Acta Geodyn. Geomater., Vol. 14, No. 2 (186), 251–254, 2017
DOI: 10.13168/AGG.2017.0008
journal homepage: https://www.irsm.cas.cz/acta

ORIGINAL PAPER

POSSIBLE SOLAR MODULATION OF GLOBAL LAND-OCEAN TEMPERATURE

Lihua MA

National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012, P.R. China

Corresponding author's e-mail: mlh@nao.cas.cn

ARTICLE INFO

Article history:
Received 19 February 2017
Accepted 7 March 2017
Available online 29 March 2017

Keywords:
Solar activity
Global land-ocean temperature
Wavelet transform

ABSTRACT

In this work, with wavelet transform, the author investigates possible connection between global land-ocean temperature and solar activity. The study shows fluctuation characteristics in the global land-ocean temperature change. The modulation action from solar activity plays an important role in the temperature change, and there is a possible association existing in the global land-ocean temperature and solar activity on decade time scales.

1. INTRODUCTION

Solar activity directly or indirectly affecting terrestrial phenomena has a profound influence on geophysical processes. Some studies showed variation of solar activity closely relates to global and regional climate change (Rasmus, 2006; Miyahara et al., 2008; Mendoza and Velasco, 2009; Ogurtsov et al., 2013; Dergachev et al., 2016). Weng (2005) analyzed solar variation, global and regional sea-surface temperature and concluded that inter-annual and centennial climate change signals were not purely internal, but also external because of solar activity. Ratnam et al. (2014) thought that solar variation can influence atmospheric circulation, and then variation of atmospheric circulation impacts precipitation process in some regions. Investigating possible influence of solar activity on precipitation in Indian and Huashan mountain area of China, Ma et al. (2007, 2010) revealed solar variation affected rainfall variations in the regions to some extent. Using global land-ocean temperature change series released from the Goddard Institute for Space Studies (GISS) analysis, here with continuous wavelet transform and cross wavelet transform, possible solar modulation function of global land-ocean temperature change is investigated in this work.

2. DESCRIPTION OF THE DATA

2.1. THE GISS SURFACE TEMPERATURE

The GISS Surface Temperature Analysis (GISTEMP) is an estimate of global surface temperature change. With the base period during 1951–1980, combined land-surface air and sea-surface water temperature anomalies (called as land-ocean temperature index, abbreviated as LOTI) are released from GISTEMP (Hansen et al., 2010). Here the monthly LOTI index from January, 1880 to October, 2016 is given in the lower panel of Figure 1.

2.2. SOLAR ACTIVITY

The number of sunspots correlates with the intensity of solar radiation. A solar cycle includes an increase and the following decrease in sunspot numbers (abbreviated as SN). The SN is an important indicator of solar activity. In 1848, Wolf devised a daily method of estimating solar activity by counting the number of individual spots and groups of spots on the face of the sun. Here we use the Wolf SN to study solar activity. The monthly SN series used in this work is obtained from the Solar Influences Data Analysis Center (SIDC) at the Royal Observatory of Belgium. The data set covers the period of time from January, 1749 to October, 2016. The SN series is given in the lower panel of Figure 2.

2.3. WAVELET ANALYSIS

Wavelet analysis is becoming a common tool for analyzing localized variations of power within a time series. By decomposing a time series into time-frequency space, one is able to determine both the dominant modes of variability and how those modes vary with time. The wavelet transform has been used for numerous studies in geophysics (for a review, see, e.g., Daubechies, 1992; Foufoula-Georgiou and Kumar, 1995, 1997; Torrence and Compo, 1998; Grinsted et al., 2004). In this work, we examine possible connection between the LOTI and solar activity especially explore the phase relationships

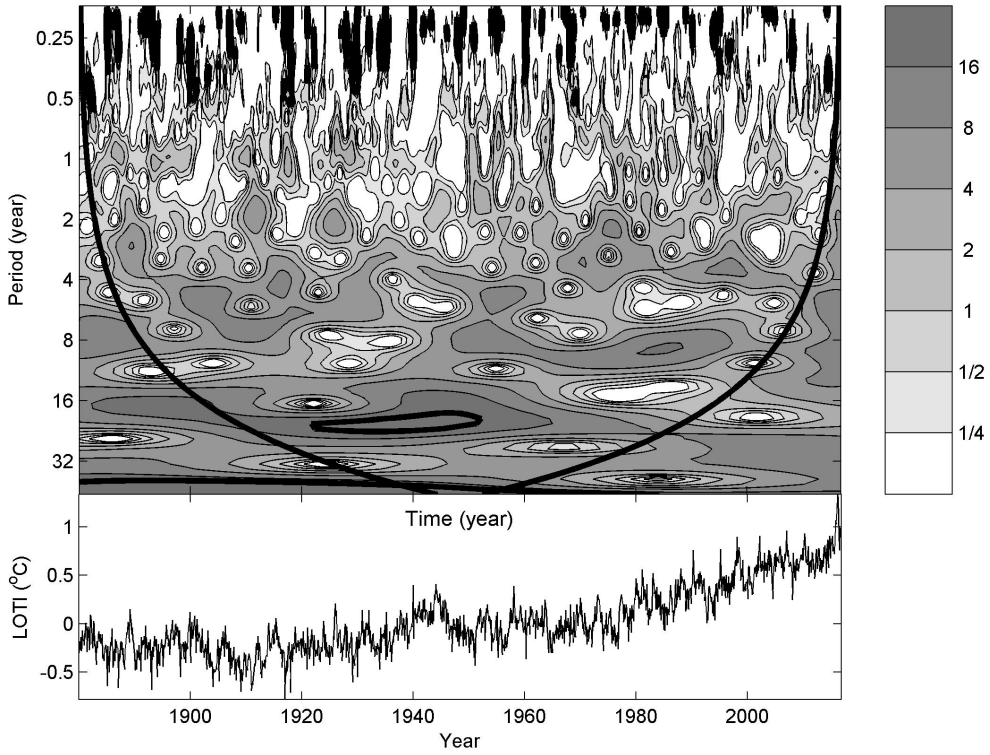

Fig. 1 The standardized time series of the LOTI (lower) and its continuous wavelet power spectrum (upper) during 1880–2016. The thick black contour designates the 5 % significance level against red noise and the cone of influence (COI) where edge effects might distort the picture is shown as a lighter shade.

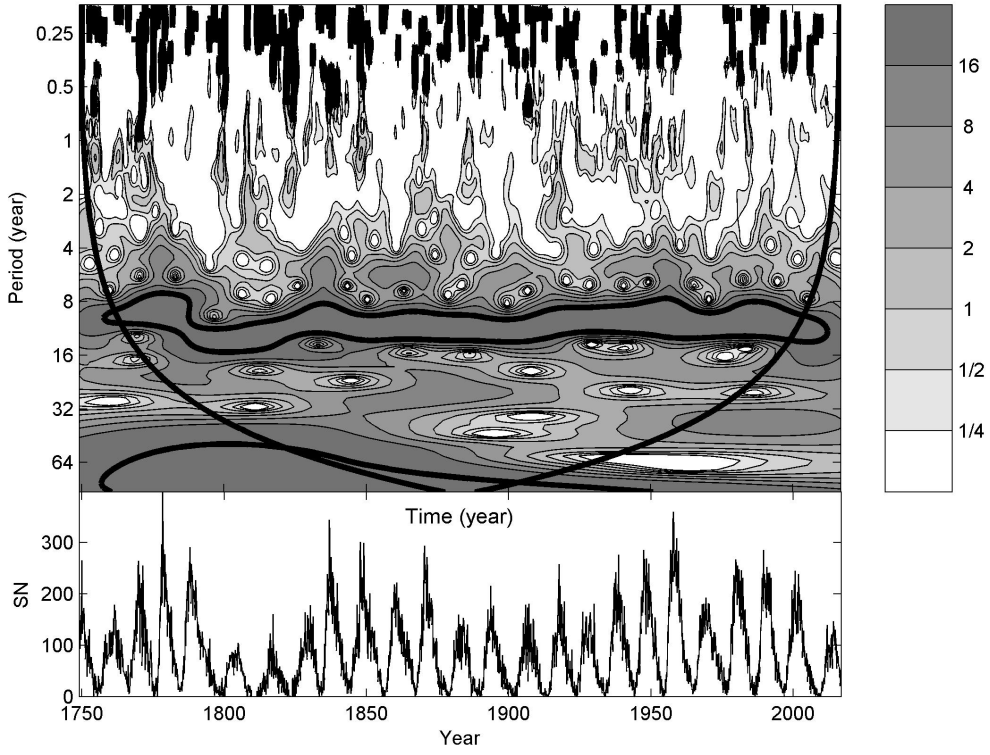

Fig. 2 The standardized time series of the SN (lower) and its continuous wavelet power spectrum (upper) during 1749–2016. Explanation of the figure is similar to Figure 1.

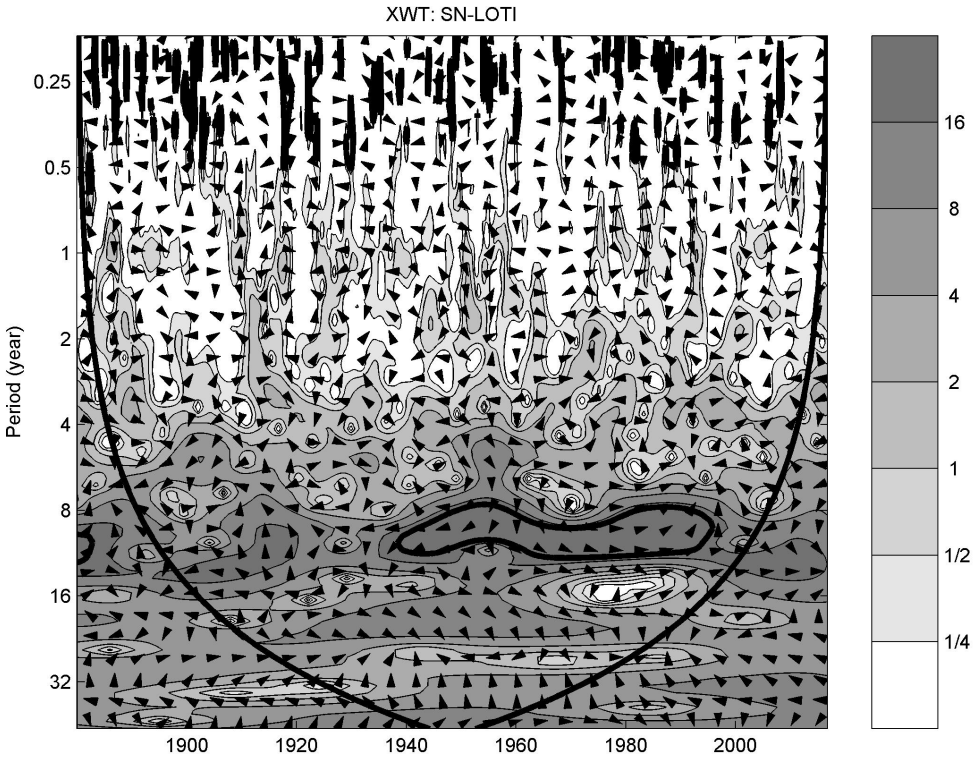

Fig. 3 Cross wavelet transform of the standardized LOTI and SN series during 1880─2016. The 5 % significance level against red noise is shown as a thick contour. The relative phase relationship is shown as arrows (with in-phase pointing right and anti-phase pointing left).

between the two time series. The two time series are normalized (zero mean; unit standard deviation) before wavelet transform is performed.

The continuous wavelet transform (CWT) of the LOTI is shown on the upper panel of Figure 1. There are relatively obvious fluctuations features with significant peaks on quasi ~20-year time scales during 1920-1950, with above the 5 % significance level. The CWT of the SN is shown on the upper panel of Figure 2. Obviously, the most remarkable oscillation in solar activity is about 11-year cycle, with exceeding the 5 % statistical significance level against red noise during the whole time span.

It is hard to diagnose if possible connection exists in the LOTI and solar activity. The cross wavelet transform (XWT) helps in this regard. The XWT of the two time series is shown in the Figure 3. Here, we notice that the common features we cannot find by eye from the individual wavelet transform. Remarkable association signals between the LOTI and solar activity exist on decadal time scales (mainly the 11-year cycle) during 1935 – 1995, with above the 5 % significance level. Therefore we speculate that there is a stronger link between the LOTI and solar activity that implied by the cross wavelet power.

Furthermore, to calculate the phase difference between the LOTI and solar activity, the mean and confidence interval of the phase over regions with higher than 5 % statistical significance is estimated. The complicated phase distribution is found in Figure 3 with directional arrow. The solar modulation signals from the Sun are found with above the 5 % significance level, especially on ~11-year time scales. According the phase variations, solar activity apparently advances the temperature change during 1935-1995. As to ~20-year oscillation, the modulation function is also found through the association signals are below the 5 % significance level.

3. SUMMARY

About 11-year period, a remarkable oscillation of solar activity, continually exists in wavelet transform of solar variation. According to the cross wavelet transform, solar activity influences global land-ocean temperature change on ~11-year time scales during 1935-1995 with above the 5 % significance level. Meanwhile the solar modulation signals of positive correlation are found in the period of time. The modulation function is also found on the ~20-year time scales during the confidence time span through the association signals are below the 5 % significance level. It should be a complicated expression of solar activity impacting on global land-ocean temperature. The detailed analysis of physical mechanism will be included in an extended article in the future.

ACKNOWLEDGEMENTS

The author is grateful to SIDC for providing the SN series and to GISTEMP for providing the LOTI series, and thanks the anonymous reviewers for helpful comments which improved the manuscript greatly. Wavelet software is provided by C. Torrence and G. Compo, and is available at: http://paos.colorado.edu/research/wavelets. Software by Grinsted, A., et al., is available at http://www.glaciology.net/wavelet-coherence.

REFERENCES

Daubechies, I.: 1992, Ten Lectures on Wavelets. SIAM, Philadelphia, PA, 377 pp.

Dergachev, V.A., Tyasto, M.I. and Dmitriev, P.B.: 2016, Palaeoclimate and solar activity cyclicity 100–150 million years ago. Adv. Space Res., 57, 4, 1118–1126. DOI: 10.1016/j.asr.2015.12.014

Foufoula-Georgiou, E. and Kumar, P.: 1994, Wavelets in Geophysics. Academic Press, San Diego, 373 pp.

Grinsted, A., Moore, J.C. and Jevrejeva, S.: 2004, Application of the cross wavelet transform and wavelet coherence to geophysical time series. Nonlinear Process Geophys., 11, 5/6, 561–566. DOI: 10.5194/npg-11-561-2004

Hansen, J., Ruedy, R., Sato, M. and Lo, K.: 2010, Global surface temperature change. Rev. Geophys., 48, 4, RG4004. DOI: 10.1029/2010RG000345

Kumar, P. and Foufoula-Georgiou, E.: 1997, Wavelet analysis for geophysical applications. Rev. Geophys., 35, 4, 385–412. DOI: 10.1029/97RG00427

Ma, L.H, Han, Y.B. and Yin, Z.Q.: 2007, The possible influence of solar activity on Indian summer monsoon rainfall. Appl. Geophys., 4, 3, 231–237. DOI: 10.1007/s11770-007-0029-4

Ma, L.H., Han, Y.B. and Yin, Z.Q.: 2010, Possible influence of the 11-year solar cycle on precipitation in Huashan mountain of China over the last 300 years. Earth Moon Planets, 107, 2, 219–224. DOI: 10.1007/s11038-010-9367-y

Mendoza, B. and Velasco, V.: 2009, High-latitude methane sulphonic acid variability and solar activity: the role of the total solar irradiance. J. Atmos. Solar-Terr. Phys., 71, 1, 33–40. DOI: 10.1016/j.jastp.2008.09.034

Miyahara, H., Yokoyama, Y. and Masuda, K.: 2008, Possible link between multi-decadal climate cycles and periodic reversals of solar magnetic field polarity. Earth Planet. Sci. Lett., 272, 1-2, 290–295. DOI: 10.1016/j.epsl.2008.04.050

Ogurtsov, M., Lindholm, M., Jalkanen, R. and Veretenenko, S.V.: 2012, New evidence of solar variation in temperature proxies from Northern Fennoscandia. Adv. Space Res., 52, 9, 1647–1654. DOI: 10.1016/j.asr.2013.07.039

Rasmus, E.B.: 2006, Solar Activity and Earth's Climate. Springer, Jointly published with Praxis Publishing, UK, 316 pp.

Ratnam, M.V., Santhi, Y.D., Kishore, P. and Bhaskara, S.V.: 2014, Solar cycle effects on Indian summer monsoon dynamics. J. Atmos. Solar-Terr. Phys., 121, 145–156. DOI: 10.1016/j.jastp.2014.06.012

Torrence, C. and Compo, G.P.: 1998, A practical guide to wavelet analysis. Bull. Amer. Meteor. Soc., 79, 61–78. DOI: 10.1175/1520-0477(1998)079<0061:APGTWA>2.0.CO;2

Weng, H.Y.: 2005, The influence of the 11 yr solar cycle on the interannual–centennial climate variability. J. Atmos. Solar-Terr. Phys., 67, 8-9, 793–805. DOI: 10.1016/j.jastp.2005.02.002