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Interactive comment on "The Earth's climate system recurrent & multi-scale lagged responses: empirical law, evidence, consequent solar explanation of recent CO_2 increases & preliminary analysis" *by* J. Sánchez-Sesma

Anonymous Referee #2

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In this study, the author investigates the lagged response of the Earth's climate to various forcings, including solar and volcanic ones, with a particular focus on a presumed 9500-year recurrence pattern. This study is a continuation of a previous study by the same author, in the same journal. Most of the analysis is based on visual comparisons and correlations between various observables.

The quality of this study if well below the standards of rigorous scientific publications: it suffers from a large number of flaws, both technical and methodological. Most claims are lacking statistical evidence, and are not supported by physical explanations. For

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that reason I recommend to reject it without revision. Some general comments are listed below, with a few examples.

** Technical comments **

The overall structure of the article is very confusing and the common thread is hard to follow: some elements that are important for understanding the reasoning either are not discussed, or are deferred to the appendix. More generally, too many claims are made without any critical discussion (see methodological comments) and there is a frequent confusion between facts and assumptions.

This problem is aggravated by a poor presentation and sentences that are hard to understand, often because of improper use of technical terms. Here are some examples: - “period” occasionally refers to periodicity and then, to time scales; - “trend” refers to what seems to be a pattern; - “advected” (page 5, line 5) cannot be used to describe solar influence on climate; - “estimates of solar forcing spanning almost an order of magnitude” (page 5, line 3): this is not only vague but also incorrect (different scenarios of the total solar irradiance differ by approximately 1% or less).

On several occasions I have been struggling with English problems, and inconsistencies of the text, trying to understand what was meant. An example of a paragraph that is hard to understand is on page 7, lines 11-15.

There is an indiscriminate use of acronyms (also in figures) some of which are not explained, such as AMOC and GOC.

Several references are not appropriate or are cited out of context, e.g. Haigh et al. (2011) on page 5, line 10. Another one is Peterson (1993) on page 10, lines 8-18. Conversely, some important references are not cited, see below. There are other types of inconsistencies: what is the “climate-ocean group of the Max Planck Institute” (page 8, line 9)?

Most plots are of poor quality, with colour codes that make them hard to read, a mix

of fonts of all sizes, legends that look more like variable names from a computer code, axis units that are unclear, etc. For example, in Fig 3a, what are the units of the volcanic signal ? And in Fig. A1, what do the different equations correspond to ? Note that the coefficients have an unrealistic large number of digits. Equally annoying is the lack of effort to make the plots more easily comparable. Why, for example, not simply use a common time abscissa in Fig. 1 ? In addition, why is Fig. 2 shown twice (same as Fig. A1)?

The title is looooong and not catchy.

** Methodological comments **

Cherry-picking : on several occasions references are selectively chosen among those that support the conclusions of the article, ignoring the numerous other studies that contradict these conclusions, or provide a different view. An example is provided below.

Lack of statistical testing : much of the evidence for lags is based on handwaiving arguments, with no rigorous statistical results to support these. The apparent correlation that is seen in Figure 3 between solar and volcanic signals, for example, is not convincing. The literature is replete of plots showing similar time series, which are then abusively interpreted as causal connections. There are simple tools for estimating such lags between time series, and, more importantly, for determining whether these lags are significant or fortuitous. None of these tests are ever used in this study, which is simply not acceptable, given the conclusions that are drawn from these lags. One example is the correlation “seen” in Figure 3 between solar and volcanic signals.

Putting up a smokescreen where simple critical reasoning is required. In several parts the reasoning is difficult to follow because 1) not all pieces of information are provided (i.e. the results are not reproducible) and/or 2) the reader is misled by information that is uselessly complicated, or simply irrelevant. One example is the power law model (see below) which is not needed to link lags to periods. Another example is the list of models given in Equations 1 to 3, which are unnecessarily complicated for the purpose

of this article.

Inconsistent results and lack of physical foundation : several physical explanations are invoked without clear justification, or without support from other studies. For example, how could one “generate a kind of resonances between lagged responses and oceanic recurrent oscillations” (page 8, line 12) ? And how could a 10:1 resonance with orbital variations give rise to a ∼9500 year period ? Note also that the planetary influences that are invoked here have been severely criticized, see for example [Poluianov and Usoskin, Solar Physics, 289 (2014) 2333]. None of these references is cited, thus giving a biased view of the problem.

Errors : on several occasions, the results are simply incorrect. In Figure 4a, for example, the TSI records is replicated several times, as if it were periodic. What allows you to do that ? Another example is the Congo River basin surface air temperature: on page 6, line 5 you state that is independent of ocean circulation. On line 25 you say the opposite. Which is correct ? Note in addition that for detecting weak climate changes, proxies from the intertropical region are preferable to those from the tropical region. The main problem, however, is with the power law model, see below.

Since there is a strong focus on the “power law” model and on the 9500-year periodicity, let me address some issues here.

** Power law model **

First, there is no evidence for a power law scaling between period and lag because your exponent beta is so close to one. You could just as well fit your results with a simple linear model - use Occam’s razor.

Second, the model is based on the premise that the physical processes behind these (widely different) time scales should lead to the same response, or at least the same phase lag. This assumption is not substantiated by physical evidence. Actually it makes no sense to compare geological and climatological time scales.

Third, and worse, this model does not tell us anything new. Most quasi-linear systems that are forced by a periodic input will respond with a lag whose value (expressed in terms of the phase) will be between 0 and 2 pi because values larger than 2 pi are ambiguous. Actually, most values should fall between 0 and pi, otherwise one would speak in terms of anticorrelation. So it is quite normal to find most lags between 0 and pi. According to Table A1 your lags range from 0.9 to 1.9 rad. Therefore, there is nothing special with lags that line up linearly with the characteristic time scale. In this sense Figure A1 merely expresses a statistical result with no deep physical meaning. And it certainly does not allow us to estimate the lag associated with the presumed 9500-year oscillation.

Finally, the regression procedure is not detailed. More importantly, the text does not say how the confidence intervals - which are crucial in this context - are derived. One approach would be to use bootstrapping with total least squares. Apparently another procedure was used because I obtain different different confidence intervals. Table A1 mentions empirical error bars for the regressors only; note that the period also has large errors (probably even larger than for the lags), which should be included.

** 9500-year periodicity **

First, how can such a periodicity be meaningfully detected in a solar proxy whose total duration barely exceeds 11000 years ? On such time scales, cosmogenic indices are affected by changes in the geomagnetic field, whose precise evolution is still an active research topic. The long 10Be ice-core records that are used in SS16 cannot be meaningfully interpreted in terms of solar periodicities because changes in atmospheric transport may play an important role here.

Second, several experts in cosmogenic indices have already looked for periodicities in cosmogenic indices, see for example [McCracken et al., Solar Physics 286 (2016) pp. 609-627]. None of them was careless enough to look for periodicities beyond approximately 3000 years. None of these studies finds evidence for a 9500-year period.

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Third, in the discussion, when other observables do not show clear evidence for a ∼9500-year period, then resonances are invoked to reach that value. Given the large error bars, this means that almost any periodicity can be combined to yield a value that is close to 9500 years. This is not only absurd, but, in addition, no physical justification is given.

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