Interplanetary scintillation observations for the solar wind disappearance event of May 1999

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Abstract. In this article we present ground-based interplanetary scintillation (IPS) measurements at 103 and 327 MHz for the period of the solar wind disappearance event of May 1999 as seen by various space probes. The solar wind velocity measurements at 327 MHz showed a variable solar wind velocity during this period at a distance of ~0.5 AU from the Sun. The average solar wind velocity from three radio sources varied in the range of 200–300 km s⁻¹. The scintillation index measurements at 103 MHz indicate that plasma density was very low in the interplanetary medium closer to the Earth and that the density was normal away from it during May 11–13. The scintillation index was enhanced significantly on May 14 after the disappearance event. The comparison with the in situ observations shows that the effect is dramatic in IPS observations. IPS and in situ measurements show that a large, tenuous, and slow plasma cloud engulfed our planet around this time, which could be because of a corotating low-density narrow stream. From the source (Sun) point of view, this was mostly a normal plasma flow in most of the interplanetary medium.

1. Introduction

During May 10–12, 1999, NASA’s Wind, IMP 8, and Lunar Prospector spacecraft, the Russian Interball satellite, and the Japanese Geotail satellite observed the most distant bow shock ever recorded by satellites. It is reported in the NASA press release on December 13, 1999, that in this event the solar wind that blows constantly from the Sun virtually disappeared. It was the most drastic and longest-lasting decrease ever observed in the solar wind. With the density dropping to a fraction of its normal density and the velocity dropping to half its normal velocity, the solar wind died down enough to allow physicists to observe particles flowing directly from the Sun’s corona to the Earth. This severe change in the solar wind also changed the shape of Earth’s magnetic field. A special session of the American Geophysical Union 1999 Fall Meeting was devoted to discussing this extraordinary event and its consequences from a solar-terrestrial perspective [Lazarus, 2000]. Lazarus [2000] reported that though there had been other instances of low density, this period of more than 27 hours was the longest having a density below 1 particle cm⁻³. The pressure exerted by the solar wind was so low that the shock front formed by the interaction between the solar wind and Earth’s magnetic field moved outward from its usual location (~15 Earth radii (RE) in front of the Earth) to at least 60 RE.

Le et al. [2000a] examined the magnetic field data from Polar Magnetic Field Experiment (MFE) to study the magnetospheric current system and found that the magnetosphere was more dipolar than usual but that the ring current did not disappear. In the inner magnetosphere the residual field, the observed magnetic field at Polar with the internal field removed, was dominated by the ring current contribution. Le et al. [2000b] examined both the upstream waves and the waves at Polar and midlatitude ground stations in the Pc3–4 band and found a near absence of upstream ULF waves on May 11, owing to a weakened bow shock and a low Mach number of the solar wind flow past the Earth.

Here we present the ground-based observations of interplanetary scintillation at 103 and 327 MHz for the period around this event, and we discuss the implications of these. Hewish et al. [1964] at the University of Cambridge, England, discovered interplanetary scintillation (IPS). The Cambridge IPS observations were extensively used to make g-maps [Tappin, 1985] and a novel form of synoptic plots [Woan, 1995]. The synoptic plots are particularly sensitive to corotating structures. The scintillation enhancement factor $g$ is defined as

\[ g = \frac{\text{observed scintillation index}}{\text{expected scintillation index}}. \]  

(Tappin [1985] found that $g$ is strongly correlated with the solar wind density, under both disturbed and ambient conditions, as

\[ g = \left(\frac{N}{9}\right)^{1/2}, \]  

where $N$ is the solar wind density (cm⁻³). IPS is the same phenomenon as the optical twinkling of stars scaled to radio wavelength. In both cases a wave traveling through an inhomogeneous medium is scattered into an angular spectrum which causes a loss of resolution in a telescope and decorrelation in an interferometer. In the case of IPS (and radio waves in general) intensity scintillation is more important. The intensity scintillation results from the interference between the plane waves of the angular spectrum. For IPS the irregularities...