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/S1743921318001631

Solar Activity Changes During Prolonged Sunspot Minima as Inferred from Indian Monsoon Rainfall Variations

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Abstract. We could find a new 5 year periodicity in the occurrences of peaks in sunspot activity and inferred deviations of annual Indian monsoon rainfall variations from the normal during the Maunder minimum (MM) period. This result is explained in terms of solar dynamo functioning in a different mode from normal during the MM where quadrupole field (first harmonic, 5-5.5 years) dominate over dipole field (fundamental, 11 years) causing extreme north south asymmetry in sunspot activity.

Keywords. Maunder minima, Indian monsoon rainfall, 5.5 year periodicity, solar activity, solar dynamo, quadrupole fields

1. Introduction

Indian monsoon rainfall is shown to be influenced by solar output variations (Hiremath *et al.* 2015).

Aim of this study is to understand solar activity changes and its influence on Indian monsoon rainfall variations during prolonged sunspot minima periods. We could find some interesting results in this context during the Maunder minima which will be discussed in detail in this paper.

2. Results and discussion

2.1. *Proxy summer monsoon rainfall variability during the Maunder minima*

Direct Indian rainfall records are not available for periods prior to the 19th century. It is known that strengthening of south-westerly wind blowing in India during the summer (June–September) is correlated with good rainfall in India during these periods. Mast ships from Europe to Asia/India travelled with the help of monsoon winds during the summer season while travelling via the Cape of Good hope (Cape) in Africa. The yearly published records of average journey duration from Cape to Batavia (modern Indonesia) taken by Dutch VOC mast ships during the years 1852–1700 CE (Mertens 2003) can be considered as a proxy to monsoon wind speed and rainfall in India during the summer season for these years. The mean journey duration of these ships for the years 1610–1794 CE for travelling from Cape to Batavia is found to be 81 days. In Fig. 1 we have plotted deviation from this mean value in days (ΔD) of the observed average yearly journey duration (D) of Dutch VOC ships from Cape to Batavia for each year from 1852–1700

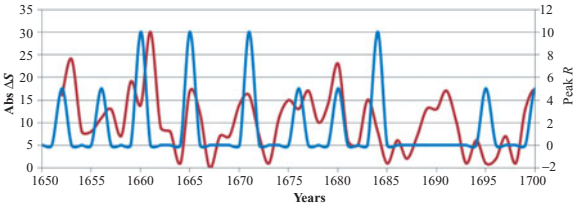

Figure 1. Occurrences of peaks in sunspot activity (blue) and absolute deviations (Abs ΔS) of journey time of VOC ships from Cape to Batavia from normals (red) during the Maunder minimum period. A 5 year periodicity is seen in both variables.

CE given by

$$\Delta D \text{ (days)} = (81 - D) \tag{2.1}$$

From Fig. 1 we can find that ΔD is predominantly negative suggesting normal AISMR during the Maunder minimum period. However during four years (1659, 1661, 1675, 1691) we could find distinct positive values of ΔD where we can expect below normal or even deficient monsoon rainfall. It is remarkable to find that the strong positive peak in ΔD during the year 1661 coincides with the period of only major drought reported in India during the MM period (Uberoi 2012) providing some independent validation for this proxy data. A weak anti-correlation (−0.24) is observed between reconstructed ΔTSI (TSI-1360 W/m^2, calculated using data available in `spot.colarado.edu/Koppg/TSI`) and ΔD variations during the MM period suggesting weak positive correlation between Indian monsoon rainfall and total solar irradiance variability.

2.2. *Five year periodicity in sunspot activity peak occurrences during the Maunder minima*

In Fig. 1 we have compared the occurrences of peaks in sunspot activity (from inferences of annual mean sunspot number in different publications like Eddy, 1976: Vaquero *et al.* 2015a) or reconstructed TSI with absolute magnitude of ΔD during the years 1650–1700 CE. Every sunspot activity/TSI peak is assigned a relative value of 5 units and if accompanied also by occurrences of peaks in Aurora (Vazquez *et al.* 2016) a relative value of 10 units is given in this plot. A 5 year periodicity in sunspot activity and proxy Indian summer monsoon rainfall deviations is clearly seen in this Figure. This period is very close to the first harmonic of the fundamental or eleven year period. If fundamental period correspond with odd parity axisymmetric (dipole symmetry) modes in the photospheric magnetic field the first harmonic (5–5.5 years) is most probably related to even parity (quadrupole symmetry) dominance during the Maunder minimum. The observed extreme north-south asymmetry in sunspot activity observed during this period (Vaquero *et al.* (2015b)) justifies the above hypothesis with solar dynamo operating in the 'first excited' mode.

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https://doi.org/10.1017/S1743921318001631 Published online by Cambridge University Press