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Atmospheric Measurement Techniques Discussions

Interactive comment on "Long-term study of cloud radiative effect, cloud fraction and cloud type at two stations in Switzerland using hemispherical sky cameras" *by* Christine Aebi et al.

Anonymous Referee #3

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General comments:

The manuscript presents calculations of the cloud radiative effect for different cloud types and cloudiness at two stations in Switzerland. Cloud cover and cloud type have been determined using hemispherical sky cameras. Sensitivity analysis have been conducted to study the impact of integrated water vapor and cloud base height on the long-wave cloud radiative effect (LCE), and the occultation of the sun by clouds on the short-wave cloud radiative effect (SCE).

Clouds are the principal modulator of the radiation budget but remain the largest uncertainty in the estimates of the Earth's changing energy budget. Therefore, such

studies are highly important and relevant in order to quantify the effects of clouds on the radiation budget and to monitor their long-terms changes. In addition, the study demonstrates the current limitations of such automated cloud observing systems and hence serve as a base for future improvements. Indeed, the lack of cloud observations at the surface is an important cause for the uncertainties related to clouds.

The manuscript is well structured and - with some exceptions - clearly written. The literature has been carefully selected and cited. Graphics and tables are clear and the captions self-explanatory. There are some issues with the used language. In particular the conclusions could be improved. When the focus is sharpened towards a more original, better structured and formulated conclusion, and some additional minor revisions will be included, this work will be a very interesting and valuable contribution to the atmospheric science community and is in my opinion absolutely suited for publication in AMT.

Specific comments:

- Abstract: The abstract should point to the most relevant results. LCE and SCErel for low-level clouds and 8 oktas cloud cover are described but no statement about the corresponding TCE is given which gives a quantitative feeling to the reader regarding the overall impact of clouds on the radiation balance. I propose to include the corresponding numbers, for instance in line 3 "The total radiative effect of low-level clouds at 8 oktas cloud coverage has a median value....The median of the corresponding long-wave cloud effect (LCE) is....For mid- and high-level clouds the TCE and LCE are significantly lower ..."

- I see one main reason - apart from the atmospheric parameters - for the substantial spread in the CRE data, particularly in the LCE (e.g., Fig. 3 and Fig.5): The deficiencies in the cloud type classification algorithm itself such as misclassification, and/or the fact that only one cloud type can be determined even if several different cloud classes occur. It is for instance not reasonable why there are almost no Cu and St-As at Payerne and

no Cb-Ns at Davos (see Fig. 2). In addition, it is unlikely that such low LCE values can occur for low level clouds (e.g., Sc, Cu, Cb-Ns) and high cloudiness (> 6 oktas) as indicated in Fig. 3. Similarly in Fig.5, it is unlikely, that LCE below 50 (40) Wm-2 occur for IWV contents < 15 (20) mm (see Fig 6, model calculations). So, it is very likely that all these data points are potential misclassifications. These issues should be addressed in the respective paragraphs (there is only a short statement on p. 13) and in the conclusions. Finally, could you derive from your dataset/figures/model calculations a rough percentage of misclassified cases?

- Conclusions: The conclusions should be shortened and better structured. The listing of well-known issues and repetitions should be avoided (e.g., "Different cloud types have differing effects on the radiation.." or the two sentences on p. 16/17 lines 25/5 and p.17 line 14 have a similar meaning (in case the first sentence refers to differences between the two stations and the latter to the differences between cloud types, it would be helpful to state the sentences at least in the same paragraph. Otherwise, the reader will be confused). Finally, the repetitive use of words and expressions such as "Our measurements/data show/It has been shown" should be minimized). Generally, only the most important results and their implications should be stated. In addition to the described results, I would also clearly state the deficiencies in the cloud type classification algorithm which lead to the large spread in the data, particularly in the LCE (see my previous comments). In fact, the authors do mention this issue in the conclusions but the paragraph appears somehow isolated. In addition, a statement about the methodology how the cloud type classification could be improved would be useful in the conclusions: Is it possible to improve the current cloud classification algorithms (and if yes how) or would it rather be a new algorithm by combining various observing systems/methods which measure/calculate the relevant parameters described in this manuscript (e.g., ceilometer for cloud base height, sky camera for cloud cover, LCE and SCE (i.e. observations and the corresponding cloud-free calculations of longwave and shortwave radiation), solar radiation data for the determination of the occultation of the sun and IWV)? Could the authors comment on these issues?

Technical corrections: some of the spelling and grammatical errors:

- Use “cloud-free” instead of “clear-sky” throughout the manuscript ("clear-sky" refers to a sky without clouds and a low aerosol load. The latter is not necessarily the case, particularly at a site in the Midlands such as Payerne. In addition, this is a study about the effect of clouds and thus I would use here rather the term "cloud-free" instead of "clear-sky").

- Use "oktas" instead of "octas" throughout the manuscript

- Use "longwave/shortwave wavelength range" instead of "longwave/shortwave wavelength region" throughout the manuscript

- p.2, line 18: "wider" instead of "broader"

- p.2, lines 19-21: You may rephrase this sentence, something like: "However, the temporal resolution of satellite products is limited. From the Meteosat Second Generation (MSG) geostationary satellites, for instance, data....(Werkmeister et al., 2015). Therefore and for the validation of cloud products from satellites, ground-based observing systems such as all-sky cameras are necessary."

- p.2, line 31: replace "their" by "sensitivity".

- p.3, line 10: write f in italic (f/8)

- p.3, line 16: traceable to the respective standard groups of the World Radiation Center (WRC)

- p.4, line 2: Equation (1): Maybe add "...= DSRobs - DSRcal,cf + DLRobs - DLR,cal,cf" to the equation, "where DSRobs and DLRobs and DSRcal,cf and DLRcal,cf are the observed and calculated downwelling shortwave and longwave fluxes for the all-sky and the corresponding cloud-free scenes, respectively." Then you can delete "which are both calculated separately". Do you assume for the cloud-free calculations the same atmospheric conditions (e.g., temperature, IWV content) as they were observed

during the corresponding (all-sky) measurements? It is nowhere clearly stated. You may state this also here.

- p.4, line 7: I would delete "usually" (or replace by "always"). Clouds increase always the observed LW radiation, don't they?

- p.4, line 19: libRadtran

- p.4, line 31: Include a sentence how you remove the distortion in the Image

- p.6, line 13: could you state a possible explanation for the opposing cloud-free/overcast conditions in winter and summer at Payerne and Davos? Similarly, after line 23, insert a new paragraph and describe the differences in cloud type between the two stations, e.g., fewer Cu and St-As at Payerne with respect to Davos but much more Cb-Ns, most likely due to deficiencies in the cloud type algorithm.

- p.7, Fig.2 in the legend: Cb instead of Cn

- p.7, line 1. "visual observations": Do you refer to routinely conducted synoptic cloud observations by trained personal, i.e. human observer?

- p.7, line 14: to some extent also for St-As.

- p.7, lines 15-20: I would state the statistics for Ci-Cs and 8 oktas coverage for Davos, even if it is too high. Concerning the causes for this particular case, I do not believe that the erroneous values are due to the fact that the camera is not sensitive to high-level clouds. It is not reasonable that the camera detects high-level clouds with lower cloud coverage (these values seem to be reasonable) but does not for overcast conditions. Thus, I would rephrase lines 15-20 which are anyways partly difficult to understand, e.g. something like: "The median for overcast (8 oktas cloud coverage) Ci-Cs conditions in Davos is clearly too high at XX Wm-2. Manually checked images indicate a misclassification of numerous cases as Ci-Cs instead of a cloud type with a lower cloud base and/or optically thicker clouds. Alternatively, the classification as Ci-Cs could be correct, but various cloud types occur at the same time including clouds with a lower

cloud base/optically thicker clouds resulting in higher LCE values for Ci-Cs. A possible reason for the misclassification could be that the algorithm is trained with a data set from Payerne." Finally, I would delete lines 20-24.

- p.7, line 26: It is Table 1 (instead of 2). It would be also helpful to include the absolute or relative numbers of occurrences for the individual cloud classes and cloud coverages (in the same table or in a separate table). Indeed, some results which are not reasonable as discussed before could be also due to a limited number of occurrences for a particular cloud class and cloud cover.

- p. 9, line 10: "at 36 Wm-2" instead of "with 36 Wm-2"

- p. 9, line 13: I would rephrase this sentence, e.g., " The difference of the median LCE values increases with decreasing cloud coverage." or similar.

- p. 9, line 14/15: I would simply write "The difference might be partly due to a higher underestimation of the calculated LW cloud-free irradiances at Payerne." or similar.

- p. 9, line 16: "higher" instead of "larger".

- p. 10, line 4: No new paragraph. Continue directly with "Table 2 summarizes..." on line 4 (and it is Table 2 not Table 3).

- p. 10, line 7: Delete "SCErel value".

- p. 11, line 4: "higher" instead of "lower".

- p. 11, line 12: 2x "conditions" instead of "condition".

- p. 11, line 13: delete "part of the shortwave radiation".

- p. 11, line "at" instead of "with" and "range" instead of "region".

- p. 11, lines 4-6: I would rephrase these two sentences, e.g.: "The largest contribution stems from the cloud class Cc-ac at 32 % of the cases, followed by Cu at 27 %, Sc (20 %), St-As (11 %)....."

- p.11, line 7: "negligibly small at 0.2 %".

- p.12, line 14: "... in 8 % of the 126,148 cloud cases, a cloud enhancement of more than 5 % SCErel is observed."

- p.12, line 25: "Schade et al. (2007) showed..."

- p.12, line 10: "...Davos and Payerne are summarized in Table 3 separately." (it is Table 3).

- p.12, line 12: "...the less negative/the more positive the TCE...".

- p. 12, line 16/p. 13, line 2: "Among other reasons": You may list two or three of them. In addition to the cloud enhancement, the positive values are most likely also due to the relatively large uncertainties in the cloud-free model. In my opinion, this should be stated here.

- p. 17, line 11: "increased" instead of "decreased".

- p. 17/18 lines 18-21: I would rephrase this last paragraph (note: the radiation (not energy) budget would be complete if upwelling fluxes were considered) , something like: "The calculations and observations in this study are limited to daylight hours since the hemispherical sky camera operates in the visible wavelength range. However, for climate-monitoring applications cloud observations during day and night are necessary. Therefore, a new observing system (infrared cloud camera) has been developed..."

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