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Evolution of seasonal temperature disturbances and solar forcing in the US North Pacific

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Abstract

We analyze the long-term evolution of seasonal temperature disturbances in a 2.5×2.5° area of the US North Pacific. Late Fall and early Winter display significant correlation of temperature disturbances and are investigated in detail. The long-term evolution of the Fall temperature disturbances from 1945 to 2008 closely follows that of solar activity. The robustness of these results is successfully controlled in a 2.5×2.5° area immediately north of the studied region. The modulation of temperature disturbances is very large (~30%) compared to the corresponding changes in solar irradiance, and has significant variability, even at small geographical scale. The physical mechanism of solar forcing of temperature disturbances remains to be understood, but a relation with cloudiness and influence of the Madden–Julian oscillation in the North Pacific is suggested.

Introduction

Although the Sun played a dominant role in pre-industrial climate change (e.g. Lean and Rind, 1999; Solanki et al., 2004; Usoskin et al., 2005; Scafetta and West, 2007; see also reviews by de Jager, 2005; Kane, 2005), causes of climate variability in the 20th century and identification of natural vs. anthropogenic contributions are a subject of ongoing debate. The current majority view holds that anthropic addition of greenhouse gases is principally responsible for “anomalous” global warming in the 20th century (IPCC, 2007). Other contributions to this warming, in particular solar influence, are generally considered negligible. Various authors, however, have argued for some significant amount of solar influence (e.g. Marcus et al., 1999; Solanki et al., 2004; Le Mouël et al., 2004; Foukal et al., (2006); Kamp and Tung, 2007; Scafetta and West, 2007). De Jager (2005) points out that, due to the extremely complex nature of the Earth's climate system, evidence for a solar signature may be highly heterogeneous in both time and space. The same author recently argued for strong links between solar activity and climate (de Jager, 2008).

In earlier work (Le Mouël et al., 2008), we analyzed temperature data from 153 meteorological stations in 6 climatic regions of the USA and 44 stations from Europe. We selected stations with long, homogeneous series of daily temperature, covering most of the 20th century with few or no gaps. We monitored the long-term behavior of temperature disturbances by calculating the mean-squared inter-annual variations or a related parameter, the “lifetime” (akin to the mean duration of temperature disturbances) of the data series. We found that the resulting curves correlated remarkably well at the longer periods, within and between the regions we analyzed. The multi-decadal trend of all of these curves is similar, with a rise from 1900 to 1950, a decrease from 1950 to 1975 and a small subsequent increase. This trend is the same as that found for a number of solar indices, such as sunspot number. We concluded that significant solar forcing is present in temperature disturbances in the areas we analyzed. In a subsequent study (Le Mouël et al., 2009a) of daily temperature and pressure series from 55 European stations, we provided further evidence of significant solar forcing of short-term variations in European temperature lasting up to the Present. Evidence was particularly strong when the winter period January–February, corresponding to the highest disturbances, was considered. The relationship between solar forcing and European climate is not stationary over a year, but strongly depends on the season. The solar signature was found to be present all over the 20th century in the wintertime European temperature disturbances, linked to the persistent winds blowing from the Atlantic Ocean to Europe. Squared temperature disturbances were shown to vary by a factor reaching 1.5 over the 20th century. The regional and seasonal approaches used by (Le Mouël et al., 2009a) were essential in extracting the signatures of solar forcing.

Recently, Bond and Vecchi (2003) have shown that atmospheric circulation anomalies over the North Pacific Ocean and precipitations in California, Oregon and Washington in the period from 1979 to 2000 were systematically affected by the Madden–Julian oscillation (MJO) in both early Winter (OND) and late Winter (JFM). The phases of the MJO that promote enhanced precipitation are substantially different between these two seasons. Temperature disturbances in the NW US region are strongly influenced by the Pacific Ocean. In Europe, they are strongly influenced by proximity of the Atlantic Ocean. Both regions are influenced in a similar way by Arctic blocking (Diao et al., 2006), on one hand, and by tropical circulation realized via the NAO in Europe (Hurrell et al., 2003) and the MJO in the North-East Pacific (Zhang, 2005), on the other hand. These similar boundary positions make temperature disturbances in both regions very sensitive to any change in the equilibrium of the global climate system.

The above considerations have led us to try and extend our previous analyses from, mainly, Europe (Le Mouël et al., 2008, Le Mouël et al., 2009a) to the NW US region analyzed in detail by Bond and Vecchi (2003). In the present paper, we therefore study the evolution of surface temperature disturbances in Oregon and Washington and test the significance of correlations between the evolutions of climate disturbances and solar activity. With this goal in mind, we analyze in detail a set of 24 meteorological stations in a 2.5×2.5° area of Oregon and southern Washington states in the USA. Another set of 29 stations in the 2.5×2.5° area immediately to the north, in Washington state and Canada, is used as a supplementary control. More precisely, we analyze minimum daily temperature data from essentially the same regions, and over the same seasons as Bond and Vecchi (2003).

We first describe the data and sources we use, then the methods: we use the methods described in our two previous papers, i.e. we monitor temperature disturbances using the mean-squared inter-annual variations and a related parameter, the “lifetime”, which is discussed further below and is defined in detail in the appendix of Le Mouël et al. (2009a). Both squared annual variation and lifetime give similar results most of the time, but lifetime is often more stable. Lifetime is a measure of the memory of a random process, and in the present case of the residence time of strong disturbances. Similar methods have been successfully used by Blanter et al., 2005, Blanter et al., 2006. We describe the seasonal variability of temperature lifetimes, and discuss their possible significance in terms of sources of forcing of the multi-decadal behavior which we evidence.

Section snippets

Temperature data and associated lifetimes

We use all minimum daily temperature series T_{min} which have at least 70 yr of data from the global historical climatological network (GHCN-DAILY, ftp://ftp.ncdc.noaa.gov/pub/data/ghcn/daily ↗). They are readily obtained through the KNMI Climate Explorer gateway (available via http://climexp.knmi.nl/ ↗). The first set of data contains 24 T_{min} series with latitudes ranging from 44 to 46.5°N, and longitude between −124.0 and −121.5°E. The time span covered by more than one record goes from 1894 to…

Seasonal variability of temperatures and lifetimes

Analysis of variability of temperatures using the classical method of superimposed epochs (all values of the data series for the first day of the year are averaged and assigned to day 1 and so on for all days of the year) shows that most of the variance in temperature disturbances occurs in the late Fall and early Winter (Fig. 2a): lifetimes are significantly larger from mid-October to mid-March. This corresponds to the OND and JFM seasons selected in their study of the same area by Bond and…

Results

We now focus on the 1945–2008 period, in which we select the two seasons which demonstrate the most significant overall mean correlation with all others, i.e. late Fall (October 5–December 5) and early Winter (December 15–February 15; vertical dashed lines in Fig. 2). This is quite close to the 3-month long cold seasons OND and JFM of Bond and Vecchi (2003), and Fig. 2b provides physical support for selecting these particular seasons as having the largest correlated lifetimes. Fig. 3 shows (for …

Discussion

The long-term evolution of seasonal temperature disturbances shows a significant increase in the coherence of different stations and seasons after 1950. There are at least two possible and non-exclusive explanations of these observations: insufficient data quality or lower and non-stationary solar activity prior to 1950. The first hypothesis finds support in the amount of gaps and increasing number of stations providing temperature data, which reaches 75% of the total number of stations only…

Acknowledgements

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Recommended articles

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Space Sci. Rev. (2005)

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Inferring geoeffective solar variability signature in stratospheric and tropospheric Northern Hemisphere temperatures

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

Show abstract

A correlation of mean period of MJO indices and 11-yr solar variation

2012, Journal of Atmospheric and Solar-Terrestrial Physics

> *Citation Excerpt :*
> …Evidence of these diverse impacts of MJO on the global climate system warrant further investigation of the phenomenon and its possible role in climate forcing. In previous papers, we have been able to identify a solar signature in the long-term evolution of seasonal temperature disturbances of the European and North Pacific regions (Le Mouël et al., 2009; Courtillot et al., 2010). These are known to be influenced by MJO activity during the same seasons (Winter in Europe and Late Fall in the North Pacific) in which we evidenced a solar signature (e.g. Higgins and Mo, 1997; Bond and Vecchi, 2003; Vecchi and Bond, 2004; Cassou, 2008) and it is reasonable to expect that MJO could impart a significant contribution to these regional disturbances of temperature.…

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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 most cited natural phenomena affecting the long term variability of climate has been the El Niño. Southern Oscillation and solar activity (Wang et al. 2000; Nuzhdina, 2002; Haigh, 2003; Raspopov et al., 2004; Souza Echer et al., 2008, 2009; Courtillot et al., 2010; Le Mouël et al., 2010). The El Niño Southern Oscillation (ENSO) phenomenon is a result of complex interaction between the atmosphere and the hydrosphere in the tropical Pacific (Cane, 2005).…

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A note on comments on papers published in Journal of Atmospheric and Solar-Terrestrial Physics and our responses

2011, Journal of Atmospheric and Solar-Terrestrial Physics

Temporal derivative of Total Solar Irradiance and anomalous Indian summer monsoon: An empirical evidence for a Sun-climate connection

2011, Journal of Atmospheric and Solar-Terrestrial Physics

> *Citation Excerpt :*
> …Meehl and colleagues mainly show that although globally averaged solar forcing at the top of the atmosphere of 0.2 W m−2 is too small to affect the climate system, but that locally, through both cloud-free region in subtropical Pacific and coupled air–sea mechanism that ultimately creates even larger cloud-free region (figure 4 in Meehl et al., 2008), the net solar flux at the surface can often has values at least a factor of 5–10 times larger than the top of the atmosphere forcing. Several other researchers have also carefully evaluated and highlighted the complex pathways and processes that may be involved in physical Sun–climate relations (van Loon et al., 2004; Perry, 2007; Miyahara et al., 2008; Usoskin and Kovaltsov, 2008; Mendoza and Velasco, 2009; Courtillot et al., 2010; de Jager et al., 2010; Harrison and Usoskin, 2010; Ogurtsov et al., 2011; Raspopov et al., 2010; Usoskin et al., 2010; Yamaguchi et al., 2010). Potential solar processes that may affect climate include biological and chemical modulations of marine phytoplankton emissions of dimethylsulphide (DMS), the sensitivity of meteorological and climatic change to magnetic polarity cycles of the Sun, the dependence of tropospheric temperature and condition on the particular nature of both toroidal and poloidal magnetic field components of the Sun, the modulation of tropospheric ionization, surface-atmospheric electricity and cloud microphysics and cover by incoming galactic cosmic rays.…

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