Anonymous Referee #1

General comments:

This article describes the third version of the Cloud Climate Change Initiative AVHRR-PM dataset; a 35 year climatology based on measurements in 5 spectral bands from the Advanced Very High Resolution Radiometer (AVHRR) instruments on board several polar orbiting satellites. This dataset includes both cloud properties retrieved from the AVHRR measurements and surface and top of atmosphere irradiances calculated using these retrieved cloud properties. The article describes changes since the previous version of the dataset and presents some evaluation of the dataset and comparisons with the previous version.

This article is generally very well written. The description of the cloud retrieval algorithm is quite brief, but this is appropriate as the previous version of the algorithm is described in detail in a previous publication (Stengel et al. 2017). The description of the radiative transfer calculations is also quite brief and in my opinion more detail is required here (see comments below for suggestions). The dataset was accessed through the given identifier and appeared to be complete and consistent with the description in the article.

Recommendation:

Accept pending minor revisions.

Minor Comments:

Referee comment:

1. Why does this article focus specifically on AVHRR-pm, as opposed to describing datasets for multiple instruments as in Stengel et al (2017)? At the very least, it seems odd not to include the AVHRR-am dataset in the scope of this article. On similar lines, would it be possible to produce a product combining AVHRR-am and AVHRR-pm measurements? Presumably the additional sampling of the diurnal cycle would lead to smaller errors in the radiation diurnal cycle corrections.

Author's response:

The Stengel et al. (2017) paper aimed at introducing all available version 2 datasets generated in the framework of the Cloud_cci project. Only a subset of those (AVHRR-AM, AVHRR-PM, ATSR2-AATSR) were reprocessed building on new developments leading to corresponding version 3 datasets. ATSR2-AATSR version 3 data will be introduced in a separate paper, which is soon to be submitted. For AVHRR we decided to put the focus more or less entirely on AVHRR-PM as this dataset is longer, more stable and of higher quality than AVHRR-AM. On the other hand, for the period covered by the AM satellites NOAA-17 and METOP-A (NOAA-12 and NOAA-15 are very difficult to handle due to their twilight orbit), the AVHRR-AM datasets is of similar quality as AVHRR-PM and does indeed provided the possibility for combining AVHRR-AM and AVHRR-PM to reduced sampling problems, although only for the years 2002 and beyond. Another difficulty is the availability of the 1.6mic channel instead of the 3.7mic channel as available on nearly all PM satellites. In the data availability section, the existence of the AVHRR-AMv3 is reflected. We will add that there is a potential to combine with AVHRR-PMv3, but also mentioning the difficulties for NOAA-12 and NOAA-15.

Author's changes to the manuscript:

We added the following sentence to the data availability section: "The AVHRR-AMv3 dataset provides the feasibility to be combined with AVHRR-PMv3 to increase sampling frequency. However, for the period of NOAA-12 and NOAA-15 the AVHRR-AMv3 dataset is of reduced quality due to the difficult twilight orbits of NOAA-12 and NOAA-15."

Referee comment:

2. It's very difficult to see any differences in most of Figs. 1,2,5,6,7,8. I would consider including difference plots, either instead of the v2/CERES images, or as an additional row/column.

Author's response:

We have included differences plots in Figures 1,2,5,6,7,8.

Author's changes to the manuscript:

We updated Figures 1,2,5,6,7,8.

Referee comment:

3. Is there any attempt to account for changes in the surface albedo with the angle of incident light in the SW radiative transfer calculations (e.g. Wang et al 2007)? Perhaps this could explain some of the differences between the CERES and AVHRR-pm surface SW upwelling irradiances?

Author's response:

Yes, for ocean surfaces we have built in an empirical method to adjust the surface albedo as a quadratic function of the angle of incident light. For land surfaces no adjustment is made. We will include a statement on this in the text.

Author's changes to the manuscript:

On page 13 line 2 we will change the sentence to "The diurnal cycle of SZA is then used to rescale the incoming and reflected solar radiation, adjust the surface albedo (using an empirical quadratic function of SZA) and the atmospheric path length for a given set of time stamps throughout the local day."

Referee comment:

4. With regards to the LW diurnal cycle correction factors, are separate factors derived for clear and cloudy scenes?

Author's response:

No, this is not the case, but probably something to consider for the future. Thanks. In this context we noticed that the LW diurnal cycle correction is only applied for land surfaces, which is not reflected in the manuscript yet. We will add this now.

Author's changes to the manuscript:

On page 13 line 7 we will modify the sentence to "For longwave radiation, a diurnal cycle correction is applied over land based on a cosine fit to an observed mean…."

Referee comment:

5. If I understand the radiative transfer model correctly, it requires the cloud to be split into layers. If this is the case, how do you determine how many layers to include cloud in (i.e. where is the cloud base?). I would expect this to have a reasonably large impact on the calculated surface LW downwelling irradiance.

Author's response:

We assume the radiative transfer in BUGSrad is meant which is employed to derive the broadband fluxes. Here we assume only one cloud layer with its top being place at the derived cloud top height. Using derived optical thickness and effective radius the geometrical thickness, thus the cloud base height is estimated. This is actually described in more detail in an ATBD, which we will include a reference to.

Author's changes to the manuscript:

On page 12 line 22 we will add the sentence "The reader is referred to ATBD (2019) for more details on the calculation of the broadband fluxes." Along with including the following reference :

ATBD – Algorithm Theoretical Baseline Document (ATBD) of CC4CL Broadband Radiative Flux Retrieval - ESA Cloud_cci, 2019, Issue 1, Rev. 1; 14/10/2019, available from http://www.esa-cloud-cci.org/?q=documentation, 2019.

Referee comment:
6. Page 15, Line 11 -13. I don't follow the argument that "the larger standard deviations...is primarily related to variances in surface albedo and cloud cover which tend to have significant annual cycles". Relating the larger s.d. to the surface albedo variance makes sense, but I don't understand why the cloud cover variance will lead to a larger s.d. as it also affects the downwelling SW irradiance.
Author's response:
Right. We will remove cloud cover.
Author's changes to the manuscript:
The revised version of that sentence will read "The larger standard deviations retrieved form the solar reflected radiation is primarily related to variances in surface albedo which tend to have significant annual cycles"

Referee comment:
7. For TOA radiation, clear-sky differences between CERES and AVHRR-pm are attributed to sampling differences. Presumably this is relatively easy to test by calculating a CERES-like value from the AVHRR-pm product?
Author's response:
Thank you for this suggestion. We performed a little experiment (covering 3 months) in which we emulated the CERES-like clear-sky sampling. And yes, when doing so the global mean TOA LW flux was increased by approx. 3W/m^2, thus the deviation to CERES was reduced. This emphasises that at least parts of the deviation can be explained by sampling. We will include the results of this experiment in the text.
Author's changes to the manuscript:
The following sentence was added: "This could be confirmed by a 3-months covering test run in which Cloud_cci LWF^up_toa was only averaged over clear-sky cases, which led to an increase by about 3~$\text{W m}^{\text{-2}}$ for the global mean value."

Referee comment:
8. To further demonstrate the usefulness of the radiation products, it would be good to see some further comparisons with other datasets, such as the ERA-Interim reanalysis, or the GEWEX radiation budget data. Perhaps you could add a couple of extra lines in table 8 to show mean values for other products?
Author's response:
Good suggestion. We will add value for ERA-Interim to table 8, and addition to tables 9 and 10. We prefer not to add the GEWEX SRB dataset as it does not fully cover the period 2003-2016 chosen for corresponding comparisons.
Author's changes to the manuscript:
We will add ERA-Interim values to Tables 8, 9 and 10.

Referee comment:
9. I really appreciate the effort undertaken to provide useful and accurate uncertainty estimates for the cloud variables. It would be very helpful to have some estimate of uncertainty in the computed radiation variables too. This could be based on further radiative transfer calculations using different cloud inputs to represent the uncertainty in the input cloud profiles, though this may be time consuming. Alternatively, a simple quality variable to indicate when the radiation calculation is uncertain due to larger uncertainty in the input cloud profiles could potentially be quite helpful.
Author's response:
Thank you for this suggestion. We have in indeed planned to provide uncertainty estimates for the radiation variables too. For the presented dataset version this was however not feasible due to time constrains, but we certainly have this on the to-do list for next versions. For the time being the radiation validation results presented do provide some guidance wrt. to certainty/uncertainty of the radiation products, although not on pixels/grid-cell level. As the determination of the radiation product heavily depend on the derived cloud properties and their uncertainty it is indeed wise to

inform the users of the data that the provided cloud property uncertainties give hints on the certainty/uncertainty in the radiation product already in the current dataset version. We will include a comment on this in the text.

<u>Author's changes to the manuscript:</u>

We added the following sentence at the end of Section 3.1 "In contrast to the cloud properties, the radiative fluxes in the presented dataset version are not accompanied by uncertainty estimates on pixel level. While the validation results presented below provide a general guidance to the quality of the radiative fluxes, user of the data are also encouraged to inspect the pixel-level uncertainties of the cloud properties as these are dominant input to the calculation of the fluxes."

<u>Referee comment:</u>

10. Looking at the daily data, there appear to be some artifacts in the retrieved cloud water path at the edges of the swaths for the descending overpasses (e.g. for the 1 June 2016 data). These do seem to correspond with very large uncertainty estimates. In such cases, where the uncertainty is much larger than the retrieved value I wonder whether it would be better to replace the retrieved value with a missing data value? In particular, I have concerns about these retrieved values undergoing further processing (e.g. passed to radiation calculations, or used in monthly mean/histogram products) and the information about the large uncertainty associated with the particular retrieval being lost.

<u>Author's response:</u>

Thank you for this observation and feedback. The descending cloud water path is based on the night-time retrievals of CER and COT, which are experimental products as listed in the manuscript. To emphasise this we will add a corresponding comment below Table 1. For monthly aggregations these night-time products are not considered. A quick inspection of the LW fluxes confirmed that this issue does not seemed to have a significant impact on the LW fluxes. SW fluxes are zero anyway during night time.

<u>Author's changes to the manuscript:</u>

Added a comment below Table 1.