A TWO-COMPONENT SOLAR CYCLE

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(Received 11 August, 1989, in revised form 27 August, 1990)

Abstract. From a previous analysis of a long series of geomagnetic data, we came to the conclusion that, during 91.5% of the time, geomagnetic activity is controlled by the solar wind flow at the Earth's orbit.

In this paper, we consider the flow of the solar wind plasma in a coronal field whose source is a dipole. The temporal evolution of the dipole source as well as any small scale evolution occurring in the associated coronal field topology can be closely monitored from the latitudinal distribution of the wind velocity.

In the geomagnetic data series, the index $Aa$ is closely linked to the wind velocity at the power 2.25. From this data set, we can reconstruct the behavior of the solar dipole field from 1868 onward.

The main results of our analysis are as follows. The solar cycle has two distinct components, dipole and toroidal, of which the respective cycles are out of phase, The toroidal component is strongly linked, with a 5–6 yr delay, to the preceding dipole component. This finding is in contradistinction to the view that the dipole field is a result of the poleward migration of the decaying toroidal field. This result should contribute to improve our understanding of the Sun's cyclical behaviour.

1. Introduction

For about 10 years, we have been involved in the analysis of a homogeneous series of geomagnetic data beginning in 1868 established by Mayaud (1973). We came to the conclusion that geomagnetic activity can be divided into two components controlled, respectively, by (1) the solar wind flow at the Earth's orbit, and (2) by shock waves generated by solar activity associated with sunspots: e.g., solar flares.

It turns out that the main source of the geomagnetic activity is not the sunspot activity itself which concerns only 8.5% of the geomagnetic data, but rather the flow of the solar wind at the Earth's orbit. The latitudinal distribution of the solar wind depends closely upon the intensity and the direction of the solar dipole. The geomagnetic activity is a consequence of a coupling between the interplanetary medium of solar origin and the magnetosphere. Therefore, from the geomagnetic data, one can study the cyclic behaviour of the solar dipole since 1868, i.e., during a series of 11 solar cycles.

In Section 2, we consider a flow of solar plasma taking place in the field of a solar dipole. In the interplanetary medium, the latitudinal distribution of the solar wind velocity depends only upon the topology of the modified dipolar field. Therefore, an appropriate sampling of the latitudinal distribution of the wind velocity supplies us with a survey of its temporal variations at large as well as at small scales.

In Section 3, we discuss several results of wind data analyses. These confirm that in the interplanetary medium the latitudinal distribution of the wind velocity depends upon...
the solar dipole. We establish the parameters to use for a study of the dipole intensity and of its inclination with respect to the solar rotation axis.

In Section 4 and in Appendix 1, we describe briefly our method of analysis of the geomagnetic phenomena for the study of the series of dipole cycles. Then we identify two phases in this cycle.

We discuss the cyclic behaviour of the dipole in Section 5, during the dipole phase, and, in Section 6, during the multipole phase.

In Section 7 we take into consideration the sunspot cycles. We establish that according to geomagnetic activity data, the cycle of the solar dipole is a forerunner of the sunspot activity cycle which starts 5–6 years later. Therefore we have to take into consideration a two-component solar cycle in which the dipole field cycle is followed by a strongly dependent toroidal field cycle.

In Section 8, we discuss our results and we list the problems raised by these new results.

2. A Coronal Field Generated by a Dipole and Subjected to the Plasma Flow Pressure

Let us start by the discussion of a simplified model of dipolar solar field subjected to the pressure of the plasma flow (Figure 1 after Pneuman and Kopp, 1971). In this modified dipolar structure, the field lines diverge at the poles and both a coronal hole and a diverging wind stream of high velocity are present. At lower latitude the field lines curve back towards the equator and the wind velocity decreases. Near the neutral sheet, at low altitude, the closed field lines are at the origin of an enhancement of the coronal density but at higher altitude, the converging field lines are open to the interplanetary medium and a slow wind flows. Therefore, going from the neutral sheet to the poles, a latitudinal gradient of the wind velocity is present which depends upon the topology of the dipolar field source. Therefore, the solar wind flow is a general property of the global field topology and not a specific property of few coronal holes.

Any change in the dipolar source intensity causes an alteration of the latitudinal distribution of the wind velocity. Any small-scale evolution of the field topology is at the origin of some small-scale alteration with respect to the 'smooth' velocity gradient of the wind velocity distribution. Therefore, by selecting some appropriate sample of the latitudinal distribution of the wind velocity, one can survey both the intensity of the dipolar source and if any, its inclination to the solar axis, as well as any temporary alteration of the coronal field topology. Of course the best sites for such a sampling are the polar and the neutral sheet regions, respectively.

The solar axis has an inclination of 7.2 deg in a direction perpendicular to the ecliptic plane. Therefore, in the interplanetary medium, the orbit of the Earth scans twice a year a 14.4 deg thick zone of the solar wind. From the wind velocity data, one can check whether the poloidal field has the above mentioned modified dipolar structure or not. In the first case, our centennial series of the $Aa$ indices offers a unique opportunity of studying the temporal and spatial evolution of the solar dipole during 11 solar cycles.