Response to Referee #2

Thank you very much for your time and effort taken to review our manuscript submitted to AMT. We really appreciate the reviewers' constructive comments that are very useful to greatly improve the manuscript. We have revised the manuscript based on your comments as explained below. Please see below for our point-by-point responses to your comments, where the original comments are shown in *italics* and our responses are shown in normal text just below your corresponding comments.

Specific Comments:

Line 85: It is not clear how the target accuracy is set as 10 W m-2. Certainly, the SW biases shown in this study are higher than this target number. Is this target number based on existing products? If so, please include the relevant references.

A. We have added a quote of (ESA, 2001) that demonstrates the scientific goals of the EarthCARE mission.

Line 113: Do these two sets of satellite products (CloudSat/CALIPSO/MODIS) and (CPR/ATLID/MSI) provide consistent cloud and aerosol parameters? The algorithm developed in this study was tested using the A-train products. Therefore, it is important whether those two sets of products have comparable parameters.

A. Yes, (CloudSat/CALIPSO/MODIS) and (CPR/ATLID/MSI) provide consistent cloud and aerosol parameters. The following text was added.

'CloudSat/CALIPSO/MODIS and CPR/ATLID/MSI will provide consistent cloud and aerosol parameters.'

Line 123-124: It is not clear how the attenuated backscatter coefficient and depolarization ratio were used to derive the vertical profiles of three aerosol types. Please include the relevant references or description of it. In addition, what are specifically vertical profiles of aerosol types? Are these aerosol extinction profiles, single scattering albedo, and asymmetry parameters?

A. The fine-mode spherical particle (WS), coarse-mode spherical particle (SS), and non-spherical particle (DS) are classified by using the ratio of attenuated backscatter coefficient at 532 nm and 1064 nm and depolarization ratio of the CALIPSO measurements. The ratio of attenuated backscatter coefficient at 532 nm and 1064 nm depends on the aerosol particle size and the depolarization ratio depends on the aerosol particle shape. The size and optical properties of these three aerosol components are listed in Nishizawa et al. (2011).

We have added the following sentences to the text in the revised manuscript.

'The extinction coefficient of fine-mode spherical particle (WS), coarse-mode spherical particle (SS), and non-spherical particle (DS) are derived from the CALIPSO observation. The vertical profiles of extinction coefficient at 532 nm for WS, DS, and SS are used in the radiative transfer calculations. The particle size and optical properties of these three aerosol components are listed in Nishizawa et al. (2011).'

Nishizawa, T., Sugimoto, N., Matsui, I, Shimizu, A., and Okamoto, H.: Algorithms to retrieve optical properties of three component aerosols from two-wavelength backscatter and one-wavelength polarization lidar measurements considering nonsphericity of dust, J. Quant. Spectrosc. Radiat. Transfer., 112, 254-267, 2011.

How was the MODIS COT used for constraining cloud radiative properties? Please provide detailed information.

A. When there is a discrepancy between the COT derived from the vertical information of CloudSat/CALIPSO and the COT from MODIS, the vertical extinction coefficient is adjusted to align with the COT from MODIS. We have included this information as follows in the revised manuscript.

'When there is a discrepancy between the COT derived from the vertical information of CloudSat/CALIPSO and the COT from MODIS, the vertical extinction coefficient is adjusted to align with the COT from MODIS.'

Line 138: Is the GEOS-4,5 different from MERRA-1 or MERRA-2?

A. The meteorological field variables from GEOS-5, which were stored in CCCM product (Kato et al. 2011), are used.

Line 140: Please provide the information about the surface emissivity assumptions used for RT calculations. Was the skin temperature from GEOS?

A. The surface emissivity varies with the type of ground surface (sea, land, or sea ice). Yes, the skin temperature from GEOS data was used. We have included this information in the revised manuscript.

'The meteorological field variables (pressure, temperature, and specific humidity, and skin temperature) from NASA's Goddard Earth Observing System (GEOS-5) Data Assimilation System (Bloom et al., 2005; Rienecker et al., 2008) are used in the radiative transfer calculations.'

Line 143: For the area of 5 km, is it assumed as completely clear and cloudy? I think the homogenous assumption would be okay for most cases, but for partly cloudy cases, this homogeneous assumption can cause positive SW biases, as discussed in earlier 3D cloud studies.

A. When verifying, the all-sky conditions include instances where the 5-km area is a mixture of clear and cloudy conditions, while the cloudy case extracts only instances where the entire 5-km area is covered by clouds. The TOA flux is compared to CERES with a footprint of 20 km, so in cloudy conditions all 20 km are covered by clouds. We have included this information in the revised text as follows.

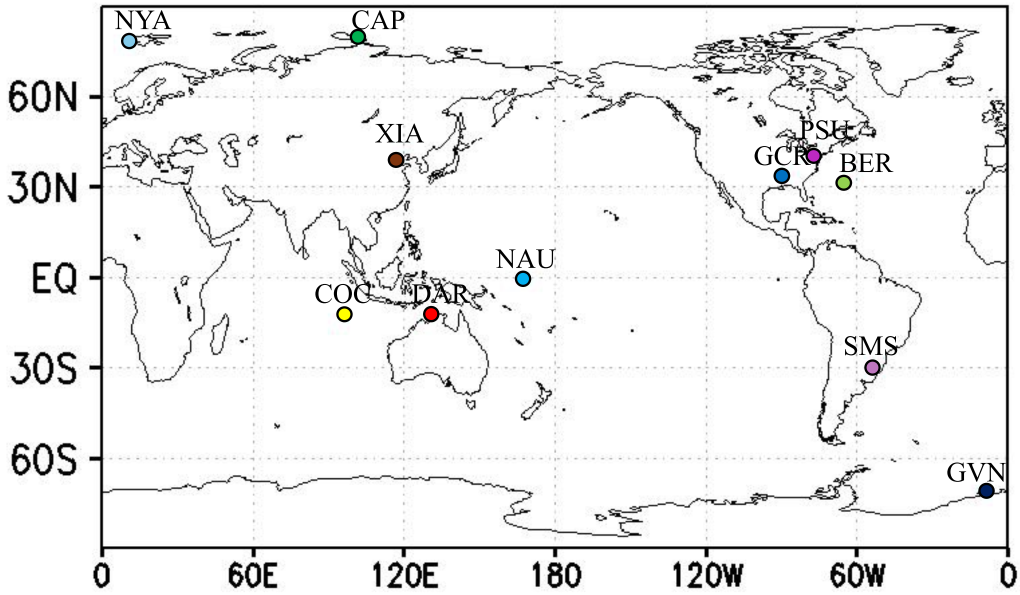
'When verifying, the all-sky conditions include instances where the 20 km area was a mixture of clear and cloudy conditions, while the cloudy conditions extract only instances where the entire 20 km area was covered by clouds'

Line 154: Which CERES product was used for the observed TOA fluxes?

A. We used the CERES data that is included within the CCCM (CALIPSO-CloudSat-CERES-MODIS) product. We have added the specific product name, CER_ES8_Aqua-FM3_Edition3, in the revised manuscript to clarify the source of the CERES data used in our study.

Line 154 or later in the result section: The surface radiation significantly varies by region as the authors noted. Therefore, it would be helpful where the ground sites are located.

A. A location map of BSRN observation sites (please see the figure below) was created and added as Figure 6e in the revised manuscript.



Line 155: The results in this study were compared with two versions (R04 and R05) of the 2B-FLXHR-Lidar product. Therefore, it would be necessary to provide a brief description of how these versions differ.

A. In 2B-FLXHR-Lidar R05, the input values for clouds and aerosols have been updated to use the R05 versions of the CloudSat products. These updates include improvements in cloud coverage, cloud physical properties, including updated cloud phase information, and the use of

CALIPSO V4 products for aerosols, which update the global distribution of aerosol types and aerosol optical depth (AOD). These enhancements allow for more accurate flux calculations.

We have added these descriptions to the text in the revised manuscript.

Line 157: Those four months were used for validations at TOA and surface? I was wondering why the sampling number is so small for the ground comparison.

A. Those four months were used for TOA and surface validation. The number of surface samples is very small because the observations used for comparison are limited to within ±0.1 degrees of the A-Train orbit for matchup of data, and also due to the limited target period.

Eq. (3): I don't see any comparison of heating rate profiles, besides the example shown in Fig. 1d.

A. Since the heating rate calculation is derived from the radiative flux, this study focuses on comparing the radiant flux. However, future studies will be needed to include the comparisons of heating rate to and to discuss any differences of our product from others.

Line 183: I believe that the CERES CCCM product also provides flux at 20 km resolution. Have the authors compared the results with what this product provides?

A. This study has not done the comparisons with the CCCM product. We would like to extend the comparisons with other products to include CCCM as well in our future studies.

Line 216: Does it mean that each point in the scatter plots was from monthly 5-degree grided points for four months in 2007?

A. Yes, that's correct. Each point in the scatter plots represents data from monthly 5 ° gridded points over four months in 2007. This statement has been added to the text as follows: "Each point in the scatter plots represents data from monthly 5 ° gridded points over four months in 2007."

Line 425: Figure 3 is the same as "Figs 2a and 2d" but separated by cloud types. I guess that the 2B-FLXHR-Lidar fluxes are not included in Fig. 3. If so, the scatter plots shown in Fig. 3a–3e are subsets of Fig. 2a? Likewise, the scatter plots shown in Figs. 3f–j are subsets of Fig. 2d? Please clarify it in the figure caption. Why some outliers shown in Fig. 3g are not shown in Fig. 2d?

A. Figure 3 is a subset of Figure 2a and 2d, showing only the cloudy cases. Since the cloud phase classification is based on MODIS observations, the comparison is limited to day-time cases only. Therefore, the outliers in Figure 3g disappear when night-time and clear-sky cases are included in the averaging process. We have revised the figure caption to incorporate these points.

Line 244-246: If the consistent ice scattering model (i.e., Voronoi-type) was used for cloud retrievals and RT calculations, this would not be a problem. Please include more discussion about it.

A. The Voronoi-type model is consistent between the retrievals and the RT calculations, but there might be other issues occurring during the retrievals or radiative transfer calculations. Our argument here intends to mean that the COT retrieval for ice clouds might be a candidate source of error, particularly given that the Voronoi assumption is common between our RT simulation and the MODIS retrieval. This is something that will need to be further investigated in future work. To clarify the point above, we have revised the text of this part as follows: "The positive SW bias could have been caused by a possible overestimation of the ice cloud optical thickness obtained from MODIS, particularly given that the assumption of Voronoi-type ice particles is common among the radiative transfer simulation and the MODIS retrieval of ice cloud optical thickness."

Line 249: Was the sensitivity study using NASA MAC06S0 performed using a consistent ice scattering model between cloud retrievals and RT calculations?

A. In NASA's sensitivity experiments, ice scattering is not consistent. However, COT tends to be lower in NASA's products compared to JAXA's products. This difference in COT is interpreted to contribute to the reduction of the positive bias.

Line 253: "LW bias by providing more accurate cloud detection through improved measurement instrumentation" It is not clear what this statement specifically refers to. Please provide relevant references or expand the discussion.

A. We appreciate the opportunity to clarify this statement. The reference to "providing more accurate cloud detection through improved measurement instrumentation" specifically refers to advancements in satellite-based remote sensing technologies, such as those utilized by EarthCARE, which offer enhanced cloud detection capabilities compared to earlier instruments. These advancements include higher resolution measurements and more sensitive detection of cloud properties, particularly those significant in the LW spectrum, which would contribute to reducing biases in LW radiative flux calculations. We have expanded the discussion to include relevant references and provide a more detailed explanation as follows: "Such advancements are expected particularly from technologies employed by the EarthCARE mission, which utilize improved instrumentation with higher spatial and spectral resolution, as well as enhanced sensitivity in detecting cloud properties, especially those significant in the LW spectrum. For example, EarthCARE's advanced radar and lidar systems allow for more precise cloud profiling, which leads to more accurate detection and characterization of cloud cover and thickness. This improved accuracy in cloud detection helps reduce biases in LW radiative flux calculations by ensuring that cloud-related inputs to radiative transfer models are more representative of actual atmospheric conditions."

Line 299: As mentioned earlier, it would be helpful if the authors could provide the location of the BSRN sites on a map.

A. A map of BSRN observation sites was created and added as Figure 8e in the revised manuscript.

Line 299: What is "a minor bias"?

A. By "a minor bias," we are referring to a small negative bias observed in the data.