and main topics covered by the paper are well laid out and the presentation of the results is clear and concise. The findings of the paper make a convincing case for the optimal channel selection of the considered future instrumentation, which should be considered by the programmes. I however feel that two important aspects of the future WV imaging concepts are not or not fully addressed. I therefore recommend a discussion in the paper concerning my following general remarks before publication as a full paper in AMT.

General remarks

1) Even though the consideration of slightly different energy regions may at this point in time not be realistic anymore on the program side (due to the maturity of the program developmental stages especially for FCI and OLCI), I am missing a motivation in the paper why the focus is solely on the NIR above 800 nm. From the above considerations and from the introduction of the paper the next obvious step leading to a more integrated and improved knowledge of WV total columns from a single instrument would be to add more (spectrally targeted) information from the visible, like from the 4nu and4nu+delta bands around 730 and 640 nm. This will very likely significantly increase the sensitivity to the lower troposphere in general and may even make high quality day-time retrievals of total columns over clear-sky oceans or dark land surfaces feasible. Since the contrast between the cloud and clear-sky case is lower in the visible the sensitivity of the retrieved column to residual cloud or scattering aerosol is also lower in the visible. The latter sensitivity is also decreased by a generally larger sensitivity to the lower troposphere. Also saturation effects play a less significant role and the dynamic range of a single channel in the visible can potentially be much larger than in the NIR providing improved calibration and sensitivity of the detector.

2) The list of parameters to which the total column retrieval will be sensitive to, surface albedo, aerosol load, and column concentration, is overall well chosen, little is however said about the sensitivity to the profile shape (water vapour in particular but also aerosol scattering layer height and cloud top height). Section four states that in addition to the 27 cases varying the targeted parameter set and for which results are presented, additionally the temperature profile has been shifted by 10K, and also the

aerosol scaling height has been altered (leading not only to a higher optical thickness but also to an on average higher layer-height). But later on it is not clear to me where these results are discussed. Is the model assuming a fixed coupling between water vapour and temperature (i.e. Clausius–Clapeyron's relation) such that the changing WV total columns imply a change in profile? This close coupling is however only true for the tropics but not necessarily, or even not at all, in the extra tropics (sees e.g. Wagner et al., 2006).

It is clear that the simulation of a realistic amount of different profile shapes (both for aerosol and water vapour) will probably largely exceed the scope of the paper. Nevertheless it would for the overall scope of the paper be beneficial to provide some results on the vertical information-content distribution for the various sensors and channel combinations, predominantly concerning the peak altitude of the information content per channel setting. The Bayesian approach used for the derivation of uncertainties is well suited for such an analysis, providing additional input (and effort) of climatological background profile information and their adjacent uncertainties (e.g. from re-analysis).

At the end of section 3.2.1 it is stated that no background information and errors are used from which averaging kernels could be derived. But then the next section (3.2.2) on information content does make use of such uncertainties (sigma_a) but is, however, using a completely different concept for the derivation of information content. Even though I acknowledge that this concept is useful for the subsequent discussion of the results (and probably straight forward and robust for implementation), it seems to be not well suited to link information content to altitude or this information, if available at all, has not been exploited. In contrast the averaging kernel concept making use of the Bayesian approach of the previous section would provide such information. From the vertical information-content distribution for the clear-sky case the potential impact on the derived total column under varying WV profile of aerosol load profile conditions can be more easily inferred even though this work might be then left to the reader or to subsequent detailed studies.

Specific comments

Abstract and introduction: For METimage, please refer to EUMETSAT Polar System (EPS) Second Generation (SG), i.e. EPS-SG instead of MetOp.

Introduction: For the reader not necessarily familiar with the future operational mission framework within this study is placed, the introduction should state why only imager data is considered here and why existing operational products from the visible (GOME/SCIAMACHY/GOME-2) and the IR (AIRS / IASI) using high-resolution spectral measurement and capable to detect WV columns and profiles over both land and ocean for cloud-free cases are neglected here. For the informed reader the reason is clear, since the target instruments are of the same (similar) measurement category or principle. This however might not be so obvious to the "uninformed" reader.

Section 2.2., l.26: Metop-B has been launched in September 2012. Metop-C is planned for 2016.

Section 3.2.1., p. 6329. l. 26/27: “For many applications...”. The sentence is incomplete.

Section 3.2.1., p.6330, l. 5: ”... the correlation between the error which is zero,...”. The sentence is incomplete. (Probably between the error of the ith and jth channel, this is assumed to be zero, thus uncorrelated.)

Section 4, p.6333, l. 7: first -> First.

Section 5.1., p. 6335, l. 2ff: and paragraph thereafter (l.6ff): “Above dark surfaces, most of the photons get scattered and thus do not travel through the whole vertical column...”.

Overall this is a confusing statement since in Figure 4 it looks like the variation of the changes with AOT is often stronger for the medium and high albedo case than for the low except maybe for MTG in the low TWVC case. Though the statement on the contribution of the scattering layers and the adjacent uncertainties is in principle correct

at first order the results seem not to support this conclusion. This is then stated in the next paragraph. This also points to the fact that the relation of the retrieval uncertainties to the “assumed” profile shapes are not that “simple”.

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