Role of solar activity in dynamics of the stratospheric circumpolar vortex

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Possible connections between the intensity of stratosphere circumpolar vortex (CPV) and variations in the number of sunspots, sector pattern of the interplanetary magnetic field, and other factors of the space weather are considered. The presence of a tight enough connection between long-period variations of CPV intensity as compared to monthly average number of sunspots is shown. Variations with a period of approximately 2 years are found, which can be associated with a quasi-biennial cycle in a dynamic behavior of the equatorial stratosphere.

Since the last century, the economic and social life in our planet depends, somehow or other, on the process called the Global Change, the global climate change being its part. There is a certainty that climatic changes (e.g., the greenhouse effect) are connected with anthropogenic activities. Still, there are as well persuasive evidences that the global climatic changes may result from long-term variations of the solar activity.[1]

The fact substantiating this connection is the Little Ice Age, which occurred in Europe and the North America late in the 17th century and coincided in time with the solar Maunder minimum, when there were no active formations (sunspots) during several decades.[2] It has been demonstrated that the level of solar radiation during the Maunder minimum was 0.15–0.35% (Ref. 2) or 0.1–0.7% (Ref. 3) lower than that fixed in the 22nd solar cycle.

There are many experimental results[4–11,etc.] indicative of relationships between meteorological parameters and various factors of cosmic weather (solar flares, variations in the number of sunspots, sector pattern of the interplanetary magnetic field, etc.) This made the NASA (USA) scientists start a scientific research program "Living with a Star,"[12] which has become international since 2002.

One of the problems this program must solve is evolvement of the physical mechanism of solar-terrestrial relationships and elucidation of the factors affecting the human environment and, consequently, the economic and social life of people.

Solar wind is a highly ionized gas. It has a strong electric conductivity and thus carries the solar magnetic flux away from the Sun creating the interplanetary magnetic field (IMF).[13,14] The Sun characteristics, such as its luminosity, are connected with its magnetic flux, though the mechanism underlying this connection is still vague.[2,15] As the force lines of the interplanetary magnetic field get joined with those of the Earth's magnetic field, this allows the solar wind energy to penetrate into the near-Earth space. It has been proved that variations in the heliospheric magnetic flux and, consequently, in the IMF affect the thickness of the Earth cloud coverage, which, in its turn can cause global climatic changes.[16]

Y. Wang and N. Sheeley (Ref. 17) directly measured the Earth orbital IMF and found that the intensity of the total magnetic field outgoing from the Sun has increased 1.4 times as compared to its intensity in 1964 (Fig. 1).

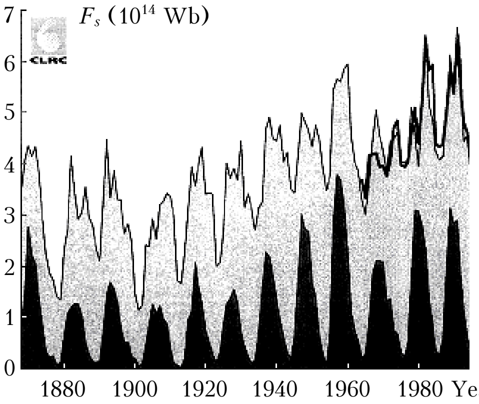

Fig. 1. Solar magnetic flux F_s calculated by R. Willson (Ref. 15) using the values of the geomagnetic index *aa* for the period 1868–1996 (the black curve finishing the grey area). A thick curve corresponds to the magnetic flux spaceship measurements between 1964 and 1996. The dark area is the average annual values for sunspots (the Wolf numbers). The figure is taken from Ref. 18.

Taking into account the information shown in Fig. 1, it seems reasonable to check if the increase in the solar magnetic flux has affected the atmospheric characteristics, in particular, the intensity of the stratospheric circumpolar vortex I.

Figure 2 shows the values of I for the successive pentads between 1972 and 1990. Each year has 72 pentads. Seasonal variations of the intensity of the stratospheric circumpolar vortex are clearly seen in Fig. 2.

In the winter season, the vortex character is cyclonic (the values of I are large and positive), while in summer it is anticyclonic (the values of I are negative).

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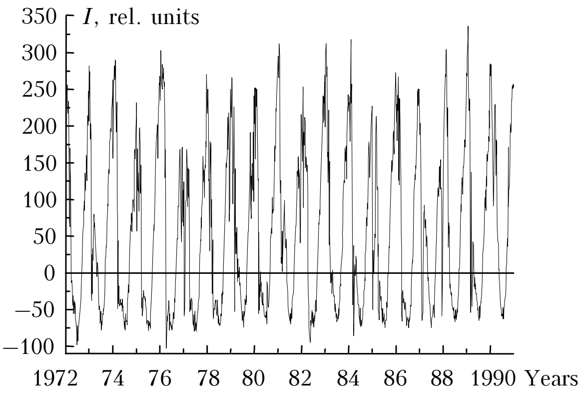

Fig. 2. Intensity variations of the stratospheric circumpolar vortex (I) for successive pentads in 1972–1990.

To study the long-term variations of I, which can probably result from the long-term variations of solar activity, we removed from the initial data in Fig. 2 its seasonal variations by smoothing it out with a moving average over 73 pentads. The long-term variations of I remained in the smoothed curve are shown in Fig. 3, where they are also compared to the monthly average number of sunspots (the Wolf numbers W).

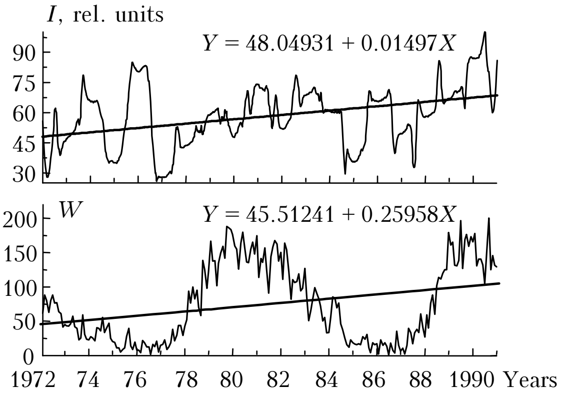

Fig. 3. Long-term intensity variations of the stratospheric circumpolar vortex I over the period 1972–1990 upon removal of seasonal variations and in comparison with the monthly averaged sunspot numbers (the Wolf numbers W). Straight lines refer to the approximation by the first order polynomial (linear regression). The regression equations are given.

Based on Fig. 3 we can infer that the intensity of the stratospheric circumpolar vortex grew from 1972 to 1990 together with the solar activity.

Besides the linear trend, the parameter I reflects the variations with the quasi-period of about two years, which can be due to quasi-biennial cycle in the dynamic regime of the equatorial stratosphere.

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