Review of "Unfiltering of the EarthCARE Broadband Radiometer (BBR) observations: the BM-RAD product" by Velázquez Blázquez et al.

27 September 2023

General comments

The manuscript prepared by Velázquez Blázquez et al. presents an approach to derive unfiltered shortwave (SW) and longwave (LW) radiances from the EarthCARE Broadband Radiometer (BBR). This is an essential processing step to remove unwanted features in the directly measured radiances that are associated with the instrument spectral response. The approach follows that of existing CERES and GERB broadband radiometer measurements that rely on spectral radiance databases simulated by a radiative transfer model. The errors associated with the unfiltering process are reported to be below 0.5% and 0.1% in the SW and LW, respectively.

The paper will serve as a useful reference within the scientific literature for any future users of the EarthCARE BBR data. Overall the paper is clear and logical, well written, and supported with appropriate figures. I noticed some inconsistencies with the EarthCARE overview paper that is also part of this special issue. There are several other aspects that I think would benefit from further clarifications and explanations, especially regarding the radiative transfer simulations. There is also a new paper for CERES unfiltering that should be considered. After addressing these concerns, as outlined in my comments below, I recommend publication in AMT.

Specific comments

L20: In Wehr et al. 2023, the spectral limits of the BBR SW and TW channels are stated as < 0.25 to 4.0 µm for SW and 0.25 to > 50 µm for TW. Here, the spectral limits are stated as 0.25 to 5 µm for SW and 0.25 to 500 µm for TW. Since both studies are new, I expect the limits have not changed, rather there is an error somewhere. In most other studies, this might seem like a picky comment because there is probably very little energy difference between the two sets of spectral limits. However, since the purpose of this study is spectral unfiltering, the instrument spectral limits seem like a basic characteristic to ensure is correct and consistent.

The spectral limits have not changed and they are indeed well defined by the spectral response of the instrument as shown in Figure 1. As shown, there is not a sharp limit, but the authors agree with the comment from the reviewer and will update the limits to those defined by Wehr et al. 2023 for consistency between the two papers.

L21: Similar to the comment above, the stated spatial resolution of the detector array (700m along track and 600 m across track) is inconsistent with that stated in Wehr et al. 2023 (648 m along track, 800 m across track). Please check that stated numbers are correct and consistent. Do these numbers represent resolution, or sampling distance? It also should be noted that these numbers are relevant to nadir only.

Thanks for pointing this out, the numbers have been verified and updated the detector array size to 648m along and across track. Note that 800 m in the paper of Wehr et al refers to the sampling distance.

L31: I calculate that, at an EarthCARE altitude of 393 km with an orbital period of 92.5 min, the duration between fore and aft 55° views of the surface is 2.79 minutes. If the authors agree, it would be better to update "about 2 minutes" to "about 3 minutes".

Thank you for pointing this out. We had written about 2 minutes because according to the technical documentation of the BBR, EC-AN-SEA-BBR-0020 Integrated energy analysis document: "The temporal separation between a SW and TW capture of a scene with the same telescope is about 60ms; the temporal separation between a nadir and an oblique capture of the same target is about 70s", therefore 140s (2.33 min) but we agree with your comment and calculation and the text have been updated to the 3 min proposed.

L32: Similar to the first two comments above, the stated swath of the detector array (~17km for the nadir view and ~28 km for the two oblique views) is inconsistent with that stated in Wehr et al. 2023 (±10.2 for nadir and ±16 for off-nadir views). Please ensure values are correct and consistent. This is information that data users are likely to pick up on and, once published, incorrect numbers can be easily propagated into other works.

We confirm the swath of the detector array is fine in our article.

Each telescope uses an array of 30 microbolometer detectors, allowing an across-track swath of ~ 17 km for the nadir view and ~28 km for the two oblique views.

L28: There is a reference to another paper that describes the BMA-FLX processor (Velázquez-Blázquez et al., 2023), but as far as I can tell this paper is not available anywhere online. It would have been good for the reviewers to at least see a draft copy of this paper if it is to be cited here.

The BMA-FLX paper is intended to be part of the EarthCARE Special Issue, and at the time of writing it was not finalized. The output of the BM-RAD processor, described in this paper is meant to be used as the main input in the BMA-FLX processor, this is why this paper is cited here.

L59-60: For the CERES instrument flying on the NOAA-20 satellite, there is a dedicated LW channel. So, the statement that LW is calculated by subtraction is not always true.

We completely agree, fixed.

Equation 6: What is the value of "A" for the EarthCARE BBR spectral responses shown in Figure 1?

The value is now A=1.08511561332069467257 (for the nadir view) but as this value is subject to change during the mission, following recomputations of the Spectral Responses due to ageing, we prefer not publish a fix value that can become inaccurate in the future.

L97, L100, and elsewhere: The paper mentions both "unfiltering factors" and "unfiltering coefficients". I think they are referring to the same quantity. Please choose one term and stick to it to avoid confusion.

Agree and corrected in the text.

L101: Does 5,544 correspond to the number of unique scenes, or does this number include multiple simulations of the same scene at different solar zenith angles? Please clarify in the paper.

616 unique scenes and including solar geometry then 5544. Clarified in the text.

L101: Why are there many more simulations for thermal? Since the solar simulations require further stratification (by SZA and RAA) I would expect that having relatively more solar simulations would be beneficial.

You are right, but this is motivated by the fact that for the LW simulations there is a higher variability in atmospheric profiles and in the surface temperatures used in the simulations.

L103-108: The reader needs some evidence that the simulations cover the full range of conditions that could be encountered in reality. For example, are the authors confident that the simulations span all combinations of clouds (optical depth, phase, altitude, effective radius, organization, etc), aerosols (optical depth, composition, size distribution, hygroscopicity, etc.), trace gases (tropical, mid-latitude, and polar atmospheres, etc), and surfaces (spectral variability, BRDF, etc)? Very limited information is given. It is not even mentioned where the atmospheric profiles are coming from for the radiative transfer. Full details are needed.

Indeed, having a database that realistically represent the conditions to be observed by BBR is crucial for this study. The authors consider that the simulations covered a significantly wide range of surface and atmospheric conditions. This is not included in the manuscript because the justification and details of the RT simulations are provided in a published technical note (i.e., Velazquez et al. 2010). Please note that the reference is already cited in the text, and link to the document is now included in data availability and in the references.

Figure 2: I usually like flow charts to vizualise the products but in this case I am left slightly confused. I see that the B-NOM and B-SNG are provided on different grids/domains, but it is not clear to me why two different product flows are needed. If the B-SNG provides measurements at the detector level, then why not just aggregate the B-SNG radiances over the small/standard/full domains? Also, I do not understand why LLW is used in the B-NOM flow chart, but LTW is used in the B-SNG flow chart. Since LLW is not directly measured, a synthetic LLW is presumably also used with the B-NOM processing. In that case, the two flows are identical other than the final step that deals with the spatial domains, so I must be missing something. To rectify these misunderstandings, I suggest the descriptions of the BNOM and B-SNG products are further expanded and contrasted in Section 4.1.

It is a very pertinent comment but you must know that the authors are not involved in the development of the L1 BBR products performed by the industry. The B-NOM and B-SNG products are both in the same grid, the BBR grid, however, in B-NOM they provide SW and LW radiances and in B-SNG they provide SW and TW. As a L2 developers we have chosen to use both B-NOM, with the defined domains, i.e., standard, full and small and, in addition, develop a configurable assessment domain in the JSG from the single pixel BBR measurements from B-SNG for the closure assessment.

Figure 3: A couple of suggestions for improvement:

• It would be clearer if each subplot was labelled individually and referred to in the caption.

• The colours of the data points in the bottom two plots are all red. It would be better to keep the same colour coding as the plots above so that it is easy for the reader to see that the points with the large residuals are the ocean sun glint points.

Good suggestion. Updated accordingly.

• The title of the upper right plot says “VZA=50”. In the text, it says VZA was 55°, which I expect is correct given the BBR VZA. Please fix this error.

Fixed.

L165-167: As well as the spread from water vapour, it seems that the cloudy points in Figure 4 are generally more to the left of the fit line, whereas the clear-sky points are generally more to the right. If Equation 6 was calculated separately for cloudy and clear (and also possibly separately for tropical, mid-latitude, and polar regions), would that help to reduce the RMS error?

Yes, indeed that could probably help to reduce the RMS error but will introduce complexity due to the needed MSI cloud information. This could be tested using night time data for which the SW channel provides the contamination due to the absence of solar radiation.

Section 4.5: Since there are no results presented in this section, it doesn’t seem to fit. I suggest removing Section 4.5 and mentioning the MSI unfiltering in Section 6 when results are shown, or even just in the conclusions.

The results of the MSI-based approach are presented in the Table 2. This is now mentioned in this section.

Figure 6: It looks like the polynomial fit is not doing very well at capturing the upper end of the thermal radiance values (clear sky). The unfiltering factor shows little dependence on the radiance magnitude beyond 90 W/m2/sr, but the fit shows a sharp increase. Does this create larger errors for the clear scenes?

Indeed, the fit doesn’t perform well for very high radiances, but the error in the LW unfiltering remains lower than 0.3% in the worst case. This will be monitored with real data and if needed a more complex fit will be adopted for very warm scenes.

Would it make sense to have a separate LW unfiltering factor fit for cloudy and clear-sky?

Given the good results in the LW unfiltering it doesn’t seem needed to introduce a dependency in the cloud products.

L208-210: The relative error values stated in the text do not seem to match those in the table. For SW, the text says ≈0.5% for clear sky but all of the SW clear-sky values in the table are less than this (0.35,0.36,0.42,0.46). For SW cloudy, the text says ≈0.4% but all values in the table are identically 0.34%. For LW the text says “well below 0.1% for all of the scene types”, but 4 out of the 10 scenes are at or above 0.1% in the table, and the values below this are only just below. Assuming the values in the table are correct, I suggest updating the text to something like: “For the solar radiation, the relative error on the unfiltered radiances is 0.34% for cloudy conditions and increases to 0.35-0.46% for clear sky conditions. For the thermal radiation, the relative error is 0.10 ± 0.02 % for all scene conditions.”

Yes indeed, thanks for your comment. The text was modified as suggested following values updated in the table.

L219-220: The claim that the MSI-based unfiltering does not perform better does not seem to be well supported by the statistics shown in Table 2. The majority of the statistics in Table 2 are improved with the MSI-based approach. This also contradicts a statement in the conclusions where it is claimed that MSI radiances are useful to further reduce the unfiltering error.

Indeed, the MSI-based unfiltering performs better, but not in a significant way, this is why it is written that it does not perform significantly better. We do not see the contradiction with the conclusions.

Table 2: I find it difficult to compare the different example scenes, and also compare to the results in Table 1, because the radiances of the scenes themselves are different. Please include the relative error in % in this table, as was done in Table 1. This will help the comparisons greatly, and is particularly important given that the errors stated in the conclusions and abstract are in %.

We agree, however, some specificities of the simulated data prevent us to make a full quantitative comparison between the scenes. For instance, solar radiances over ocean are too dark with simulated radiances as low as 15 W m -2 sr-1 in clear conditions for the nadir view. Also, the simulated radiances are limited in terms of wavelength range (0.2-4µm for the SW and 4-400 µm), which introduce some artificial error in the estimation of the inter-channel contamination. Furthermore, Halifax and Baja scene have a systematically high solar zenith angle which makes the relative error important on those simulations (~1% for the SW). Still we think it is important to provide the Table 2 as the RMS errors show that the unfiltering performs well within the mission requirements or 2.5 Wm-2sr-1 for SW and 1.5 Wm-2sr-1 for LW.

Data availability: The doi given to the EarthCARE demonstration products does not seem to include the radiative transfer database used for unfiltering. Per AMT policy, I think the libRadtran simulation database (radiative transfer input profiles and output spectra) should be made available since this is essential underlying data required for this study.

The link to the radiative transfer database and description has been added to the data availability.

A paper describing the updated unfiltering algorithm for the CERES instruments is now in the public domain: https://doi.org/10.5194/egusphere-2023-1670. The authors did not refer to this paper, which is understandable since it has only been available for about 2 months. However, given the relevance to the EarthCARE unfiltering algorithms, I think the authors need to consider this paper in their revision. It includes several important updates compared to the earlier CERES unfiltering algorithm (already cited). For example, they implemented the Cox-Munk BRDF model over ocean, MODIS retrieved BRDFs over land, considered seasonal variations, increased angular resolution, and used MODTRAN version 5 that has several advantages (see paper for details) to build their simulation database. I recommend adding a paragraph or two comparing and contrasting the EarthCARE BBR approach with this new CERES method. Future users of the EarthCARE BBR data will likely find such a comparison very useful.

We have had a close look at this interesting paper that provides several improvements with respect to the current CERES unfiltering process and we are looking forward to the implementation of this work in the CERES processing. We propose to add the following sentence: It is worth to mention that a CERES team is currently reviewing its unfiltering process and a several improvements are proposed in Liang et al. (2023) for possible inclusion in Edition 5.

Technical corrections L42: “data bases” -> “databases”

Corrected

L45: remove “the“

Removed