

THE RELATIONSHIP BETWEEN SOLAR WIND VELOCITY AND SOLAR WIND THERMAL PRESSURE

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1. Introduction

Many processes in the Earth's magnetosphere are controlled by the solar wind parameters. One of such parameters is the velocity of the solar wind V . In particular, it has been shown that the velocity correlate with the level of geomagnetic activity on the ground. *Gleisner and Lundstedt* [1997] found the dependence of AE index on V in the form of equation $AE \sim \sqrt{n} \cdot V^3 \cdot B_S$, where n is proton number density, and B_S is the IMF southward component. *Lubchich et al.* [2001] gave an example of close correlation of AE index with V for two consequent high-speed solar wind streams. *Goncharova and Maltsev* [2001] demonstrated the correlation between Kp index and V . Although the velocity of the solar wind is one of the main parameters determining the energy input into the magnetosphere (e.g. *Akasofu* [1979]) and the solar wind electric field $\vec{E} = \vec{V} \times \vec{B}$, the particular mechanism of above-mentioned correlations is unknown. A possible explanation may relate to the strong influence of the velocity on the solar wind dynamic pressure $n \cdot m \cdot V^2$ where m is the proton mass. The dynamic pressure correlates with the intensity of the magnetic field in the near-Earth and mid-tail, that is, with the intensity of the cross-tail current (*Fairfield and Jones* [1996]). Thus, high dynamic pressure produces better conditions for the development of current instabilities, plasma heating and precipitation affecting the ionospheric currents (appearing as an increase of AE and Kp indices).

Perhaps, the most spectacular geophysical phenomenon correlating with the velocity of the solar wind is the appearance of substorm signatures at very high latitudes (Inv. Lat. $>75^\circ$) during periods of high-speed solar wind. Such correlation has been found for high latitudinal propagation of the substorm-related electrojet (*Sergeev et al.* [1979], *Dmitriev and Sergeev* [1984]), auroras (*Gussenhoven* [1982]), and riometer absorption (*Weatherwax et al.* [1997]).

Very high latitudes map, presumably, to the far magnetotail. Influence of the dynamics pressure is negligible there, because the solar plasma flow is almost parallel to the magnetopause. Does another physical parameter exist which depends on V and which influence might be crucial for substorm instability in the far tail? The far-tail lobe

magnetic field and cross-tail current should be controlled by solar wind (magnetosheath) magnetic pressure $\frac{B^2}{2 \cdot \mu_0}$ and thermal pressure $n \cdot k \cdot (T_p + T_e)$. Here T_p (T_e) is a proton (electron) temperature, μ_0 is a magnetic permeability constant, and k is the Boltzmann constant. The aim of our study presented in this paper is to find out if these pressures depend on the V .

A significant disadvantage of studies of the thermal solar wind is the lack of the solar wind electron measurements onboard many past spacecraft. As a result, the OMNI database (<http://nssdc.gsfc.nasa.gov/omniweb/>), which is often in use for statistical studies, does not contain electron parameters. Only few papers dealt with the solar wind electrons (see, for example, *Sittler and Scudder* [1980]), neither correlative features of the electron parameters were established in details. Some authors simply suggest a proportionality of the electron thermal pressure and the proton one (see, for example, *Fairfield and Jones* [1996] and references therein). Fortunately, recently, the data from the ISTP WIND spacecraft became available (http://cdaweb.gsfc.nasa.gov/cdaweb/istp_public/). Below we will present the result of a statistical study of the relationship between magnetic and the thermal pressures and velocity of the solar wind on the basis of this database.

2. Data

In this paper two sets of data have been used. The first one is the widely used OMNI database containing the solar wind parameters for about 30 years. The 1-hour averaged data on the plasma velocity, proton density and temperature as well as on the interplanetary magnetic field have been selected from the database. Another set of data is the ~1-minute averaged proton and electron parameters obtained onboard the WIND spacecraft in 1995. During this year (which is the year around of the solar activity minimum) a lot of recurrent high-speed plasma flows were detected, so the velocity varied considerably.

3. Results

Figure 1 presents how the proton thermal pressure and magnetic pressure of the solar wind depend on the velocity. The solar wind parameters were obtained from the OMNI database for 1963-1991. It is clear that the magnetic

pressure does not depend on the velocity, while the proton thermal pressure increases when velocity exceeds 500 km/s. Although this fact agreed with the hypothesis claimed in the *Introduction* that the solar wind velocity affects the far magnetotail through the thermal pressure, further consideration disprove this idea.

Figures 2 shows the dependence of the electron and proton temperature as well as plasma density on the solar wind velocity obtained from data of the Wind spacecraft. The data of the Wind 3-D Plasma Analyzer instrument were used. The velocity increases as the plasma density decreases, the proton temperature T_p increases, and the electron temperature T_e decreases. The behavior of electron temperature is in agreement with observations of *Sittler and Scudder* [1980] who found that near the Earth the electron temperature in the solar wind relates to the plasma density as

$$T_e = T_{e0} \cdot \left(\frac{n}{n_0} \right)^{1/6}, \text{ where } T_{e0} \text{ and } n_0 \text{ are long-term averages.}$$

Figure 3 shows the regression lines for proton, electron, and total thermal pressure. The proton pressure increases when the solar wind velocity increases (in agreement with the dependence shown in Figure 1), but electron pressure decreases. As the result the total pressure does not vary significantly (one can note that total pressure even decreases).

Finally, Figure 4 demonstrates the dependence of the dynamic pressure on the solar wind velocity. The dynamic pressure increases with the velocity, but the dependence is far from a quadratic function. This means that the density variations are significant for dynamic pressure.

4. Conclusion

The results of this study show that the velocity of solar wind does not correlate with the solar wind thermal pressure. In particular this means that the thermal pressure is not a factor determining the appearance of substorms at high latitudes. The mechanism of the solar wind influence on the high-latitude substorm propagation is still unknown.

Acknowledgements. The work has been supported by the grant INTAS 99-00078. Data needed for this study were borrowed from http://cdaweb.gsfc.nasa.gov/cdaweb/istp_public/. The principal Investigator of the Wind 3-D Plasma Analyzer instrument is R.Lin. OMNI data were taken from NSSDC CD-ROM obtained by the courtesy of J. King.

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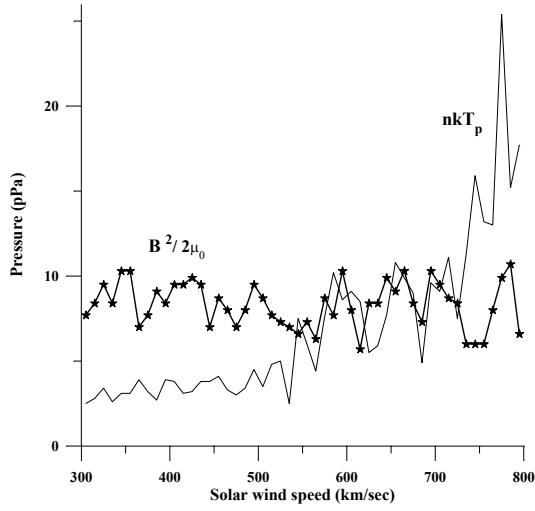


Figure 1.
Dependence of the thermal and magnetic pressure on the solar wind velocity (OMNI database).

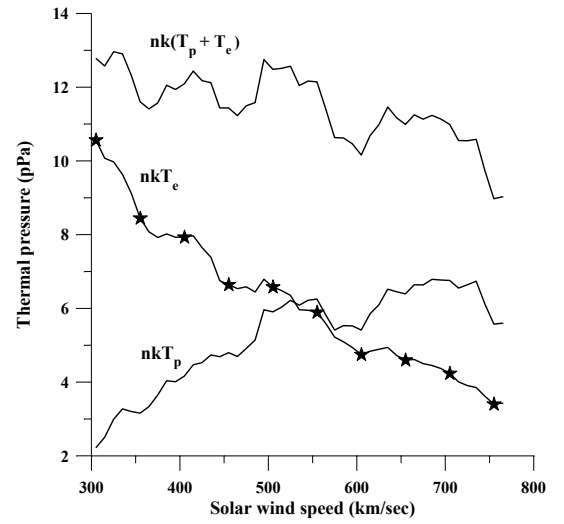


Figure 3.
Dependence of the thermal pressure on the solar wind velocity (WIND data).

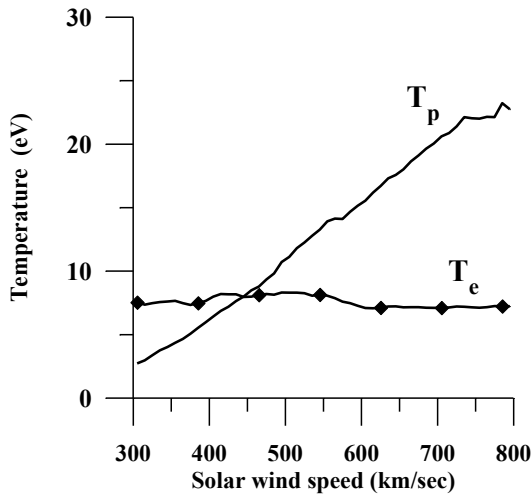
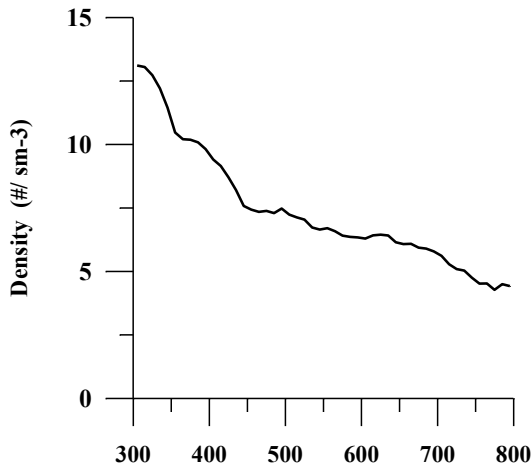


Figure 2.
Dependence of the electron and proton temperature (bottom), and the density (top) on the solar wind velocity (WIND data).

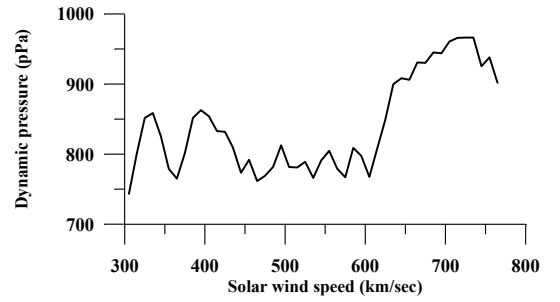


Figure 4.
Dependence of the dynamic pressure on the solar wind velocity (WIND data).