Long-Term Datasets for the Understanding of Solar and Stellar Magnetic Cycles
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Solar cycle variation of coronal mass ejections contribution to solar wind mass flux

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Abstract. Coronal Mass Ejections (CMEs) contribute to the perturbation of solar wind in the heliosphere. Thus, depending on the different phases of the solar cycle and the rate of CME occurrence, contribution of CMEs to solar wind parameters near the Earth changes. In the present study, we examine the long term occurrence rate of CMEs, their speeds, angular widths and masses. We attempt to find correlation between near sun parameters of the CMEs with near the Earth measurements. Importantly, we attempt to find what fraction of the averaged solar wind mass near the Earth is provided by the CMEs during different phases of the solar cycles.

Keywords. Sun: coronal mass ejections (CMEs), Sun: solar wind

1. Introduction

Coronal Mass Ejections (CMEs) are important as they carry a huge amount of magnetized plasma from the Sun to the near Earth environment. Earlier studies have attempted to quantify the contribution of CMEs to background solar wind mass flux wherein the contribution of CMEs ranged from 3 to 16% (Hildner *et al.* 1977, Howard *et al.* 1985, Jackson & Howard 1993, Lamy *et al.* 2017). For correct utilization of data of CME occurrence rate, the data should be corrected under consideration of instrument-dependent effects, mass and geometrical distributions of CMEs. Earlier studies were based on the shorter period of data from different coronagraphs (e.g., Skylab, Solwind, and SMM) and thus involved different duty cycle corrections and inter-calibration of visibility function. In our study, we reexamine the CMEs contribution using their homogeneous data sets obtained from a single instrument, the Large Angle and Spectroscopic Coronagraph (LASCO) onboard SOlar and Heliospheric Observatory (SOHO) spacecraft Brueckner *et al.*(1995), for solar cycle 23 and 24.

2. Methodology and Analysis

The occurrence rate of CMEs, their angular size, speeds and mass are based on LASCO onboard SOHO observations. The occurrence rate of Interplanetary counterparts of CMEs (ICMEs) near the Earth and their speeds are based on the in in-situ observations of ACE and WIND. We have also calculated the contribution of CMEs to the solar wind mass flux measured at 1 AU near the Earth on an annual basis and its variation over the solar cycle 23 and 24. For this purpose, we calculated the annual average of CME mass per day ejected into the equatorial latitude bin of 10° width by making appropriate corrections for CMEs latitude and their angular sizes, following the method of Howard *et al.* (1985). Assuming that mass ejected into the ecliptic plane is distributed uniformly at all the longitudes, we determined the equatorial mass flux at 1 AU. Further,

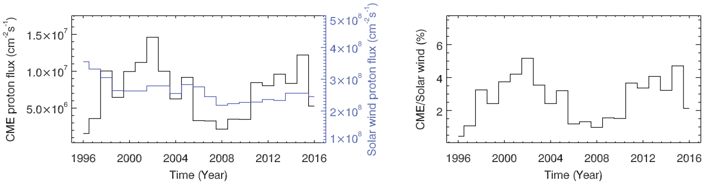

Figure 1. The variation of the CMEs and solar wind proton fluxes at 1 AU in the near-ecliptic region is shown in the left panel. The ratio of CME to solar wind mass flux is shown in the right panel.

assuming that helium constitutes 10% of this mass, we determined the proton flux at 1 AU due to CMEs.

3. Results and Discussion

Based on our analysis, we find that in the ecliptic region, the contribution of CMEs to the solar wind mass flux is negligibly small during the solar minimum but increased to ≈5% at the maximum of solar cycles 23 and 24. It is also noted that the fractional contribution of CMEs to the solar wind mass flux closely tracks the solar cycle. In ecliptic near the Earth, averaged solar wind flux is relatively constant compared to the CME flux during different phases of the solar cycle 23 and 24 (Figure 1).

The analysis also shows that although the occurrence rate of CMEs is more for Solar cycle 24 than 23, the speeds of CMEs and ICMEs are lower in solar cycle 24 than those during solar cycle 23. The occurrence rate of CMEs tends to track the solar activity cycle 23 and 24 in both amplitude and phase except in the descending phase of cycle 23. Although sunspot numbers in solar cycle 24 are half of that in previous cycle, the rate of CMEs is little higher in solar cycle 24 than that in the corresponding phase of previous cycle 23. This may be possible because of inclusion of many faint events after the middle of solar cycle 23. In contrast to the total number, the mass loss rate at any solar latitude is lesser for solar cycle 24 than cycle 23. It is possible that fast and massive CMEs may show a stronger dependence on the sunspot numbers than weaker CMEs. The CMEs in solar cycle 24 are noted to be slower on average having a narrow speed range than those during the solar cycle 23. During the solar maximum, CMEs are wider and more uniformly distributed in latitude than during the solar minimum.

For calculating mass flux of CMEs, we have made several approximations regarding structure of CMEs, their masses and distributions. Our approach to calculate latitude of CMEs from their central position angle (CPA) may not be perfectly valid for all the CMEs. Further study is required to assess the consequence of such approximations on the estimated CMEs contribution to solar wind mass flux.

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