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# Decrease in Solar Wind Parameters after a Minimum of 22-23 Solar Cycles

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**Abstract.**

On the basis of the OMNI database data, the behavior of solar wind plasma and magnetic field parameters of 21-24 solar cycles (1976-2019) is studied. In the analysis, the data are selected according to the types of large-scale solar wind phenomena in the site http://www.iki.rssi.ru/pub/omni [*Yermolaev et al.*, 2009] and phases of solar cycles. The analysis showed that during the minimum of 22-23 solar cycles, the parameter values decreased by 20-40% in different types of solar wind and continued to be low during the 23 and 24 cycles [*Yermolaev et al.*, 2021]. The effect of this decrease in solar wind parameters on space weather is discussed.

## Introduction

One of the aims of solar, interplanetary and solar-terrestrial physics is the experimental investigation of long-term variations in solar wind (SW) parameters. Variations in the interplanetary parameters with scales ~1 year are an important characteristic of solar activity and the basis for a long-term space weather forecast [*Dmitriev et al.*, 2009; *Yermolaev et al.*, 2012; 2021; *Gopalswamy et al.*, 2015]. Changes in the parameters can be associated both with a change in the number of different large-scale types of SW and with variations in the values of these parameters at different phases of the solar cycle (SC) and during the transition from one cycle to another. Therefore, in this work, we average the data selected by the types of large-scale SW phenomena and phases of solar cycles 21-24, and study their changes in the period 1976-2019.

## Data and Methods

In this work, we use two sources of information: (1) Hourly data of OMNI base parameters for 1976-2019 (https://spdf.gsfc.nasa.gov/pub/data/omni/low_res_omni, *King and Papitashvili*, 2005), and (2) Intervals of different types of SW of the catalog of large-scale phenomena (http://www.iki.rssi.ru/pub/omni, *Yermolaev et al.*, 2009), created on the basis of the OMNI database. The data were divided into intervals of SC phases, as shown in Table. 1.

Table 1. *Averaging intervals over phases of the solar cycle*

| № interval | № Cycle | Phase of cycle | Years |
|---|---|---|---|
| 1 | 21 | minimum phase | 1976 |
| 2 | | rising phase | 1977,1978 |
| 3 | | maximum phase | 1979-1981 |
| 4 | | declining phase | 1982-1984 |
| 5 | | minimum phase | 1985-1987 |
| 6 | 22 | rising phase | 1988 |
| 7 | | maximum phase | 1989-1991 |
| 8 | | declining phase | 1992-1994 |
| 9 | | minimum phase | 1995-1997 |
| 10 | 23 | rising phase | 1998-1999 |
| 11 | | maximum phase | 2000-2002 |
| 12 | | declining phase | 2003-2005 |
| 13 | | minimum phase | 2006-2009 |
| 14 | 24 | rising phase | 2010,2011 |
| 15 | | maximum phase | 2012-2014 |
| 16 | | declining phase | 2015-2016 |
| 17 | | minimum phase | 2017-2019 |

## Results

Figs 1-6 present time profiles of parameters of solar wind plasma and interplanetary magnetic field (IMF) averaged over phases of solar cycles (Table 1): minimum – black circles, rising phase – blue triangles, maximum – purple squares, declining phase – green inverted triangles, without selection with phases – red open squares. The data for magnetic clouds are widely scattered in all figures due to the small number of events. The largest scatter is observed for the proton temperature T, and since it has a lognormal distribution [Dmitriev et al., 2009], we averaged the logT value.

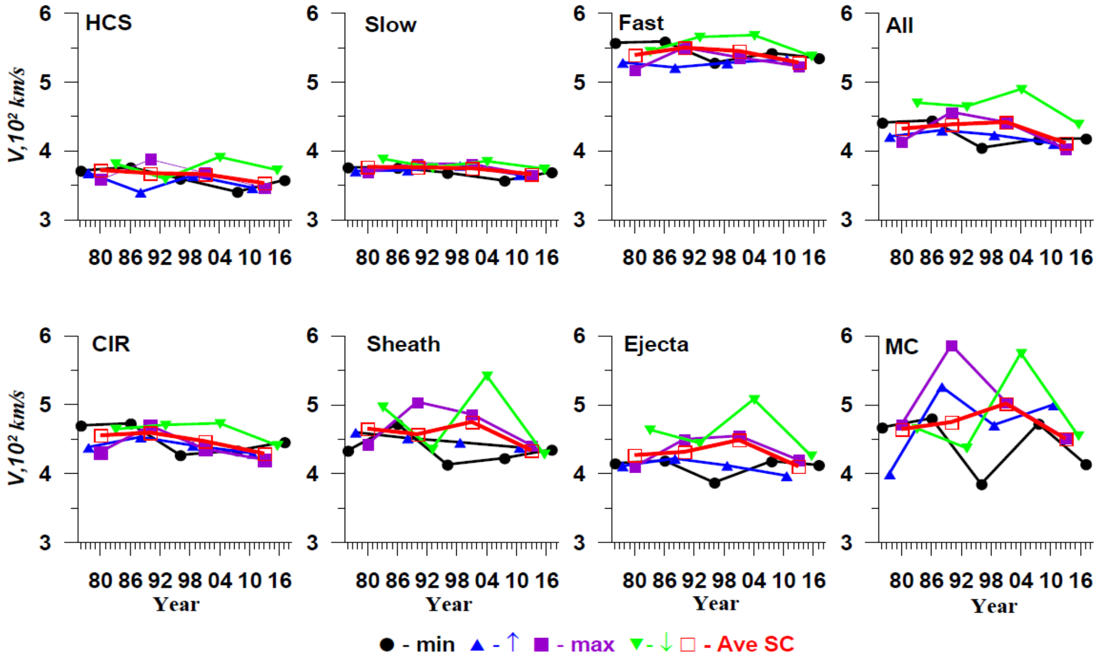


*Fig.1. Time profiles of bulk velocity V in 7 different types of SW (heliospheric current sheet – HCS, Slow and Fast streams, CIR, Sheath, Ejecta and MC) and without SW type selection (All)*

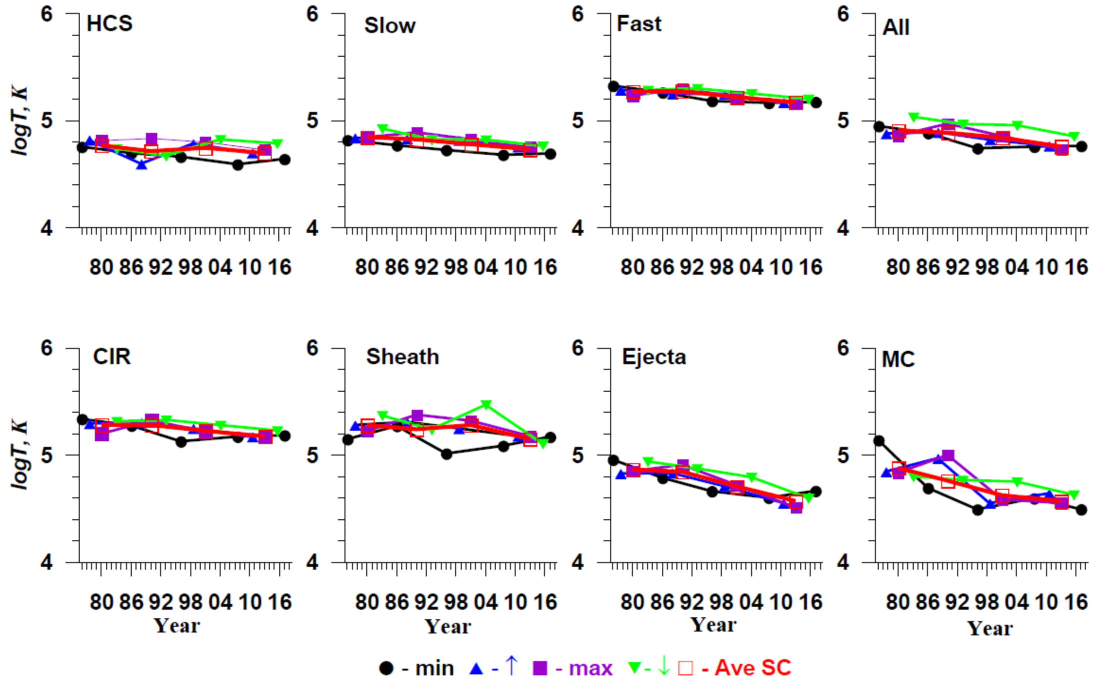


*Fig.2. Time profiles of logarithm of proton temperature T*

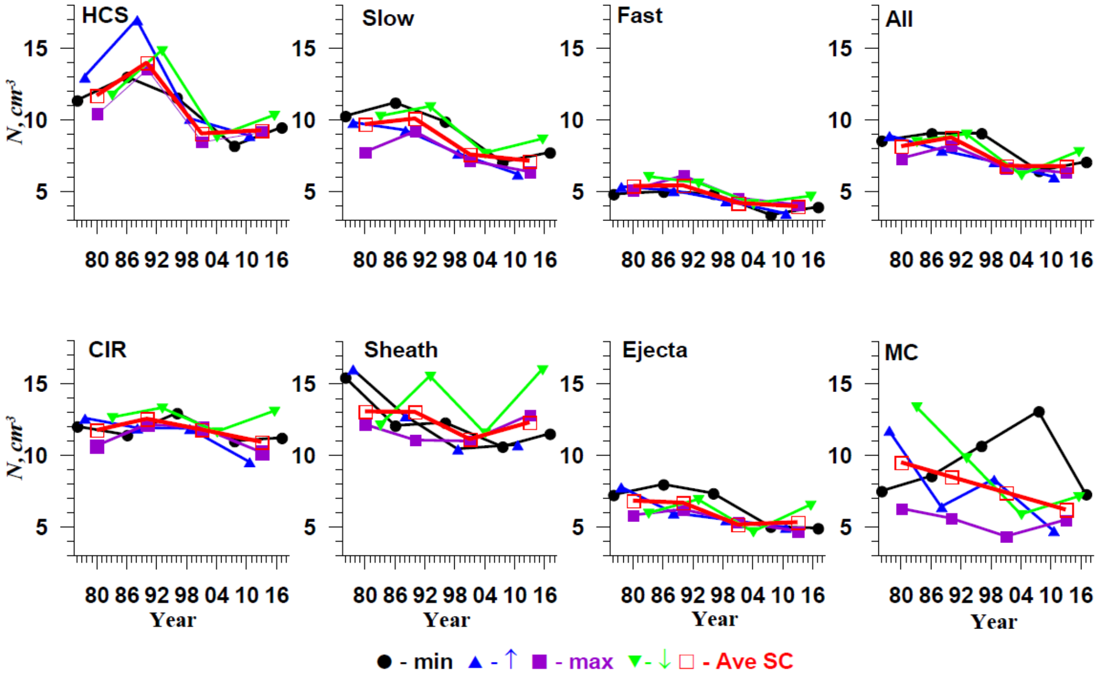


*Fig.3. Time profiles of density N*

The speed (V) and temperature (log T) depend little on the phase of cycle, but show a weak decreasing trend with an increase in the SC number. Density changes in a similar way, but shows a higher dependence on phase (higher in minimum phase) and a sharper drop in the middle of the interval. The parameters calculated on the basis of V, T and N change in a similar way with more obvious decreases at ~1995 (not shown here).

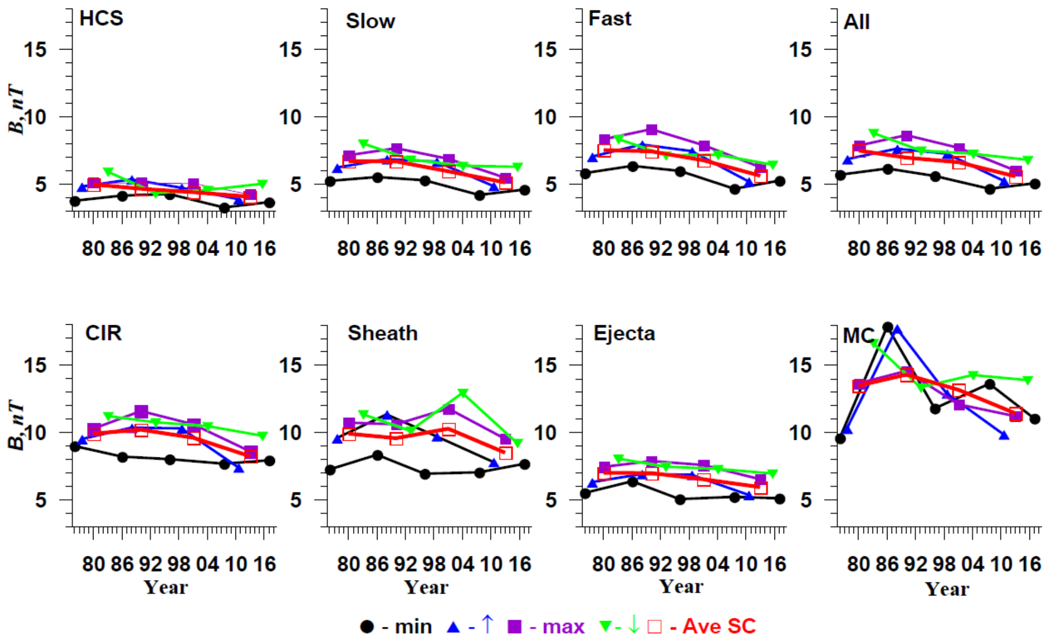


*Fig.4. Time profiles of magnitude of IMF B*

Magnitude of IMF B depends rather strongly on the SC phase (lower in minimum phase) and clearly decreases near the minimum of 22-23 cycles.

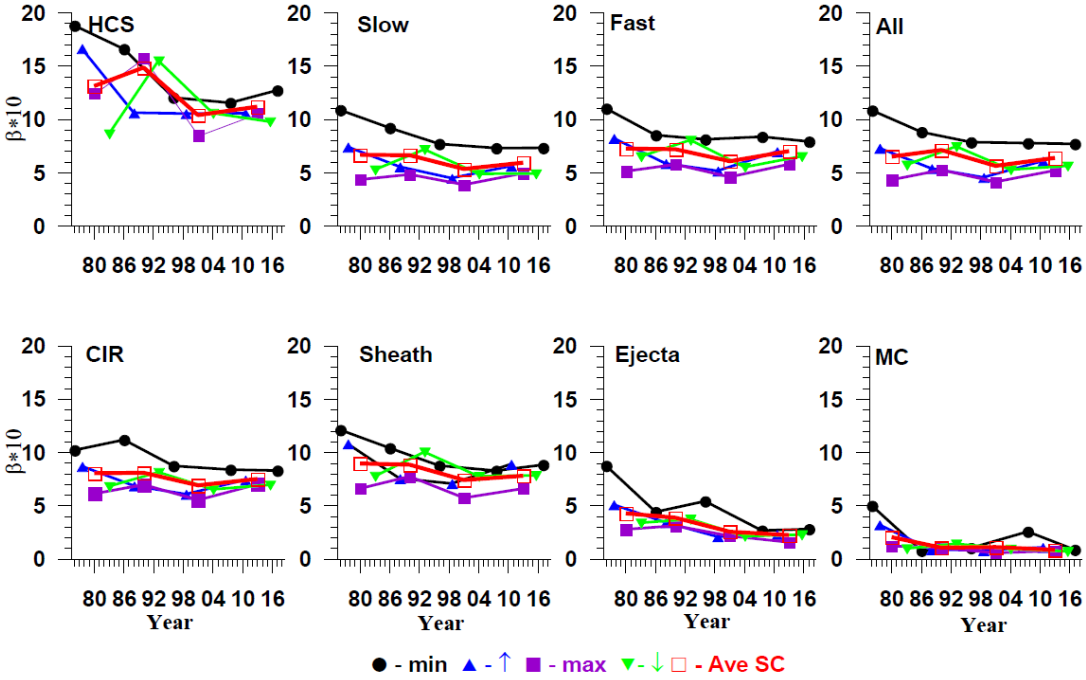


*Fig.5. Time profiles of proton β-parameter*

Despite the fact that the β-parameter is the ratio of thermal to magnetic pressures, which have decreasing trends over time, the β-parameter has a clear dependence on the SC phase and clearly decreases near the minimum of 22-23 cycles.

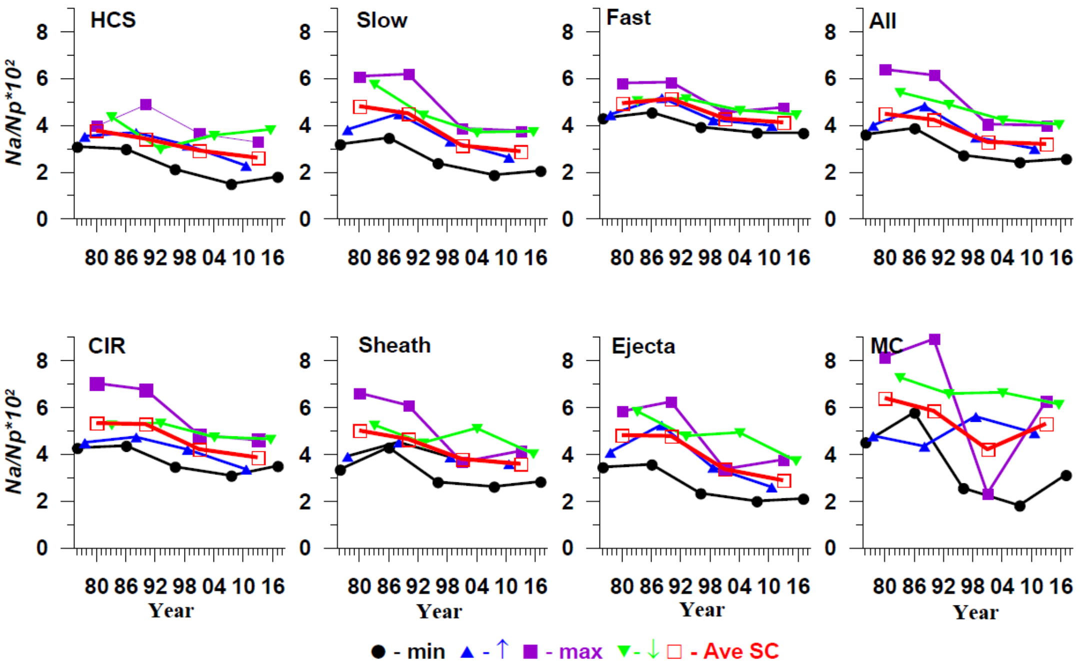


*Fig.1. Time profiles of helium abundance Nα/Np*

Helium abundance Nα/Np depends rather strongly on the SC phase (lower in minimum phase) and clearly decreases near the minimum of 22-23 cycles.

## Discussion and Conclusions

Thus, we examined the behavior of interplanetary plasma and IMF parameters over 21-24 solar cycles on the basis of OMNI database (https://spdf.gsfc.nasa.gov/pub/data/omni) [*King and Papitashvili*, 2005]. We selected the intervals in accordance with various types of solar wind using the catalog of large-scale solar wind types for 1976-2019 (http://www.iki.rssi.ru/pub/omni, [*Yermolaev et al.*, 2009]) and in accordance with the phases of the solar cycles, and averaged the parameters at selected intervals. As a result of this analysis, the following important conclusion can be drawn. In addition to the well-known fact that in 23-24 solar cycles the number of disturbed types of solar wind (ICME and related Sheath types) sharply decreased, at the end of the 20th century and the beginning of the 21st century there is a noticeable drop (by 20-40%) in the values of the parameters plasma and magnetic field in various types of solar wind and the low level of parameters persists or continues to decrease in 23-24 cycles [*Yermolaev et al.*, 2021].

It should be noted that the above results on the decrease in parameters in 23-24 cycles were obtained for different physical quantities measured by various methods and different instruments on various spacecraft included in the OMNI database. This greatly reduces the likelihood that this decline is associated with some methodological effects and increases the reliability of the results and conclusions.

Such a drop in the solar wind parameters in 23-24 cycles is apparently associated with a decrease in solar activity and results in a noticeable decrease in space weather factors.

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