Reply to Referee #1 on the Earth System Science Datasets manuscript

” CLARA-A3: The third edition of the AVHRR-based CM SAF climate data record on clouds, radiation and surface albedo covering the period 1979 to 2023 ”

by
Karlsson et al, 2023

Repeating general comment:

This paper describes the third edition of the product (CLARA-A3), including surface albedo, surface radiation, and TOA radiation budget products ranging from 1979 to 2020. Various validations for cloud and radiation products were done, and show a good agreement with other or ground-based measurements. Overall, this manuscript is clear. However, there are several issues that need to be taken care of before this paper becomes acceptable for publication.

Reply:

Answers to the referee’s comments and questions are given below together with suggestions on how to improve and update the manuscript.

Detailed comments:

1. L285, Figure 2. The cloud fraction from CLARA-A3 and previous version CLARA-A2 show a large difference, especially overestimation of cloud fraction, why?

   Author reply: The reviewer's interpretation is not correct. Cloud amounts in CLARA-A3 are improved (and not overestimated) in comparison to those in CLARA-A2. This is also clearly stated on lines 272-278. More details on the validation results can be found in the CLARA-A3 Validation Report and in a recent publication by Karlsson et al., 2023, in the Remote Sensing journal (https://www.mdpi.com/2072-4292/15/12/3044).

   Cloud amounts in CLARA-A2 suffered in particular from underestimated cloud amounts over the polar regions during the polar winter. This is described by Karlsson and Håkansson, 2018 (https://amt.copernicus.org/articles/11/633/2018/).

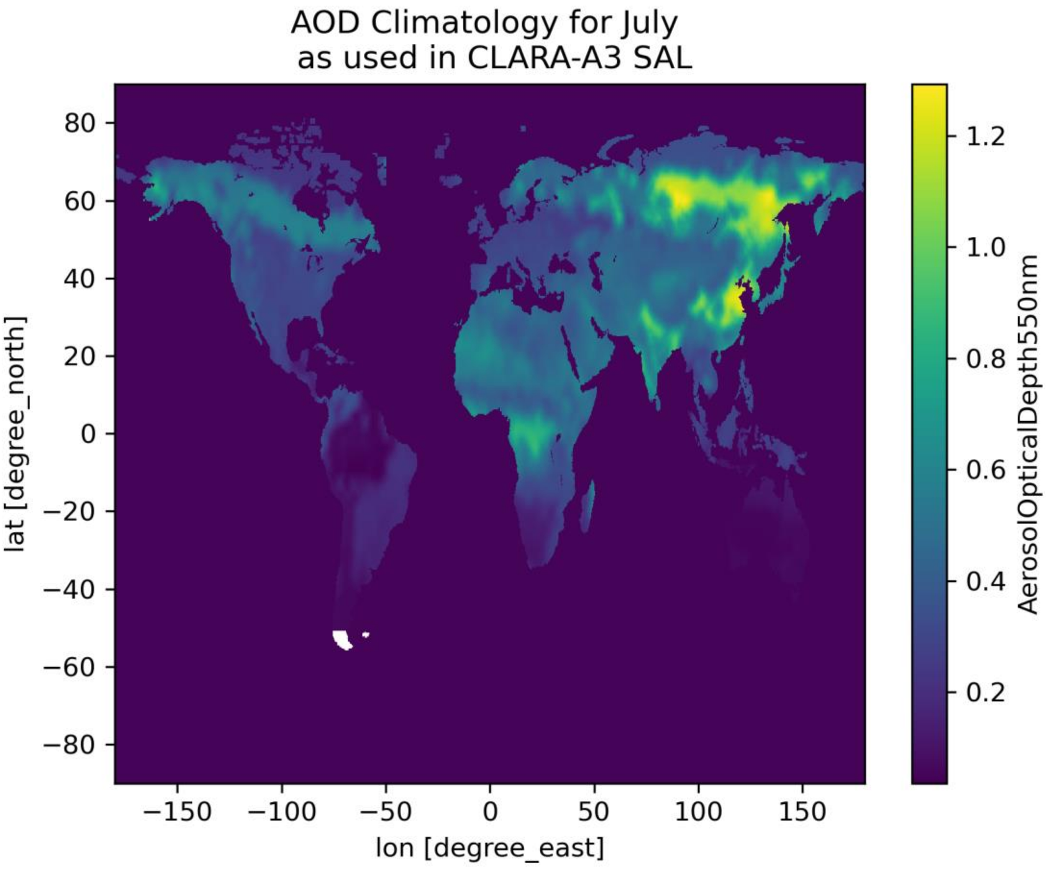
2. How about the cloud fractions over polar regions? I am curious about these products' performance over polar regions between snow/ice and cloud detections.

   Author reply: As mentioned in the previous point, previous cloud amounts over the polar regions in CLARA-A2 suffered from large underestimations in the polar winter (https://amt.copernicus.org/articles/11/633/2018/). However, after repeating the same validation effort against CALIPSO-CALIOP data for CLARA-A3, it is clear that polar winter results have improved for the Arctic region (see in particular Figure 4 in https://www.mdpi.com/2072-4292/15/12/3044). However, results over Antarctica have not improved in the same manner and it is clear that conditions are more challenging here. The problems over extremely cold surfaces at night are well-known (and encountered for most passive imagers) and it is clear that a sensor like AVHRR does not provide enough of useful information for being able to perform an efficient cloud screening under such conditions. Daytime results are, however, much more reliable indicating that the snow-cloud discrimination problem is manageable for solar illuminated surfaces. This is important for e.g. the estimation of the surface albedo product in the polar areas.

   We suggest to add a few sentences about this and more clearly refer to the paper in Remote Sensing for more details.

3. Why are there many invalid values of surface albedo in Eastern China?

Author reply: The atmospheric correction necessary for the surface albedo retrieval becomes uncertain over areas with high aerosol loading in the atmosphere. In practice, we discard all land surface observations with AOD > 1.0 at 550 nm. This limit is generally exceeded over both Eastern Siberia and Eastern China over much of the summer period (see attached figure for the monthly mean AOD for July as used in the retrievals for 2016 as an example). Therefore, most of the observations are discarded, although some data may still end up being accepted if it originates over large rivers and lakes and is therefore identified as water albedo, which follows a separate model-based retrieval path where AOD restrictions do not apply.



There is content on lines 513-515 about the influence of AOD, we could simply amend the sentence there to say “(Siberia and Eastern China in the example)”.

4. L610, Figure 10. For global mean flux, the CLARA-A3 RSF is close to CERES-SYN, both underestimation of CERES-EBAF, why? And the ISCCP-FH show totally overestimation.

   Author reply: The referee identifies some remarkable differences between some of the data records, and we agree that some of it may be briefly explained in the text. The CERES-EBAF product differs from the CERES-SYN in the way the diurnal cycle is derived (it makes use of so-called diurnal asymmetry ratio's instead of simple matching to the observed diurnal cycle from geostationary satellite (GEO), avoiding the typical GEO edge artefacts) but more importantly for your question, CERES-EBAF is also subject to some a posteriori "tuning" to match the scientific consensus regarding global energy imbalance measurements (as derived from ocean heat data records). Mainly the latter is responsible for the offset between the two products that we notice in Figure 10. Furthermore, indeed, ISCCP-FH shows a large overestimation: it should be stressed that for ISCCP-FH the fluxes are not directly observed but calculated by radiative transfer models and using cloud observations as main input (similar like the CLOUD_CCI approach). But for this, the choice of radiative model as well as the quality of the input data is important for the end result, and also the treatment of processes like diurnal cycle interpolation and orbital drift corrections. As far as we know this is not taken into account in ISCCP-FH. However, we don't feel we should elaborate on that in the text. So, to conclude, as a response to the author's comment, we suggest adding the following sentence in L610:

   "Compared to CLARA-A3 and CERES-SYN, the RSF from CERES-EBAF is consistently about 1.5 Wm^{-2} higher (green curve in Figure 10), which can be explained by the EBAF adjustments made to comply with current consensus estimates of the global energy imbalance."

5. The algorithm of radiation updated from CLARA-A2 to CLARA-A3 is not clear, authors should present more details in this paper.

   Author reply:
   The basic algorithm to estimate surface solar radiation from the AVHRR data has not been updated from CLARA-A2 to CLARA-A3. The changes and improvements in the data quality of the CLARA-A3 surface solar radiation data record (compared to CLARA-A2) can be attributed to the use of improved input data, i.e., the probabilistic cloud mask (compared to the binary cloud mask used in CLARA-A2) to distinguish between clear

sky and cloudy pixels, and the reflected solar radiation flux, which had been estimated with a very basic method in CLARA-A2 and is now being derived with a much more advanced algorithm (see the Section on the top-of-the-atmosphere radiation). In addition, the use of surface albedo from ERA-5 (compared to a climatology used in CLARA-A2) also improves the surface radiation estimation for cloudy and clear-sky pixels.
These changes will be stated more clearly in the revised version of the manuscript.

6. The algorithm of instantaneous radiation converting to daily mean is very important (Eq. 1), did the authors try another interpolation algorithm? Such sinusoidal fit, or Wang & Pinker method?

Author reply:
We agree that the calculation of daily averages from the instantaneous retrieval of surface solar radiation is critical for the accuracy of the daily (and subsequently the monthly) surface solar radiation data record. As described our method uses the daily mean of the clear-sky surface radiation (derived with a clear-sky solar radiative transfer model) as a 'first estimate' of the all-sky surface solar radiation. By weighting the clear-sky daily mean with the ratio of the sum of all all-sky observations to the sum of the corresponding clear-sky estimations this method easily handles a variable number of observations and provides good estimates also for very few observations (In the case of a clear-sky day, even one single observation is sufficient!).
The method by Wang and Pinker, 2009, has been designed for MODIS observations with two observations at given times; its applicability to the AVHRR instruments, with changing number of available instruments over time appears complex. In addition, the Wang and Pinker approach, as well as the sinusoidal fit, only considers the incident radiation at the top-of-the-atmosphere (represented by the solar zenith angle) for the scaling of the radiation estimates. In contrast, the use of the daily mean clear sky surface solar radiation (as in the approach used in the CLARA data records) is better representing the spatial (e.g., varying surface albedo) and the temporal (e.g., varying water vapor) variability on the daily average surface solar radiation, which is expected to provide more accurate estimates even though no detailed comparison between different methods to derive daily averages from polar-orbiting satellite instruments have been conducted so far.

7. How did the authors get daily mean longwave radiation at the surface from instantaneous data?

   Author reply:
   Daily mean surface longwave radiation is not derived within the CLARA retrieval algorithm; this will be stated more clearly in the revised version of the manuscript. The surface longwave radiation in the CLARA-A3 data record is only estimated and provided as monthly averages. These data are closely linked to the corresponding estimates from ERA-5.

8. It is recommended to introduce the current status and characteristics of relevant cloud and radiation products in the introduction of the paper, and highlight the advantages and characteristics of the new product (such as long time series characteristics and fine cloud and radiation parameters). Related products including JAXA's GCOM-C product (https://suzaku.eorc.jaxa.jp/GCOM_C/) (Nakajima et al., 2019), CARE (http://www.slrss.cn/care/) cloud characteristics and radiation products (Letu et al., 2020, 2022; Xu et al., 2022). This product is based on the latest geostationary satellites spliced together to form a high spatiotemporal resolution and high-precision remote sensing product.

   Author reply: Our opinion is that we have introduced the CDR in a reasonable way, emphasizing the important changes that were introduced with references to previous editions (lines 65-77). Furthermore, for every sub-section related to individual product components, improvements and changes have been described with references to earlier works and validation studies. We feel that a major revision of the introduction section, in order to give a richer background and status description, will automatically also lead to the need for a major revision of all individual sub-sections. We ask the reviewer to reconsider this recommendation based on the described consequences which could substantially delay the final publication.

   Regarding the recommendation to also compare products to the mentioned additional datasets GCOM-C and CARE, we have to say that the core CLARA-A3 dataset (i.e., not including ICDR data) ends in 2020 and our main task has been to use available global long-term datasets on (at least) the decadal scale to validate our products. The two mentioned datasets have either not covered long enough time to be considered (CGOM-C) or they have not provided global coverage (CARE). Nevertheless, the two datasets are certainly interesting for the near future regarding the continuous monitoring of the ICDR products. We propose to add the following statement (e.g., after the first sentence in the paragraph starting on line 805):

"ICDR products will be continuously monitored with relevant reference datasets where also new datasets like GCOM-C (Global Climate Observation Misson - Climate, Nakajima et al., 2019) and CARE (The Cloud remote sensing, Atmosphere radiation and Renewal Energy application product, Ri et al., 2022) will be considered."

Suggested additional references:

Nakajima, T. Y., Ishida, H., Nagao, T. M., Hori, M., Letu, H., Higuchi, R., ... & Yamazaki, A. (2019). Theoretical basis of the algorithms and early phase results of the GCOM-C (Shikisai) SGLI cloud products. Progress in Earth and Planetary Science, 6(1), 1-25.

Ri, X., Tana, G., Shi, C., Nakajima, T. Y., Shi, J., Zhao, J., ... & Letu, H. (2022). Cloud, Atmospheric Radiation and Renewal Energy Application (CARE) Version 1.0 Cloud Top Property Product From Himawari-8/AHI: Algorithm Development and Preliminary Validation. IEEE Transactions on Geoscience and Remote Sensing, 60, 1-11.