Comment on the paper “Characteristic time scales of decadal to centennial changes in global surface temperatures over the past 150 years ” by J.L. Le Mouël, F. Lopes and V. Courtillot First published: 14 October 2019 in Earth and Space Science

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Abstract

In their paper, Le mouël et al, (2019) argued that over the past 150 years “most of the variability of surface temperatures could be natural and primarily controlled by the Sun”. We do not agree with their conclusions for several reasons which are (1) a biased interpretation of the Fourier and SSA spectrum, which show no significant co-variability between sunspot amounts and emperature, (2) the small radiative forcing associated with the long-term sunspot variability, and finally the evidence that the slowly-varying components of the temperature and sunspots time-series show opposite trend in the last 30 years.

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Key Points:

- No compelling results showing a significant co-variability between sunspot amounts and temperature
- The radiative forcing associated to slow solar components (60 years, trend) is very weak over the past 150 years
- The global temperature and slow solar sunspots number components have opposite trend in the last 30 years

Abstract

Based on SSA analysis of global earth surface temperature and solar activity (sun spots) the authors suggest that the variability in earth surface temperature observed since 1850 is natural and controlled by the sun. We carefully read their article, but we cannot agree with their conclusions for several reasons exposed below: the lack of compelling results from the Fourier spectra and SSA estimates which are provided without confidence intervals, the small radiative forcing associated with the sunspot variability and finally the simple evidence that the slowly varying components of the temperature and sunspots time show opposite trends in the last 30 years.

First of all, the standard Fourier spectra of sunspots (ISSN) and HadCrut temperature (simply temperature hereafter) time series provided in Fig.1 and 11 by the authors look very different and do not seem at first sight to share any common significant peak. Moreover, the authors did not provide any confidence interval to allow meaningful conclusions. For this reason, we have recomputed the frequency spectra of temperature and ISSN sunspots to compare their relative amplitudes at different periods and provide a confidence interval (Figure A1 a and b). We used the Thomson multi-tapered method (Ghill et al, 2002) with a time-band width product of 3, a method which is well adapted to a spectrum which exhibits both continuous and singular components. Each spectrum was normalized by its signal variance to ease the comparison. The only significant peaks that exceed the 95% confidence interval level are the well-known 11-year peak and its harmonic at 5.5 years in the ISSN time series; but there is no corresponding significant peak at the 11 and 5.5 year periods or any other one in the temperature time series. The 60-year period shows unsurprisingly more energy in the temperature signal (the temperature, as many geophysical time series, is a ‘red signal’ with more energy at low frequencies). Still, we could not isolate a clear distinctive peak at this period on the temperature spectrum; nor on the ISSN one. This may be a limit of the spectral analysis, as the length of the time series is too short to single out a component at a period so close to its total length, but so far the frequency analysis did not suggest any significant common periods between the two time series.

Can we learn more from the SSA performed by the authors? Unfortunately, the SSA eigenvalues of the temperature and ISSN time-series computed by the authors suggest the same conclusion (Fig.A1 c and d): the dominant frequencies are completely different between the two time series; the temperature SSA is dominated by a 60-years eigenvalue which is simply absent in the ISSN SSA. The ISSN SSA spectrum is dominated by the 11-years component which emerges only at rank 15 in the temperature SSA spectrum (such a high rank is usually associated with noise). In addition, we do not have any indication whether these weak 22, 11 and 5.5 year components are even significant in the temperature SSA (by construction, the SSA method will produce peaks at single frequencies even in a purely random noise time-series). Although the SSA significance is not straightforward to assess, it could be have been tested using a Monte Carlo SSA test (Ghill et al, 2002). Since this crucial information is lacking, we can attempt to select the significant components by locating the slope break in the temperature SSA (Ghill et al, 2002): the idea being that there is a sharp break between the highest (significant) eigenvalues and the lowest un-significant ones. This suggests that all components shorter than 60 years period are not significant for the temperature, a conclusion that is consistent with the frequency spectral analysis.

So, if these short period components associated with the solar activity are likely not significant in the temperature series, is there a more robust signal for the longer periods? The main problem here is that the 60-year period that dominates the temperature SSA is absent in the ISSN SSA, as acknowledged in the paper. The authors managed to extract a 60 year component in the ISSN sunspot series by processing the SSA, as described in the beginning of section 4 (« The 60 year component does not show as such explicitly in the eigenvalue spectrum of ISSN… It is actually extracted from a re-analysis of the first component, i.e. the trend, again by changing the L value – L is the length of the time series - to one that is better adapted to long periods but not to shorter ones »). This methodology seems extremely obscure: the adapted L value is not given, making the result impossible to interpret or reproduce, and once again a confidence estimate is missing. In addition, the fact that the solar and temperature 60-year components are in phase before 1950, but out of phase in the 2000s (as noticed by the authors), makes it unlikely that one could cause the other. Finally, and not surprisingly since we are dealing with a “ further singular spectrum analysis of the trend”, the extracted 60 years component in the ISSN is extremely small (0.3 solar sunspot peak to peak) which literally corresponds to the thickness of the line if compared to the original time serie (fig11a). It is interesting in this respect to compare fig16 and 14 upper panels showing the reconstructed time series at 11 and 60 year periods for ISSN and temperature. The authors suggest that sunspots oscillations of amplitude of+/- 80 sunspots at the 11 years period induce temperature fluctuations of +/- 0.02°C, while much smaller oscillations of amplitude of +/- 0.15 sunspot at 60 years would induce much larger temperature fluctuations of +/- 0.15°C. This would represent a huge gain increase of the global temperature response of a factor of ~5000 for a solar forcing at a 60 years periods compared to the forcing at 11 years period, which seems physically unrealistic. This discrepancy was not discussed by the authors.

- Let us now consider the second point. The energy fluxes associated with the solar periodicities are unable to drive the earth surface temperature variations due to their low amplitude. The strongest sunspot variability (0-250 sunspots) occurs for a 11-year period and corresponds to a variation in the solar radiation of 1. Wm^{-2}, which implies a variability of the solar flux absorbed by the planet of 0.2 Wm-2 after taking the sphericity of the planet and its albedo into account. This is small compared with the anomalous energy fluxes due to anthropogenic greenhouse gas increase, which have been of the order of 2. Wm^{-2} since the pre-industrial era (IPCC 5th assessment report). This discrepancy only worsens when considering longer-term changes: the ISSN 60-year component has a very small peak to peak amplitude of at most 0.3 sunspots (fig 15); a one sunspot difference corresponds to 0.2/250 ~ 0.0008 Wm^{-2}, therefore the amplitude of this component is at most~0.3*0.0008=0.00024 Wm^{-2}, that is about four order of magnitude lower than the anthropogenic greenhouse effect. The sunspot trend is a bit larger: it reaches about a 16 sunspots difference over the 1850-2017 period, which corresponds to a small radiative addition of 0.013 Wm^{-2}, but this is still two orders of magnitude lower than the anthropogenic greenhouse gas effect over the same period. Moreover, the long-term trend of the ISSN sunspots was computed over 1700-2017 while the temperature trend over 1850-2017 (see Fig.20 caption) making any conclusions hazardous.

No physical mechanism is provided by the authors to explain how radiative forcing of such vastly different amplitudes whether comparing long-term solar to greenhouse effect, or to the 11-year solar cycle – could have comparable impacts on the global temperature. The Occam razor's principle--invoked by the authors would naturally lead to think that the radiative forcing from anthropogenic greenhouse gas increase, being orders of magnitude larger than the one from solar variability, would dominate the long-term temperature trends. Indeed, general climate models that include detailed radiative transfer calculations, and are forced by both observed changes in greenhouse gas concentrations and in solar forcing, show a very good agreement with observed temperature changes. As shown in the recent study by Hausfather et al (2020), since the earliest ones developed around the 1970s climate models have predicted the recent temperature trends with a correct amplitude, and consistently attributed it predominantly to greenhouse gases.

The main point of the Le Mouël et al paper was that the solar activity and global temperature time-series shared low-frequency components, and therefore -- in a big leap of faith -- the former should cause the latter: to quote them "When components are shared by two different time series, it is reasonable to assume that there is a common source to these variations, without having to know the full theory of that source" and in the conclusions "It could therefore be argued, as an application of Occam's razor, that most of the variability of surface temperatures could be natural and primarily controlled by the Sun "Obviously, correlation does not imply causality (or even common cause), and the authors provide no possible mechanism. But more than that, we showed that

- From a statistical viewpoint, no common significant frequency peak can be found in the temperature and sunspot time-series, whether analyzed with the SSA technique or with a standard spectral transform.

- From a quantitative, physical viewpoint, the sunspot fluctuations over longer periods (60 years up to long-term trend) are small and lead to radiative forcing two to four orders of magnitude smaller than the anthropogenic green-house effect.

As a concluding sanity check, we go back and compare in figure A2 the raw time-series of global-mean temperature and ISSN sunspot numbers. A quick glance immediately reveals that the two raw series behave completely differently: the temperature is slowly increasing (faster near the end of the record), while the solar activity is dominated by the 11-year cycle. An additional 11-year smoothing is then applied to the sunspot series to isolate its slowly varying component. It is clear that while the filtered sunspot series tracks the temperature for ~70 years between 1900 and 1970, a period when both are increasing, this is not true before 1900 (decreasing sunspots) and especially since 1970 when both are moving steadily in opposite directions. From this figure, the fit in the first half of the 20th century clearly looks like a coincidence, that does not even solve the energy flux amplitude discrepancy, or the lack of 11-year signal in the temperature time series.

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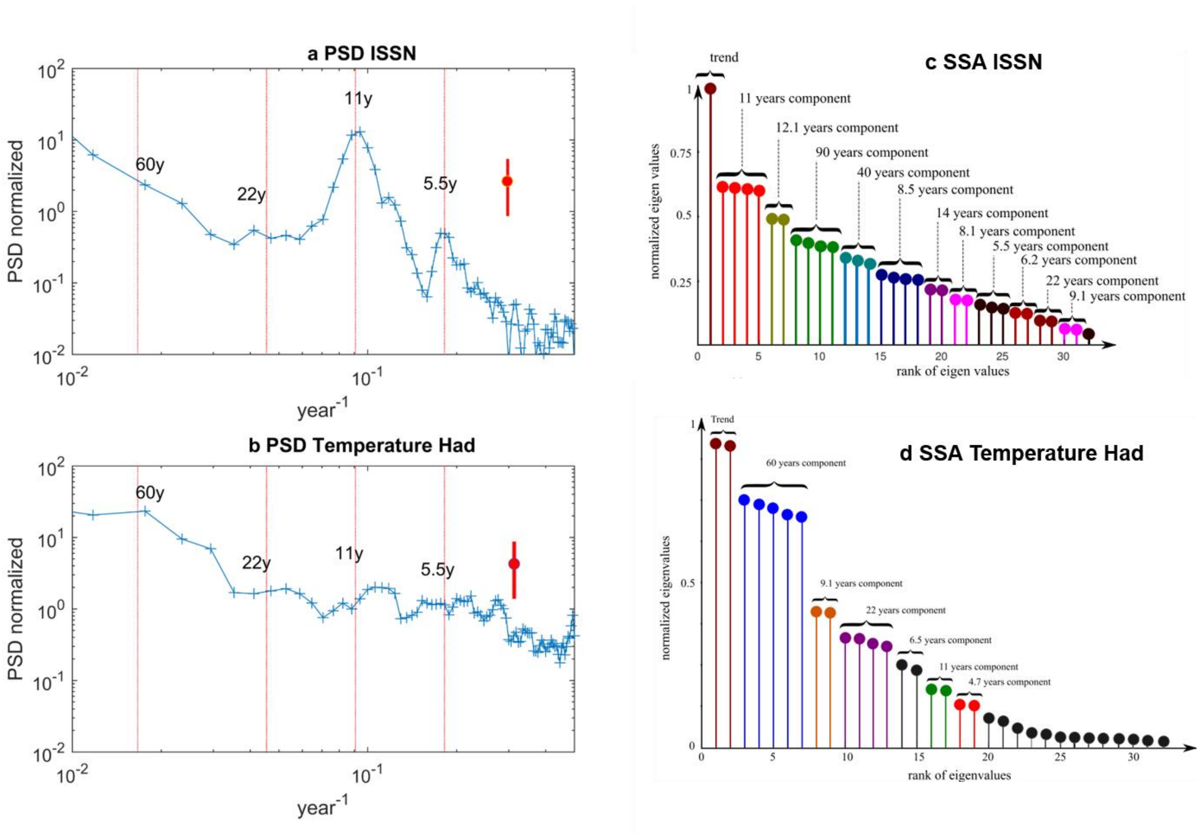

Figure A1 (a) Power spectrum of sun spots number (ISSN) using the Multi Taper Method with a time-bandwidth product of 3 (b) same for the HadCRUT temperature time series. The red bars in each case represent the 95% confidence. Vertical lines indicate the main periods (60, 22, 11 and 5.5 years) studied in Le Mouël et al (2019). (c) ISSN and (d) Temperature SSA components from L Mouël et la (Fig3 and Fig13) reproduced here for the sake of convenience.

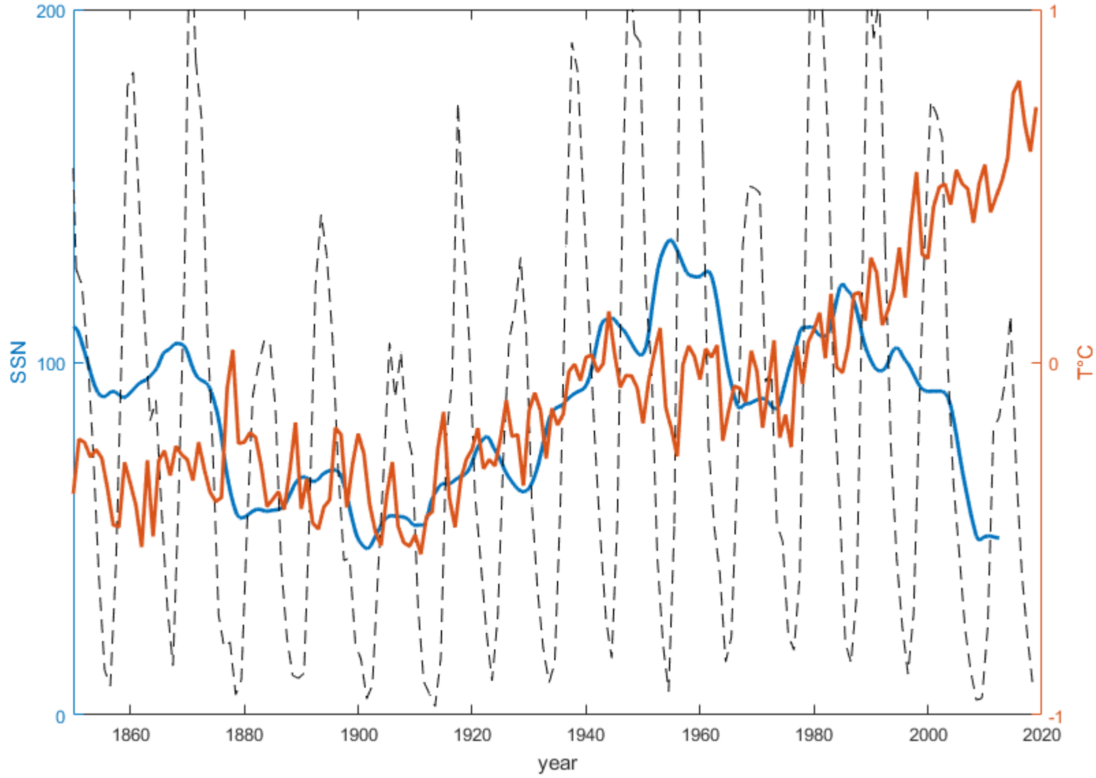

Figure A2 (a) ISSN (Solar sun spots) time serie (black dashed line) with 11 year sliding average (blue line), HadCRUT observed temperature time serie (orange).