On the PCA and geomagnetic field variations during Solar Proton Events on October 2003

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Abstract

One of the largest and most complex active regions of solar cycle 23, labeled NOAA 10486, has produced several intense flares as the X17 (S16, E08) and the X10 (S15, W02) occurred on 28/10 (11:30 UT), 29/10 (20:54 UT) respectively. Using the characteristics of the associated CMEs measured with SoHO/Lasco coronagraphs and the temporal evolution of solar energetic protons/electrons recorded by GOES11/GOES10 spacecrafts, we investigated the correlated observations of the interplanetary perturbations (ICMEs), the ionospheric absorption measured by riometers at Antarctic station of Casey (76° 44' S, 183° 93' E geomagnetic coordinates) and Davies (76° 49' S, 128° 20' E geomagnetic coordinates) and the geomagnetic activity recorded at Scott Base (Antarctica).

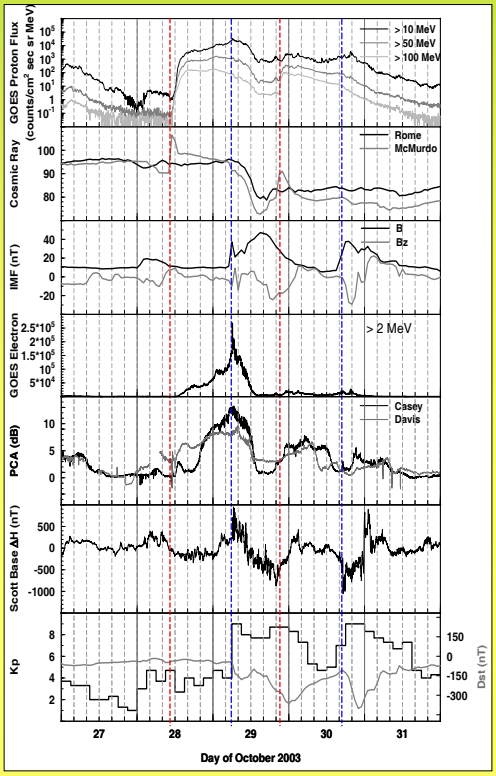

Figure 1: Several data time series are displayed for the period 27-31 October, 2003.
From upper panel; GOES Solar proton, Galactic Cosmic Ray from Neutron Monitors, Interplanetary Magnetic Field, GOES Electron flux, Casey and Davis PCA, Scott Base ΔH, and geomagnetic indices Kp and Dst

Occurrences of the solar flares (red dashed lines) and the starts of geomagnetic disturbances (after the blue dot/dashed lines) are displayed in Fig.1. Enhancements of relativistic solar protons (GLE) were well detected by a polar neutron monitors such as McMurdo observatory while lower-energy particles were recorded by GOES spacecrafts.
Geomagnetic activity is shown by the rapid enhancement of Kp values at 6 a.m. and the decrease of Dst that recovers at the end of Day 30 when the CME associated to the second flare (X10) produces a new geomagnetic storm.
We are mainly interested in evaluating the effect produced by the flare (X17) of October 28 and the related CME on polar terrestrial environment as described by McMurdo Neutron Monitor, ΔH geomagnetic component at Scott base, and Polar Cap Absorbtion of Casey and Davis stations.
Behavior of the Polar Cap Absorption (PCA) shows a good sensitivity to the incoming solar protons and electron flux, as well to the interplanetary and geomagnetic field perturbations.

In order to evaluate the impact of solar particle fluxes on PCA event, proton energy spectra averaged on time intervals of 4 hours just before and after (until 4, 8, and 12 hours respectively) have been computed.
Figure 2 displays enhancements in proton fluxes for different energy values during the occurrence of the flare (on the left) showing the higher increase at medium energies (10 – 100 MeV).
On the right of Fig. 2 the same spectra are computed for the ICME occurrence. In this case only lower energies (< 10 MeV) show increase of flux.

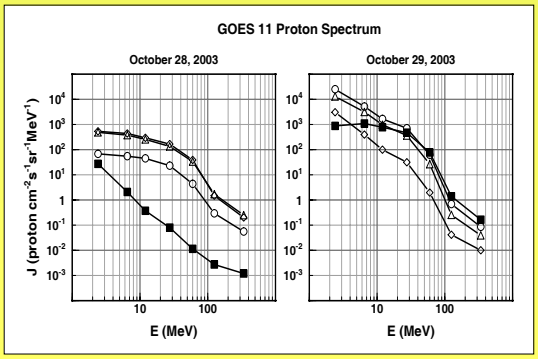

Figure 2: GOES solar proton spectra comparison among pre-increase (4 hours before -■-) and post-increase (until 4, 8, and 12 hours after -o-Δ-◊- respectively) by considering the zero-time the X-17 flare of October 28 (left panel) and the related Shock arrival on October 29 (right panel).

Electron spectra (from ACE and GOES) show a large increase for the whole range of measured energies after the flare (Figure 3 left).
At the shock arrival only GOES (>2 MeV) is enhanced respect the pre-increase values.

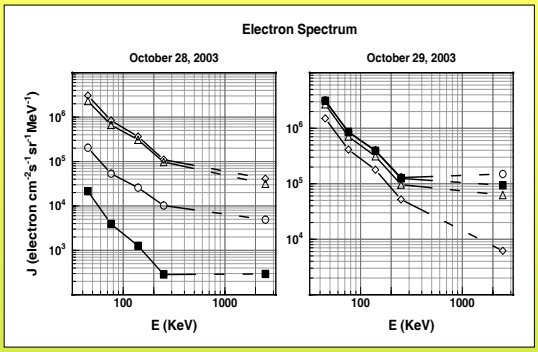

Figure 3: Electron fluxes (ACE 38-315 KeV and GOES >2 MeV) spectra comparison among pre-increase (4 hours before -■-) and post-increase (until 4, 8, and 12 hours after -o-Δ-◊- respectively) by considering the zero-time the X-17 flare of October 28 (left panel) and the related Shock arrival on October 29 (right panel).

We can summarize that during the PCA event of October 28 and 29 the incoming ICME produced increased fluxes for low energy protons (<10 MeV) and high energy electrons (>2 MeV). Time series of the above mentioned fluxes are displayed in Figure 4 (upper panel).

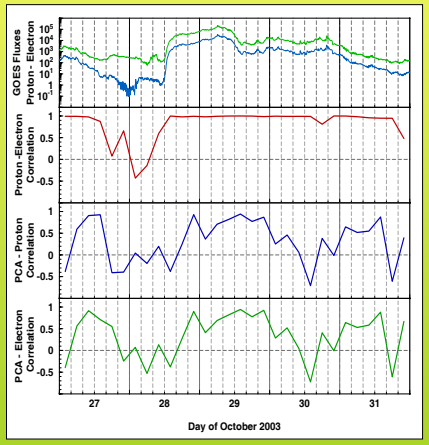

Figure 4: Electron (>2 MeV) and proton (<10 MeV) GOES fluxes (upper panel) are correlated at every 4 hours for the period October 27-31, 2003 (2nd panel). Correlation coefficient between PCA (Casey) and proton flux (3rd panel) and between PCA (Casey) and electron flux (lowest panel)

Time series of protons (<10MeV) and electrons (>2 MeV) appear to have similar profile after the flare occurrence (after 11:30 of October 28). In fact the correlation coefficient remains at very high values until the end of the event (2nd panel of Fig 4).

As already known (*) Polar Cap Absorption from Casey station in Antarctica shows a good correlation with GOES proton flux as shown on 3rd panel of Fig. 4.
We also found the same good correlation with the GOES electron flux (lowest panel).

These two correlations between PCA and particle fluxes appear with higher values and similar profiles during periods of high correlation between proton and electron (i.e. when they are accelerated by a solar transient event).

Data analyses have suggested possible clues for forecast evaluation of effects produced by the interplanetary perturbations at the Earth's orbit. Moreover Antarctic observations have again proved to be useful for the comprehension of these Sun-Earth connections.

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