PROCEEDINGS OF SCIENCE

The Relationship between Cosmic Ray Intensity, Sunspot Cycle with Geomagnetic Activity

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Abstract

A number of parametric relationships between solar and geophysical parameters has been investigated during the solar cycle 22 to 25. The purposes of this paper is to access how those solar parameters which most directly affect the terrestrial plasma environment vary during a sunspot cycle and to observe the relationship between the magnitude of the sunspot maximum and their influence on the geomagnetic activities. The geomagnetic activity index shows a clear modulation corresponding to the 11- year sunspot cycle. However, the 27day averages of geomagnetic activity do not maximize at the time of sunspot maximum. During solar cycle 22 to 25 both the parameters V and B are correlated with geomagnetic indices Ap and Kp are showing the similar trend of variation during the maximum phase of solar cycle. We used Cosmic ray intensity (CRI) data from three neutron monitor sites in this study: Oulu (0.81 GV), Moscow (2.41 GV), and Beijing (9.56 GV). The results are compared with earlier solar cycles.

Keywords: Sunspot Number, Cosmic Ray Intensity and Geomagnetic Activity.

38th International Cosmic Ray Conference (ICRC2023)
26 July - 3 August, 2023
Nagoya, Japan

PoS(ICRC2023)1312

1. Introduction

The effects of solar variations on cosmic rays and geomagnetism have been previously studied using data from ground-based detectors (mainly the global grid of ultraneutron monitors) in combination with other solar geophysical factors. (Ables et al. 1965, Agrawal et al. 1965). 1980, Usoskin et al 1998 Jaroslav et al 2021). The interrelationship between these factors is called the Sun-Earth relationship. Long-term changes in galactic cosmic rays, as well as short-term variations in CRI (cosmic ray intensity), remain an open problem in cosmic ray research. Various studies show that the cosmic ray flux is modulated by the 11-year solar cycle of sunspot activity, reaching a maximum during the stationary phase of the solar cycle and a minimum near the peak of the solar cycle, i.e., near the peak of the solar cycle. is shown. H. The intensity of cosmic rays changes with a time lag of 1-2 years depending on the solar cycle. Lockwood (1971) found that the count rate of a neutron monitor is intrinsically related to the tilt angle of the neutron current plate at the start of the current modulation cycle. Kota and Jokipii (1991) studied the modification of cosmic rays by co-rotating interaction zones in a paradigm involving both drift and diffusion. Agrawal et al. (1993) used the spherical harmonics of the solar magnetic field to improve the correlation between cosmic ray intensity and solar activity. Forbush (1954) showed that the mean intensity of cosmic rays has an apparent anticorrelation period of 11 years with solar activity.

The continuous recording of cosmic ray intensity by neutron shielding techniques has greatly inspired his work on the characteristics of the 11-year variability over the past decades. Lockwood (1960) pointed out that the greatest reduction in long-range versatility occurs after a large reduction in the Forbush effect that lasts for some time, followed by a similar large reduction that further reduces overall power. A number of researchers have reviewed several research efforts to elucidate long-term variations in cosmic ray intensity, which partly explain the time lag between sunspot numbers (Singh & Mishra 2019; Agrawal et al. 1993). Ahluwalia, H.S. & Lopate 2001). Attempts have been made to clarify the long-term management of astronomical radiation using new tuning parameters (Bakare & Chukwuma 2010, Prasad et al. 2021). Real-world tests have been performed to determine long-range cosmic ray power based on the collective effects of several geomagnetic highlights (Calisto et al. 2011, Singh et al. 2015). They conclude that the giant structure of the solar wind is responsible for the 11-year cycle of cosmic-ray force diversity. Mori (1996) proposed that the 22-year-old instrument is related to reversal of the solar dipole field. They proposed that high-power conditions, in which the galactic and solar gravitational fields are parallel to each other, facilitate the propagation of cosmic-ray particles within the heliosphere. It is now known that galactic cosmic rays contrast with sunspot number (SSN), with the greatest force occurring at the base of the sunspot cycle (Gupta et al. 2006 and Singh et al. 2012). Beam power change, SSN, tilt point (TA).

This study uses the monthly mean sunspot number as a solar measure of solar activity and correlates it with cosmic ray intensity. Plasma geomagnetic properties and geomagnetic indices have also been used to link different consequences of long-term variations in cosmic rays. The results found are compared with the conclusions of previous studies on cosmic-ray modulation. Various long-term variations in cosmic-ray intensities are characterized and described using available mechanisms. Yearly estimates of cosmic ray intensity calculated using monthly averages from three neutron monitoring stations:

Oulu, Moscow, Beijing. For long-term studies, mean data for solar wind speed, magnetic field, sunspot number and geomagnetic Ap index were also obtained from the Omni website. Forbush (1958) found that fluctuations in cosmic ray intensity lag solar activity by 6 to 12 months. In this study, we recorded annual estimates of his CRI from his three different neutron screens in Beijing, Oulu and Moscow. This study used the Wolf sunspot number (SSN) as a sunlight-based index over the solar cycle from 1996 to his 2022. According to this analysis, the radiance lagged behind the Sun-oriented cycle from 1996 to 2022. In any case, temporary lulls are not the same as various solar-dependent cycles.

2. Methodology

Many statistical and data science techniques are used to examine the results. Various graphs, charts, plots and correlations have been considered for long-term and short-term studies of cosmic ray modulation. We will apply regression analysis. A regression study is a technique that evaluates the relationship between a dependent variable and a set of independent factors. Regression analysis can be used as a descriptive data analysis approach without making assumptions about the underlying processes that generate the data.

We compared solar/geomagnetic activity and cosmic ray intensity (CRI) over the period 1996-2022, covering the solar cycle 22-24 and solar cycle 25 upturn phases. The importance of the geomagnetic Ap index in long-term tracking of solar activity is as follows (Lee and Fisk 1981, Kane 2007). For this purpose, we chose sunspots (Rz), solar wind speed (V), geomagnetic perturbation index (Ap), and magnetic field (B). The modulation parameter (V * B) is proportional to the product of the solar wind plasma velocities. (V) and the strength of the interplanetary magnetic field (b). This study used cosmic ray intensity (CRI) data from three neutron monitoring sites:

Oulu (0.81 GV), Moscow (2.41 GV), Beijing (9.56 GV). Data for solar and geomagnetic parameters are obtained from monthly averaged data from various websites.

www.geomag.bgs.ac.uk/daaservice/dat, data source: National Geophysical Data Center (http:

http://www.ngdc.noaa.gov/stp/SOLAR/ftpsunspotnumber.html). Such datasets should represent individual 11-year cycles with a temporal resolution well suited for solar cycle prediction. Such information has been available in geomagnetic indices since 1868. Attempts have been made to reconstruct the age and even the amplitude of the solar maximum over the past 2000 years from eastern naked eye records and aurora observations (Anatoly et al 2021, Singh and Mishra 2015, Bullaga 1985). However, these reconstructions currently have too many uncertainties to be used as a basis for prediction.

3. Result and Discussion

It is well known that the 11-year variation in cosmic ray intensity is inversely proportional to the number of sunspots. However, sunspot maxima and minima are often different from cosmic-ray intensity minima and maxima. To demonstrate the relationship between cosmic ray intensity and sunspot frequency, Popielawska (1992) reported a thorough analysis considering data including cosmic ray intensity and sunspot number. To investigate the relationship between the number of sunspots and the intensity of cosmic rays during the solar cycle 22–24, she calculated the correlation coefficient between the monthly mean values of these two parameters. In September 2001, her Rz value at solar cycle 23 reached a high of 150.7 and in October 2007 reached a low of 0.9. Solar cycle 24 peaked in April 2014 with a 23-month sunspot number of 81.8, while cycle 23 began in May 1996 and peaked in September 2001. Compared to other current solar cycles, this maximum was significantly lower. A striking correlation between geomagnetic activity near the solar minimum and subsequent solar cycle magnitude was found by Brown and Williams (1969), Kaushik and Srivastava (2000), Gupta and Badruddin (2010). Figure 1 shows the cosmic ray (CRI) intensity for various neutron observatories in Beijing, Oulu and Moscow from 1996 to 2021, with

Oulu (0.81 GV), Moscow (2.41 GV) and Beijing (9 GV) limit stiffness. , 56GV).

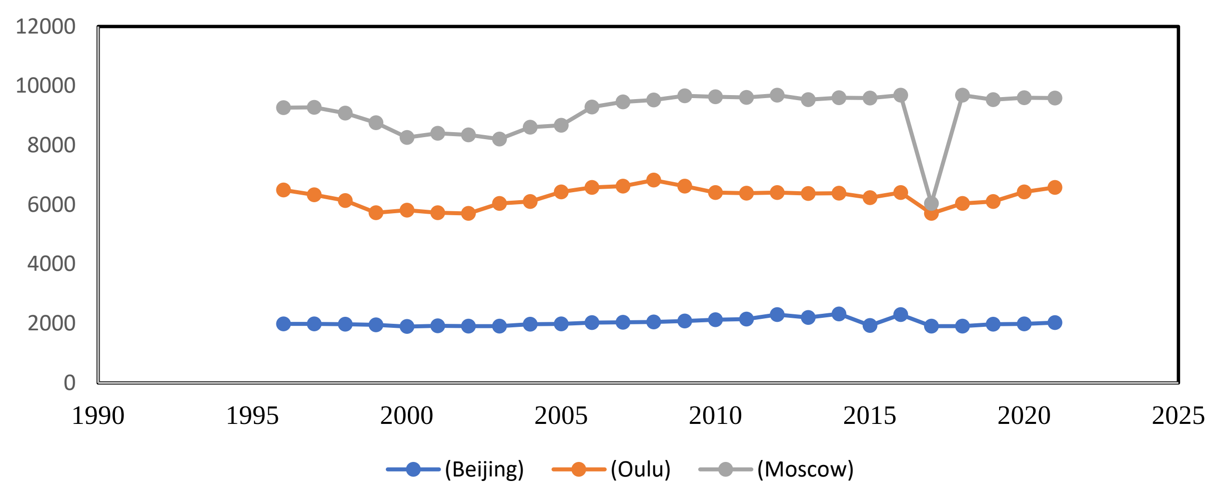

Fig 1: - Neutron monitor stations Beijing, Oulu &Moscow from years 1996 to 2021.

3.1 Inter-Relation of Cosmic rays with Geomagnetic Activity

Cosmic rays from different cut-off stiffness observatories (Beijing, Oulu, Moscow) were analyzed by various parameters such as sunspot number (Rz), exponent (Ap), solar electric jet exponent (Ae), geomagnetic field (B) and solar wind speed. compared with the normal solar parameters. (V) and V.B are the solar cycles. Sun-Earth interactions also play an important role in explaining some of his 11- and 22-year variations in galactic cosmic rays. Variations in the intensity of cosmic rays as a function of the solar cycle (sunspot number Rz) have been observed, with the maximum intensity occurring about 7 months after the sunspot minimum. However, this is not true for all solar cycles. The time difference between the solar cycle and the cosmic ray cycle depends on the solar cycle. It also varies with the phase of the solar cycle. Many previous studies have investigated temporal variations in cosmic ray intensity and sunspot number (Forbush, 1957, Mishra & Mishra 2018, Sham & Mishra 2019, Ross & Chaplin 2019). They found an inverse relationship between the intensity of cosmic rays and the number of sunspots.

A correlation analysis between astronomical radiance (CRI) and sunspot number (Rz) was performed for solar-based cycles 23 and 24 (Draper and Smith 1998). Correlation studies used average annual gains of super neutron screens in Beijing, Oulu and Moscow. Over a continuous period (1996 to 2022), we observe a negative correlation between the number of infinite rays and sunspots. Using annual mean estimates of sunspot number (Rz) and infinite radiance, the relationship coefficient was derived for the period 1996–2022, including sun-based cycles 22 and 24. Among them, the shape of the even solar cycle curve is similar to the next even solar cycle curve shape, and the odd solar cycle curve shape is similar to the other odd solar cycle curve shape. We calculated a correlation coefficient that indicates . Figure (2) shows the relationship between cosmic ray intensity (owl) and the product of sunspot number Rz, geomagnetic index Ap and B*V during the rising phases of solar cycles 23-24 and 25. Note from Figure (2) that there is an inverse relationship and variation profile. The Ap index, sunspot number, and B*V exhibit negative fluctuations during solar cycles 22–24 as CRI increases during periods of high solar activity.

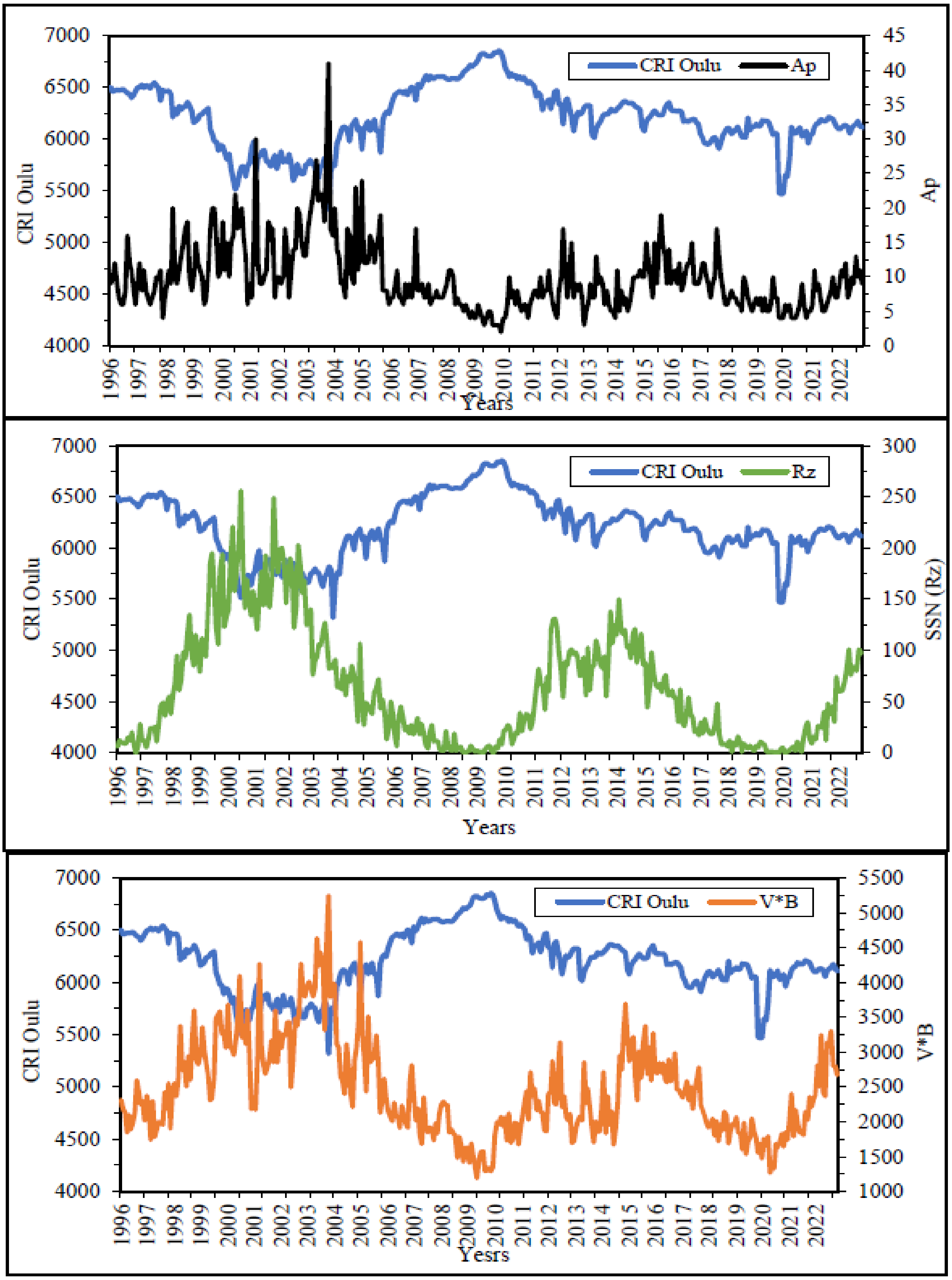

Fig 2: Yearly values of cosmic rays' intensity for Oulu stations along withGeomagnetic Solar index (Ap), Vector magnetic field (V*B) & sunspot number (Rz) for years 1996-2021.

The long-term correlation coefficients between CRI, sunspot number Rz, Ap index and B*V are -0.9, -0.6 and -0.7, respectively (Fig.3)

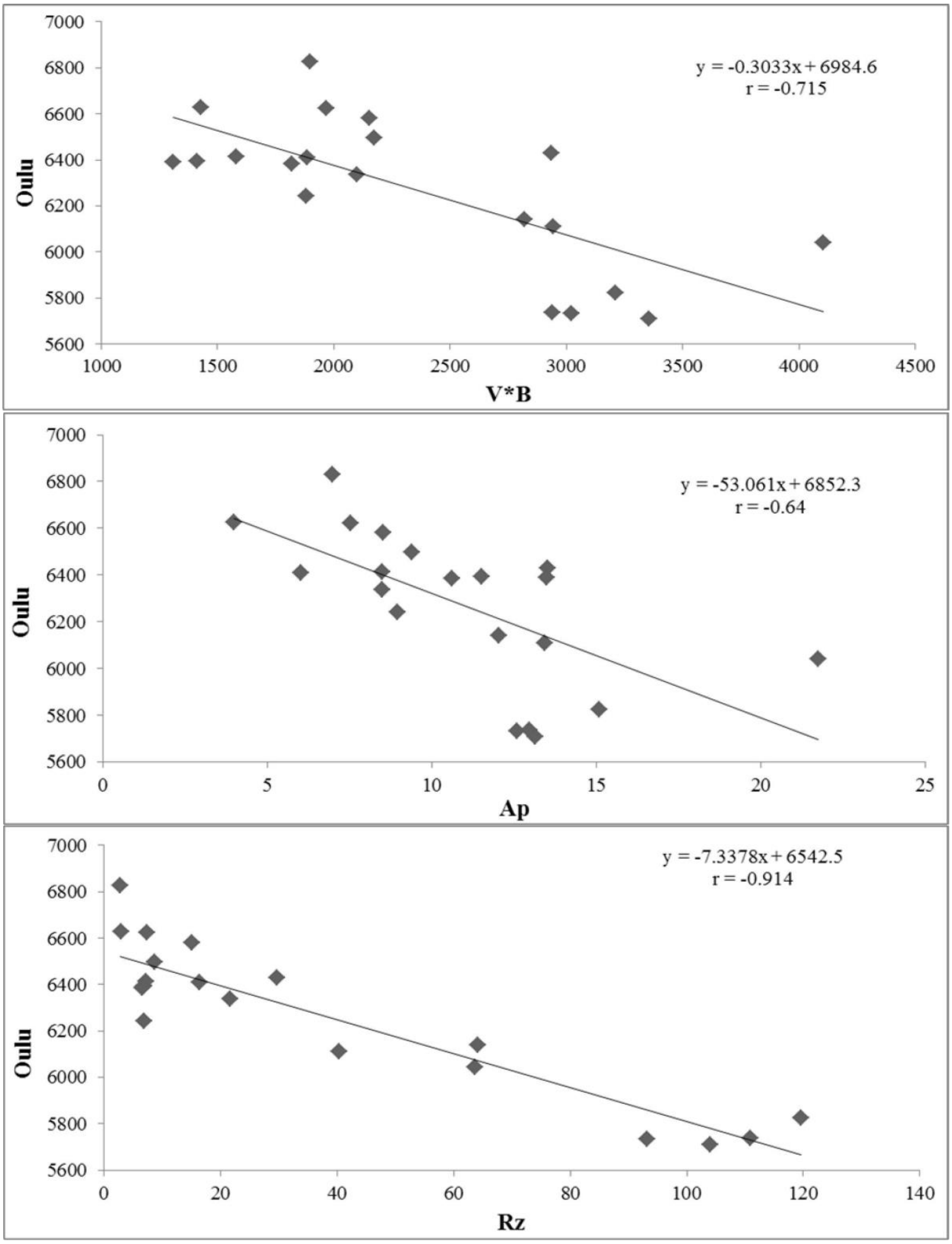

Fig 3: Correlative cross plot between Oulu Geomagnetic solar index (Ap),vector magnetic field (V*B) & sunspot number (Rz) for years 1996-2021.

Conclusions

The authors of the current study presented long-term aspects of day-to-day change. I study the effects of solar cycle variations (on high-amplitude and low-amplitude wave train events). These events were classified according to different phases of the solar cycle, including periods of minimum solar activity, periods of maximum solar activity, and descending phases of the solar cycle. During both solar cycles, only low-amplitude wavetrains are observable when solar activity is minimal. Cycle 24 contains a much longer minimum CRI period. Brown and Williams (1969) identified a strong correlation between geomagnetic activity and future solar cycle magnitude. It has been shown that there is a high correlation between the number of days when the geomagnetic field is anomalously quiet and the magnitude of the upcoming solar cycle. Combining solar cycles 23 and 24 with solar cycle 25, it was concluded that solar cycle 25 was more active and influenced space weather. Statistical models predict that the number of monthly sunspots will peak in 2013 between 50 and 70. Models based on the strength of the solar pole's magnetic field suggest that it could peak as early as 2012. It's interesting to follow the evolution of Cycle 25 compared to more recent cycles.

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