8. Summary

The scientific objective of this study, being part of the German contribution CGAUSS (Coronagraphic German and US Solar Probe Plus Survey) to the Wide field Imager for Solar Probe (WISPR), was to model the solar wind environment for the Parker Solar Probe mission (formerly Solar probe Plus) to be launched mid 2018 as.

For this purpose we derived lognormal representations of the frequency distributions' shapes of the four key solar wind parameters magnetic field strength, proton velocity, proton density and proton temperature for the near-Earth solar wind OMNI data, and the Helios 1 and 2 data obtained over the distance range 0.29–0.98 au. The dependencies of these frequency distributions on the solar activity cycle and on radial distance to the Sun were modelled with analytical relations and then extrapolated to the Parker Solar Probe or-bit, taking into account predictions of the sunspot number. With the resulting CGAUSS empirical solar wind model for PSP the following estimations for the solar wind median values at PSP's first perihelion in 2018 at a solar distance of 0.16 au and for PSP's closest perihelion in 2024 at 0.046 au (9.86 RS) are obtained:

- The dependency of the magnetic field strength median value on solar activity and radial distance is
  $B_{med}(ssn, r) = (0.0131\ nT \bullet ssn + 4.29\ nT) \bullet r^{-1.66}$. (12)
  This approximation starts to reveal uncertainties of about 20 % in the distance range below 20 RS from the Sun.
- The estimated magnetic field values for PSP's first and closest perihelion are 87 nT and 943 nT.
- The radial dependency of the median velocity value for slow and fast solar wind is
  $v_{slow}(r) = 363\ km\ s^{-1} \bullet r^{0.099}$ (13)
  $v_{fast}(r) = 483\ km\ s^{-1} \bullet r^{0.099}$. (14)
  These relations appear valid to distances of about 20 RS before they overestimate the actual solar wind velocities obtained from remote measurements.
- The calculated median values for PSP's first and closest perihelion are 340 km s−1 and 290 km s−1.

- The solar wind frequency distribution dependence on solar activity as measured by the internaionasl sunspot number was found to be c(ssn) = 0.00180 ssn + 0.64. At solar minimum and sunspot numbers around 0 the slow wind contributes to 64% to the overall solar wind distribution, dropping to 28 % at solar maximum conditions with ssn around 200.

– The density relation is found to be

nmed(ssn, r) = 0.0038 cm−3 • ssn + 4.50 cm−3 • r−2.11 . (15)

This relationship seems valid throughout the full PSP orbital distance range, even down to about 8 RS.

- The estimated proton density values for PSP's first and closest perihelion are 4015 cm−3 and 9733 cm−3.

– The derived correlation function for the temperature is

Tmed(ssn, r) = (197 K • ssn + 57 300 K) • r−1.10 . (16)

Around PSP's perihelion this relationship seems provides too high proton temperature values in comparison to coronal measurements.

- The estimated proton temperature values for PSP's first and closest perihelion are 503 000 K and 1 930 000 K.

The limitations of the extrapolated values at distances below 20 R indicate the occurrence of solar wind acceleration and heating processes. PSP will thus be able to directly measure these processes as planned.

The results of the modelled solar wind environment will be useful to help optimize the WISPR and in situ instrument science plannings and PSP mission operations. This also applies for the Heliospheric Imager (SoloHI) (Howard et al. 2013) and the in situ instruments on board the Solar Orbiter spacecraft.

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ABSTRACT

Context. The Parker Solar Probe (PSP) (formerly Solar Probe Plus) will be humanity's first in situ exploration of the solar corona with a closest perihelion at 9.86 solar radii distance to the sun. It will help answer hitherto unresolved questions on the heating of the solar corona and the source and acceleration of the solar wind and solar energetic particles. The scope of this study is to model the solar wind environment for its unprecedented distances during its prime mission phase during the years 2018–2025. The study is performed within the project Coronagraphic German And US Solar Probe Survey (CGAUSS) which is the German contribution to the PSP mission as part of the Wide field Imager for Solar PRobe (WISPR).

Aims. We present an empirical solar wind model for the inner heliosphere which is derived from OMNI and Helios data. The German-US space probes Helios 1 and Helios 2 flew in the 1970s and observed solar wind in the ecliptic up to heliocentric distances of 0.29–0.98 au. The OMNI database consists of multi-spacecraft intercalibrated in situ data obtained near 1 au and provides data for more than five solar cycles. The sunspot number and its predictions are used to derive the dependency of the solar wind on solar activity and to forecast its properties for the PSP mission.

Methods. The solar wind key parameter frequency distributions for the magnetic field strength, proton velocity, number density and temperature of the OMNI and Helios data are represented by lognormal functions. In addition, we consider the solar wind velocity distribution's bi-componental shape, consisting of a slower and a faster part. Based on the analysis of the OMNI and Helios data sets an empirical solar wind model is derived accounting for solar activity and for solar distance through adequate shifts of the lognormal distributions. From the found relationships of the functions with solar activity the solar wind parameter frequency distributions are fitted with power law dependencies. Finally, through extrapolation the empirical solar wind model for the PSP orbit and its expected phase of the sunspot cycle is obtained.

- *Results*. The CGAUSS empirical solar wind model for PSP yields dependencies of the solar wind parameter median values on solar activity and radial distance. The estimations for the solar wind median values for PSP's first perihelion in 2018 at a solar distance of 0.16 au are 87 nT, 340 km s−1, 4015 cm−3 and 503 000 K and 943 nT, 290 km s−1, 9733 cm−3 and 1 930 000 K for PSP's closest perihelion in 2024 at 0.046 au (9.86 RS). The modeled values below 20 RS appear overestimated in comparison with existing ob- servations. Thus below 20 RS PSP is expected to directly measure solar wind acceleration and heating processes as planned.

Key words. solar wind – sun: heliosphere – sun: corona, Parker Solar Probe