Review of "Retrieval of top-of-atmosphere fluxes from combined EarthCARE LiDAR, imager and broadband radiometer observations: the BMA-FLX product" by Velázquez Blázquez et al.

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General comments

This paper describes the BMA-FLX product that is used to retrieve radiative fluxes from the broadband radiometer (BBR) on the EarthCARE satellite mission. The product retrieves a SW and LW radiative flux for each of the three view angles of the BBR and then averages them to provide a best estimate of the fluxes. This best estimate is compared to the calculated fluxes for some example scenes, with an overall goal of obtaining radiative closure within 10 W/m2.

It is important to document the details of the BMA-FLX product so that future users of EarthCARE data can understand how the data is generated. The paper is thorough and mostly well written. However, I believe some substantial additional explanations are needed. I am also left concerned as to whether the performance of the product is sufficient to meet the EarthCARE goals based on the analysis presented. I outline these concerns in my specific comments below. After addressing these comments, I believe the study could be appropriate for publication in AMT.

Specific comments

Terminology: There is some debate in the ERB community as to whether "flux" is the correct term for the quantity considered in this paper that has units of W/m2. While "flux" is widely used, some argue that it is fundamentally wrong and that "flux density" is correct. Another alternative, "irradiance", is becoming more widely used because it is less ambiguous. I do not insist that the authors rename their product, but I do think that it is worth mentioning in the introduction that several different terms exist in the literature. These terms are often used interchangeably within the scientific community with some debate, but they all refer to the same quantity.

L57: It would be good to add a sentence or two to justify why the EarthCARE radiative closure goal is 10 W/m2, otherwise this seems rather arbitrary. What is the physical origin of this requirement? What does 10 W/m2 achieve that eg. 15 W/m2 does not? What limits a more ambitious goal of eg. 5 W/m2? Also, is this requirement defined based on the RMSE, which seems to be a focus of the results later in the paper and in the conclusions?

L66-69: Following from the previous comment, a more general question is why is the EarthCARE radiative closure goal defined in terms of radiative flux? As noted in the paper, the conversion from radiance to flux inevitably introduces a substantial uncertainty. Unless I am missing something, it seems entirely possible to use a radiative transfer model to calculate *radiances* at the three view angles of the BBR using the scene properties derived from the other EarthCARE instruments, and compare those radiances to the directly observed radiances from the BBR. While flux is usually the quantity of most interest for atmospheric energetics, I think for the purpose of radiative closure, performing the closure in radiance-space provides a much tighter constraint and avoids the introduction of ADM uncertainty. Some mention of the justification to do radiative closure with fluxes in the introduction of this paper would be helpful to further motivate the BMA-FLX product.

L77-81: It is understandable that the algorithm needs to meet contingency requirements of the mission, but at the same time it does seem like a missed opportunity that the flux retrieval does not take advantage of the multi-angle views of BBR directly to constrain the radiance to flux conversion. Could this be mentioned as a potential future research activity?

L81: I think there is an error here. The outgoing flux should NOT depend on the viewing geometry. Do the authors mean the solar geometry?

L103-105: These two sentences do not make sense to me. I think I know what the authors mean, but I suggest revising the wording.

L108: I do not understand why the scene type is defined separately for forward and backward scattering directions. Please clarify in the paper why this is needed.

L134-135: Using an AOD climatology might be an important source of uncertainty here. This is because the large spatio-temporal variability of aerosol means that the actual AOD for any given CERES measurement can be quite different from the climatology and therefore create a different anisotropy. Do the authors think this is important and have they considered using an aerosol retrieval product from MODIS to match instantaneously with the CERES measurements?

L143: I like the idea of using the MSI radiances directly as an input to the ANN because they contain information about cloud properties without introducing uncertainty from an intermediate cloud property retrieval. That said, I am a bit surprised by the choice of bands: 0.67, 0.865, 10.8, and 12.0 µm. The most relevant cloud properties for anisotropy are cloud fraction, optical depth, phase, and effective radius. Are the authors confident that information about these cloud properties is sufficiently represented by the 4 MSI bands that are chosen? Some supporting references would help.

L153-159: If I understand correctly, different datasets are used to determine the surface type for the scene identification (GLCC and X-MET) than what is used in the CERES training data (IGBP and NSIDC). Why not use the same datasets to minimize errors associated with different dataset definitions?

L232: Some more information about the ADM uncertainty is needed. Where does this uncertainty estimate come from?

Fig. 3: The cloud optical depth would be easier to visualise with a much more limited colour bar, or maybe a non-linear colour bar. Otherwise, the vast majority of the data points are in a very limited range and it is difficult to see the variability.

Figure 4: It is not very useful to plot the land cover codes and refer the reader elsewhere for the definition of the codes. Can the codes be replaced by the definitions directly in the plot? Or put in a nearby table?

Figure 4 and 5: They are referenced in reverse order in the text. I suggest switching the order.

392-393: Are the significantly worse results in Figure 6 concerning? I believe this is the most relevant uncertainty estimate because when the algorithm is applied to actual EarthCARE observations, BMA-FLX will need to use the M-CLD retrieved cloud properties, correct?

L423, Table 1, and Table 2: There are several instances for both the assessment domain and the standard resolution where the combined RMSE in the SW exceeds 10 W/m2. If the RMSE is indeed the

relevant quantity (see earlier question), I interpret this to mean that the radiative closure goal will regularly be exceeded, which then leads me to question whether BMA-FLX is sufficient to achieve the closure goal of the mission. I expect that this is not the impression that the authors would like to leave the reader. I think the conclusions need some additional discussion to relate these results back to the mission requirements and what this means for the adequacy of the BMA-FLX product.