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Annual variations of the probability distributions of solar wind parameters using Helios data near 0.3 AU

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RESUMEN

Hemos distribuido las observaciones promediadas por hora del satélite Helios 1 en seis períodos anuales (fines de 1974-1975, 1976, 1977, 1978, 1979 y 1980). Para cada período, se obtuvieron las curvas de distribución de probabilidad de los siguientes parámetros del viento solar: velocidad, temperatura y número de partículas por cm^3, alrededor del perihelio (0.3-0.5 AU). Estas curvas muestran la evolución de dichos parámetros desde el mínimo de actividad solar hasta el máximo para la región cercana al Sol. Encontramos una clara separación entre la distribución de baja velocidad y la de alta velocidad. La distribución de baja velocidad se puede ajustar bien con una distribución Gaussiana. El máximo en la distribución de baja velocidad, usando un ajuste Gaussiano, es independiente del ciclo solar. También se encuentra que durante los años de transición, 1978 y 1979, existe una distribución de velocidad intermedia poco usual, la cual no había sido reconocida anteriormente.

PALABRAS CLAVE: viento solar, ciclo solar, Helios 1.

ABSTRACT

We have sorted the Helios 1 hourly average data into six yearly bins (late 1974-1975, 1976, 1977, 1978, 1979 and 1980). Probability distribution curves were then obtained for each yearly bin for the solar wind parameters: velocity, temperature and number density at perihelion (0.3 - 0.5 AU). These curves show the evolution of these solar wind parameters from solar minimum through solar maximum for the region close to the sun. We find a clear separation between the low-speed and high-speed distributions. The low-speed distributions can de well fit by a Gaussian distribution. The low-speed peak velocity obtained by Gaussian fit is independent of the solar cycle. We also find that the transition years, 1978 and 1979, show an unusual intermediate-speed distribution not previously recognized.

KEY WORDS: solar wind, solar cycle, Helios 1.

INTRODUCTION

Sorting the Helios 1 hourly average data near perihelion (0.3 - 0.5 AU) allows us to study solar cycle variations with less influence from in-transit effects and stream-stream interactions than similar studies using data from 1 AU. The solar cycle variations thus obtained should be more characteristic of the solar wind source regions. With this in mind, we have investigated the annual evolution of the solar wind parameters close to the sun over the solar cycle from solar minimum through solar maximum. We accomplished this by computing the annual probability distributions for various solar wind parameters for six years using Helios 1 hourly average data near perihelion. The velocity probability distributions show a clear separation of slow speed and high speed wind.

METHODOLOGY

Helios 1 hourly average data were first sorted into the 0.3 to 0.5 AU range and then sorted into six yearly bins (late 1974 - 1975, 1976, 1977, 1978, 1979 and 1980). For each yearly bin, probability distributions were computed for all the parameters; proton number density, proton bulk velocity and proton radial temperature.

The hourly average values of each parameter were next sorted into smaller size bins, for example, for velocity 10 km/s; number density, 1 cm^{-3}; and temperature, 5000 degree K. Every time the value of a parameter fell in a particular bin, the count in that bin was incremented by 1. The number of events was then computed for each bin and plotted as a function of that parameter to yield the number distribution curve. The number distribution curves for velocity, temperature and number density for the six year period are shown in figures 1, 2 and 3 respectively. The annual algebraic mean and number of events are also shown.

Years 1975 and 1976 represent solar minimum, year 1980 represents solar maximum and years 1978 and 1979 indicate the period of increasing solar activty. We will refer to 1978 and 1979 as the transition years.

Figure 1, which shows the velocity distributions for years from 1975 through 1980, indicates a separation of low-speed and high-speed components. The low-speed component is peaked between 313 km/s to 362 km/s and is evident in every year. The high-speed component is peaked at about 600 km/s and is more pronounced in 1975 and 1976 (solar minimum) and is also evident in 1977. The velocity distributions are quite different for the transition years 1978 and 1979 indicating the presence of a component with a peak around 450 km/s to 500 km/s. This

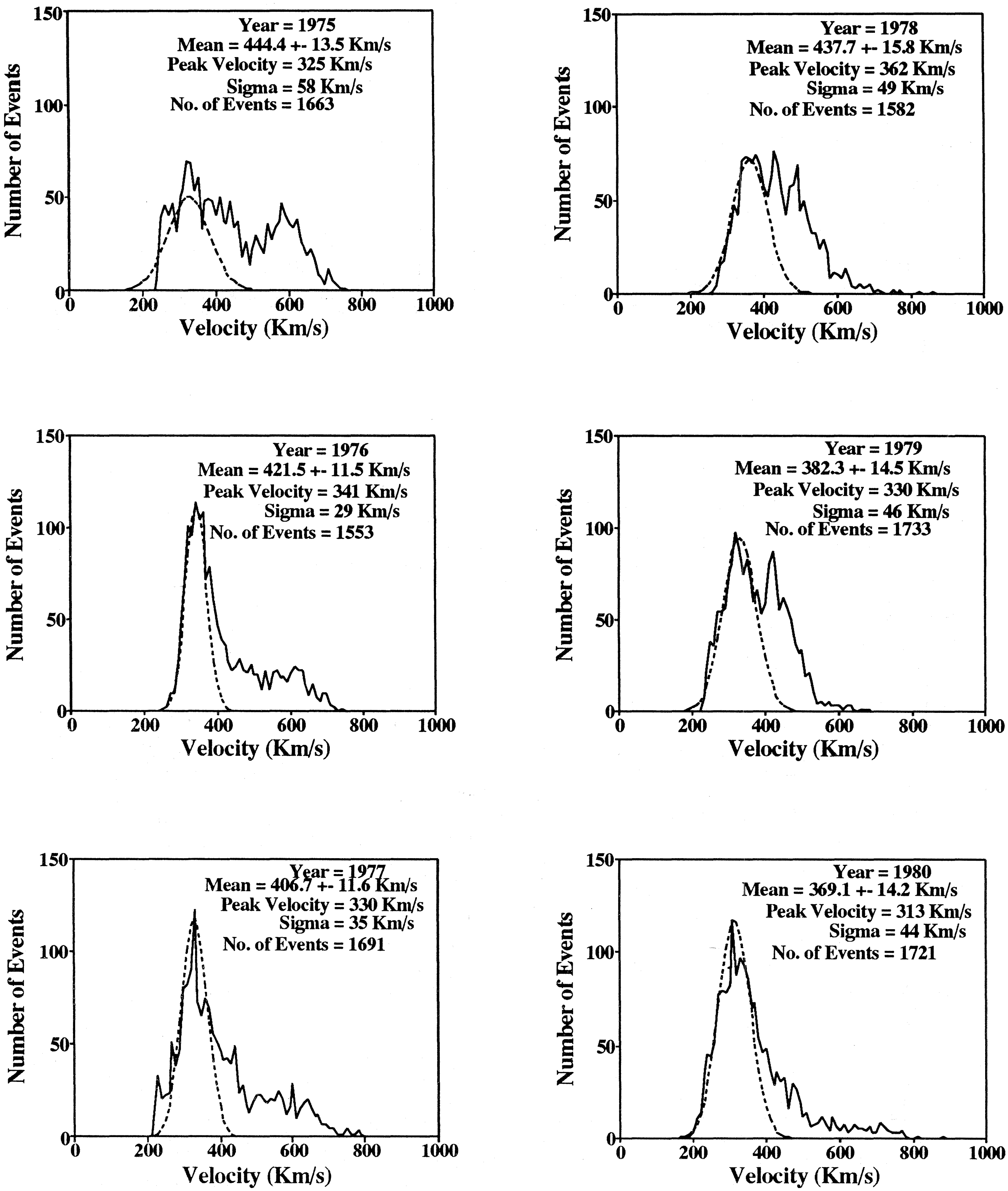

Fig. 1. Velocity distributions at perihelion (0.3 - 0.5 AU) Helios 1.

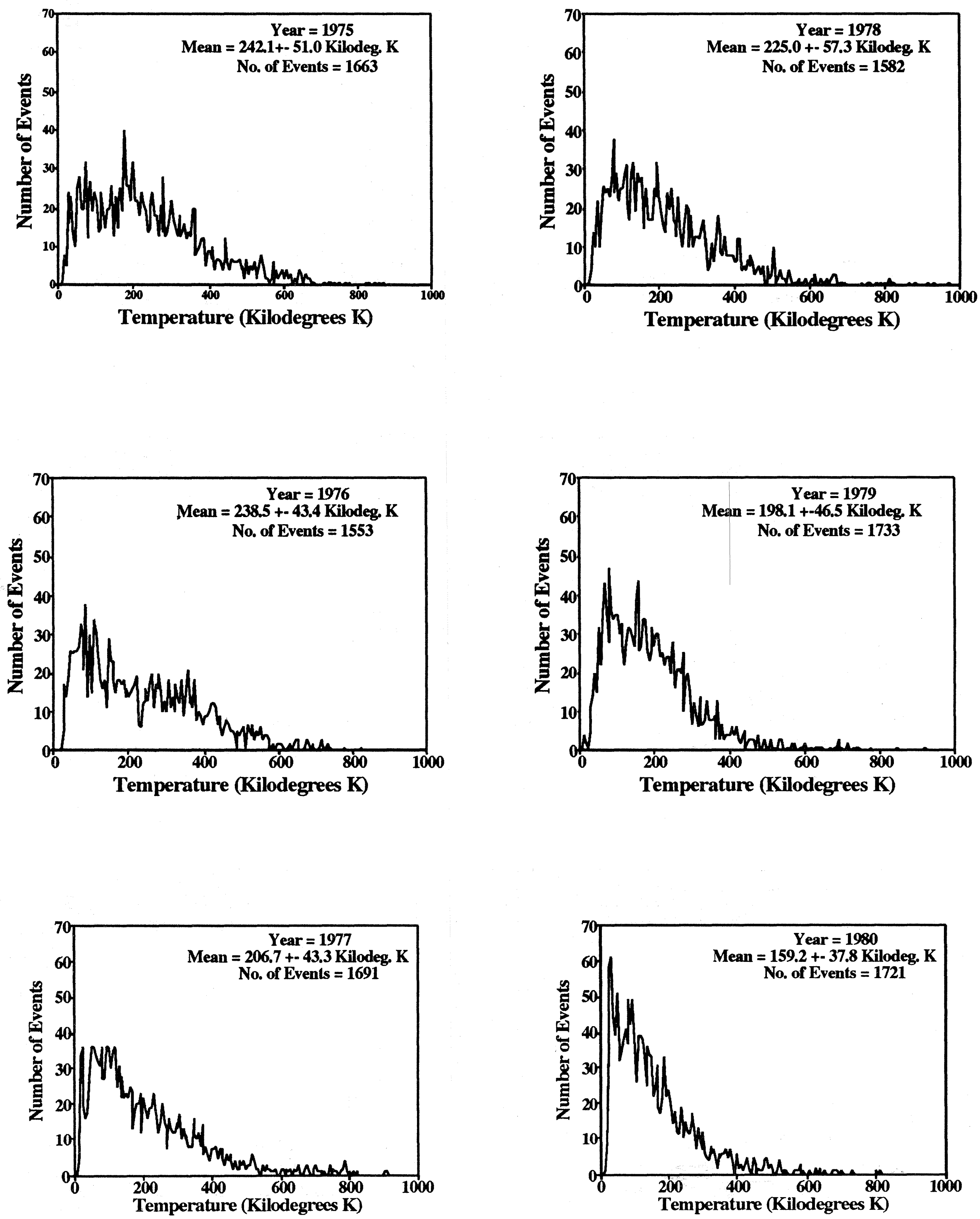

Fig. 2. Temperature distribution at perihelion (.3 - .5AU) Helios 1.

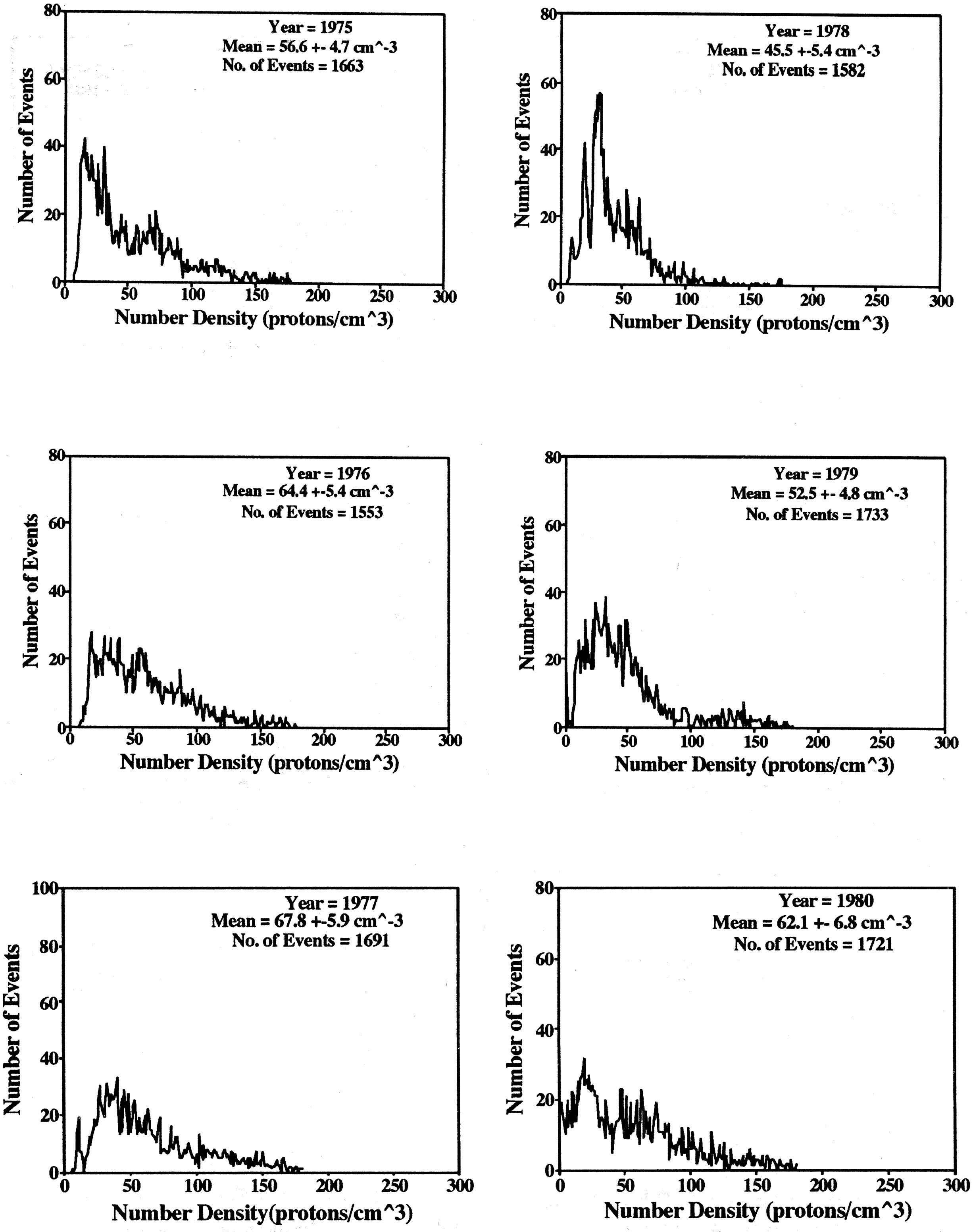

Fig. 3. Number density distribution at perihelion (.3 - .5 AU) Helios 1.

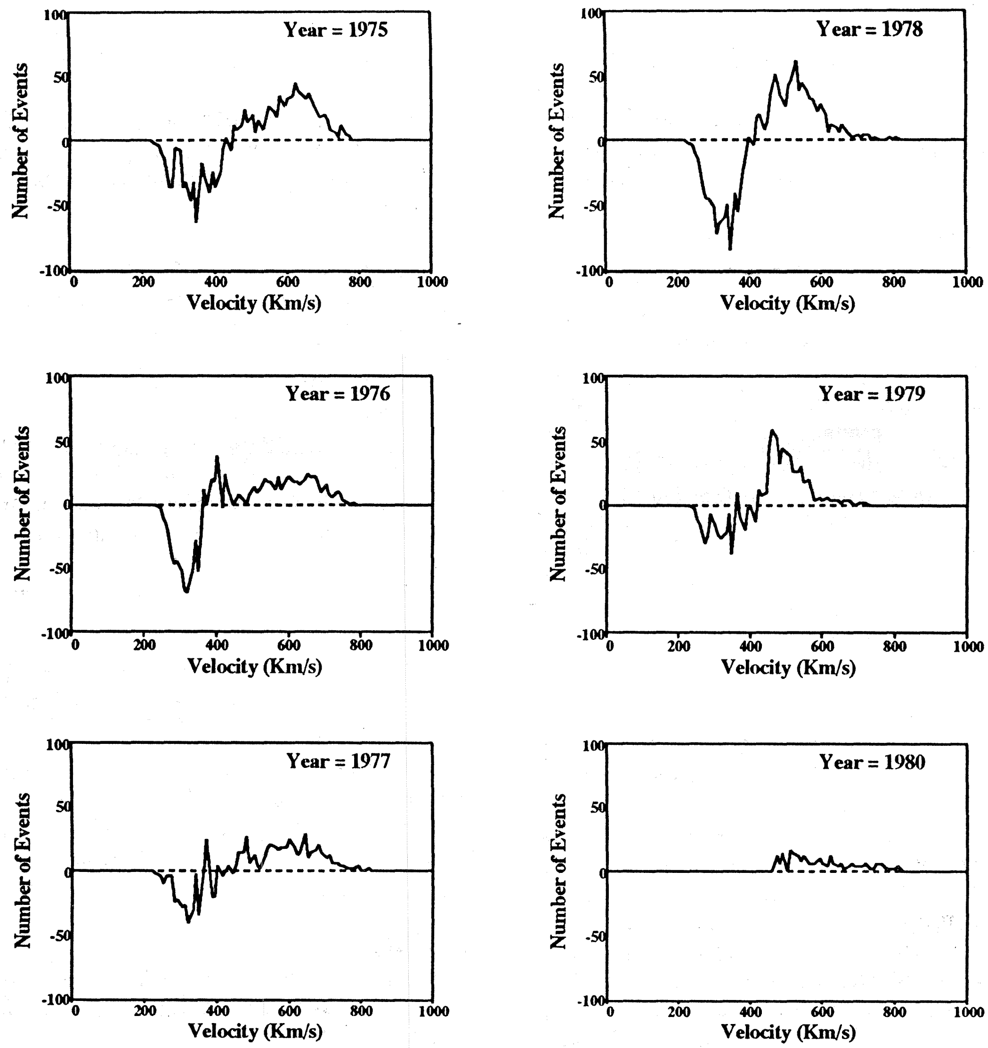

Fig. 4. Velocity distribution at perihelion with low speed in 1980, subtracted.

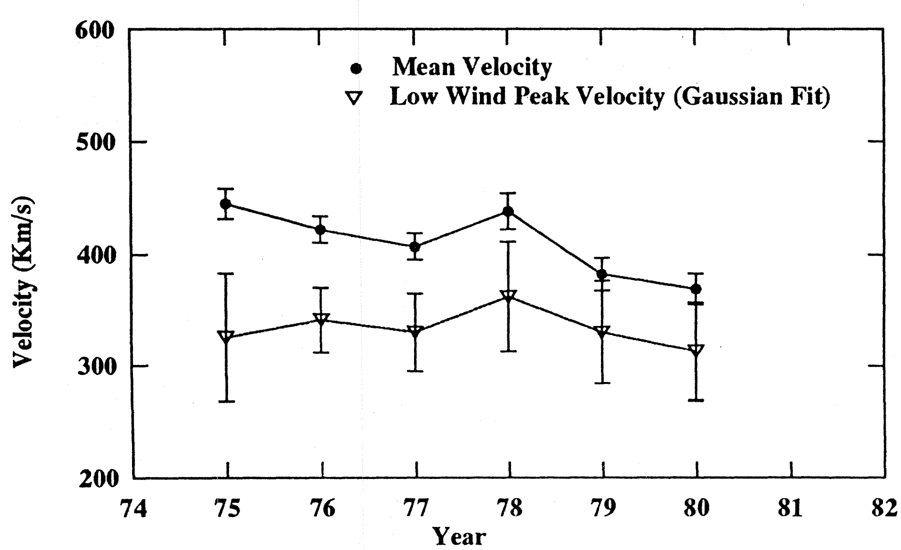

Fig. 5. Annual variations of solar wind velocity.

intermediate component is not present in years 1975 and 1976 (solar minimum) or in 1980 (solar maximum). The dotted curves in figure 1 are Gaussian fits to the low-speed component of the velocity distribution. The peak velocity and sigma of the Gaussian fits for each year are also shown in figure 1.

We have subtracted the low-speed distribution as seen in 1980 from the other years and the resulting distributions are shown in Figure 4. Figure 4 shows a clear profile of the high-speed wind during solar minimum and also the unusual intermediate speed wind profile in the transition years. Figure 5 shows the annual variations of algebraic mean velocity and peak velocity of the slow speed component obtained from the Gaussian fit. We see the expected decline in the mean velocity associated with the dissapearance of high speed streams as we move to solar maximum. Note however, that the fitted Gaussian peak velocity for the low-speed wind is essentially a constant from solar minimum to solar maximum. 1978 appears to be an anomalous year.

Figure 2 shows the temperature distributions for six years from 1975 through 1980. Each distribution curve shows a peak at low temperature and a tail extending to high temperatures. The high temperature tail grows less pronounced as we move from solar minimum to solar maximum. Figure 3 shows the number density for six years from 1975 through 1980. Each distribution shows a peak at low density and a tail extending to high density. The high density tail is evident in all years from 1975 through 1980 with the exception of 1978 when it is barely recognizable. This analysis has been repeated with Helios 2 data. Similar results were obtained.

CONCLUSIONS

1. The velocity distributions between 0.3 and 0.5 AU show a clear separation of the low-speed wind and high-speed streams, hence variations over the solar cycle can be easily seen.

2. The low-speed wind can be well fit by a Gaussian distribution and peak velocity obtained by Gaussian fits is independent of the solar cycle.

3. The transition years, 1978 and 1979, show probability distributions which are distinctly different from the solar maximum and solar minimum distributions.

4. Subtracting the low-speed wind distribution, as seen in 1980, from the other years leads to a clear profile of the high-speed wind during solar minimum and an unusual intermediate speed wind profile in the transition years. This intermediate speed wind may be the high-speed wind decreasing to lower velocities.

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