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Earth System Dynamics
Discussions

Interactive comment on "Multi-millennial-scale solar activity and its influences on continental tropical climate: empirical evidence of recurrent cosmic and terrestrial patterns" *by* J. Sánchez-Sesma

Anonymous Referee #2

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Dear Editor, The paper on the above subject by J. Sanchez-Sesma has been well written and I believe that it should be presented to the community at large with only a few minor additions in terms of additional references from the solar physics community. It addresses an ongoing discussion in the scientific community regarding the current declining solar activity and whether solar activity will die down in the near future to the level and duration, to justify it as being called a "Grand-Minimum" This paper on the other hand takes and entirely different line of thought in that it looks for long term signatures in solar activity, and identifies, based on empirical modelling of solar activity,

a 9500 year solar activity cycle which suggests "Grand Minima" like conditions for the period 2050-2250. There has been a significant amount of work in recent times among the solar physics community regarding this issue and the author being a climatologist has missed some of these contributions, which would add greatly to the overall impact of the paper. I list here some of the important contributions that may be cited by the author to make a much more convincing case. For example, Janardhan, Bisoi and Gosain, Sol. Phys., 267, 267-277 were one of the first to report a steady and systematic decline in solar polar magnetic fields starting from around 1995. Later work, (Janardhan, et al., (2011) Geo. Res. Lett, 38, L20108) showed that the decline in solar magnetic fields was mirrored in the solar wind, by a similar decline in solar wind micro-turbulence levels. A study of the consequences of this decline on the earth's ionosphere showed that itsignificantly reduced the ionospheric cut-off frequency to radio waves, normally about 30 MHz, to well below 10 MHz (Janardhan et al. (2015) Sun and Geosphere (in press)). The most recent report (Janardhan et al., (2015) J. Geo. Res. 120, 5306-5317) has shown that the decline in solar activity has to continue at least until 2020 and there is a good posibility of the onset of a Grand solar minimum from solar-cycle 26 onwards (2031). In addition, Choudhuri, and Karak (2012), Phys. Rev. Lett., 109,171103, and Karak, and Choudhuri (2013), Res. Astron. Astrophys., 13, 1339, used 11000 years of sunspot data derived from carbon 14 records in tree rings and showed that gradual changes in solar surface meridional flow velocity lead to a gradual onset of grand minima while abrupt changes lead to an abrupt onset. In addition, these authors also showed that one or two solar cycles before the onset of grand minima, the cycle period tends to become longer. It is noteworthy that surface meridional flows over Cycle 23 (Hathaway, and Rightmire (2010), Science, 327, 1350) have shown gradual variations and Cycle 24 started _1.3 years later than expected. There is also evidence of longer cycles before the start of the Maunder and Sporer minimum.

I would also like to point out that 10Be is a much better proxy for solar activity than Carbon 14 as it has a very short residence time in the atmosphere compared to carbon

14 and therefore it is good that the author has used 10Be records rather than Carbon 14 which is prone to larger errors. However, it must be noted that the abundance of 10Be in polar ice is also affected by local climate processes and atmosphere air mass mixing (Kocharov et al. 1989; Radiocarbon, 31, 163; McHargue & Damon 1991, Rev. Geophys., 29, 141). The climatic effect though is minor for polar sites (particularly for the South Pole) where 10Be most closely retains cosmic ray signal (Raisbeck et al. 1981, Geophys. Res. Lett., 8, 1015; Bard et al. 1997, Earth Planet. Sci. Lett., 150, 453). My concern therefore is regarding the reconstructions made from different reservoirs, eg. ice cores from Greenland will be greatly affected by climatic changes especially during the Holocene. Also, the interior of Greenland experiences mostly “dry” gravity aided deposition of 10Be carrying aerosols while in the coastal belt the deposition processes is wet deposition. Have the authors taken these constraints into consideration while looking at the data ? Could they comment on this.

Another often discussed issue in connection with long term solar activity is that very often, one finds that cooling events have been attributed to reduced solar magnetic activity due to the corresponding enhanced cosmic ray flux at earth. This is an effect that is very hard to pin down because it connects to cosmic rays which charge aerosols, which in turn are more efficient in cloud seeding, thereby producing enhanced cloud cover and albido, leading to cooling. H.H. Lamb’s winter severity index has often been used to show severe cooling over Europe during the Maunder minimum. However, it is known that this cooling was confined to Europe and was not global. Also, a plot of Lamb’s winter severity index will show that the two coldest decades in the record are not associated with solar minima and the Dalton and Maunder minimum gradually warmed over the period of the minimum. So I’m glad that that the author has not added this aspect in the paper. This is just a comment and requires no response from the authors.

In conclusion, I agree entirely with the author that looking for short term signatures or time scales of practical consequences i.e. in years is in essence "missing the forest

for the trees". One needs to look at long term signatures and this study by the authors has yielded the first multi-millennial scale solar activity oscillation which is modulated, as the author suggests, by solar dynamics, essentially the solar dynamo and helio-seismology, with long term patterns. This is a significant step forward in gaining an overall perspective of the sun climate system and I hope the solar community can now take this forward.

Interactive comment on Earth Syst. Dynam. Discuss., 6, 1237, 2015.