Atmos. Chem. Phys. Discuss.,
https://doi.org/10.5194/acp-2018-1096-AC2, 2019

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Trends in surface radiation and cloud radiative effect at four Swiss sites for the 1996–2015 period" *by* Stephan Nyeki et al.

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Received and published: 20 July 2019

20 July 2019

Dear Editor and Referees.

Please find our corrections below. We thank both Referees for their thoughtful comments and detailed corrections. It has taken longer than anticipated to correct our paper, but the effort has definitely been worthwhile. We therefore hope that we have answered the questions as best as possible and that the latest version meets with the Referees approval.

During the revision, we came across an interesting review paper by Pepin et al. (2015), published in Nature Climate Change. Two small paragraphs have been added to the new paper on page 7 line 21 and page 9 line 41.

Pepin, N., Bradley, R. S., Diaz, H. F., Baraër, M., Caceres, E. B., Forsythe, N., Fowler, H., Greenwood, G., Hashmi, M. Z., Liu, X. D. and Miller, J. R.: Elevation-dependent warming in mountain regions of the world, Nature Climate Change, 5, 424, doi: 10.1038/nclimate2563, 2015.

Best Regards Stephan Nyeki

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âĂČ Referee 2: Comments

General comments

It is important to investigate the trends of radiation and cloud radiative effect at the surface and put forward the possible explanations that account for the phenomenon. However, there are some weakness that requires more supporting material. The clouds identification methods are not accurate which may induce a contamination of radiation fluxes, since a slight change of cloud cover may significantly influence the radiation fluxes at the surface. Aerosol burden also has significant effects on shortwave radiation at the surface. Using climatological average of AOD to fill in the missing data of AOD during 2013 through 2015 may cause an artificial error in the trend analysis. Without any detailed description of how clouds change, it is quite arbitrary and blurry to infer the relationship between the variations of CRE and clouds.

Question: The clouds identification methods are not accurate which may induce a contamination of radiation fluxes, since a slight change of cloud cover may significantly influence the radiation fluxes at the surface.

Answer: This is correct. However, we would point out that sky-camera measurements have only been conducted for several years, and reliable data are only available for PAY

and DAV. The only way to enable cloud-free DSR and DLR analyses to be extended back to the 1990s is with a proxy parameterisation of cloud-cover, APCADA in our case. The original manuscript already discusses the advantages and disadvantages of using APCADA. In our opinion, this is currently the only way to conduct such analyses. However, we have made some changes to Section 2.2 so that the advantages of using sky-cameras are better highlighted.

New text: "Apart from these aspects, the use of proxy parameterisations for cloud cover will introduce uncertainties, but we estimate that these are generally low. A more accurate assessment will only be possible when cloud cover data from sky cameras are long enough to conduct reliable time series analysis, which is generally a period of 10 years and longer. While cloud cover can be accurately and objectively determined with sky cameras, measurements are only available during daylight hours."

Question: Aerosol burden also has significant effects on shortwave radiation at the surface. Using climatological average of AOD to fill in the missing data of AOD during 2013 through 2015 may cause an artificial error in the trend analysis.

Answer: We agree. On the other hand, the 17-year AOD time series is only being extended with a 3-year climatology to 20 years, so a large deviation from the prevailing trend is not to be expected. We have therefore introduced the following sentence:

"While this may introduce an error in the AOD trend, a large change is not expected in the 18-year AOD time series."

Question: Without any detailed description of how clouds change, it is quite arbitrary and blurry to infer the relationship between the variations of CRE and clouds.

Answer: We agree with the Reviewer. We have therefore changed our discussion at several points in the text so that a change in macro and microphysical cloud properties

is mentioned rather than a change in cloud cover or in cloud type. Please see further comments below (Referee comment: 6. Page 8 and line 15).

Specific comments

Referee comment: 1. Page 5 and line 25: 'In contrast, the specific humidity and IWV are higher during all-sky conditions which in turn results in higher DLR values.', please mention the source of the specific humidity data?

Answer: Specific humidity was calculated from T2m, RH and pressure. This has been included in a revision of the paragraph on the IWV parameterisation. Please see next Referee comment.

Referee comment: 2. Page 5 and line 30: 'IWV at JFJ was based on a widely-used parameterization using T2m and relative humidity', where is relative humidity data from and what is the accuracy of this parameterization? Please add description of these in the section of methods and data.

Answer: This small paragraph has been moved to Section 2.1 and has been changed to:

"As a result, IWV at JFJ was based on a commonly-used parameterisation by Leckner (1978) using T2m and RH. Gubler et al. (2012) estimated that the uncertainty in IWV using this parameterisation was up to 100 %."

Gubler, S, Gruber, S., and Purves, R. S.: Uncertainties of parameterized surface downward clear-sky shortwave and all-sky longwave radiation, Atmos. Chem. Phys., 12, 5077-5098, doi:10.5194/acps-12-5077-2012, 2012.

Referee comment: 3. Page 5 and line 35: 'which are probably associated with synoptic scale weather patterns', what kind of weather patterns are they?

Answer: Rather than go into further detail on this subject for which there are few observational studies, we have removed the latter part of the sentence so that the following remains.

"Weak seasonal variations are seen to occur at all sites".

Referee comment: 4. Page 6 and line 25: 'the DSR trend at PAY is not monotonic but steeply', as DSR has obvious changes, could you show its trend at four sites like Figure 1?

Answer: We would prefer not to add another figure with, in our view, little scientific value to the overall paper. The word "steeply" was an overemphasis and has therefore been removed.

Referee comment: 5. Page 7 and line 20: what are the '<' and '-<'?

Answer: Thank you for highlighting this. This has been corrected to <-0.5 Wm-2 and <4 Wm-2.

Referee comment: 6. Page 8 and line 15: 'suggesting that a decrease in fractional cloud cover or a different cloud type has occurred during the 1996 – 2015 period', there are many factors may affect cloud radiative effects such as cloud height and optical depth. A decrease of CRE magnitude doesn't mean there can be the decrease of cloud fraction. What are the variations of different clouds during the 1996 – 2015 period?

Answer: We agree with the Reviewer that both, macrophysical cloud properties (e.g., cloud cover, cloud base height (cloud base temperature), cloud top height etc.) and microphysical cloud properties (e.g., cloud optical thickness, cloud droplet size, cloud particle size distribution, liquid water content, liquid water path, ice water content, hydrometeor size, hydrometeor size distribution, hydrometeor phase etc.) determine CRE and thus changes in CRE are a result of changes in these parameters. Regarding cloud fraction, we refer to Fig. 3 and Fig. 4 in Aebi et al., 2017 which indicate an increase in the magnitude of cloud radiative effects with increasing cloud fraction, particularly in the long-wave. In addition, various studies (listed in lines 16-23) conclude that cloud cover over Europe has decreased and thus it is likely that this decrease has contributed to the decrease of CRE.

Due to the lack of long-term cloud observations (macrophysical and microphysical cloud properties) it is not possible to determine the variations of different clouds during the 1996 – 2015 period. Indeed, continuous active remote sensing techniques are only available at Payerne but time series are not longer than 10 years. Cloud type observations from human observers, which are subjective to some extent and difficult to analyse, were finally stopped in 2005.

The original sentence on p.1 lines 18-19 has been changed from:

"CRE decreased in magnitude by 0.9 – 3.1 W m-2/decade which implies a reduction in cloud cover and/or a change towards a different cloud type over the four Swiss sites."

to:

"CRE decreased in magnitude by 0.9 – 3.1 W m-2/decade which implies a change in macrophysical and/or microphysical cloud properties."

The original sentence on p.8 lines 9-10 has been changed from:

"As a result of the positive CRE trends in Table 5, there is an overall decrease in the CRE magnitude, suggesting that a decrease in fractional cloud cover or a change

towards a different cloud type has occurred during the 1996 – 2015 period.2

to:

“As a result of the positive CRE trends in Table 5, there is an overall decrease in the CRE magnitude, suggesting that changes in macrophysical and/or microphysical cloud properties, which determine CRE, have occurred during the 1996 – 2015 period.”

The original sentence on p.8 line 16 has been changed from:

“A reduction in cloud cover over Europe . . .”.

to: A decrease in cloud cover might be one of the cloud parameters which has contributed to the decrease of the CRE magnitude. Indeed, a reduction in cloud cover over Europe. . ..

The original sentence on p.8 line 24 has had the following text added on:

“Apart from changes in cloud cover and other macrophysical cloud properties, microphysical cloud properties can also have a substantial impact on CRE. However, the observation of these properties using active remote sensing techniques is limited to a few super sites-worldwide while long-term time series are rarely available. The same is also valid at the four Swiss SACRaM stations in this study. Macrophysical and microphysical cloud properties have only been routinely measured at PAY since 2010 and 2005, respectively. In addition, cloud observations from human observers were discontinued in 2000 – 2005 at the SACRaM locations.”

The original sentence on p.9 line 39 has been changed from:

“. . . over the 1996 – 2015 period, which implies a decrease in cloud cover or a change towards a different cloud type.”

to:

“...over the 1996 – 2015 period, although no trends were significant at the 95% confi-

dence level. This decrease in CRE is probably caused by variations in macrophysical and microphysical cloud properties. However, it is not possible to determine and quantify, which cloud properties have changed and contributed to the decrease in CRE due to the lack of corresponding continuous long-term observations.”

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