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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Validation of cloud property retrievals with simulated satellite radiances: a case study for SEVIRI" *by* L. Bugliaro et al.

L. Bugliaro et al.

luca.bugliaro@dlr.de

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We thank Referee 3 for his suggestions and corrections. They have been considered by the authors in the new manuscript version. Major changes are listed here:

- a more exhaustive discussion of the method's limitations has been added
- cloud particle effective radius has been evaluated more thoroughly for the APICS retrieval
- cloud water path has been extracted from cloud optical thickness and cloud effective radius for APICS and it has been evaluated together with the corresponding

CMSAF variables

- histograms of cloud top temperatures are discussed in addition to the plots already contained in the original manuscript version
- CMSAF data was processed again because of a small bug that affected mainly cloud optical thickness. Cloud effective radius is not a standard output variable for CMSAF and is not considered any longer.

In the following we review and answer all *reviewer comments (italic)* regarding our manuscript.

However the authors do not explain clearly enough the limitations of the technique which I see as being primarily the dependence of the agreement between real and retrieved properties on the input values used to model the cloud fields. The most obvious (although probably not the only) of these is the ice crystal scattering properties which are consistent with the APICS retrieval and not with the CMSAF retrieval. This is mentioned too briefly by the authors when explaining better agreement between with the optical depth retrievals of the APICS retrieval with the simulated measurements, but they fail to mention clearly enough that this may also impact on the level of agreement between the other cloud properties (to a lesser or greater extent).

This line of argument then implies a limitation of the technique where the input parameters into the models are well known with high accuracy then the cloud properties such as CTT are reasonable well validated. However where the accuracy of the input parameters is not well characterised i.e ice crystal optical properties then the techniques can only be used to evaluate algorithms sensitivity to the input parameter and not the accuracy of the retrieval.

This is not to say that the technique is useless just that it is would be most useful assessing different algorithms consistently when they use the same optical properties and input data as the model used to simulate the radiances.

The comparison between APICS and CM_SAF is complicated by these factors and it is difficult to definitively say which is better. However by using the 2 different cases the strengths and limitations of the technique are illustrated!

A discussion of the method has been included in the Conclusions that has been partly rewritten.

Furthermore, reference to this issue is now present in the subsection related to cloud optical thickness, cloud effective radius and cloud water path.

Finally, our intention was not to make a comparison between two cloud schemes to find out which is the beter one but to propose a new technique for algorithm validation.

The new conclusions read like this:

Based on three-dimensional cloud distributions from the COSMO-EU model and a downscaling procedure, a cloud dataset has been produced with a resolution of 2.33 km appropriate for the simulation of SEVIRI radiometer observations aboard the geostationary european MET-8 satellite (MSG-1). These clouds were input to detailed bias-free one-dimensional radiative transfer calculations to produce a realistic synthetic MET-8/SEVIRI satellite scene. In this exercise, the channels were assumed to be perfectly calibrated and instrumental noise was not considered.

The outcome of this study is a unique data set for the validation of retrieval algorithms of atmospheric, cloud, and surface properties from Meteosat Second Generation. Using the known cloud properties as a reference (i.e. as reality), we could quantitatively validate the outcome of two cloud retrieval algorithms in a closed-loop test where both input and output data sets are known.

The APICS and CMSAF cloud retrieval algorithms applied here for illustration purposes both proved to be able to satisfactorily reproduce the cloud distribution and its properties although some of them could be better retrieved than other. As far as cloud detection is concerned, APICS' largest inaccuracy consisted in a misclassified (i.e. inexistent) cirrus cloud field while the CMSAF algorithm had difficulties when dealing with cloud edges.

Cloud top temperatures could also be retrieved in a correct way throughout but a large variability was shown. For instance, APICS overestimated some cirrus cloud edges while it underestimated some other cirrus field. CMSAF instead underestimated the same cirrus cloud edges and also some water clouds.

For cloud optical thickness one has to differentiate between water and ice clouds. For water clouds, where the underlying optical properties were parameterised with Mie theory, a good agreement between reality and retrieval was observed, although CMSAF's scattering was slightly larger than APICS'. For ice clouds, where a-priori assumptions about shape and composition are required, the agreement between reality and model was slightly worse for CMSAF. APICS, which used the same ice optical properties parameterisation "as the real clouds", had a strong advantage and reproduced ice optical thicknesses fairly well but with a tendency to underestimation. CMSAF used a different parameterisation for ice crystal optical properties and nevertheless it could derive ice cloud optical thickness in a good way but with some scattering. As expected, pixels containing both water and ice clouds caused the largest inaccuracies and the largest scattering of results for both retrievals.

Cloud particle effective radius is difficult to evaluate since it changes with height inside real clouds while retrieval algorithms obtain a single value representative of some distance from cloud top. Thus, we used a weighting of the vertical profiles of effective radii to first extract one quantity to be used in the comparison with the APICS cloud scheme. It shows that the distribution of effective droplet radii larger than 5 µm could be reproduced correctly only. Occurrences of ice cloud and mixed-phase cloud effective particle radii were also derived accurately.

The cloud water path APICS retrieval proved to be quite reliable, especially for water and ice clouds. Although CMSAF derived quite accurate cloud optical thicknesses,

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cloud water paths were less reliable probably because of the accuracy of the effective radius retrieval and because of the larger scattering observed in CMSAF optical thickness with respect to reality.

The proposed validation technique is thus a powerful tool for detailed investigations of the performance of satellite retrievals because objective information about clouds is available. Since it is based on accurate radiative transfer calculations its basis is sound. However, the underlying cloud model plays an important role: although large scale cloud structures are realistic and consistent with the ambient conditions thanks to the COSMO-EU weather model, the small scale cloud variability is underestimated as the horizontal resolution is limited to 2.33 km. Furthermore, ice cloud properties, in particular shape and size distribution, are probably the most arbitrary factor of the entire simulation since ice crystal habit is unknown. In this study we selected hexagonal columns in all ice cloud boxes. Of course, retrievals that are consistent with this choice have a clear advantage in retrieving ice crystal effective radius. The determination of ice cloud optical thickness, however, is only slightly affected by this choice. In contrast, the representation of water cloud optical and microphysical properties is not arbitrary and is based on the exact Mie theory for spherical water droplets. The optical properties are then determined by the effective droplet radius while the details of the droplet size distribution function inside each box are of minor importance. Another issue is surface albedo: we used data from spaceborne measurements, and if a retrieval assumes the same a-priori surface albedo it certainly has an advantage compared to a completely independent retrieval. This, however, is only true in the case of thin (mainly ice) clouds.

Finally we did not consider real-world issues like inaccurate calibration, noise, incorrect geolocation, channel cross-talk, imprecise interchannel registration, or sensor saturation. All these effects have been excluded from the simulation since we intended to study the performance of the retrievals and assess deficiencies inherent to them which are not produced by external, instrument-related factors. On the other side, every cloud

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retrieval algorithm has eventually to deal with real data and is designed to cope with all these aspects. This means that the performance of the investigated retrievals when applied to real satellite measurements may slightly differ from the one that is obtained in this study. Instrument-related effects could be quantified in a separate study. It has to be noted that – since retrieval algorithms are often tuned by the actual satellite observations including for instance their calibration biases – their performance when applied to real data could be better than when applied to the bias-free simulations produced in this study.

All these things considered, the proposed validation method for space-borne retrievals is a powerful tool. Since all parameters used in the simulation are realistic and typical for the selected day and time, all retrievals should be able to produce meaningful results. Of course, "free" parameters like ice crystal shape will lead to some uncertainty in the retrieval output and schemes that are fully consistent with the simulation apparatus will have an advantage.

In summary, we have shown the potential of this method for the evaluation of space-borne algorithms and recommend its usage to the scientific retrieval community as one possible effective way to test and tune algorithms. Conceivable applications of this approach are manifold: a) the quantitative evaluation of further satellite algorithms as shown here; b) investigations about the impact of different NWP models (for the extraction of the ancillary data needed by the retrieval schemes) on the retrieved quantities, in particular cloud top temperatures; c) studies about the uncertainty of calibration accuracy on the retrieved (cloud) properties; d) implications of point spread functions for space-borne retrievals; e) effect of solar geometry on retrievals; f) impact of ice cloud particle shape on retrieved cloud optical properties. In future, we will also include the effect of the one-dimensional radiative transport approximation usually made in the retrievals. Furthermore, by simulating the same scene from the point of view of a polar orbiting and a geostationary satellite, synergistic effects could be examined in a detailed quantitative way.

Add reference to Khokanovsky paper (Kokhanovsky et al. The inter-comparison of major satellite aerosol retrieval algorithms using simulated intensity and polarization characteristics of reflected light Atmos. Meas. Tech., 3, 909 932, 2010) which has validated aerosol algorithms in a similar (but not identical) manner.

Done.

P21933 line 24 not always to not all

We really meant here 'not always' because we can imagine that some retrieval may work well under some conditions but it may fail under some other conditions. This may be due to the tuning that has been done, for instance during the determination of threshold values for cloud detection.

p21935 line 8 remove exemplarily

P21951 line 1 remove paradigmatic

The aim of this paper is really to show how one can perform an objective validation of cloud property retrievals and not to validate two of them. This is way we would like to keep these words to remind the readers of this.

p21936 line 1 is inherited really the right word?

We replaced 'inherited' with 'adopted': our original word could imply that the same spectral channels are present on both sensors, which is not completely correct.

P21944 line 12 remove exemplarily

Done.

P21952 line 9 remove Anyway; Line 15 replace quantity with statistics

Done.

P21955 discussion on CTT differences is confusing.

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Interactive Comment

This discussion has been modified.

I do not see why effective radius cannot be compared in a similar manner to the optical depth although the conclusions with regards to internal consistency will be similar. The effective radius is as mentioned sensitive to the vertical structure but so other cloud properties to a greater or lesser extent depending on the retrieval technique used, you already mention this with regards to CTT and this is an interesting aspect gained from the comparison.

A more detailed investigation of cloud particle radius has been added to the text. However, we implemented a vertical weighting function for cloud particle effective radii inspired by Platnick (2000). The reason is that the effective radius determined by a satellite retrieval does not correspond to the effective radius at cloud top but to a weighted mean of the effective radii in the “upper cloud layers”. However, our weighting function, as well as those proposed by Platnick (2000), only represent approximations to what happens in real world and are thus not the “truth”.

Nevertheless, this additional investigation is an interesting contribution to the paper. Section 6.5 has been thus rewritten and can be read in the new version of the manuscript.

It would be interesting to see regional maps of differences between real and retrieved effective radius, optical depth and cloud water path as per Figure 7. In case the differences are associated with particular cloud structures, for example, cloud edges, optical depth, snow etc as well as with multi phase clouds (in which case thin cirrus over water cloud is a particularly interesting example).

This is for sure a valuable suggestion that could enable an even better evaluation of the algorithms. However, through the introduction of the APICS cloud water path and the new effective radius evaluation together with a new cloud top temperature figure, the number and size of the figures in the manuscript has already grown large and we would not like to add a new figure with regional maps.

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Interactive Comment

The CMSAF cloud water path is calculated simply using equation 2 surely the APICS cloud water path can be calculated similar and the results compared to be consistent with the rest of the comparison.

We added a new output variable for the APICS retrieval and evaluated both retrievals with respect to cloud water path. To this end, it was necessary to insert a new short subsection for the description of this APICS retrieval quantity and the validation section related to CWP had to be re-written. Now a new figure similar to the one for cloud optical thickness is present and discussed. It contains histograms and scatter plots for both APICS and CMSAF.

Platnick, S.: Vertical photon transport in cloud remote sensing problems, J. Geophys. Res., 105, 22919–22935, 2000.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 21931, 2010.

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Interactive Comment