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Solar activity and climate change during the 1750 A.D. solar minimum

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The number of sunspots and other characteristics have been widely used to reconstruct the solar activity beyond the last three decades of accurate satellite measurements. It has also been possible to reconstruct the long-term solar behavior by measuring the abundance on Earth of cosmogenic nuclides such as carbon 14 and beryllium 10. These isotopes are formed by the interaction of galactic cosmic rays with atmospheric molecules. Accelerator mass spectrometry is used to measure the abundance of these isotopes in natural archives such as polar ice (for 10Be), tree rings and corals (for 14C).

Over the last millennium, the solar activity has been dominated by alternating active and quiet periods, such as the Maunder Minimum, which occurred between 1645 and 1715 A.D. The climate forcing of this solar variability is the subject of intense research, both because the exact scaling in terms of irradiance is still a matter of debate and because other solar variations may have played a role in amplifying the climatic response. Indeed, the past few decades of accurate solar measurements do not include conditions equivalent to an extended solar minimum. A further difficulty of the analysis lies in the presence of other climate forcings during the last millennium, which are superimposed on the solar variations. Finally, the inherent precision of paleotemperature proxies are close to the signal amplitude retrieved from various paleoclimate archives covering the last millennium.

Recent model-data comparisons for the last millennium have led to the conclusion that the solar forcing during this period was minor in comparison to volcanic eruptions and greenhouse gas concentrations (e.g. Schurer et al. 2013 J. Clim., 2014 Nat. Geo.). In order to separate the different forcings, it is useful to focus on a temperature change in phase with a well-documented solar minimum so as to maximize the response to this astronomical forcing. This is the approach followed by Wagner et al. (2005 Clim. Dyn.), who focused their data-model comparison on the Dalton Minimum, which occurred between 1790 and 1830 A.D. and which, fortuitously, included several major volcanic eruptions such as the Tambora eruption in 1815. Their conclusion was that the global imprint of the volcanic forcing was significantly larger than that of contemporaneous solar forcing and the increasing atmospheric CO_2 concentrations.

A different approach is to consider another recent solar minimum over a period characterized by a low volcanicity and minimal changes of greenhouse gases. Such a minimum does exist between the Maunder and the Dalton Minima and lasted for a mere two decades between 1745 and 1765 A.D. The sunspot number exhibits a clear 11-year cycle, but it only reaches a maximal value lower than 100, i.e. less than observed for the past seven 11-year cycles. Incidentally, the maximal values observed between 1745 and 1765 are similar to those observed during the maximum of the present solar cycle.

The 1750 A.D. solar minimum can also be studied in other records such as counts of auroras at mid-latitudes and cosmogenic isotopes such as 14C and 10Be. In addition to reviewing published time series, we will report a new 10Be record from a well-dated ice core from Dome C in Antarctica. Sulfate concentration, a proxy for volcanic eruptions, has also been measured in the very same samples, allowing a precise comparison of both 10Be and sulfate profiles. The full record covers the last millennium and will be presented separately by Baroni, Bard and the ASTER Team. Zooming in on the century between 1700 and 1800 A.D. allows to identify an extended period of low volcanicity and to observe a clear 10Be increase corresponding to the solar minimum. We will present the new data over the 18th century as well as their first interpretation in the context of other useful records based on greenhouse gas concentrations, paleotemperature proxies and climate modeling available in the literature.