Long-Term Datasets for the Understanding of Solar and Stellar Magnetic Cycles
Proceedings IAU Symposium No. 340, 2018
D. Banerjee, J. Jiang, K. Kusano & S. Solanki, eds.

doi:10.1017/S1743921318001734

Prediction of upcoming grand episodes of solar activity

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Abstract. Sunspots are active regions on the surface of the Sun having strong magnetic fields. Activity level of the Sun shows long-time scale phenomena known as grand episodes-Grand maxima and Grand minima. Present study examines grand episodes shown by sunspot numbers (1090-2017), using methods of wavelet transform and sinusoidal regression. Time interval analysed includes two grand maxima and four grand minima. Interval in between grand episodes are regular oscillations. Phase changes found from periodicity analysis clearly show the presence of upcoming grand episodes. The forthcoming grand episodes are suggested to be two grand minima which are likely to occur between the years 2100-2160 and 2220-2300.

Keywords. Sunspots, solar cycle, solar activity, etc.

1. Introduction

Activity level of the Sun shows grand episodes-Grand maxima and Grand minima. Grand maxima of solar activity is a period when sunspot number (SN) exceeds 50 during at least two consecutive decades. Grand minimum is a period when the SN level is less than 15 during at least two consecutive decades. Solar dynamo theories are still trying to explain the frequency of occurrence and regularity of these episodes of solar activity. Present study examines periodicities in reconstructed yearly averaged SNs during grand episodes – Medieval maximum (1100-1250), Wolf minimum (1280-1340), Spörer minimum (1420-1530), Maunder minimum (1645-1715), Dalton minimum (1790-1820) and Modern maximum (1924-2009) – using wavelet transform and sinusoidal regression techniques.

2. Data and methods of analysis

Yearly averaged SN (1090 - 2017) is taken for the analysis of grand episodes in solar activity. Data from 1090 to 1699 is the extended SN time series (Nagovitsyn 1997) and subsequent years of data up to 2017 is taken from the website of SIDC (http://www.sidc.be).

Wavelet analysis is an alternative method with multi-resolution characteristic compared to Fourier transform. Continuous Wavelet Transform (CWT) is calculated by convolution between signal and analysis function. Solar activity contains strong cyclic components. Cyclic components in the temporal variation of soar activity is extracted by sinusoidal regression using Cramers rule.

3. Results and discussion

10.2 and 10.9 years periodicities are the two distinct periodicities in SN (Fig. 1). Almost 180 degree phase shift between basic 10.2 and 10.9 years periodicities in sunspot activity is an indication of the interval of occurrence of grand episodes. And this episode will be a maximum when the same interval in the combination of modulating periodicities of 10.2 and 10.9 years is a maximum and viceversa. Almost in phase oscillations in between

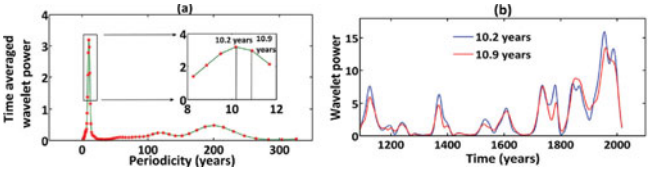

Figure 1. Yearly averaged SN (1090-2017) (a) Global Wavelet Power Spectrum (GWPS)-Temporal variation of average wavelet power of individual periodicities (b) Modulated 10.2 and 10.9 years periodicities obtained from wavelet spectrum.

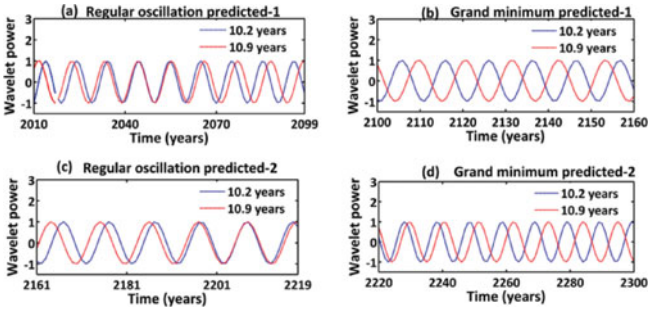

Figure 2. Comparison of basic parts of 10.2 and 10.9 years periodicities in yearly averaged SN.

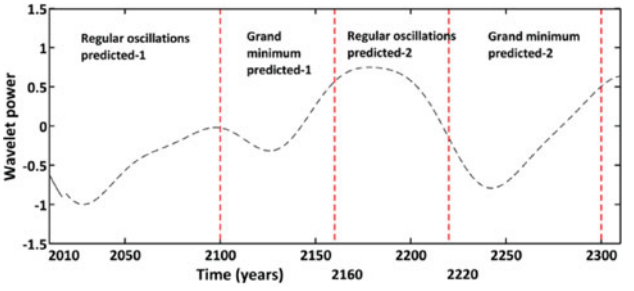

Figure 3. Combination of major modulating periodicities (283.4 years, 200.4 years, 187 years, 115.1 years, 107.4 years, 57.6 years and 53.7 years) of 10.2 and 10.9 years periodicities in SN.

basic 10.2 and 10.9 years periodicities are found during the episodes of regular oscillations (intervals in between grand episodes). Above obtained results are verified during the past two grand maxima, five episodes of regular oscillations and four grand minima. Grand episodes are predicted by comparing the extrapolated basic and modulating parts of 10.2 and 10.9 years periodicities (Fig. 2 and Fig. 3).

4. Conclusion

10.2 and 10.9 years periodicities are the two significant periodicities in sunspot activity. Simultaneous occurrence of 180 degree phase shift between their basic parts and extrema in the combination of their modulating parts can predict the intervals of grand episodes in solar activity. So they have close connection with the solar dynamo mechanism behind grand episodes. Forthcoming grand episodes are predicted to be two grand minima, which are likely to occur between the years 2100-2160 and 2220-2300.

References

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https://doi.org/10.1017/S1743921318001734 Published online by Cambridge University Press