Unusual solar energetic proton fluxes at 1 AU within an interplanetary CME

T. MULLIGAN[1], J. B. BLAKE[1], R. A. MEWALDT[2].
[1]*The Aerospace Corporation, Space Sciences Applications Laboratory, Los Angeles, CA, USA*
[2]*California Institute of Technology, Pasadena, CA, USA*
Tamitha.Mulligan@aero.org

Abstract: In mid December 2006 several flares on the Sun occurred in rapid succession, spawning several CMEs and bathing the Earth in multiple solar energetic particle (SEP) events. One such SEP occurring on December 15th was observed at the Earth just as an interplanetary CME (ICME) from a previous flare on December 13th was transiting the Earth. Although solar wind observations during this time show typical energetic proton fluxes from the prior SEP and IP shock driven ahead of the ICME, as the ICME passes the Earth unusual energetic particle signatures are observed. Measurements from ACE, Wind, and STEREO show unusual proton flux variations at energies ranging from ∼3 MeV up to greater than 70 MeV. Within the Earths magnetosphere Polar HIST also sees unusual proton flux variations at energies greater than 10 MeV while crossing open field lines in the southern polar cap. However, no such variation in the energetic proton flux is observed at the GOES 10 or GOES 11 spacecraft in geosynchronous orbit. Differential fluxes observed at GOES 12 in the 15-40 MeV energy range show some variation. However, the overall energetic particle signature within the ICME at GEO orbits remains unclear. This event illustrates the need for caution when using GEO data in statistical studies of SEP events and in interplanetary models of energetic particle transport to 1 AU.

Introduction

In mid December 2006 several flares on the Sun occurred in rapid succession, spawning several CMEs and bathing the Earth in multiple solar energetic particle (SEP) events. One such SEP occurring on December 15, 2006 was observed at the Earth coincidentally as an interplanetary CME (ICME) associated with a previous solar flare on December 13, 2006 was transiting the Earth. In situ observations of these events were made in the solar wind with several spacecraft including ACE [1], Wind [2], and STEREO [3], and in the Earths magnetosphere with Polar [4] and GOES 10, 11, and 12 satellites [5]. Neutron monitors provided the context for more detailed comparisons of the in situ measurements.

On December 14, 2006, a shock driven by the transiting ICME was observed at ACE and Wind at ∼1355 UT. At this time, ACE and Wind were on opposite sides of the Earth-Sun line and above the heliospheric neutral sheet, separated by ∼100 Re along the dawn-dusk line. Both spacecraft were near the L1 Lagrangian point at ∼240 Re sunward of the Earth. The newly launched STEREO spacecraft were just outside the Earths bow shock at ∼20 Re on the dawn side and on the way towards the moon to get a gravitational assist.

Prior to the December 15, 2006 SEP event, the energetic proton flux remained elevated from December 13, 2006 SEP and interplanetary shock driven ahead of the ICME. Shortly after the shock passage, the second SEP with a harder spectrum was observed on December 15, 2006 at XXXX UT, coincident with the Earth crossing into the leading edge of the ICME. It is during this time that measurements from ACE, Wind, and STEREO showed a similar, but unusual temporal profile in the integrated proton flux at energies ranging from ∼3 MeV up to greater than 70 MeV.

Within the Earths magnetosphere during this period, Polar HIST also observed proton flux variations at energies greater than 10 MeV while crossing open field lines in the Earths southern polar cap at ∼9 Re. The temporal profile of these variations was similar to those observed in the solar wind at

ACE, Wind, and STEREO. Polar continued to observe these variations until it plunged into the radiation belts at ∼ 0400 UT on December 15, 2006.

The energetic proton flux observations differed substantially at GOES in geostationary orbit from those observed in the polar cap at Polar and in the upstream solar wind. Although GOES 10 was at dusk, GOES 11 at dawn, and GOES 12 is in the subsolar region during the SEP onset, no such variation in the integral proton fluxes was observed at GOES 10 or GOES 11. (GOES 12 integral flux data was unavailable at this time.) From GOES 10, 11, and 12 differential proton fluxes from ∼1 MeV to 80 MeV energies, only GOES 12 showed evidence of some short-scale variability, and only in the 15-40 MeV energy range. GOES 10 and 11 showed little, if any short-scale variability at any energy.

Considering the flaring region on December 15, 2006 was near the center of the solar disk, better magnetic connectivity was expected at dawn due to nominal Parker spiral field direction. However, this was not observed. Thus, the overall energetic particle signature within the ICME at GEO orbits remains unclear. We will show these detailed comparisons and comment on their significance in statistical studies of SEP events and in interplanetary models of energetic particle transport that rely heavily on GEO particle data at 1 AU.

Acknowledgements

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