Reply to Referee #3 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:

The authors present some results from the CLARA-A3 validation against other similar cloud and radiation products. Production of this dataset is a significant accomplishment and an important addition to global climate studies of cloud and radiation. It is also clear from the link in Section 5 that there is a great deal of documentation and validation supporting this paper, which therefore necessitates selection of a few ‘highlights’ to be included here. That said I believe there are areas that require more detail in order for this to be considered useful as a stand-alone article.

Reply:

We thank the referee for these encouraging words. 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. L180: My understanding is there is no attempt at multilayer detection, and the cloud top phase is assumed to extend throughout the cloud column when deciding whether to calculate IWP or LWP. In that case I assume there is additional uncertainty in IWP estimates where it is unknown when ice overlaps water? It would be nice to know how uncertainty is estimated for these products and whether multi-layer clouds translate to higher uncertainty.

   Author reply: There is indeed no multilayer detection and for LWP/IWP calculation a single phase throughout the column is assumed. The presence of multiple phases, typically when low liquid clouds reside below high ice clouds, leads to an error in the optical and microphysical cloud property retrievals. However, the uncertainty estimates do not

include deviations from the assumption of horizontal and vertical homogeneity of the clouds as a source of error, and therefore such deviations will not be reflected in the uncertainty estimates.

We will try to update the text for clarifying these issues.

Changes in revised manuscript with tracked changes:
- Lines 188-189
- Lines 277-279

2. L252: The description of CPH, COT, and CRE are very brief, and we don't see any figures showing results from these products. Have the updates listed here resulted in lower uncertainty, or simply higher confidence in the reported uncertainty? Some numbers describing the changes in uncertainty for these products would be helpful.

Author reply: The descriptions of the CPH, COT and CRE retrieval are of similar length as the other cloud products (CMAPROB, CTO). Because of the many products included in CLARA-A3, these descriptions need to be brief in order not to further blow up the size of an already extensive manuscript. The same holds for the number of figures. However, there are figures showing CPH (Fig. 4) and LWP/IWP (Fig. 5), which is in fact a combination of COT and CRE. For CPH, clear improvements of the product are visualized in Fig. 4, in the sense that CLARA-3 results agree better than CLARA-A2 with state-of-the-art results from MODIS (if ignoring the negative trend in MODIS results in recent years which we for the moment do not know the explanation). For LWP/IWP results in Fig. 5, results are also a bit closer to MODIS results, at least for the IWP product. The update in L253 has presumably made the uncertainty estimates more realistic because more error sources, such as surface reflectance and atmospheric water vapor column, have been taken into account, although this is very hard to prove. We will emphasize this better in the text. The overall magnitude of uncertainty estimates has not changed much compared with CLARA-A2.

Changes in revised manuscript with tracked changes:
- Lines 283-285

3. Figure 2: There is a great deal of overlap making it difficult to differentiate among the records. Perhaps an anomaly plot would help? If it were deseasonalized we could also determine whether the records showed different trends over time.

Author reply: Yes, we are aware of this problem but still think it could be useful to give an overall plot of all original data despite these weaknesses. Instead of changing this plot, we suggest to refer to another paper where both anomaly plots and deseasonalized plots are presented and discussed more in depth. That paper had a quicker review process than this manuscript which means that it is already published.

Deseasonalized anomaly plots are available here (Figure 6 in the mentioned paper):

Devasthale, A.; Karlsson, K.-G. Decadal Stability and Trends in the Global Cloud Amount and Cloud Top Temperature in the Satellite-Based Climate Data Records. Remote Sens. 2023, 15, 3819. https://doi.org/10.3390/rs15153819
A corresponding plot is also presented for global mean cloud top temperature in the same paper (Figure 7).

Changes in revised manuscript with tracked changes:
- Line 330
- Lines 337-338.

4. L292: Was a statistical test applied to the CTP records in Figure 3 to deduce there are no significant trends? If so could that information be included here?

Author reply: This has been done. Results were published in the paper referred to in the previous point but only for the cloud top temperature parameter, not CTP. However, CTT and CTP are strictly related (as is mentioned on line 166 in the manuscript). We will refer to that paper on this topic.

Changes in revised manuscript with tracked changes:
- Line 330
- Lines 337-338

5. Figure 4: Is the liquid cloud fraction a percentage of total cloudiness phase (i.e. liquid / liquid + ice)?

Author reply: The liquid cloud fraction in Fig. 4 is defined here as the liquid cloud amount relative to the total cloud amount, i.e. liquid / (liquid + ice). This information will be added to the caption in the revised manuscript.

Changes in revised manuscript with tracked changes:
- Line 355

6. L380-391: I find this paragraph confusing. When are the instantaneous versus daily irradiance calculations used? Is one for Level 2 and one for Level 3? Also, an aerosol record that extends from 1979-2025 is used, but only to create a 12-month climatology? Is this also the case for atmospheric gases? For example, is CO_2 rise accounted for?

   Author reply: We are sorry for the confusion and try to explain better here.

   The instantaneous (all sky and clear sky) and the daily (clear sky) irradiance values are used to derive the daily all sky irradiance data (i.e., the final product of the data record) via formula (1). This formula allows the accurate estimation of all-sky daily irradiance by weighting the clear-sky daily irradiance (derived from a RTM) with the ratio of the sum of the instantaneous all-sky (derived from the satellite retrieval) and the sum of the instantaneous clear-sky (derived from a RTM) irradiance. Different aerosol information is used for the instantaneous and the daily irradiance estimations. As formula (1) includes the ratio of the 2 instantaneous irradiance values (all-sky and clear-sky) the aerosol impact on the instantaneous irradiance on the daily mean surface irradiance is limited; the aerosol effects in the daily all sky irradiance data are dominated by those represented in the estimation of the clear sky daily irradiance.

   The clear-sky daily irradiance is used for the generation of the 'Level 3' daily averaged surface irradiance. Thus, the instantaneous surface irradiances (clear-sky and all-sky) could be considered 'Level 2'-products, even though the terminology in this case is not well defined (and no Level 2-type products are accessible for users).

   The aerosol data from 1979 to 2020 was used to estimate a monthly climatology, which was used for the estimation of the clear-sky daily mean irradiance. We consider the temporal variability and the long-term trend of the aerosol optical depth, which was derived from model simulations, to be only of moderate accuracy; to limit the impact of the aerosol information (with unknown / moderate accuracy) on the final surface irradiance data record we decided to only use the climatological information in the surface irradiance estimation; we acknowledge that the direct aerosol effect is not considered in the final surface irradiance data

record; this fact should be considered in the interpretation of longer-term variability and trends derived from the CLARA-A3 SIS data record.

For atmospheric gases, in particular water vapor and ozone, instantaneous and daily data are used for the estimation of the instantaneous and the daily surface irradiance, respectively. The impact of CO_2 on the surface solar irradiance is negligible and is not considered; for the longwave surface radiation, the increase in CO_2 accounted for based on ERA-5.

We think that a lot of this information is, in fact, already described in the text. In the interest of keeping the size of the text not too long, we did not modify the text further but hope that it is enough with this explanation.

7. L592: How is the instantaneous OLR estimated for the AVHRR/1 where channels 4 and 5 are the same?

   Author reply: The instantaneous OLR is estimated from AVHRR/2 and AVHRR/3 using regression fits with 6 predictors (i.e. 7 coefficients), among which are the channel 4 and channel 5 brightness temperatures. For AVHRR/1, there is a different set of regression fits which do not make use of the channel 5 brightness temperature, resulting in only 4 predictors (5 coefficients). The article Clerbaux et al. (2020), cited at the end of that paragraph on line 599, describes this in full (including a validation of its impact). We do agree with the reviewer that it is not clear for the reader, and will therefore add the following clarification on line 593: "This is done by regressions on the same large database of collocated AVHRR-CERES observations (as used for the RSF); for AVHRR/1 the regressions only make use of the channel 4 brightness temperature, for AVHRR/2 and AVHRR/3 both channel 4 and 5 are used (Clerbaux et al., 2020)."

   Changes in revised manuscript with tracked changes:
   - Lines 666-669

Editorial comments:

L114: ‘Full’ shouldn’t be capitalized. **Author reply:** Yes, will be corrected.

Changes in revised manuscript with tracked changes:
- Line 117

L264: ‘in addition’ is repetitive. **Author reply:** Yes, will be corrected.

Changes in revised manuscript with tracked changes:
- Lines 295-296

L361: There should be a space between ‘LUT’ and ‘that’ **Author reply:** Yes, will be corrected.

Changes in revised manuscript with tracked changes:
- Line 409

L566: ‘then’ should be capitalized. **Author reply:** Yes, will be corrected.

Changes in revised manuscript with tracked changes:
- Line 640

L712: There is an extraneous ‘t’ after CLARA-A3. **Author reply:** Yes, will be corrected.

Changes in revised manuscript with tracked changes:
- Line 798