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Title: Decadal variations in estimated surface solar radiation over Switzerland since the late 19th century

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Response to G. Stanhill

General comment

I recommend publication of this interesting and well-presented article after the authors have responded to the following comments.

We appreciate the reviewer's comments and support. The specific comments are addressed below

Specific Comments

Section 3 dealing with the homogenization of the Swiss series of sunshine duration measurements requires clarification. The methods adopted ensure spatial rather than instrumental homogeneity; however as the authors point out (line 56, page 10820) the latter source of non-homogeneity is of special importance because the change of instrumentation from the Campbell-Stokes to the Haenni sunshine recorders in the late 1970's coincided with the change in sunshine to cloud relationship referred to in the manuscript. It is known from the Japanese and UK networks that the replacement of sunshine duration instruments, whose records are subjectively evaluated, by instruments with automatically evaluated outputs, leads to a reduction in sunshine duration. One comparison of the two instruments used in the Swiss network shows that the reduction varied seasonally between 16% in a mid-summer month to 3% in a mid-winter month (Major, 1985). The authors need to present evidence that the change in instruments was not responsible for the changes they report.

We agree with the reviewer on the well-known effect of automation on the sunshine duration records. Nevertheless, in Switzerland the Haenni instruments were adjusted to the performance of the previous Campbell-Stokes recorders. We have added an additional reference in German (Baumgartner, 1979) where the comparison between both devices is detailed. Equally, we have slightly changed this paragraph in the Introduction in order to emphasize the reviewer's comment regarding the impact of automation on the measurements. In the revised manuscript the paragraph now reads as: "However, since the late 1970s and early 1980s all SD measurements have been automated in Switzerland, which might produce breaks in the time series (e.g. Major, 1986; Stanhill and Cohen, 2008). However, these new devices were adjusted to the performance of the Campbell-Stokes recorders after a comparison of both instruments (Baumgartner, 1979; Lindfors and Vuilleumier, 2005; L. Vuilleumier, pers. comm., 2011)."

In addition, in the manuscript we explain that in the homogenization of the sunshine duration data set we used some long-term homogenous series from the surroundings of Switzerland extracted from the HISTALP database (Auer et al., 2007). These additional series have been selected especially to check possible breaks around the 1980s as a result of the instrumentation change, as for these stations the Campbell-Stokes recorders were still in use during the 1980s. Additionally, these series have been previously homogenized as detailed in Auer et al. (2007). The sentences that summarize this information reads as: “Additional homogenous SD monthly series, provided by the HISTALP database (Auer et al., 2007), are used from Austria, Germany, France and Italy (Table 2) in order to support the homogenization of the monthly SD series in Switzerland” in Section 2, and “For the SD homogenization some stations in the surroundings of Switzerland have been used (Table 2), as previously detailed, especially to check possible breaks around the 1980s as a result of the instrumentation change.” in Section 3. Overall, no significant breaks are observed in the 1980s in the Swiss sunshine duration series, which confirm the reliability of the adjustments performed when the Haenni instruments replaced the Campbell-Stokes recorders.

Section 4 where possible the non-dimensional relationship between global radiation and sunshine duration presented in Table 3 should be supplemented with the conventional analysis to allow their results to be compared with previous studies and enable the uncertainties in the estimates of all and clear sky irradiances to be expressed in Wm^2

The conventional analyses dealing with the relationship between global radiation and sunshine duration have been applied using independent fits for each station. In this study we propose a method to estimate regional mean time anomalies series instead of individual time series that it is not the goal of our manuscript. These individual fittings are more sensitive to remaining inhomogeneities in the series, as well as local peculiarities and noise. Nevertheless, we have slightly changed this section and the Table 2 caption in in order to clarify the method.

On the other hand, we are planning to perform in the future a detailed analysis for the whole Europe in the framework of a project (<http://www.iac.ethz.ch/people/arturos/suncloud/>), including an estimation of the uncertainties in the estimates of all and clear sky irradiances.

Section 5 more detail is needed concerning the non-parametric Mann Kendall test of trend significance used. In particular were the data series pre-whitened as recommended (von Storch,1999) to remove the effect of auto-correlation common to most climate series and shown to exist in sunshine duration series?

We agree with the reviewer comment, but in the series with significant trends (Table 4 and 5) we found no significant values in the first (lag 1) autocorrelations, and consequently pre-whitened series do not change our conclusions. For some of the time series and periods with no trends a significant lag-1 serial correlation coefficient is found, but as the trend is not significant it is not necessary to assess its impact in the analyses. Nevertheless, we have included two new references in order to provide more information on the Mann Kendall test.

Section 6 Clear sky irradiance. The authors could compare their results with those obtained using the more direct approach suggested by Galindo Estrada and Fournier D’Albe (1960), an

approach supported by evidence for a common linear relationship between sunshine duration and direct beam irradiance in two very different radiation climates (Stanhill, 1998).

We appreciate the reviewer's suggestion, but unfortunately we have no access to measurements of direct irradiances to perform these analyses. Further research is needed in this area, and maybe in the future an assessment of the relationship between direct radiation and sunshine data will be performed for selected series over Europe with collocated long-term time series of both variables. Nevertheless, following the reviewer's comment we have included the references suggested by the reviewer in the Introduction of our revised manuscript, as well as slightly modified the sentence that now reads as: "This variable is considered an excellent proxy measure of direct solar radiation (e.g. Galindo Estrada and Fournier D'Albe, 1960; Stanhill, 1998), as well as of SSR at interannual and decadal scales (e.g. Stanhill, 2003, 2011; Stanhill and Cohen, 2001, 2005, 2008), and plays an important role in the description of the dimming and brightening and their uncertainties (Sanchez-Lorenzo et al., 2009; Wild, 2009, 2012)."