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A solar pattern in the longest temperature series from three stations in Europe

Jean-Louis Le Mouël [a], Vladimir Kossobokov [a b], Vincent Courtillot [a]

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Abstract

We analyze the longest temperature series from Prague, Bologna and Uccle. We partition daily minimum and maximum temperatures and their differences in two subsets as a function of high vs low solar activity, using the superimposed epochs method. Differences display patterns with significant amplitudes and time constants ~3 months. These are recognized in all stations and are stable against a change in the analyzed period. Amplitude of variations is ~1 °C. Differences between average annual values corresponding to high vs low activity periods are also ~1 °C. Solar activity may account for these long-term temperature variations. These variations also present local characteristics, which may render identification of a global correlation delicate. We discuss possible physical mechanisms by which solar variation could force climate changes (e.g. through solar activity itself, the EUV part of the solar flux, cosmic rays, the downward ionosphere-earth current density, etc.).

Introduction

There is a strong interest in the recent evolution of climate on Earth, at both the global and more regional scales. The 2007 IPCC report illustrates mean global temperature anomalies since 1850 for each main continent, for the overall continental set, for oceans and for the entire globe (Figure SPM-4 of the Working Group 1 part of the IPCC Fourth Assessment Report, 2007). All these curves display significant warming, which is mainly attributed to the recent increase in anthropogenic greenhouse gases (GHGs) release. Indeed, current physical understanding argues for a much larger contribution of CO_2 to the general heat budget than variations for instance of total solar irradiance (but see Lindzen and Choi, 2009). We recently re-analyzed temperature data from Europe and North America (Le Mouël et al., 2008), with particular focus on temperature variability. We provided evidence that temperature variability is modulated by solar activity, estimated using the classical sunspot numbers or other classical (aa index) or less classical (range of daily variations of geomagnetic field components; Le Mouël et al., 2005) proxies.

This has led us to analyze in more detail series of daily temperature data in another way, in order to search for statistically significant changes in evolution of these temperatures. This is feasible only if one can obtain very long time series of high quality data. We are fortunate that the European Climate Assessment dataset (Klein Tank et al., 2002), available at http://eca.knmi.nl/, contains three long, high-quality series: non-blended data on temperatures recorded at Praha-Klementinum (Prague), Czech Republic, from 1775/01/01 to 2005/04/30 (source id 100079 for daily minimum temperature TN and 100081 for daily maximum temperature TX), Bologna, Italy, from 1814/01/01 to 2000/12/31 (source id 100548 for TN and 100549 for TX), and Uccle, Belgium, from 1833/01/01 to 1999/12/31 (source id 100044 for TN and 100045 for TX). These are the three longest series of the ECA database with no missing data for durations (respectively) of 230, 187, and 167 years. TN and TX values are all of the highest quality code in ECA at each of the three locations. We have used non-blended daily data, that is raw data taken at face value, without making further tests of data quality. But we have not used data resulting from some form of model prediction calculated from fragmentary observations. It is a general observation that one must trust the way ancient observers did the maximum they thought possible to obtain the best data, since many of the details of instrument and baseline control are only rarely reported. This is true with meteorological or magnetic observatories, and may remain partly true up to fairly recent times. The longest series of non-blended data in the data bases is indeed from Praha-Klementinum (http://www.chmi.cz/meteo/ok/klemhiste.html↗). Although regular measurements there began in 1752, they were not the first instrument-based records. But earlier observations were not systematic, often not published and their records preserved in private letters or parish chronicles. Measurements remained fragmentary until 1774, and the beginning of the series we use is on January 1, 1775. From then on, air temperature was measured twice a day: in the morning, either at sunrise or in summer 2h after sunrise, and in the afternoon around 3 pm. The two ECA series are continuous and free of gaps as viewed against modern criteria, and start a few years before the invention of the maximum–minimum thermometer: James Six introduced his U-tube thermometer in 1782. Meteorological observations have continued at the Klementinum to this day and although they have naturally been influenced by a number of factors (exact location of measurement, urban growth effect, changes in instruments), they represent a quite unique and valuable source of information on weather and climate over two and a half centuries. One may wonder why we have not analyzed here the very long series of central England temperatures (Parker et al., 1992): the reason is that the non-blended data in that series start only in 1881 (see also Klein Tank et al., 2002).

The top line of Fig. 1a shows daily minimum temperature data in Prague (in blue) and a centered 3-year average (in red) at the same scale, illustrating the large amplitude of short-term and annual variations compared to longer-term variations. Respective amplitudes range from 40 °C for raw data to 3 °C for the smoothed data and underline the need for careful statistical treatment to extract meaningful long-term properties of the data sets. The second to fourth rows of Fig. 1a display at a larger scale the 3-year centered moving averages of the minimum daily temperature series from (from top to bottom) Prague, Bologna and Uccle. Fig. 1b displays a similar set of frames for the maximum temperatures. A feature that is common to all plots and the subject of much ongoing research is the warming (or positive trend) in the last half to quarter of the 20th century. But there are also significant differences between stations. The respective behaviors of the TN and TX curves in Prague are rather similar, in terms of both decadal to centennial (or secular) trends and shorter-term features, such as the sharp 1940 temperature minimum or step-like increase around 1987, both found to be a general signature of 20th century European climate (Le Mouël et al., 2008). On the other hand, the two TN and TX curves at the other two stations differ significantly, for instance from 1865 to 1880 in Bologna, when a large flat positive anomaly of 2 °C lasting 15 years is seen in TX and not in TN; we have no evidence of human-induced changes that would lead us to consider this feature as an artefact. Another observation is that from 1950 to 1980 in Uccle the decadal trend is positive for TN but negative for TX. It is well-recognized that climate evolution, and notably temperature evolution, is a mix of more smoothly varying regional features (responses) with more local ones, with high spatial variability (e.g. Hartmann, 1994; De Jager, 2005).

In order to analyze whether we can detect any significant contributions to temperatures that could be linked to variations in solar activity, we use the sunspot (Wolf) number as a proxy. The longest time series of values is available at the world data center for the sunspot index at the Royal observatory in Brussels (http://sidc.be/sunspot_data/↗). Fig. 2 shows the annual average of the sunspot series from 1775 (that is the onset of the longest temperature series in Prague) to 2005. Sunspot cycles are actually longer than the interval between successive minima and sunspots of two successive cycles overlap. For instance, we are currently in a deep solar minimum and the few spots and flares observed could be attributed to either cycle 23 or 24. We chose to avoid the fuzzy classification of time that would result from taking this into account. It is a very minor effect, since in the case of Prague only 6 out of 230 years could be affected (see Table 1 and Fig. 1).

We first introduce a number of partitions of the Prague data set as a function of the amount of solar activity indicated by solar cycles. We then analyze the annual signature of maximum and minimum temperatures (along with their difference and the first time differences of the three) belonging to partitioned sets (that is 5 different time series for each station) as a function of calendar date. We next perform the same analyses on the Bologna and Uccle stations and describe common results and differences. The paper ends with a discussion section.

Section snippets

Splitting temperatures and temperature variations into high- and low-solar activity subsets (the case of Prague)

We split the solar cycles themselves into cycles of low and high activity. The generally accepted dates of onsets (and terminations) of solar cycles 3–23 are from http://sidc.be/sunspot_data/ ↗ (see also Table 1). We use the number of sunspots for each year $n(i)$, then sum up the total number of sunspots in each one of the 21 cycles under consideration ($N_j = \Sigma n(i_j)$ for all years i_j belonging to cycle j). The median M of the 21N_j values is equal to 618.4. High-activity cycles are defined as those for …

Analysis for Bologna and Uccle

After having tested our method on the longest available series, that from Prague, it is important to see whether it carries to other locations. For this, we present in this section the results obtained with the other two stations with the next longest series of observed temperatures, i.e. Bologna and Uccle. The three stations may in a way represent the European oceanic (Uccle), central European (Prague) and Mediterranean (Bologna) climatic regions of Europe. Both common and different features…

A connection between temperature, temperature variation, and solar forcing

Splitting long series of daily temperature data according to the level of solar activity as defined in this paper reveals statistically significant patterns, which it is reasonable to interpret as the signature of a solar effect on these temperatures. Should this signature be attributed to another cause, this cause would have to still be present in the rather complex time distribution of high versus low solar cycles (Fig. 2). Two consequences should be emphasized at this point.

(a) The average…

Discussion and conclusion

In recent papers, we have focused on temperature perturbations (which can also be called activity, or variability), which we have measured using inter-annual squared variations or lifetimes (e.g. Le Mouël et al., 2008). Using these tools, we have shown the existence of solar effect contributions to temperature perturbations (at least in Europe and in the USA—Le Mouël et al., 2009; Courtillot et al., 2009): a rather clear correlation with a number of solar proxies (sunspot numbers, aa index,…

Acknowledgements

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2018, Journal of Atmospheric and Solar-Terrestrial Physics

> *Citation Excerpt :*
> …The solar influence on climate cannot be directly measured, but correlations between the solar activity and climate parameters were found, such as the well-known correlation between the mean temperature of the Northern Hemisphere and the length of the solar cycles, published by Friis-Christensen and Lassen (1991). Recently, many studies focused on the Sun – Earth's climate relationship, providing statistically significant signatures of solar activity changes on climate at the 11-year solar cycle timescales (Bucha and Bucha Jr., 1998; Cliver et al., 1998; Bucha and Bucha Jr., 2002; Le Mouël et al., 2005; El-Borie and Al-Thoyaib, 2006; Valev, 2006; Courtillot et al., 2007; Le Mouël et al., 2008; Le Mouël et al., 2009; Dobrica et al., 2009, 2010; Courtillot et al., 2010; Le Mouël et al., 2010; Yiou et al., 2010). The analyses of long-term instrumental temperature records for highlighting long period variations have shown clear appearances of variations on timescales of about 2.2–2.4 years and of 3–4 years, but on longer timescales, individual records showed peaks at different frequencies (Haigh, 2007; Johnson, 2009).…

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Possible effects of atmospheric teleconnections and solar variability on tropospheric and stratospheric temperatures in the Northern Hemisphere

2014, Journal of Atmospheric and Solar-Terrestrial Physics

> *Citation Excerpt :*
> ...Correlations between temperature anomalies and solar proxies have also been found at regional level. In a study of several temperature time series at various European locations, Le Mouël et al. (2009, 2010) found that correlation coefficients between local temperatures in Europe and solar variations exist. Their results have been criticized by Legras et al. (2010); however, correlations between temperature and solar proxies have been found in various other regions....

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Variability of rainfall and temperature (1912-2008) parameters measured from Santa Maria (29°41'S, 53°48'W) and their connections with ENSO and solar activity

2012, Journal of Atmospheric and Solar-Terrestrial Physics

> *Citation Excerpt :*
> ...The search for possible influences of solar activity on the different meteorological or climatological parameters is one key element that has been widely used to prove the Sun–climate connection. The literature contains an extensive history of this issue (Rigozo et al., 2004; Valev, 2006; Kilcik et al., 2008; Dobrica et al., 2009; Souza Echer et al., 2009; Le Mouël et al., 2010). Despite the scientific works supporting the view that meteorological phenomena must respond to variations of solar activity, this subject is far from being settled (Tsiropoula, 2003; Lockwood and Frohlich, 2007)....

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Geomagnetic South Atlantic Anomaly and global sea level rise: A direct connection?

2012, Journal of Atmospheric and Solar-Terrestrial Physics

> *Citation Excerpt :*
> ...This might explain also the minor agreement of SAA area with the global mean temperature and also a remaining solar effect. In principle, Eq. (6) could be used to obtain an approximate estimate of the change of temperature from the change of SAA area, although we cannot exclude here other factors (e.g. production of greenhouse gases in the atmosphere from anthropic activities or some form of solar forcing—e.g. for the latter see Le Mouël et al., 2008, 2009, 2010) influencing the mean global temperature as well as the SAA. In this paper we have compared the sea level change over the last 300 years with the surface area of the SAA, in terms of area enclosed by the 32 000 nT isoline from 1700 to the present....

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2010, Journal of Atmospheric and Solar-Terrestrial Physics

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