Atmos. Meas. Tech. Discuss., 6, C2126–C2139, 2013
www.atmos-meas-tech-discuss.net/6/C2126/2013/

Atmospheric Measurement Techniques
Open Access
Discussions

Interactive comment on "A robust threshold-based cloud mask for the HRV channel of MSG SEVIRI" *by* S. Bley and H. Deneke

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Received and published: 19 August 2013

Reply to Anonymous Referee #2

We thank the referee for his/her helpful comments on our manuscript, which helped to improve the present work.

In the following, the comments of the reviewer (RC) are written in italic, the authors answers are signed as AC and the changes we have done in the text to address these points are written in bolt. The line numbers are referring to the latest document, uploaded on 20 March 2013.

RC: Few case studies: Only a few case studies have been performed and Fig.2 clearly

shows that by far not enough meteorological and surface conditions are covered to draw conclusions about the global usefulness of the proposed method. Cloud detection can be tricky above bright (e.g., desert or sunglint) surfaces, in tropical regions with frequent cirrus clouds, or in regions with high aerosol loads. The revised version should include more scenarios or discuss in detail which conclusion can (or can not) be drawn for a disc-wide application of the proposed method.

AC: The method is aimed for cloud detection over Europe. This is our area of interest. We tried to find out a threshold for the solar channels 0.6 μm and 0.8 μm above desert areas, but the clear sky reflectance was to high to calculate a stable threshold. Recently, we found a better and clearer definition of a cloud and the limits of the HRV cloud mask depending on the underlying surface albedo which is described below. Thus no HRV cloud mask is derived over desert.

Page 2834, line 22: Due to our future plans to investigate the diurnal cycle of shallow cumulus convection we are using the Rapid Scan Service (RSS) of METEOSAT over the European region. The presented algorithm is limited in terms of the surface albedo which is discussed in section 3 (Fig. 4).

AC: We agree with the referee's opinion about the disc-wide application of the HRV cloud detection algorithm. To address this point we have added to the manuscript the following sentence:

Page 2843, line 2: For a disc-wide application of the HRV cloud mask more regions with a higher amount of cirrus clouds or high aerosol loads should be considered.

RC: Definition of "cloud": The authors describe a cloud detection scheme but they give no definition for "cloud". At which clouds are they aiming in terms of cloud fractional coverage and cloud optical thickness? E.g., shall a cloud with an optical thickness of 0.05 and a fractional coverage of 0.3 be detected as cloud or cloud free? Obviously, there is a smooth transition from cloud free to cloudy. It shall be discussed that this results almost always in overlapping histograms (Sec.3).

AC: Our main goal is to study the sub-pixel information and shallow convective cloud impacts on cloud sizes and the coverage inside low resolution MPEF cloud mask pixels. We have used a simple model to quantify the accuracy of the HRV algorithm depending on the underlying surface, which is described in the text below. In our case the results obtained a minimum ascertainable cloud optical thickness of 0.88, 2.62, 2.62 and 2.95 over the Atlantic, Alps, Upper Rhine Valley and Spain during the summer period. This result demonstrates the negligence of thin cirrus clouds over land. Even over the Atlantic the optical thickness (0.88) is too high to detect optical thin cirrus clouds reliably. We have added many details and a figure about these limits to the paper:

Page 2830, line 16: The HRV cloud mask is aiming for small-scale convective sub-pixel clouds which are missed by the EUMETSAT cloud mask. The major limit of the HRV cloud mask is the minimum cloud optical thickness (COT) that can be detected. This threshold COT was found to be about 0.8 over ocean and 2 over land and is highly related to the albedo of the underlying surface.

Page 2835, line 24: One of the major problems that causes the overlap is the broadness of the cloudy histogram due to different cloud types with different COTs. This broadness is strongly related to the definition of the cloud the user wants to capture with his cloud mask. In our study it is related to the minimum COT that can be detected reliably by the HRV cloud mask depending on the underlying surface albedo. In order to quantify the accuracy of the cloud detection algorithm and the implication of the underlying surface we calculate the minimum COT using a simple, qualitative model (Eq. 1 by Lacis and Hansen (1974)). The change in the planetary albedo due to the occurrence of clouds is based on a expression by Liou (1980) to take into account multiple scattering between the cloud and the underlying surface. Furthermore no absorption within the cloud is considered in this formula:

Ap=Ac+Rs[(1-Ac)^2/(1-RsAc)] (1)

Thereby is AP the change in the planetary albedo, AC the cloud albedo and RS the

albedo of the underlying surface. The cloud albedo can be approximated by:

Ac=τc/(τc+7.7) (2)

where τc is the cloud optical thickness (Lacis and Hansen, 1974). The statement of equation 1 is illustrated by figure 4 for four different COTs. The curves show the change in planetary albedo due to the occurrence of clouds with a particular COT from 0.2 to 2 over a surface with different clear sky reflectances between 0 and 0.55. δ (planetary albedo - surface albedo) indicates the accuracy of the threshold that is necessary to detect a cloud over a specific ground. The thin blue area (COT=0.2-0.5) illustrates that a high accuracy of the threshold is necessary to detect those optical thin clouds. A smaller δ (planetary albedo - surface albedo) is related to a higher accuracy. This accuracy has to be even higher with a increasing clear sky reflectance of the underlying surface (Fig. 4). For a higher COT the δ (planetary albedo - surface albedo) is obvious higher, although substantial decreasing with a decreasing clear sky reflectance.

Fig. 4: Change in planetary albedo due to the occurence of clouds with a COT of 0.2 (blue), 0.5 (green), 1 (red) and 2 (cyan) as function of the clear sky reflectance of the underlying surface. The δ (y-axis) demonstrates the accuracy that is necessary to detect a cloud over a surface with a specific clear sky reflectance. This simple model is based on formula 1 by Lacis and Hansen, 1974.

Applying Eq. 2 to the average clear sky reflectances (Tab. 2) for our four regions results in a minimum ascertainable COT of 0.88, 2.62, 2.62 and 2.95 over the Atlantic, the Alps, the Upper Rhine Valley and Spain during the summer period. This result demonstrates a negligence of thin cirrus clouds over land solely with the solar channel information. In summary, it can be stated that for a clear sky reflectance higher than 0.25 it is very difficult to detect clouds above such bright surfaces. Over surfaces with about 0.35 clear sky reflectances or even higher no accuate cloud mask can be derived (Fig. 4). Eq. 2, Fig. 4 and Tab. 2 indicate that no cloud with a COT above 1 can be detected reliably by the HRV cloud mask over the regions which are investigated in this study.

RC: Thinning of histograms: The proposed method of thinning the cloud-free histograms is a good idea and certainly helps finding a better discrimination. However, the authors shall discuss that the main problem is the much broader histogram of the cloudy cases (see e.g., Fig.3, Spain). The broadness of the cloudy histograms is strongly related to the definition of clouds the reference cloud mask is able to detect.

AC: As you mentioned the main uncertainty of finding a better discrimination between the clear sky and the cloudy histogram is the high variability of the cloudy histogram. We use the histogram of the HRV references but the separation of the reflectances relies on the MPEF cloud mask. Obviously, we cannot thin the cloudy histogram with this information basis, but we are now using our definition of the cloudy pixel to limit this problematic. See page 2835, line 22 (already mentioned) for details.

Page 2835, line 18: Several reasons can cause the broadness of the clear sky histogram and thus the overlap in the HRV reflectance histograms (Fig. 3).

RC: Cloud free composites: Eq.1 assumes that the low resolution reference cloud mask can reliably detect cloud free scenes. However, the paper aims at a HRV cloud mask because the reference cloud mask is assumed to have deficiencies, e.g., with sub-pixel cloud coverage. Therefor, I would suggest to use the median or 25 percentile to calculate the clear sky reflectance but not the average (which includes also pixels with potential cloud contamination).

AC: We have already changed the method of calculating the clear sky composite by using the median and it results into an improvement of the clear sky map and thus in a higher accuracy of the normalized HRV reflectance field.

Page 2836, line 2-3: Each clear sky composite is calculated as average value of all clear sky reflectances observed during a 16 day period. The clear sky composite is based on the median value rcs of all clear sky reflectances observed during a 16 day

period. The median is chosen as alternative to the average value to neglect sub-pixel small scale clouds which are labeled as clear by the MPEF cloud mask. The average value would include biases such as small scale undetected clouds or cloud shading. The length of this period seems appropriate to ensure relatively constant

RC: Iteration (Fig.5): Please make clear why iteration can help. If pixels are misclassified within the first iteration, the decision of thresholds will base on “wrong” histograms which will subsequently result in non-ideal thresholds. I can understand that the threshold value may converge to a certain value but I’m not convinced that this value is better than the first selected value.

AC: As we are using the median of the monthly clear sky areas, the clear sky composite looks considerably smoother compared with the clear sky composite based on average values. Nevertheless, in our opinion the iteration is important to use the first outcoming relative threshold for generating the high resolution cloud mask and to calculate the clear sky composite based on the HRV cloud mask but not on the low resolution MPEF cloud mask as next step. Additionally, we have changed the stop criterion as you can see in the text changes below:

Page 2837, line 20-25: With the help of this... This clear sky composite consists of HRV reflectances but the assignment between clear sky and cloudy pixels is based on the MPEF cloud mask (see sec. 3.1 for details). In the next iteration we consider the sub-pixel cloud coverage in the MPEF cloud mask to get a clear sky composite which is based on detected clear sky HRV pixels. The normalized HRV reflectance field is improving with a higher accuracy of the clear sky composite (Fig. 6, middle plot on the right panel). The variability of the cloudy histogram is decreased as well, because thin cirrus clouds below the defined minimum COT are not any longer considered by the HRV cloud mask (Fig. 6). The calculation of the quality criteria is based on the MPEF cloud mask and the normalized HRV reflectance field. The corresponding reflectance of the maximum of the MCC is defined as the relative threshold trel . trel of each iteration is then applied to the reflectance field and results to a higher accuracy of the

HRV cloud detection algorithm. The MPEF cloud mask is the constant reference mask for this calculation. The resulting HRV cloud mask of this algorithm is used as new input for the whole procedure. The iteration algorithm will stop, if the deviation of the relative threshold between two iterations is below 0.001.

RC: Re-definition of cloud coverage (Sec. 3.2): What is the justification to re-define especially those pixels as cloudy where the high resolution cloud mask was cloud free in every sub-pixel. The given explanation ("This is done in recognition of the fact...") sounds that the reference cloud mask is more trustworthy and could be used to justify re-definition of every high-resolution pixel.

AC: The HRV cloud mask is gaining to resolve small-scale clouds in sub-pixels of the EUMETSAT cloud mask. Therefore the re-definition of cloud coverage in terms of thin cirrus clouds doesn't manipulate the obtained information. We flagged these redefined pixels in the output for the user to give him the chance to choose the cloud type that will be investigated depending on the application. We added the following sections to the text:

Page 2838, line 4-6: These redefined HRV pixels are flagged in a different way than cloudy pixels which are introduced as cloudy from the HRV cloud detection algorithm (Fig. 6). This is mainly done due to the fact to give the user of the cloud mask the choice of what cloud type will be investigated depending on the application (e.g. clear sky composites). The thin cloud restoral has no impact on small scale clouds which are undetected by the MPEF cloud mask. On future plan is to use the cloud type description of the Support to Nowcasting and Very Short Range Forecasting (NWCSAF) for the investigation of thin cirrus clouds (see sec. 5 for details).

Page 2842, line 10: These redefined pixel blocks are flagged in a different way than the cloudy pixels which are introduced by the HRV cloud mask. The HRV cloud mask is gaining to resolve sub-pixel small-scale clouds which are missed by the MPEF cloud mask. In our example, we found an amount of 10 % of these small-scale cumulus

clouds over the Upper Rhine Valley. This study shows that the HRV channel offers important sub-pixel information for the remaining low resolution channels.

RC: Cloud restoration: It remains unclear how the "cloud restoral" (Sec. 3.2) works. The physical background is not sufficiently discussed (why is 8.7μm so sensitive to thin clouds?). Which thresholds are used? Why using 8.7μm but not 10.8μm even though the surface emissivity at 10.8μm is closer to unity in many cases (e.g. deserts). A larger emissivity would increase contrasts between cold clouds and warm surfaces.

AC: We agree with the referee's comment concerning the 8.7 μm channel and its poor sensitivity to thin clouds. Usually, the brightness temperature difference IR-10.8 μm minus IR-12.0 μm is applied to all surfaces to detect thin cirrus clouds (e.g. Meteo-France, 2012). To explain our message of Fig. 7 (now 8) (in response: Fig. 2) better, we are using the brightness temperature difference IR-10.8 μm minus IR-3.9 μm, because it shows a better occurrence of thin cirrus clouds in our example (Frey et al., 2008). At the moment, the thin cloud restoral is just based on the redefined pixel blocks, but we plan to include the cloud type classification of NWCSAF to consider thin cirrus clouds with the HRV cloud mask in future. The brightness temperature difference is now included in the case example (page 2839, line 1-7 and fig. 8).

RC: Validation: A comparison with the reference cloud mask (Fig.9) is not a prove that the high resolution cloud mask is doing anything meaningful. It just ensures that the high resolution cloud mask is consistent with the low-resolution cloud mask in terms of cloud coverage. Showing some larger scale example-images (in addition to Fig.7 (in response: Fig. 2)) of the HRV channel in comparison with the reference as well as the HRV cloud mask could help to illustrate the value of the HRV-mask. However, strong conclusions about potential improvements due to adding the HRV channel are only possible after a validation with independent observations. Ideally, validation results should be shown within the paper. If this goes beyond the scope of the paper (which I do assume), the authors shall discuss this comment within the conclusions.

AC: We agree that the MPEF cloud mask is not a prove that the HRV cloud mask is working well, especially in terms of small-scale cumuli clouds, because they are not found in the MPEF cloud mask. The difference plot between both cloud masks (Fig. 8 (d)) (in response: Fig. 2) illustrates very good how both cloud masks are gaining different information about the cloud types. While the red colors show the thin cirrus clouds, which are missed by the HRV cloud mask, the blue colors show explicitly small-scale clouds with an optical thickness above our threshold, which cannot be detected by the MPEF cloud mask. This example demonstrates a high amount of small-scale clouds, which are missed by the MPEF cloud mask.

Page 2839, line 1-7: One particular case over the Upper Rhine Valley has been chosen to illustrate the complementary information of the MPEF and the HRV cloud mask (Fig. 8). This case example demonstrates very well how both cloud masks are gaining different information about the cloud types. Misclassified cloud pixels by the HRV cloud mask against detected cloud pixels by the MPEF cloud mask can be explained by optical thin clouds with a COT underneath a critical threshold (Fig. 8, red pixels). Areas which are contaminated with small-scale shallow convection with a optical thickness above our threshold can not be detected by the MPEF cloud mask (Fig. 8, blue pixels).The HRV reflectance misses a high amount of cloudy pixels corresponding to thin cirrus clouds. This example demonstrates that the capabilities of the HRV channel for detecting thin cirrus clouds are limited. When considering the brightness temperature difference BT 10.8 μm - BT 3.9 μm, the thin cirrus clouds can clearly be recognized in the North-Western corner of the region. Usually the brightness temperature difference BT 10.8 μm - BT 12.0 μm is applied over all surfaces to detect thin cirrus clouds (Derrien et al., 2010). To give a better feeling for our statement about figure 8(c), we are using the brightness temperature difference BT 10.8 μm - BT 3.9 μm for that, because it shows a better occurrence of thin cirrus clouds in the North-Western corner in our case example (Frey et al., 2008).

Fig. 8.: (a) SEVIRI HRV reflectance over the Upper Rhine Valley on 5 July 2011, 12:00

UTC and (b) HRV cloud mask (white = cloudy, black = clear sky). (c) Corresponding brightness temperature difference BT 10.8 μm - BT 3.9 μm while (d) difference between MPEF and HRV cloud mask (white = cloudy, black = clear sky, red = HRV clear sky versus MPEF cloudy and blue = HRV cloudy versus MPEF clear sky).

Page 2839, line 14: The most valuable benefit of the HRV cloud mask is the high proportion of small-scale cumulus clouds which are likely missed by the MPEF cloud mask. This effect is indicated by the blue areas in Fig. 8 (d). Concerning the frequency of cloudy HRV pixels which are assigned as clear by the MPEF cloud mask, we found an amount of 10 % over the Upper Rhine Valley. This frequency demonstrates the number of small-scale cumulus clouds missed by the MPEF cloud mask (false positive) divided by the number of all clouds (true positive + false positive).

AC: Indeed, validation with independent observation data is very important, especially to validate the small-scale cloud areas. The MPEF cloud mask is used to show the consistency between both masks in terms of cloud coverage. We are planing to compare the HRV cloud mask with data from the cloud retrieval evaluation workshop (CREW) and from MODIS and CLOUDSAT, but this study is beyond the scope of this paper. We have added the following conclusions to the text:

Page 2843, line 2: To validate the HRV cloud mask, we have used the MPEF cloud mask as reference and pointed out the consistency between both masks, but they have different limitations. The cloud retrieval evaluation workshop (CREW) introduces some studies which will be used as independent validation data for the HRV cloud mask in further research (Roebeling et al., 2012). However, more validation has to be done to quantify the accuracy of the HRV cloud mask and the improvements of using the HRV channel for cloud detection schemes. Ideally, the comparison should include MODIS and CLOUDSAT data as it has already been done with the MPEF cloud mask (Ricciardelli et al., 2008).

Page 2843, line 6: We thank the two anonymous reviewers for improving this paper.

Edited by: A. Kokhanovsky

We have added the following references:

Derrien, M., Gl ÌĄ eau, H. L., and Fernandez, P.: Algorithm theoretical basis document for Cloud products (CMa-PGE01 v3.0, CT-PGE02 v2.0 CTTH-PGE03 v2.1), ftp://ftp.eumetsat.int/pub/MET/out/watts/SAFMeteoF/ SAF-NWC-CDOP-MFL-SCI-ATBD-01 v3.1d.pdf (last access: 5 June 2013), 2010.

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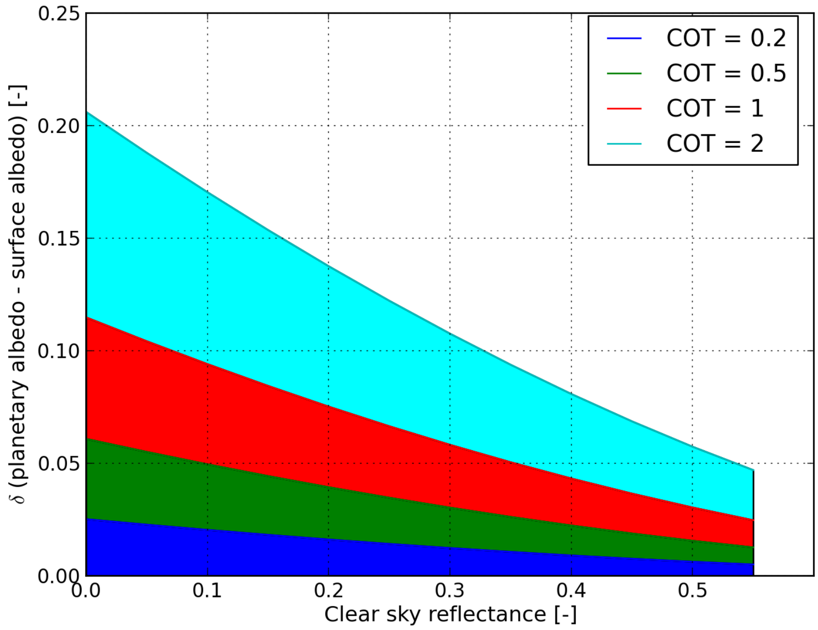

Fig. 1. Change in planetary albedo due to the occurence of clouds with a COT of 0.2 (blue), 0.5 (green), 1 (red) and 2 (cyan) as function of the clear sky reflectance of the underlying surface.

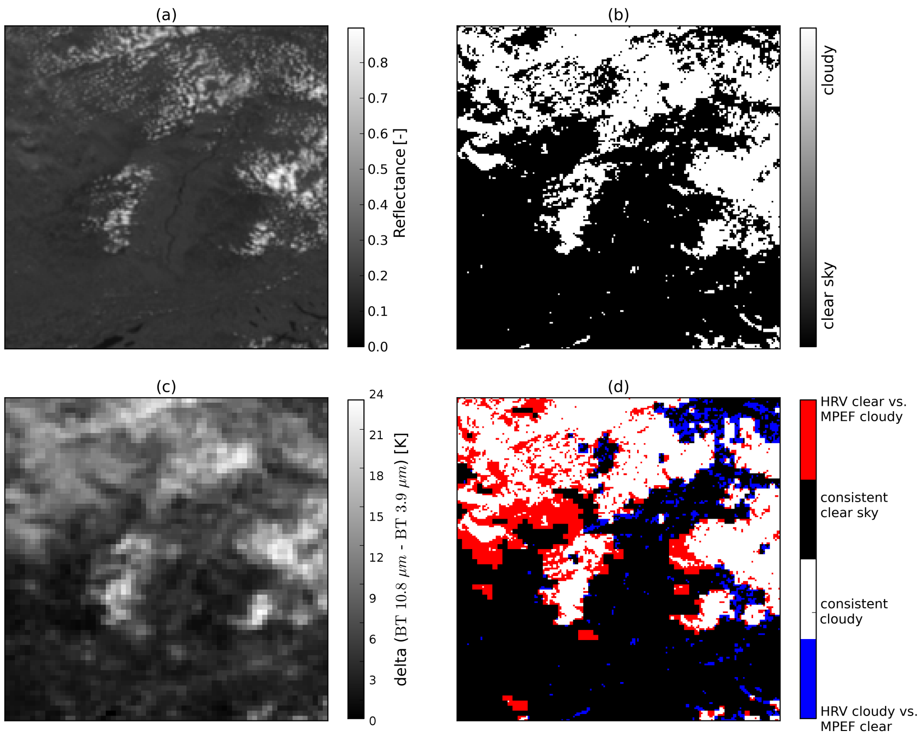

Fig. 2. (a) SEVIRI HRV reflectance over the Upper Rhine Valley on 5 July 2011, 12:00 UTC and (b) HRV cloud mask ,(c) BT 10.8 μm - BT 3.9 μm and (d) difference between MPEF and HRV cloud mask.