Atmospheric Measurement Techniques Discussions

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Comment on amt-2021-392

Anonymous Referee #2

Referee comment on "The surface longwave cloud radiative effect derived from space lidar observations" by Assia Arouf et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2021-392-RC2, 2022

General Comments

The paper introduces a parameterization for inferring longwave (LW) cloud radiative effect (CRE) at the surface from 5 cloud properties derived from the CALIPSO satellite. Retrievals are compared with other data products that use active sensors, surface measurements and a product that uses passive sensors.

Concerns:

Methodology:

- Today's modern radiative transfer codes are very fast and quite accurate in the LW. In fact, they are often used to calculate LW CREs instantaneously in global products. Additionally, it is now common for satellite retrievals of surface flux to account for sub-daily variations in temperature/humidity and capture regional variations (e.g., east vs west tropical Pacific), climate events (e.g., ENSO) and extreme changes over polar regions. In this paper, LW surface CREs are determined using a simple parameterization approach that relates pre-calculated CRE values against only 5 CALIPSO cloud properties. Temperature/humidity profiles are prescribed using climatological means from ERA-Interim. The authors do not explain why such a simple approach is used when they could have used advanced radiative transfer codes to produce a more accurate product and account for temperature/humidity variations.

Uncertainties:

- Uncertainties associated with the use of climatological monthly temperature/humidity profiles every 2 deg in latitude (with no dependence on longitude) are not adequately quantified. Only one very limited example (Fig. 5) is shown on the impact of humidity variability. The authors should provide a more comprehensive assessment. For example, how does their parameterization approach handle temperature/humidity variations over the maritime continent and subsidence regions in the same 2-deg latitude zone? In polar regions with a strong temperature inversion? Under different ENSO conditions (El Nino vs La Nina)? The use of climatological profiles likely leads to systematic errors that vary from region-to-region. These should be highlighted and discussed in the revised version of the paper.

Comparisons with other datasets:

- The active sensors completely miss significant portions of the Earth since they are restricted to the satellite ground-track of sun-synchronous satellites with 16-day repeat cycles. As a result, sampling issues are quite challenging. The paper does not explain how the 2x2 gridded product is created, how it is compared with other products or how the comparisons with surface measurements are made. These details matter and should be explained.
- The comparisons of CALIPSO-GOCCP with other data products summarized in Sections 6.1 and 6.2 are quite meaningful, as the authors collocated the data amongst CALIPSO-GOCCP, CERES-CCCM and 2BFLX, thereby providing consistent sampling. One can draw clear conclusions about the differences shown, separate from sampling uncertainties. These comparisons should be retained and even expanded upon.
- The other comparisons are very difficult to interpret. The gridded monthly CERES EBAF surface fluxes are determined using full-swath CERES and MODIS data supplemented by geostationary imager measurements, thereby providing hourly global coverage. In contrast, CALIPSO-GOCCP only samples at the time of the satellite overpass and only over the satellite ground-track, resulting in far less spatial and temporal coverage. Because of the differences in sampling, it is not obvious if these should agree even if both products were perfect. This makes it difficult to explain any differences between these products. As a result, the comparisons with CERES-EBAF should be removed from the paper as they add little value.
- Comparisons with ground measurements:
- The methodology used to compare CALIPSO-GOCCP with ground measurements are not adequately explained. For example, are the surface measurements averaged in time or are instantaneous values used? How far from the ground site are the CALIPSO measurements? Are only coincident CALIPSO and ground site data used or are monthly means determined independently? If CALIPSO LW CREs were perfect, how closely should the LW CREs be to the ground-based measurements, given the sampling differences? Answering this last question will require some extra work. For example, one could envision using synthetic data with complete coverage and then compare that the CALIPSO sampling. Without such analyses, it is difficult to interpret the results.

Readability:

- The paper could use substantial restructuring, shortening and editing by the co-authors whose first language is English. Some suggestions are below but there are many more.

Specific Comments:

Line 17: delete "long-term". Thirteen years is short from a climate perspective.

Lines 18-20: "The global surface LW CRE is estimated using long-term observations from space-based radiometers (2000–2021) but has some bias over continents and icy surfaces."

This isn't entirely true from results shown in the paper. Over continents, diurnal cycles are quite pronounced, yet the CALIPSO-GOCCP method introduced in this paper does not resolve them. The impact of not sampling the maxima/minima in diurnal cycle heating on surface LW CRE is not discussed. The noisy surface LW CREs for CALIPSO-GOCCP in Fig. 17d is worrisome (by comparison, CERES-EBAF variations are smooth). Thus, to state categorically that CERES-EBAF is biased without pointing the obvious issues CALIPSO-GOCCP (Fig. 17d) is misleading. I suggest deleting this sentence.

Lines 20-21: "To develop a more reliable long time series of surface LW CRE over continental and icy surfaces".

The statement is not supported by results in the paper. As noted in the last comment, CALIPSO-GOCCP is very noisy over land and does not resolve the diurnal cycle. Also, thirteen years is not a long time series.

Lines 22-25: "We show from 1D atmospheric column radiative transfer calculations, that surface LW CRE linearly decreases with increasing cloud altitude. These computations allow us to establish simple relationships between surface LW CRE, and five cloud properties that are well observed by the CALIPSO space-based lidar: opaque cloud cover and altitude, and thin cloud cover, altitude, and emissivity."

The authors are really using a simple parameterization to infer surface LW CRE. They should change: "These computations allow us to establish simple relationships…" to "These computations are used to develop a simple parameterization for estimating surface LW CRE from five cloud properties observed by the CALIPSO space-based lidar: etc."

Lines 25-26: “We use these relationships to retrieve the surface LW CRE at global scale over the 2008–2020 time period (27 Wm-2).”

Is this sentence necessary? The one number doesn’t say much on its own. Consider deleting this sentence.

Lines 40-41: “defined as the change in the SW and LW radiation reaching the surface induced by the presence of clouds”.

How is clear-sky defined? For example, by recalculating flux after removing clouds or by determining flux from cloud-free regions?

Lines 59-65: As noted earlier, thirteen years is a relatively short record. While it may be tempting to think this record can be seamlessly continued with EarthCARE, as noted in the conclusions on line 617, there are some major hurdles to overcome: (i) EarthCARE will fly in a different orbit than CALIPSO (1400 h with 25-day repeat cycle), so that its groundtrack will not sample the same locations as CALIPSO; (ii) the EarthCARE lidar instrument characteristics (355-nm HSRL lidar) are very different from CALIPSO, so that their retrievals likely won’t be consistent; (iii) it is unlikely CALIPSO and EarthCARE will overlap in time due to delays with the EarthCARE launch (currently March 2023). These issues will make it exceedingly difficult to construct a robust long-term CALIPSO-EarthCARE time series of surface LW CRE that is free of a discontinuity.

The authors should consider simply stating that the thirteen-year record can be useful for climate model evaluation and comparing against other satellite products without claiming this is a “long-term” record etc.

Line 98: Please define what a “gridbox” is. I believe it’s a 2x2 deg latitude-longitude region?

Line 120: “Figure 2 illustrates etc.”

It appears there was a lot of smoothing and/or data gap filling used to produce Fig. 2. It would be far more informative to show these maps on a 2x2 deg latitude-longitude grid without any smoothing/gap filling to see how limited lidar sampling impacts the 13-year regional means.

Sections 2.2.1 and 2.2.2: The descriptions of the CERES EBAF and 2BFLX products is inadequate. For example, one gets the impression that surface fluxes in CERES EBAF are inferred directly from CERES measurements, when in fact the main cloud property inputs to the radiative transfer model calculations are from MODIS and geostationary imagers, atmospheric reanalysis, etc. Two authors on this paper are responsible for those products. Surely, they can provide a better summary of their products?

Line 151-152: "This product is sensitive to retrieval errors and biases introduced by the limited spatial and temporal characteristics of CloudSat and CALIPSO."

This is also true of the CALIPSO-GOCCP product introduced in this paper, but appears to be significantly downplayed for some unknown reason.

Line 160: "we selected three sites located in different regions".

Why only three sites? There are easily an order-of-magnitude more sites available (e.g., BSRN, SURFRAD, etc.). This is particularly surprising given the poor sampling obtained from CALIPSO.

Sampling (or lack thereof) over these three sites is not adequately discussed. It appears from lines 179-180 that ground measurements at CALIPSO satellite overpass times are extracted and then averaged over each month. If there are days in which CALIPSO has no sampling over the site, are ground measurements from those days also excluded in the monthly means? How many CALIPSO samples per month are there over a typical site? How is the spatial matching of CALIPSO and ground measurements determined? Are you using 2x2 deg latitude-longitude boxes centered on the ground site to match them (meaning there could be a >100-km separation between clouds from CALIPSO and the surface site)? Are the surface measurements averaged in time or are only instantaneous values used?

Similarly, when comparing surface measurements with CERES, are you including surface measurements over all 24-h of the day, since that is what CERES does? Are you ensuring the same days are sampled by CERES and the surface site in determining monthly mean differences? Is the CERES also aggregated over 2x2 deg regions like CALIPSO? There are so many unanswered questions…

Lines 166-167: "Here, the clear sky flux is computed using a radiative transfer algorithm with measurements of temperature and humidity profiles".

How is all-sky determined? What instruments are used? What is the uncertainty in LW CRE from the ground site?

Lines 171: “Here, the clear sky flux is computed from measurements of near surface temperature and vertical distribution of humidity”.

Only near-surface temperatures? Why not use temperature/humidity profiles throughout the troposphere? Are they not available? If not, what uncertainty on LW CRE does this introduce?

Lines 190-195: It appears temperature and humidity profiles in the parameterization are specified using climatology for every month of the year and at every 2 deg in latitude (see also Fig 6). Surprisingly, the parameterization does not appear to account for longitudinal variations in temperature and humidity, which can be very large (e.g., west tropical vs east tropical Pacific). In addition, year-to-year variability due to ENSO can result in very large variability in temperature and humidity. In polar regions, temperature inversions are frequent and moisture advection from lower latitudes can also cause large variations in temperature and humidity.

The paper notes, “small variability of water vapor does not affect CRE very much compared to the fluxes themselves as the equivalent clear sky contribution is removed from CRE.” While this may be true for small variations, what about the actual variations that occur in nature? As noted above, the temperature and humidity variations can be quite pronounced.

To address the question of how humidity variations impact the parameterization, the reader is sent to entirely different sections of the paper (Section 4.1-4.3, yet only Section 4.2 is relevant). Only one simple example is provided (Fig. 5), in which we’re told figure 5a uses a “standard humidity profile” and figure 5b uses an “enhanced humidity profile”, which are shown in Fig. A4. There is no explanation of where these profiles come from nor how representative they are of day-to-day or region-to-region variability in temperature and humidity. Nevertheless, they show a LW CRE difference of up to 7.7 Wm-2 just from a 10% change in humidity. This example does not address temperature profile differences since the standard and enhanced profiles are quite similar, as shown in Fig. A4b. This one example showing the sensitivity in CRE to temperature and humidity profile variations is insufficient.

Lines 197-209: What is the main point that’s being made here? Is it simply that space based lidars overestimate cloud base height and therefore underestimate surface LW CRE for opaque clouds? If so, please state that up front. As it stands, it is unclear.

Line 209: “To retrieve the surface LW CRE…”

It may be helpful to insert “from satellite” after “LW CRE” since the previous paragraph discussed surface lidar.

Section 3.2: Is this section necessary? It’s obvious by the way CRE is calculated that the same surface temperature is used for clear and cloudy skies. That’s all that can be done from satellite and is consistent with how GCMs calculate CRE. It is well known that CRE does not account for surface temperature changes due to the presence of the cloud. Consider removing this section altogether or shortening it.

Line 250: “we establish the relationship between”

Consider revising to “we derive a parameterization between”

Line 253: So, the atmosphere only goes to 40 km? Please clarify.

Lines 273-275: “We tested both Z_FA and Z_Topaque for estimating etc.”

Couldn’t the choice of whether to use Z_FA or Z_Topaque be better determined from radiative transfer model simulations instead of comparisons with other data products/ground measurements? Using other data sources introduces all kinds of additional issues, making the decision more complicated.

Line 342: Section 5.2 Gridded Product

How is the gridded product determined? CALIPSO sampling is restricted to the satellite ground-track. Are the CALIPSO lidar measurements simply gridded and averaged into 2x2 deg latitude-longitude regions or is a different approach used? Is there a minimum number of CALISPO samples required in each 2x2 gridbox? Are monthly regional averages determined from daily means or are all CALIPSO samples in a month summed and divided by the total?

Line 343: Figure 9: Was any smoothing/gap filling used to create this figure? It would be far more informative to show the actual map with no smoothing/gap filling and for 2x2 deg latitude-longitude resolution.

Line 372: Fig. B1 (bottom) compares CERES-EBAF against CALIPSO-GOCCP whereas

Figure 10 compares CERES-CCCM. Is the label incorrect in Fig. B1?

Line 378: I believe the CCCM approach uses full-resolution CALIPSO/CloudSat data along the ground-track over 20 km CERES footprints, so it should detect anything CALIPSO-GOCCP detects. There should be no "missing" clouds. Please clarify.

Section 6.1: What conclusions can one make based upon these comparisons? It's not enough to just show the differences. Can one say that by not including CloudSat, CALIPSO-GOCCP LW CREs are biased low by 15-20 Wm-2 compared to CCCM and 2BFLX in regions of deep convection and stratocumulus?

Line 386: "CERES-CCCM (20 km footprint)". As noted above, CCCM uses full-resolution CALIPSO and CloudSat data but reports the results over 20-km CERES footprints. Please revise "20 km footprint" as it makes it sound like the full CALIPSO-CloudSat data are not used in CCCM, which is not the case.

Line 433: "In global annual mean, CALIPSO–GOCCP is equal compared to CERES–EBAF and slightly higher compared to 2BFLX"

How do we know the consistency between CALIPSO-GOCCP and CERES-EBAF is for the right reasons given how different their time-space sampling is? This agreement could be for all the wrong reasons, which makes such comparisons of limited value.

Line 457: "Section 6.4 Comparison with ground-based stations at gridded scale"

Lines 485-489: "CALIPSO does not see the cloud base in many stratiform-type clouds, as an example, but this does not lead to as big of an issue in the surface LW CRE retrieval because the stratiform cloud base is not very far from the point of attenuation of the lidar."

This statement is inconsistent with the example shown in Fig. 10 (orbit C), which shows CALIPSO-GOCCP to be lower than CERES-CCCM by 15 Wm-2. Please clarify.

Lines 506-510: This argument acknowledges the challenges of comparing ground-based and satellite estimates but does not quantify the impact of these challenges. As a result, it is unclear what to conclude from those comparisons? If CALIPSO-GOCCP were perfect, how closely to the ground measurements should the LW CREs be, given the substantial sampling challenges? This is hard for the reader to know since the methodology for comparing the ground and satellite LW CREs was not provided.