SOLAR INFLUENCE ON GLOBAL TEMPERATURE

SPPI

Science & Public Policy Institute

"science-based policy for a better world"

SPPI & CO2SCIENCE ORIGINAL PAPER ♦ April 17, 2013

SOLAR INFLUENCE ON GLOBAL TEMPERATURE

Citation: Center for the Study of Carbon Dioxide and Global Change. "Solar Influence on Global Temperature." Last modified April 17, 2013. http://www.co2science.org/subject/s/summaries/solartempglobal.php.

The claim that anthropogenic greenhouse gas emissions have been responsible for the warming detected in the twentieth century is based on what Loehle (2004)[1] calls "the standard assumption in climate research, including the IPCC reports," that "over a century time interval there is not likely to be any recognizable trend to global temperatures (Risbey *et al*., 2000), and thus the null model for climate signal detection is a flat temperature trend with some autocorrelated noise," so that "any warming trends in excess of that expected from normal climatic variability are then assumed to be due to anthropogenic effects." If, however, there are significant underlying climate trends or cycles-or both-either known or unknown, that assumption is clearly invalid.

In conducting his own investigation on possible underlying cycles, Loehle used a pair of 3,000-year proxy climate records with minimal dating errors to characterize the pattern of climate change over the past three millennia simply as a function of time, with no attempt to make the models functions of solar activity or any other physical variable. The first of the two temperature series was the sea surface temperature (SST) record of the Sargasso Sea, derived by Keigwin (1996) from a study of the oxygen isotope ratios of foraminifera and other organisms contained in a sediment core retrieved from a deep-ocean drilling site on the Bermuda Rise. This record provides SST data for about every 67th year from 1125 BC to 1975 AD. The second temperature series was the ground surface temperature record derived by Holmgren *et al*. (1999, 2001) from studies of color variations of stalagmites found in a cave in South Africa, which variations were caused by changes in the concentrations of humic materials entering the region's ground water that were reliably correlated with regional near-surface air temperature.

A comparison of the mean record with the South Africa and Sargasso series from which it was derived "shows excellent agreement," and that "the patterns match closely," concluding that "this would not be the case if the two series were independent or random."

With respect to *why* Loehle used these two specific records, he reports that "most other long-term records have large dating errors, are based on tree rings, which are not reliable for this purpose (Broecker, 2001), or are too short for estimating long-term cyclic components of climate." Also, in a repudiation of the approach employed by Mann *et al*. (1998, 1999) and Mann and Jones (2003), he reports that "synthetic series consisting of hemispheric or global mean temperatures

[1] http://www.co2science.org/articles/V7/N4/EDIT.php.

are not suitable for such an analysis because of the inconsistent timescales in the various data sets," noting further, as a result of his own testing, that "when dating errors are present in a series, and several series are combined, the result is a smearing of the signal."

But can only two temperature series reveal the pattern of global temperature change? According to Loehle, "a comparison of the Sargasso and South Africa series shows some remarkable similarities of pattern, especially considering the distance separating the two locations," and he says that this fact "suggests that the climate signal reflects some global pattern rather than being a regional signal only." He also notes that a comparison of the mean record with the South Africa and Sargasso series from which it was derived "shows excellent agreement," and that "the patterns match closely," concluding that "this would not be the case if the two series were independent or random."

Returning to the analysis portion of Loehle's paper, he proceeds to fit seven different time-series models to the two temperature series and to the average of the two series, using no data from the twentieth century. And in doing so, in all seven cases he reports that good to excellent fits were obtained. As one example, the three-cycle model he fit to the averaged temperature series had a simple correlation of 0.58 and an 83 percent correspondence of peaks when evaluated by a moving window count.

Comparing the forward projections of the seven models through the twentieth century lead directly to the most important conclusions of Loehle's paper. He notes, first of all, that six of the models "show a warming trend over the 20th century similar in timing and magnitude to the Northern Hemisphere instrumental series," and that "one of the models passes right through the 20th century data." Such results suggest, in his words, "that 20th century warming trends are plausibly a continuation of past climate patterns" and, therefore, that "anywhere from a major portion to all of the warming of the 20th century could plausibly result from natural causes."

Twentieth century warming trends are plausibly a continuation of past climate patterns and, therefore, anywhere from a major portion to all of the warming of the 20th century could plausibly result from natural causes.

As dramatic and important as these observations are, they are not the entire story of Loehle's insightful paper. His analyses also reveal a long-term linear cooling trend of 0.25°C per thousand years since the peak of the interglacial warm period that occurred some 7,000 years ago, which result is essentially identical to the mean value of this trend that was derived from seven prior assessments of its magnitude and five prior climate reconstructions. In addition, Loehle's analyses reveal the existence of the Medieval Warm Period of 800-1200 AD, which was shown to have been significantly warmer than the portion of the Current Warm Period experienced so far, as well as the existence of the Little Ice Age of 1500-1850 AD, which is shown to have been the coldest period of the entire 3,000-year record.

As corroborating evidence for the global nature of these major warm and cold intervals, Loehle cites 16 peer-reviewed scientific journal articles that document the existence of the Medieval Warm Period in all parts of the world, as well as 18 other articles that document the worldwide occurrence of the Little Ice Age. And in one of the more intriguing aspects of his study - of which Loehle makes no mention, however - both the Sargasso Sea and South African temperature records reveal the existence of a major temperature spike that began sometime in the early 1400s. This abrupt warming pushed temperatures considerably above the peak warmth of the twentieth century before falling back to pre-spike levels in the mid 1500s, providing support for the similar finding of higher-than-current temperatures in that time interval by McIntyre and McKitrick (2003) in their reanalysis of the data employed by Mann *et al*. to create their controversial "hockey stick" temperature history, which gives no indication of the occurrence of this high-temperature regime.

In another accomplishment of note, the models developed by Loehle reveal the existence of three climate cycles previously identified by others. In his culminating seventh model, for example, there is a 2,388-year cycle that he describes as comparing "quite favorably to a cycle variously estimated as 2200, 2300, and 2500 years (Denton and Karlén, 1973; Karlén and Kuylenstierna, 1996; Magny, 1993; Mayewski *et al*., 1997)." There is also a 490-year cycle that likely "corresponds to a 500-year cycle found previously (e.g. Li *et al*., 1997; Magny, 1993; Mayewski *et al*., 1997)" and a 228-year cycle that "approximates the 210-year cycle found by Damon and Jirikowic (1992)."

The compatibility of these findings with those of several studies that have identified similar solar forcing signals caused Loehle to conclude that "solar forcing (and/or other natural cycles) is plausibly responsible for some portion of 20th century warming" or, as he indicates in his abstract, maybe even all of it.

In spite of potential smearing and dating errors, other globally represented datasets have provided evidence of a solar influence on temperature. The 16 authors of Mayewski *et al*. (2004)[2], for example, examined some 50 globally distributed paleoclimate records in search of evidence for what they call rapid climate change (RCC) over the Holocene. This terminology is not to be confused with the rapid climate changes typical of glacial periods, but is used in the place of what the authors call the "more geographically or temporally restrictive terminology such as 'Little Ice Age' and 'Medieval Warm Period'." RCC events, as they also call them, are multi-century periods of time characterized by extremes of thermal and/or hydrological properties, rather than the much shorter periods of time during which the changes that led to these situations took place.

Mayewski *et al*. identify six RCCs during the Holocene: 9,000-8,000, 6,000-5,000, 4,200-3,800, 3,500-2,500, 1,200-1,000, and 600-150 cal yr BP, the last two of which intervals are, in fact, the "globally distributed" Medieval Warm Period and Little Ice Age, respectively. In speaking further of these two periods, they say that "the short-lived 1200-1000 cal yr BP RCC event coincided with the drought-related collapse of Maya civilization and was accompanied by a loss of several

[2] http://www.co2science.org/articles/V7/N51/C3.php.

million lives (Hodell *et al*., 2001; Gill, 2000), while the collapse of Greenland's Norse colonies at ~600 cal yr BP (Buckland *et al*., 1995) coincides with a period of polar cooling."

With respect to the causes of these and other Holocene RCCs, the international team of scientists says that "of all the potential climate forcing mechanisms, solar variability superimposed on long-term changes in insolation (Bond *et al*., 2001; Denton and Karlén, 1973; Mayewski *et al*., 1997; O'Brien *et al*., 1995) seems to be the most likely important forcing mechanism." In addition, they note that "negligible forcing roles are played by CH_4 and CO_2," and that "changes in the concentrations of CO_2 and CH_4 appear to have been more the result than the cause of the RCCs."

In another study with global implications, eight researchers hailing from China, Finland, Russia, and Switzerland published a paper wherein they describe evidence that makes the case for a causative link, or set of links, between solar forcing and climate change. Working with tree-ring width data obtained from two types of juniper found in Central Asia-*Juniperus turkestanica* (related to variations in summer temperature in the Tien Shan Mountains) and *Sabina przewalskii* (related to variations in precipitation on the Qinghai-Tibetan Plateau)-Raspopov *et al*. (2008)[3] employed band-pass filtering in the 180- to 230-year period range, wavelet transformation (Morlet basis) for the range of periods between 100 and 300 years, as well as spectral analysis, in order to compare the variability in the two tree-ring records with independent $\Delta^{14}C$ variations representative of the approximate 210-year de Vries solar cycle over the past millennium. These analyses indicated that the approximate 200-year cyclical variations present in the palaeoclimatic reconstructions were well correlated (R^2 = 0.58-0.94) with similar variations in the $\Delta^{14}C$ data, which obviously suggests the existence of a solar-climate connection. In addition, they say "the de Vries cycle has been found to occur not only during the last millennia but also in earlier epochs, up to hundreds of millions [of] years ago."

> Throughout the past millennium, and stretching back in time as much as 250 million years, the de Vries cycle has been "one of the most intense solar activity periodicities that affected climatic processes."

After reviewing additional sets of published palaeoclimatic data from various parts of the world, the eight researchers satisfied themselves that the same periodicity is evident in Europe, North and South America, Asia, Tasmania, Antarctica, and the Arctic, as well as "sediments in the seas and oceans," citing 20 independent research papers in support of this statement. This fact led them to conclude that there is "a pronounced influence of solar activity on global climatic processes" related to "temperature, precipitation and atmospheric and oceanic circulation."

Complicating the matter, however, Raspopov *et al*. report there can sometimes be "an appreciable delay in the climate response to the solar signal," which can be as long as 150

3 http://www.co2science.org/articles/V11/N23/EDIT.php.

years, and they note that regional climate responses to the de Vries cycle "can markedly differ in phase," even at distances of only hundreds of kilometers, due to "the nonlinear character of the atmosphere-ocean system response to solar forcing." Nevertheless, the many results they culled from the scientific literature, as well as their own findings, all testify to the validity of their primary conclusion, that throughout the past millennium, and stretching back in time as much as 250 million years, the de Vries cycle has been "one of the most intense solar activity periodicities that affected climatic processes."

As for the more recent historical significance of the de Vries cycle, Raspopov *et al*. write that "the temporal synchrony between the Maunder, Sporer, and Wolf minima and the expansion of Alpine glaciers (Haeberlie and Holzhauser, 2003) further points to a climate response to the deep solar minima." In this regard, it could be added again that Earth's recent recovery from those deep solar minima could well have played a major role in the planet's emergence from the Little Ice Age, and, therefore, could well have accounted for much of twentieth century global warming, as suggested a full quarter-century ago by Idso (1988).

The Sun's influence on global climate was also noted in a lengthy review paper, published contemporaneously by eighteen climate scientists. Hailing from thirteen research institutions scattered throughout Switzerland, Germany, the United Kingdom, Belgium and Russia, Wanner *et al*. (2008)[4] developed what they described as "a general framework for understanding climate changes during the last 6000 years," and when all was said and done, they ended their analysis of the several hundred papers they cited with a summary consisting of two main points, the second of which is germane to the subject at hand. Specifically, Wanner *et al*. concluded that "at decadal to multi-century timescales, climate variability shows a complex picture with indications of a possible role for (i) rapid changes of the natural forcing factors such as solar activity fluctuations and/or large tropical volcanic eruptions, (ii) internal variability including ENSO [El Niño Southern Oscillation] and NAO [North Atlantic Oscillation], (iii) changes of the thermohaline circulation, and (iv) complex feedback mechanisms between ocean, atmosphere, sea ice and vegetation." They also report that "notable swings occurred between warm and cold periods, especially the hemispheric-scale warming leading into the Medieval Warm Period and subsequent cooling into the Little Ice Age," the latter of which periods they say "appears at least to be a hemispheric phenomenon." Last of all, they say that model simulations support the inference that the Little Ice Age "may have been brought about by the coincidence of low Northern Hemisphere orbital forcing during the Late Holocene with unusually low solar activity and a high number of major volcanic events."

Writing as background for their work, de Jager and Duhau (2009)[5] note that (1) "solar activity is regulated by the solar dynamo," that (2) "the dynamo is a non-linear interplay between the equatorial and polar magnetic field components," and that (3) "so far, in Sun-climate studies, only the equatorial component has been considered as a possible driver of tropospheric temperature variations." Thus, the pair of researchers set out to examine the neglected polar field's possible influence on global temperature. So what did they find?

---

[4] http://www.co2science.org/articles/V12/N6/C2.php.

[5] http://www.co2science.org/articles/V12/N21/C1.php.

Based on "direct observations of proxy data for the two main solar magnetic field components since 1844," de Jager and Duhau derived "an empirical relation between tropospheric temperature variation and those of the solar equatorial and polar activities." When the two researchers applied this relationship to the period 1610-1995, they found a rising linear association for temperature vs. time, upon which were superimposed "some quasi-regular episodes of residual temperature increases and decreases, with semi-amplitudes up to ~0.3°C," and they note that "the present period of global warming is one of them."

Viewed in this light, it is easy to see, as de Jager and Duhau state, that "the amplitude of the present period of global warming does not significantly differ from the other episodes of relative warming that occurred in earlier centuries." Why? Because the late 20th-century episode of *relative* warming, as they describe it, is merely "superimposed on a relatively higher level of solar activity than the others," which gives it the *appearance* of being unique, when it really isn't. Thus, there is little need to ascribe a unique cause to late 20th-century global warming (such as elevated atmospheric CO_2 concentrations), as this latest warming is merely a run-of-the-mill *relative* warming, sitting atop a solar-induced *baseline* warming that has been in progress for the past four centuries.

There is little need to ascribe a unique cause to late 20th-century global warming (such as elevated atmospheric CO_2 concentrations), as this latest warming is merely a run-of-the-mill relative warming, sitting atop a solar-induced baseline warming that has been in progress for the past four centuries.

Further linking of the Sun to the recent uptick in temperatures during the Current Warm Period can be made from the study of [Qian and Lu (2010)](http://www.co2science.org/articles/V14/N20/C1.php)[6]. Introducing their study, the two authors state that "to understand the causes of 20th century global warming, the contributions of natural variability and human activities need to be determined," adding that "to make sound predictions for this century's climate, understanding past climate change is important."

In an attempt to gain that understanding, Qian and Lu began with the reconstructed global-mean temperature anomaly history of Mann *et al*. (2008), combined with HadCRUT3 data for 1000-2008, relative to 1961-1990 (Brohan *et al*., 2006); and after removing the mean temperatures of the Medieval Warm Period (MWP), the Little Ice Age (LIA) and what they denoted the Global Warming Period (GWP), they used a wavelet transform procedure to identify four oscillations in the millennial temperature time series with periods of 21.1, 62.5, 116.0 and 194.6 years. Next, they similarly examined a reconstructed 400-year solar radiation series based on ^{10}Be data (Lean *et al*., 1995; Bard and Frank, 2006), using the results they obtained "to analyze their causality relationship" with the periodic oscillations they had detected in the reconstructed millennial global-mean temperature series. In doing so, the two

6 http://www.co2science.org/articles/V14/N20/C1.php.

Chinese researchers determined that "the ~21-year, ~115-year and ~200-year periodic oscillations in global-mean temperature are forced by and lag behind solar radiation variability," and they report that the "relative warm spells in the 1940s and the beginning of the 21st century resulted from overlapping of warm phases in the ~21-year and other oscillations," noting that "between 1994 and 2002 all four periodic oscillations reached their peaks and resulted in a uniquely warm decadal period during the last 1000 years," which latter time interval represents the approximate temporal differential between the current Global Warming Period and the prior Medieval Warm Period.

In considering Qian and Lu's findings, it is important to note that, once again, no help from greenhouse gas emissions was needed to reconstruct the past thousand-year history of Earth's global mean temperature; it was sufficient to merely employ known oscillations in solar radiation variability. And as for the future, the two authors predict that "global-mean temperature will decline to a renewed cooling period in the 2030s, and then rise to a new high-temperature period in the 2060s." Given the cessation in warming observed in the surface and lower tropospheric temperature records over the past decade, it appears their prediction is well on its way to being validated.

Clearly, there is much to recommend the overriding concept that is suggested by the data of these several papers, i.e., that the Sun rules the Earth when it comes to orchestrating major changes in the planet's climate. It is becoming ever more clear that the millennial-scale oscillation of climate that has reverberated throughout the Holocene is indeed the result of similar-scale oscillations in some aspect of solar activity. Consequently, as Mayewski *et al*. (2004) suggested a decade ago, "significantly more research into the potential role of solar variability is warranted, involving new assessments of potential transmission mechanisms to induce climate change and potential enhancement of natural feedbacks that may amplify the relatively weak forcing related to fluctuations in solar output." We only hope that more scientists will take note and examine the intriguing relations between our nearest star and our planet's temperature.

REFERENCES

Bard, E. and Frank, M. 2006. Climate change and solar variability: What's new under the sun? *Earth and Planetary Science Letters* **248**: 1-14.

Bond, G., Kromer, B., Beer, J., Muscheler, R., Evans, M.N., Showers, W., Hoffmann, S., Lotti-Bond, R., Hajdas, I. and Bonani, G. 2001. Persistent solar influence on North Atlantic climate during the Holocene. *Science* **294**: 2130-2136.

Broecker, W.S. 2001. Was the Medieval Warm Period global? *Science* **291**: 1497-1499.

Brohan, P., Kennedy, J.J., Harris, I., Tett, S.F.B. and Jones, P.D. 2006. Uncertainty estimates in regional and global observed temperature changes: A new dataset from 1850. *Journal of Geophysical Research* **111**: 10.1029/2005JD006548.

Buckland, P.C., Amorosi, T., Barlow, L.K., Dugmore, A.J., Mayewski, P.A., McGovern, T.H., Ogilvie, A.E.J., Sadler, J.P. and Skidmore, P. 1995. Bioarchaeological evidence and climatological evidence for the fate of Norse farmers in medieval Greenland. *Antiquity* **70**: 88-96.

Damon, P.E. and Jirikowic, J.L. 1992. Solar forcing of global climate change? In: Taylor, R.E., Long, A. and Kra, R.S. (Eds.) *Radiocarbon After Four Decades*. Springer-Verlag, Berlin, Germany, pp. 117-129.

de Jager, C. and Duhau, S. 2009. Episodes of relative global warming. *Journal of Atmospheric and Solar-Terrestrial Physics* **71**: 194-198.

Denton, G.H. and Karlén, W. 1973. Holocene climate variations-their pattern and possible cause. *Quaternary Research* **3**: 155-205.

Gill, R.B. 2000. *The Great Maya Droughts: Water, Life, and Death.* University of New Mexico Press, Albuquerque, New Mexico, USA.

Haeberli, W. and Holzhauser, H. 2003. Alpine glacier mass changes during the past two millennia. *PAGES News* **1** (1): 13-15.

Hodell, D.A., Brenner, M., Curtis, J.H. and Guilderson, T. 2001. Solar forcing of drought frequency in the Maya lowlands. *Science* **292**: 1367-1369.

Holmgren, K., Karlén, W., Lauritzen, S.E., Lee-Thorp, J.A., Partridge, T.C., Piketh, S., Repinski, P., Stevenson, C., Svanered, O. and Tyson, P.D. 1999. A 3000-year high-resolution stalagmite-based record of paleoclimate for northeastern South Africa. *The Holocene* **9**: 295-309.

Holmgren, K., Tyson, P.D., Moberg, A. and Svanered, O. 2001. A preliminary 3000-year regional temperature reconstruction for South Africa. *South African Journal of Science* **99**: 49-51.

Idso, S.B. 1988. Greenhouse warming or Little Ice Age demise: A critical problem for climatology. *Theoretical and Applied Climatology* **39**: 54-56.

Karlén, W. and Kuylenstierna, J. 1996. On solar forcing of Holocene climate: evidence from Scandinavia. *The Holocene* **6**: 359-365.

Keigwin, L.D. 1996. The Little Ice Age and Medieval Warm Period in the Sargasso Sea. *Science* **274**: 1504-1508.

Lean, J., Beer, J. and Bradley, R. 1995. Reconstruction of solar irradiance since 1610: Implications for climate change. *Geophysical Research Letters* **22**: 3195-3198.

Li, H., Ku, T.-L., Wenji, C. and Tungsheng, L. 1997. Isotope studies of Shihua Cave; Part 3, Reconstruction of paleoclimate and paleoenvironment of Beijing during the last 3000 years from delta and ^{13}C records in stalagmite. *Dizhen Dizhi* **19**: 77-86.

Loehle, C. 2004. Climate change: detection and attribution of trends from long-term geologic data. *Ecological Modelling* **171**: 433-450.

Magny, M. 1993. Solar influences on Holocene climatic changes illustrated by correlations between past lake-level fluctuations and the atmospheric ^{14}C record. *Quaternary Research* **40**: 1-9.

Mann, M.E., Bradley, R.S. and Hughes, M.K. 1998. Global-scale temperature patterns and climate forcing over the past six centuries. *Nature* **392**: 779-787.

Mann, M.E., Bradley, R.S. and Hughes, M.K. 1999. Northern Hemisphere temperatures during the past millennium: Inferences, uncertainties, and limitations. *Geophysical Research Letters* **26**: 759-762.

Mann, M.E. and Jones, P.D. 2003. Global surface temperatures over the past two millennia. *Geophysical Research Letters* **30**: 10.1029/2003GL017814.

Mann, M.E., Zhang, Z.H., Hughes, M.K., Bradley, R.S., Miller, S.K., Rutherford, S. and Ni, F. 2008. Proxy-based reconstructions of hemispheric and global surface temperature variations over the past two millennia. *Proceedings of the National Academy of Sciences USA* **105**: 13,252-13,257.

Mayewski, P.A., Meeker, L.D., Twickler, M.S., Whitlow, S., Yang, Q., Lyons, W.B. and Prentice, M. 1997. Major features and forcing of high-latitude northern hemisphere atmospheric circulation using a 110,000-year-long glaciochemical series. *Journal of Geophysical Research* **102**: 26,345-26,366.

Mayewski, P.A., Rohling, E.E., Stager, J.C., Karlén, W., Maasch, K.A., Meeker, L.D., Meyerson, E.A., Gasse, F., van Kreveld, S., Holmgren, K., Lee-Thorp, J., Rosqvist, G., Rack, F., Staubwasser, M., Schneider, R.R. and Steig, E.J. 2004. Holocene climate variability. *Quaternary Research* **62**: 243-255.

McIntyre, S. and McKitrick, R. 2003. Corrections to the Mann *et al*. (1998) proxy data base and Northern Hemispheric average temperature series. *Energy and Environment* **14**: 751-771.

O'Brien, S.R., Mayewski, P.A., Meeker, L.D., Meese, D.A., Twickler, M.S. and Whitlow, S.E. 1995. Complexity of Holocene climate as reconstructed from a Greenland ice core. *Science* **270**: 1962-1964.

Qian, W.-H. and Lu, B. 2010. Periodic oscillations in millennial global-mean temperature and their causes. *Chinese Science Bulletin* **55**: 4052-4057.

Raspopov, O.M., Dergachev, V.A., Esper, J., Kozyreva, O.V., Frank, D., Ogurtsov, M., Kolstrom, T. and Shao, X. 2008. The influence of the de Vries (~200-year) solar cycle on climate variations: Results from the Central Asian Mountains and their global link. *Palaeogeography, Palaeoclimatology, Palaeoecology* **259**: 6-16.

Risbey, J.S., Kandlikar, M. and Karoly, D.J. 2000. A protocol to articulate and quantify uncertainties in climate change detection and attribution. *Climate Research* **16**: 61-78.

Wanner, H., Beer, J., Butikofer, J., Crowley, T.J., Cubasch, U., Fluckiger, J., Goosse, H., Grosjean, M., Joos, F., Kaplan, J.O., Kuttel, M., Muller, S.A., Prentice, I.C., Solomina, O., Stocker, T.F., Tarasov, P., Wagner, M. and Widmann, M. 2008. Mid- to Late Holocene climate change: an overview. *Quaternary Science Reviews* **27**: 1791-1828.

Cover photo of sunshine through
forest trees provided by Microsoft.