Long-Term Variations in the Growth and Decay Rates of Sunspot Groups

J. Javaraiah

Abstract Using the combined Greenwich (1874 – 1976) and Solar Optical Observatories Network (1977 – 2009) data on sunspot groups, we study the long-term variations in the mean daily rates of growth and decay of sunspot groups. We find that the minimum and the maximum values of the annually averaged daily mean growth rates are \( \approx 52\% \, \text{day}^{-1} \) and \( \approx 183\% \, \text{day}^{-1} \), respectively, whereas the corresponding values of the annually averaged daily mean decay rates are \( \approx 21\% \, \text{day}^{-1} \) and \( \approx 44\% \, \text{day}^{-1} \), respectively. The average value (over the period 1874 – 2009) of the growth rate is about 70% more than that of the decay rate. The growth and the decay rates vary by about 35% and 13%, respectively, on a 60-year time scale. From the beginning of Cycle 23 the growth rate is substantially decreased and near the end (2007 – 2008) the growth rate is lowest in the past about 100 years. In the extended part of the declining phase of this cycle, the decay rate steeply increased and it is largest in the beginning of the current Cycle 24. These unusual properties of the growth and the decay rates during Cycle 23 may be related to cause of the very long declining phase of this cycle with the unusually deep and prolonged current minimum. A \( \approx 11\)-year periodicity in the growth and the decay rates is found to be highly latitude and time dependent and seems to exist mainly in the \( 0^\circ – 10^\circ \) latitude interval of the southern hemisphere. The strength of the known approximate 33 – 44-year modulation in the solar activity seems to be related to the north-south asymmetry in the growth rate. Decreasing and increasing trends in the growth and the decay rates indicate that the next 2 – 3 solar cycles will be relatively weak.

1. Introduction

Magnetic flux, in the form of large flux tubes, emerges to the surface – presumably from near the base of the convection zone (where the dynamo process is believed to be taking place) – and responsible for sunspots and other solar active phenomena (see Rosner and Weiss, 1992; Gough, 2010). A sunspot lasts from a few hours to several weeks. The typical sizes of sunspots range from 10 msh (millionth of the solar hemisphere \( \approx 3 \times 10^6 \, \text{km}^2 \)) to \( 10^3 \) msh.

J. Javaraiah (✉)
Indian Institute of Astrophysics, Bangalore 560 034, India
e-mail: jj@iiap.res.in
Although individual sunspots are common, the majority of sunspots are parts of groups. Spot groups are often large and complex. The daily area of a spot (or spot group) is one of the most important parameters used to describe the spot (or spot group) development. The area of a spot (or spot group) is closely connected with the magnetic flux of the spot (or spot group) (130 msh area ≈ \(10^{22}\) Mx magnetic flux, e.g., see Wang and Sheeley, 1989). That is, the development of the spot (or spot group) area reflects the development of the solar magnetic field. Therefore, the increase/decrease in the areas of spots or spot groups, i.e., the growth/decay of spots or spot groups, can affect significantly the strength, configuration and topology of the magnetic structure in the solar atmosphere. Hence, the studies of growth and decay of sunspots or sunspot groups are important for understanding configuration and topology of the magnetic structure on the solar surface, the solar variability and the underlying mechanism of it. Several such studies have been made and many characteristics of the growth and decay of the spot groups are found (see Lustig and Wöhl, 1995; Hathaway and Choudhary, 2008).

Howard (1992a, 1992b) analyzed Mt. Wilson sunspot and sunspot group data during 1917–1985 and determined many properties of the day-to-day changes in the sunspot umbral areas (spot growth/decay). Howard (1992a) also studied the variations in the annual averages of the umbral area increases, but no systematic variations are found. In the present study we analyze a large data set of sunspot groups and attempt to detect the long-term variations in daily rates of growth and decay of sunspot groups.

In the next section we describe the methodology and the data analysis. In Section 3 we present the results. In Section 4 we draw conclusions and briefly discuss the implications of them on the long-term solar variability.

2. Methodology and Data Analysis

Here we have used the combined Greenwich (1874–1976) and Solar Optical Observation Network (SOON) (1977–2009) sunspot group data, which are taken from David Hathaway’s website http://solarscience.msfc.nasa.gov/greenwch.shtml. These data included the observation time (the Greenwich data contain the date with the fraction of the day, in the SOON data the fraction is rounded to 0.5 day), heliographic latitude (\(\phi\)) and longitude (\(L\)), central meridian distance (CMD), and corrected umbra and whole-spot areas (in msh) etc., of the spot groups for each day of observation. The positions of the groups are geometrical positions of the centers of the groups.

The Greenwich data have been compiled from the majority of the white light photographs which were secured at the Royal Greenwich Observatory and at the Royal Observatory, Cape of Good Hope. The gaps in their observations were filled with photographs from other observatories, including the Kodaikanal Observatory, India. The SOON data included measurements made by the United States Air Force (USAF) from the sunspot drawings of a network of the observatories that has included telescopes in Boulder, Colorado; Hawaii; etc. David Hathaway scrutinized the Greenwich and SOON data and produced a reliable continuous data series from 1874 up to date (also see Hathaway and Choudhary, 2008). In case of SOON data, we increased the area by a factor of 1.4. David Hathaway found this correction was necessary to have a combined homogeneous Greenwich and SOON data (see the aforementioned website of David Hathaway).

The method of analysis is similar to that in Howard (1992a). Howard used daily umbral areas of the spots measured in Mt. Wilson Observatory during the years 1917–1985. We have used the corrected daily whole-spot areas (umbral value + penumbral value) of spot