Atmos. Chem. Phys. Discuss.,
doi:10.5194/acp-2016-206-AC2, 2016

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Detection of dimming/brightening in Italy from homogenized all-sky and clear-sky surface solar radiation records and underlying causes (1959–2013)" *by* Veronica Manara et al.

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Received and published: 27 June 2016

Anonymous Referee #1 Review of ACPD manuscript entitled "Detection of dimming/brightening in Italy from homogenized all-sky and clear-sky surface solar radiation records and underlying causes (1959-2013)" authored by V. Manara et al. General remarks: Using surface observations of surface solar radiation in Italy during 1959-2013, long-term trend of surface solar radiation and its potential causes were studied. The current study has scientific solid approaches for providing data quality control, filling time gaps in the time series and homogenization of the data. The time series used

cover an adequate time span for such studies and the spatial distribution of the stations is good enough.

We would like to thank the referee for her/his comments and suggestions. The revisions suggested by the referee are addressed below. I suggest accept it after following issues are addressed.

1. REFEREE: One of most interesting features of this research is that the authors evaluated SSR trend under clear and cloudy skies to discuss aerosol and cloud effect separately. Clear sky is defined using cloud threshold of 1 okta, which is said to allow to select more samples of clear sky condition, however, there is no indication that how many samples each month are selected on average.

AC: The average of clear-sky days per station and month is 9% for the 0-okta threshold and 18% for the 1-okta threshold. These fractions are however higher in summer when SSR is more important, reaching the maximum value in July with 17% of 0-okta days and 34% of days with less than 1-okta cloudiness. We will add this information in Section 2.4 of the revised manuscript as suggested by the referee.

REFEREE: Additionally, when we use clear sky SSR measurements or departure to study long-term trend of SSR, we should keep it in mind that SSR varies to some extent with solar zenith angle that varies gradually. Suppose an extreme case, there are only two days selected at first two days in one January and last two days in another January, when we compare SSR values directly, variation of solar zenith angle on SSR may exert potential effect on SSR, so I suggest to use the ratio of SSR measurement to SSR at the top of the atmosphere in order to minimize solar zenith angle effect.

AC: The referee is right: the availability of a small number of clear-sky days could give rise to problems due to the fact that the solar radiation at the top of atmosphere changes within each month. For this reason, we obtained the clear-sky series with two thresholds: 0 okta and 1 okta. As we explained in lines 281-285, the advantage of the 0-okta threshold is that it allows to select only the real clear-sky conditions but the limitation of this choice is that it allows to select only a low number of days. On the contrary, using the 1-okta threshold allows to obtain a more stable series selecting a higher number of days, which are however not completely clear. The records obtained with these two thresholds show the same decadal variability (Fig. 6 of the manuscript) with correlation coefficients ranging from 0.86 to 0.97 in the North and from 0.87 to 0.95 in the South (line 269-271). Considering these results, we assumed that the problems due to the fact that the clear sky days may not be representative of the average monthly conditions are negligible. However, in order to further investigate this issue, we followed the suggestion of the reviewer and we obtained the regional clear-sky SSR records (0-okta threshold) transforming the daily station SSR data into clearness index data as first step of data analysis. The results give evidence of very similar records than those we obtained starting from the absolute value data. Figure 1 (reported below) shows the agreement between the records obtained with the two methods for the annual time scale. At seasonal level (not shown), the differences are slightly greater. However, they are comparable to the differences between the 0-okta threshold records and the 1-okta threshold records we show in Fig. 6 (of the manuscript). Moreover, the use of the records obtained using the clearness index does not give rise to significant differences for any of the values shown in Table 2 (of the manuscript).

2. REFEREE: Data homogeneity is a big issue for the evaluation of long-term trend, therefore, it is valuable for carefully evaluation of this issue, however, when we detect abrupt jump in the raw time series using some homogeneity analysis methods, it is very important to determine whether the jump is true or not based on metadata, so the authors should say some words on this issue.

AC: In order to homogenize our dataset we used a relative homogeneity test based on statistical methods supported by metadata information. Specifically, we compared, by means of the Craddock test (Craddock, 1979), each test series against 10 other reference series. This methodology is suitable to calculate correcting factors, but the identification of an inhomogeneity is not always easy and unambiguous (Brunetti et

al., 2006). For this reason, we homogenize a period only when more reference series give coherent adjustment estimates. In this way, we can be more confident that the inhomogeneity is “real” and ascribable to the test series and not to the reference series. The reference series that result homogeneous in a sufficiently long sub-period centered on the break year, are then selected to estimate the adjustments. We use several series to estimate the adjustments to increase their stability and to avoid unidentified outliers in the reference series from producing wrong corrections. By comparing the obtained breaks of each series with the corresponding metadata we found in most of the cases a reasonable agreement between the breaks indentified by the statistical method with the information reported by the metadata. We will clarify this point in the revised manuscript.

3. REFEREE: The corresponding author published results on sunshine duration in JGR, I’d wonder whether sunshine duration and SSR are consistency in interannual and decadal variations.

AC: There is another paper in preparation focused on the comparison between SD and SSR where the agreement/disagreement in interannual and decadal variability will be discussed and related to changes in other meteorological variables. Actually the issue is rather complex because it requires the analysis of additional variables besides SD and SSR (e.g. relative humidity) and we think it should be addressed in a specific paper (as we are doing) which aims to investigate the reasons which cause the two records to show specific patters in some periods and in some seasons. In this paper we refer to SD (Manara et al., 2015) in the Section 4 (lines 458-474) more as a support to our results than to compare the two variables.

4. REFEREE: It was suggested that mineral dust variations on SSR variability may be used to support that the dimming shown regional dependence, however, there is no indication whether long-term trend in the long-range transport of mineral dust from outside agrees with the observed dimming.

AC: Unfortunately, we have not found studies with this kind of information because the most part of studies on the long-range transport of mineral dust from outside report analyses for particular events and never for periods longer than few years (e.g., De Angelis and Gaudichet, 1991; Bonasoni et al., 2004; Gkikas et al., 2013; Pey et al., 2013). We compared the SSR records for Northern and Southern Italy with the Sahel Precipitation Index finding a good agreement with a high correlation coefficient for Southern Italy (lines 424-430). But this was not enough to establish a relationship between the SSR variability in Italy and the variability of mineral dust observed in the same area (caused by a variation in the concentration at the source but also by a variability in the long-range transport). However, we know from Maggi et al., (2006) that measurements of dust accumulation in Alpine snow (Colle del Lys, Italian Alps) give evidence of a clear increase of mineral dust since the early 1970s with high values after the 1980s. This suggested that the variation in the dust concentration observed at the source caused also a variation in the concentration of the dust transported in the Alpine region and, as a consequence, a variation of aerosol load over the Mediterranean area. Moreover, African dust is emerged as the largest PM10 source in regional background of the Mediterranean area (Pey et al., 2013) with a latitudinal variability both in intensity and frequency, with decreasing values from south to north (Gkikas et al., 2013). Combining all this information, we have hypothesized a higher contribution of mineral dust in the South than in the North and during spring, summer and autumn respect to that observed in winter (Pey et al., 2013) and we have hypothesized that this could be the reason of a stronger dimming in spring, summer and autumn in the Southern region than in the Northern region despite lower pollution. In any case, this point should be investigated in more detail in the future also using other variables, as for example visibility records.

Minor comments:

1. REFEREE: L66-76, there are a few other publications showing significant contribution of cloud to the interannual variation of SSR, for example, in China (Xia X., Spa-

tiotemporal changes in sunshine duration and cloud amount as well as their relationship in China during 1954-2005, JGR, 2010, 115, DOOK06, doi:10/1029/2009JD012879; Xia X., A closer looking at dimming and brightening in China during 1961-2005, Ann. Geophys., 201, 28, 1121-1132). Furthermore, in polluted region such as in Beijing metropolitan area, interannual variation of SSR may be also related to that of air pollution, which was supported by the fact that the correlation coefficient between interannual variation of SSR and AOD may range from -0.44 to -0.81 (Zhang et al., On the drivers of variability and trend of surface solar radiation in Beijing metropolitan area, International J. Climatol., 2015, 35, 452-461). This is not surprising since annual mean aerosol direct effect on SSR (24 Wm-2) is comparable to that of cloud effect (-42 Wm-2) in this polluted region (Li et al., Aerosol optical properties and their radiative effects in northern China, JGR, 2007, 112, D22S01, doi:10.1029/2006JD007382). Therefore, aerosol and cloud effects on interannual and decadal variation of SSR may depend on aerosol loading level that should be noticed.

AC: The referee is right. We will add these references in the revised manuscript in order to complete our description.

2. REFEREE: L89-90, Since aerosol loading is highly variable from year to year, interannual variation of clear sky SSR may be related to aerosol direct effect.

AC: The referee is right. We will revise lines 89-92 in a less ambiguous way. The point that we would like to underline is that African dust is the largest PM10 source in regional background of the Mediterranean and as a consequence it should be considered. We will clarify this point in the revised manuscript.

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Fig. 1: Average annual Northern (left) and Southern (right) Italian SSR records obtained under clear-sky conditions (0-okta threshold) plotted together with an 11-year window – 3-year standard deviation Gaussian low pass filter. The series are expressed as relative deviations from the 1976-2005 period. The blue line represents the records

obtained starting from the absolute daily station SSR data as already shown in Fig. 6 of the manuscript. The red line represents the records obtained transforming the daily station SSR data into clearness index data as first step of data analysis.

Interactive comment on Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2016-206, 2016.

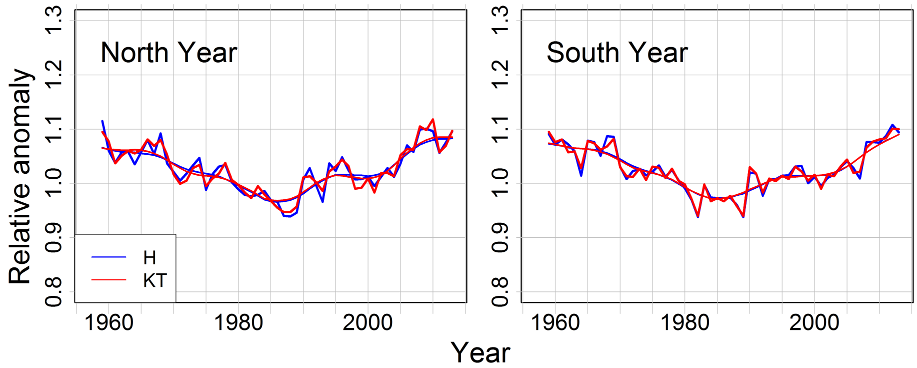

Fig. 1. See caption above