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The response of Los Cerrillos detectors to the 1989/90 GLE events

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RESUMEN

Durante la fase ascendente de la actividad solar del ciclo N.22 de Schwabe se registraron once grandes incrementos de intensidad al nivel del suelo (GLEs) mediante la red de detectores terrestres de rayos cósmicos. Ocurrieron el 25 de julio, el 16 de agosto, el 29 de septiembre, 19, 22 y 24 de octubre, 15 de noviembre de 1989 y 21, 24, 26 y 28 de mayo de 1990 (es decir, todos ellos han sido registrados dentro de un intervalo de un año después de una pausa de alrededor de cinco años). Para estos acontecimientos poco usuales, se presentan los datos obtenidos en Chile (Santiago: 'Los Cerrillos'; coordenadas geográficas: 33°27'S, 70°31'W; altura: 570 m) con el monitor de neutrones standard (6 - NM - 64) y el telescopio de muones multidireccional.

PALABRAS CLAVE: Rayos cósmicos, partículas solares en el ambiente terrestre, incrementos de intensidad al nivel del suelo, Santiago, Chile.

ABSTRACT

During the ascending solar-activity phase of Schwabe cycle N.22 eleven ground-level enhancements (GLEs) have been registered by the ground-based network of cosmic-ray detectors. They are: July 25, August 16, September 29, October 19, 22 and 24, November 15, 1989 and May 21, 24, 26 and 28, 1990 (i.e., they all have been recorded within a year interval after a pause of about five years). Data obtained in Chile (Santiago: "Los Cerrillos"; geographic coordinates: 33°27'S, 70°31'W; height: 570 m) with the standard neutron monitor (6 - NM - 64) and the multidirectional muon telescope are presented for these unusual events.

PALABRAS CLAVE: Cosmic rays, Solar particles in the Earth environment, Ground-level enhancements, Santiago, Chile.

INTRODUCTION

GLE (Ground-level enhancement) events are intensity increases recorded by the cosmic-ray detectors on the Earth ground. They are due to the arrival of relativistic particles from energetic solar flares. From the start of continuous cosmic-ray measurements to 1990 fifty GLEs have been registered (Gentile *et al.*, 1990). They generally affect high-latitude detectors with geomagnetic threshold rigidity lesser than 5 GV, while only few events have been seen in low-latitude neutron-monitor data.

During the present solar cycle (Schwabe cycle N.22), eleven GLEs have been identified in the world-wide network of cosmic-ray stations and we are checking the response of the Chilean detectors (Cordaro, 1989) to them. Preliminary results are reported here.

LOS CERRILLOS DETECTORS

The Chilean cosmic-ray data are obtained in the outskirts of Santiago, at station 'Los Cerrillos' (geographic coordinates: 33°27S, 70°31'W; 570 m a.s.l.). Figure 1 reports, as an example, the monthly averages of the atmospheric pressure measured at the cosmic-ray laboratory of 'Los Cerrillos' for 1983-87.

The cosmic-ray detectors are:

- a multi-directional muon telescope continuously recording from August 1983. It consists of two layers (2 m x 2 m each) of four plastic scintillators each with 2 m separation between them (cubic geometry). To absorb the soft component of cosmic rays, a lead layer of 0.05 m thickness has been placed just underneath the upper-layer detectors. Both layers (the upper and the lower) operate in coincidence. The detectors are also used as four telescopes by means of the two-fold coincidences in the following directions: 45 S, 45 N, 45 E and 45 W from the nominal zenith angle.

- a standard neutron monitor (type: 6 - NM - 64) continuously recording from August 1988 to December 1990. In January 1991 the monitor was removed (Cordaro and Storini, 1991) to operate on King George Island (Antarctica).

Taking into account the geomagnetic field intensity (Smart and Shea, 1985), only cosmic ray particles with energy greater than 10 GeV are expected to reach 'Los Cerrillos' detectors.

THE NEUTRON MONITOR DATA

Figure 2 gives the monthly attenuation coefficients computed from August 1988 to October 1989. An average coefficient of 0.92% mmHg was estimated and applied to the uncorrected cosmic ray data. Figures 3 -13 show the pressure-corrected intensities registered with the 6 - NM - 64 detector around the GLE periods: the flare start-time has

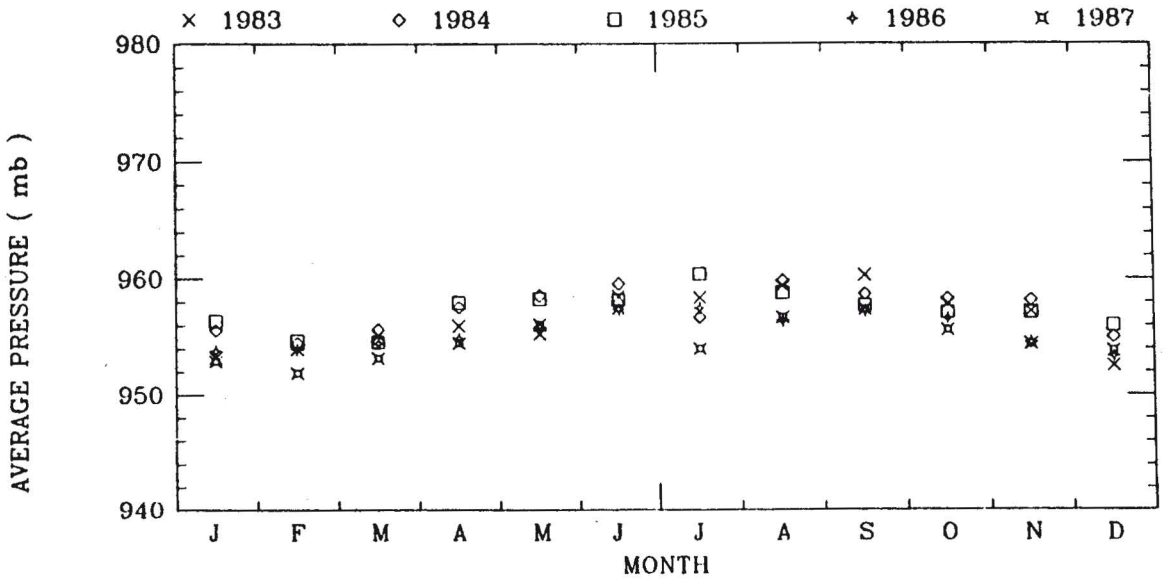

Fig. 1. Monthly average pressure observed at 'Los Cerrillos' (Santiago, Chile) from 1983 to 1987. Yearly symbols are reported on top.

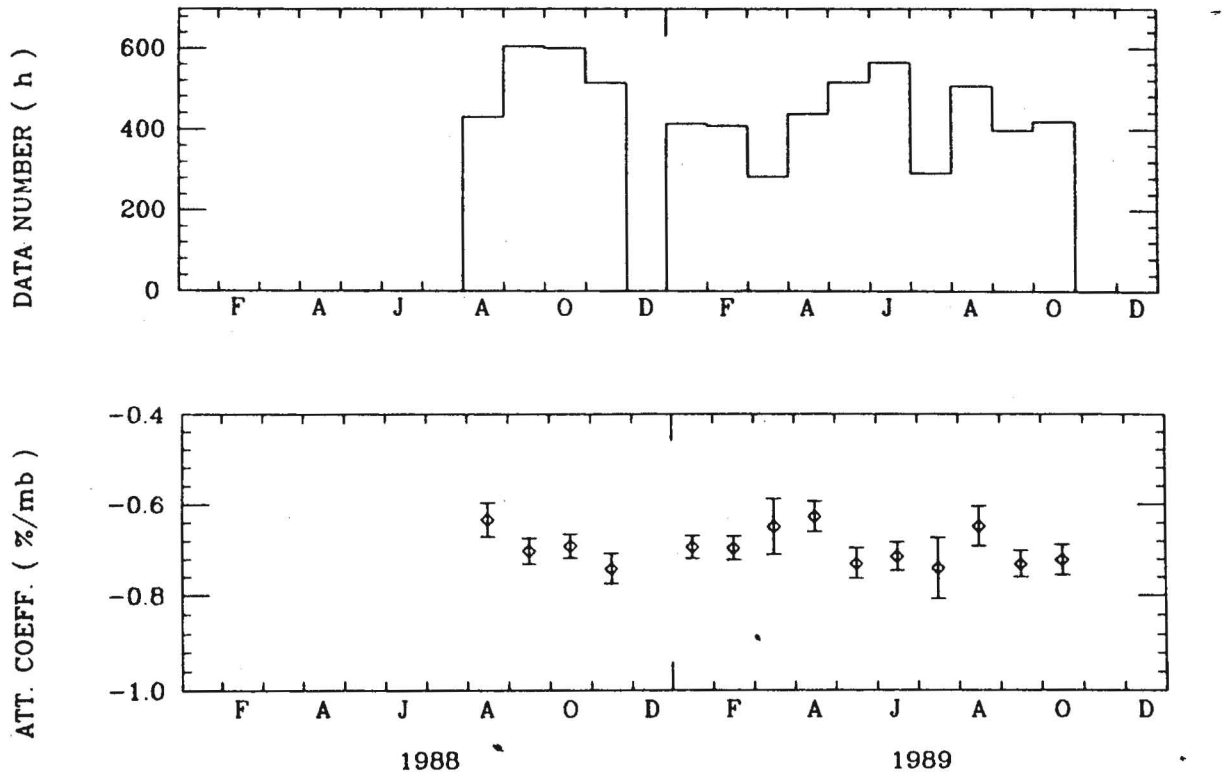

Fig. 2. Monthly attenuation coefficients for the nucleonic component of galactic cosmic rays estimated from August 1988 to October 1989 (lower panel) at 'Los Cerrillos' and the number of hourly-data used (upper panel).

been marked by a star symbol, while doubtful values were omitted (see the 'D' symbol). In each case the records for the smallest time-interval available have been selected. Table 1, compiled from SOLAR GEOPHYSICAL DATA (1989-90), presents the associated solar flare phenomena while Table 2 summarizes the results obtained. No appreciable increases from the cosmic ray background within three standard deviations (N.A.I.) are indicated, even if in this preliminary analysis the contamination of solar particles could not be always excluded. The September 29, 1989 event remains the outstanding GLE (Cordaro *et al.*, 1990).

Table 1

Solar parameters for GLE events

N.	GLE start date	Lat.	Long.	Associated flare phenomena Region	Alpha	X	II	IV
40	July 25, 1989	N26	W85	5603	Y	Y	Y	Y
41	Aug. 16, 1989	S15	W85	5629	Y	Y	N	Y
42	Sept.29, 1989		W105?	5698?	N	Y	Y	Y
43	Oct. 19, 1989	S25	E09	5747	Y	Y	Y	Y
44	Oct. 22, 1989	S27	W32	5747	Y	Y	Y	Y
45	Oct. 24, 1989	S29	W57	5747	Y	Y	Y	Y
46	Nov. 15, 1989	N11	W28	5786	Y	Y	Y	Y
47	May 21, 1990	N35	W36	6063	Y	Y	N	Y
48	May 24, 1990	N33	W78	6063	Y	Y	Y	Y
49	May 26, 1990		W105?	6063?	N	Y	N	Y
50	May 28, 1990		W132?	6063?	N	Y	?	Y

Table 2

Parameters for cosmic ray data

GLE N.	DOY	Interval (U.T.)	Reference level Intensity counts/30 min.	Pressure (mmHg)	Max. increase A(%)	interval
40	206	07-08	114000 +/- 473	713.4	0.88	0900-0930
41	227	23-24	105450 +/- 455	719.0	N.A.I.	
42	272	10-11	107100 +/- 458	718.5	34.83	1200-1230
43	292	11-12	105800 +/- 455	718.3	N.A.I.	
44	295	16-17	105800 +/- 455	715.5	1.89	1800-1830
45	297	16-17	104500 +/- 453	717.4	N.A.I.	
46	319	05-06	..... G A P ..	717.0		
			-- counts/5 min. --			
47	141	21-22	17500 +/- 185	715.8	N.A.I.	
48	144	19-20	17551 +/- 185	717.2	N.A.I.	
49	146	19-20	16753 +/- 181	722.5	N.A.I.	
50	148	03-04	17372 +/- 185	718.5	N.A.I.	

THE MUON DATA

Multi-directional cosmic-ray intensities have been also checked to look for effects induced by energetic solar particles. No evidences of clear increases (outside statistical errors) are found, except for the major GLE of September 29, 1989.

Uncorrected data for atmospheric and temperature effects are presented, the latter because of lack of information about temperature changes in the upper atmosphere. For the major GLE the daily variations of the ground temperature and the atmospheric pressure at 'Los Cerrillos' are reported in Figure 14. Moreover, the counting-rates obtained every 15 minutes from the lower (L) and upper (U) levels together with the vertical cubical-coincidence counts (V) are shown in Figure 15. Intensity increases are: about 17%, 19% and 26% for the L, U and V channels. Figure

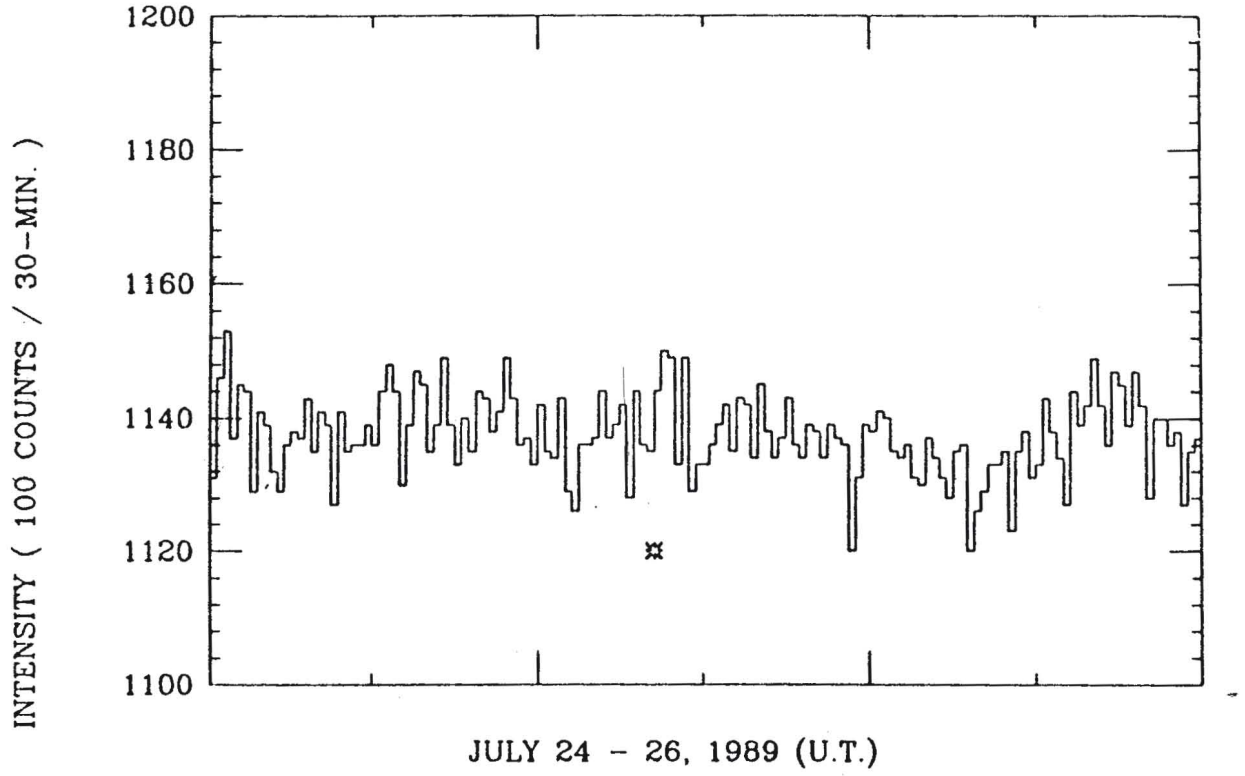

Fig. 3. Pressure corrected 6 - NM - 64 intensity detected at 'Los Cerrillos' (Santiago, Chile) from July 24 to 26, 1989 on 30-min base. Solar flare start-time is denoted by star symbol.

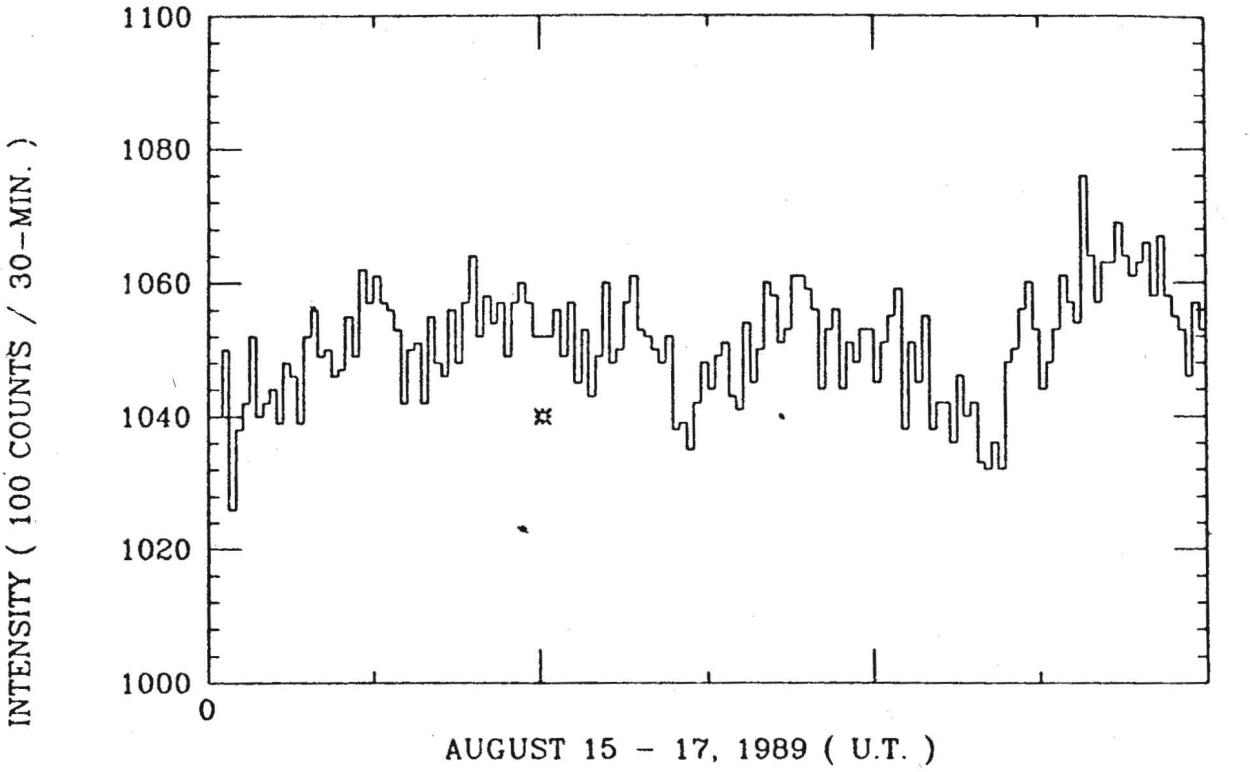

Fig. 4. Pressure-corrected 6 - NM - 64 intensity detected at 'Los Cerrillos' (Santiago, Chile) from August 15 to 17, 1989 on 30-min base. Solar flare start-time is denoted by star symbol.

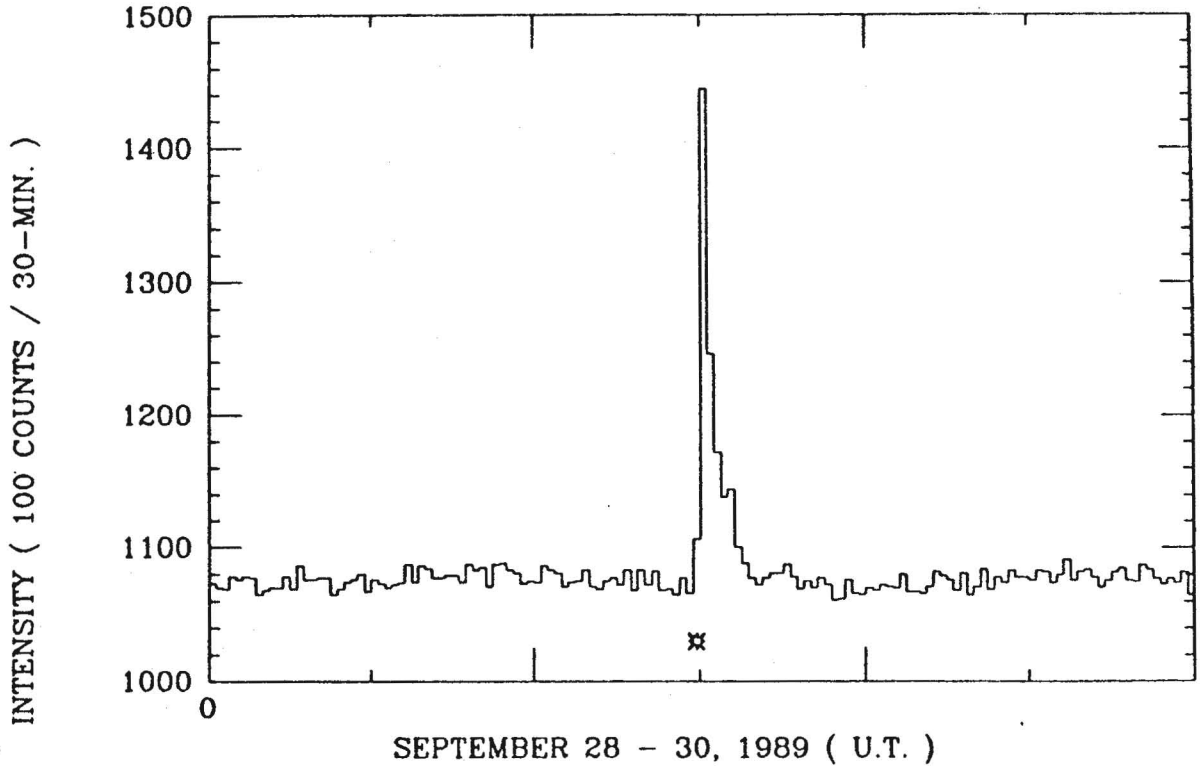

Fig. 5. Pressure-corrected 6 - NM - 64 intensity detected at 'Los Cerrillos' (Santiago, Chile) from September 28 to 30, 1989 on 30-min base. Solar flare start-time is denoted by star symbol.

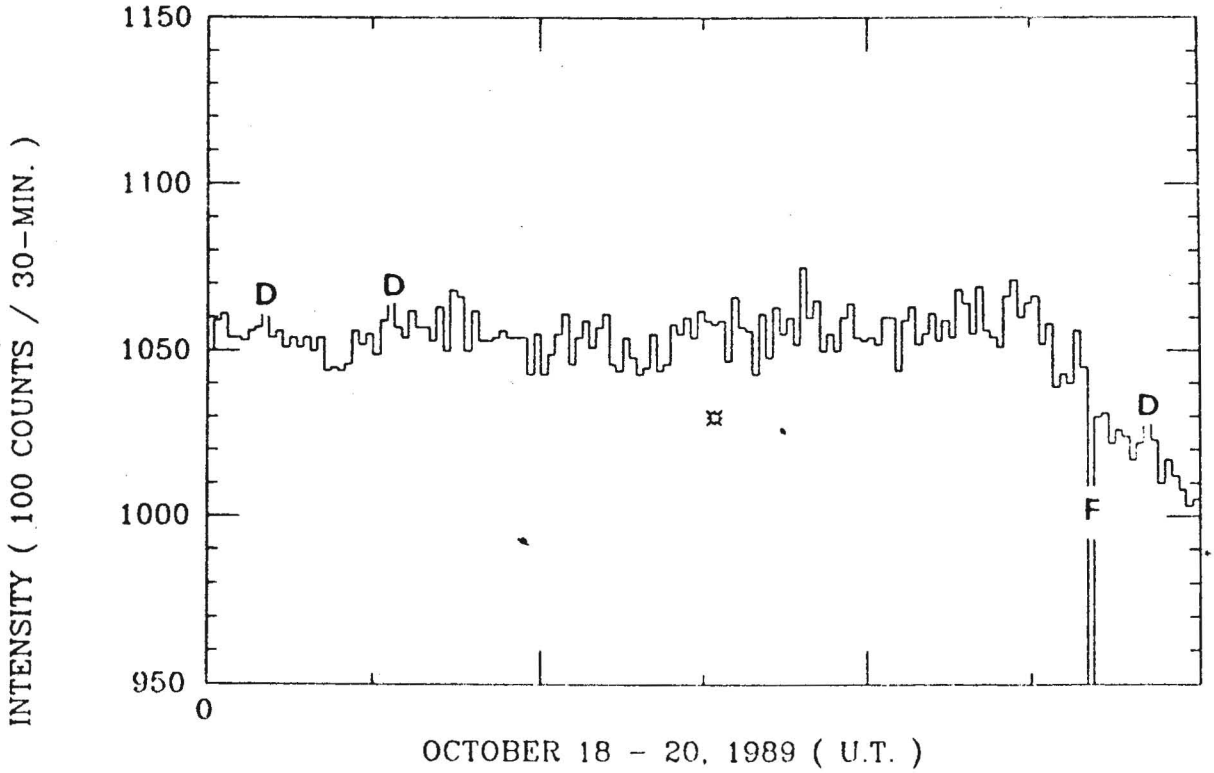

Fig. 6. Pressure-corrected 6 - NM - 64 intensity detected at 'Los Cerrillos' (Santiago, Chile) from October 18 to 20, 1989 on 30-min base. Solar flare start-time is denoted by star symbol; 'F' stands for instrumental failure.

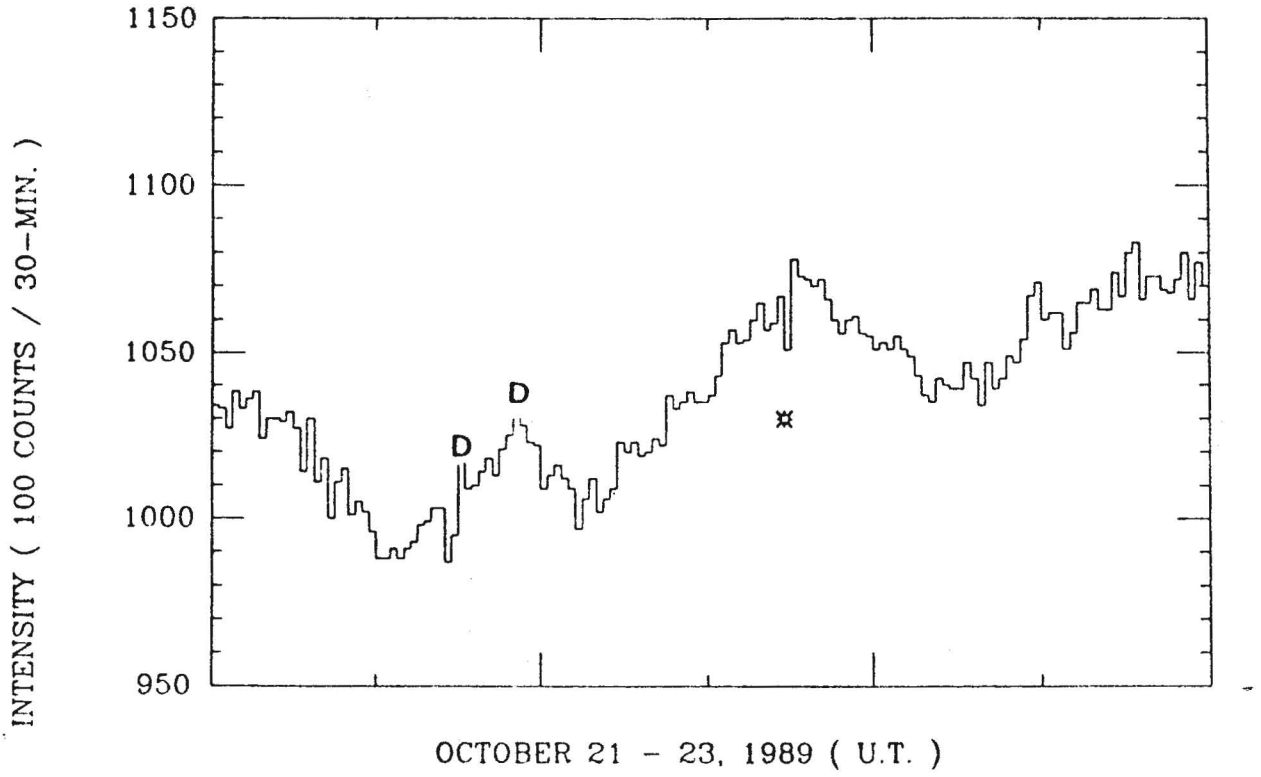

Fig. 7. Pressure-corrected 6 - NM - 64 intensity detected at 'Los Cerrillos' (Santiago, Chile) from October 21 to 23, 1989 on 30-min base. Solar flare start-time is denoted by star symbol.

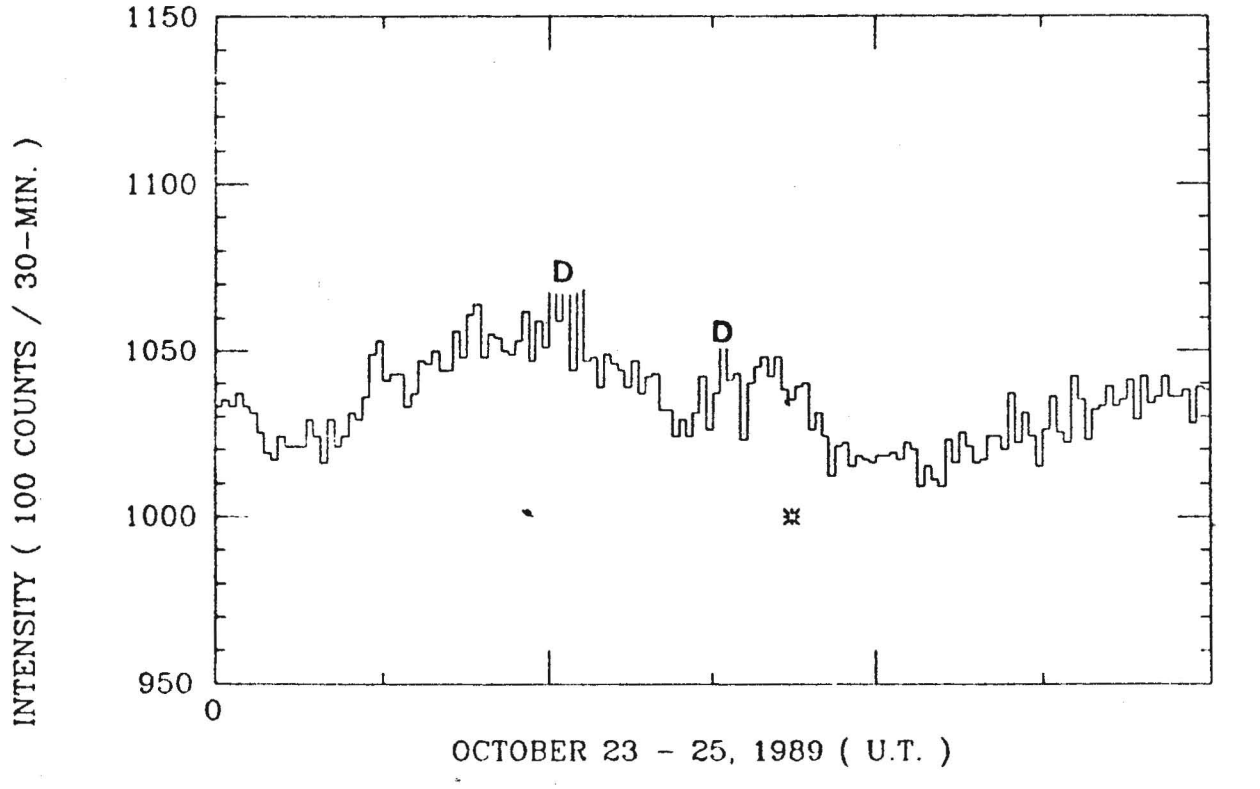

Fig. 8. Pressure-corrected 6 - NM - 64 intensity detected at 'Los Cerrillos' (Santiago, Chile) from October 23 to 25, 1989 on 30-min base. Solar flare start-time is denoted by star symbol.

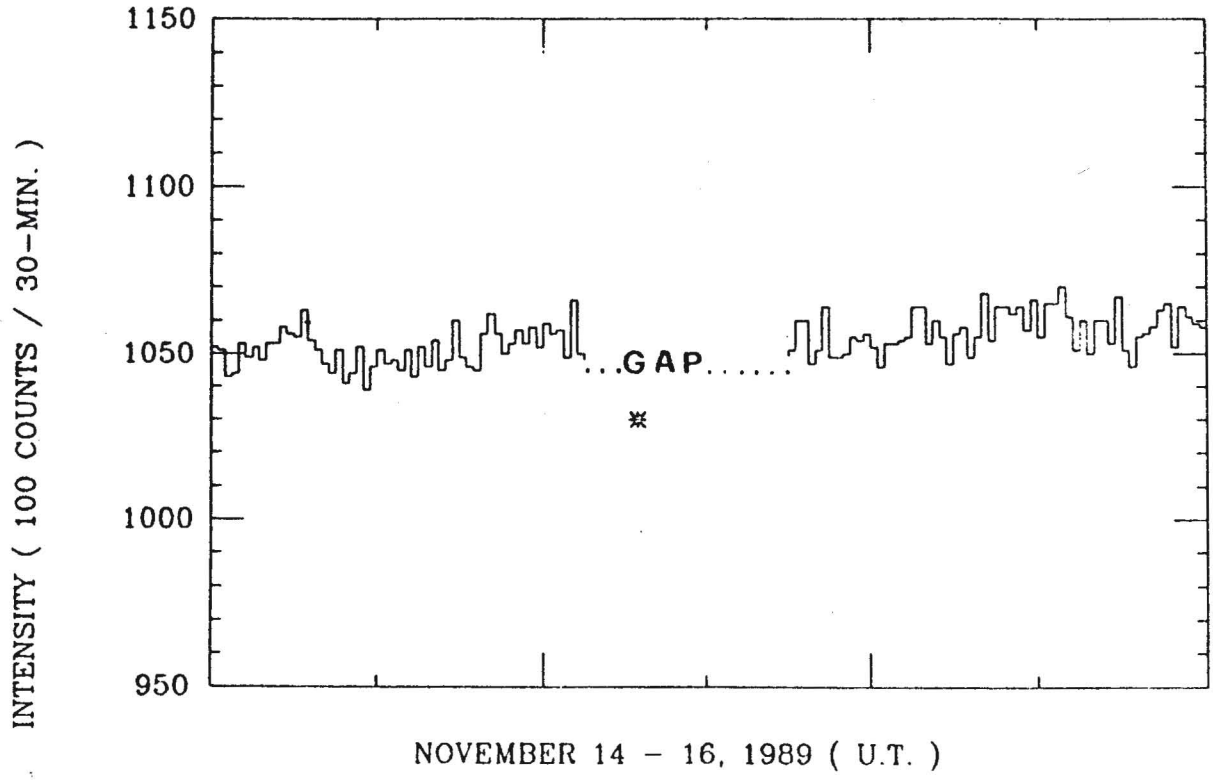

Fig. 9. Pressure-corrected 6 - NM - 64 intensity detected at 'Los Cerrillos' (Santiago, Chile) from November 14 to 16, 1989 on 30-min base. Solar flare start-time is denoted by star symbol.

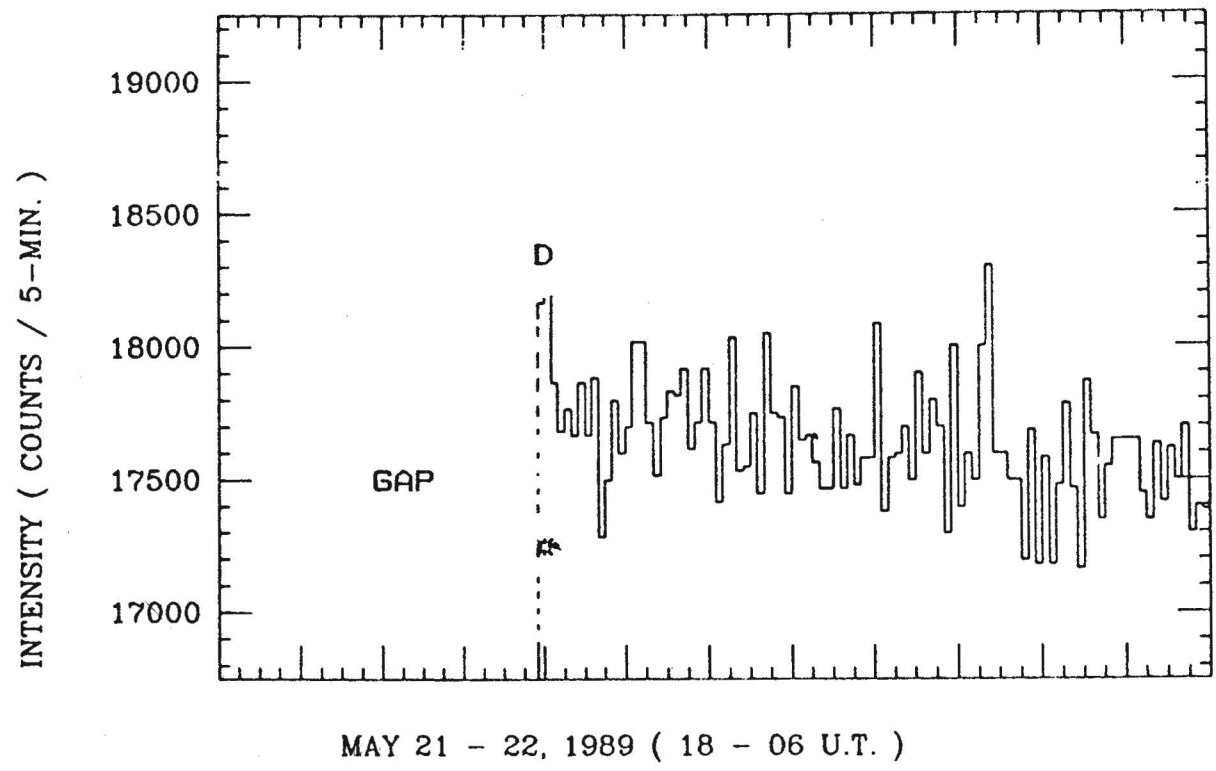

Fig. 10. Pressure-corrected 6 - NM - 64 intensity detected at 'Los Cerrillos' (Santiago, Chile) from May 21 (U.T.) to 22 (0 U.T.), 1990 on 5-min base. Solar flare start-time is denoted by star symbol.

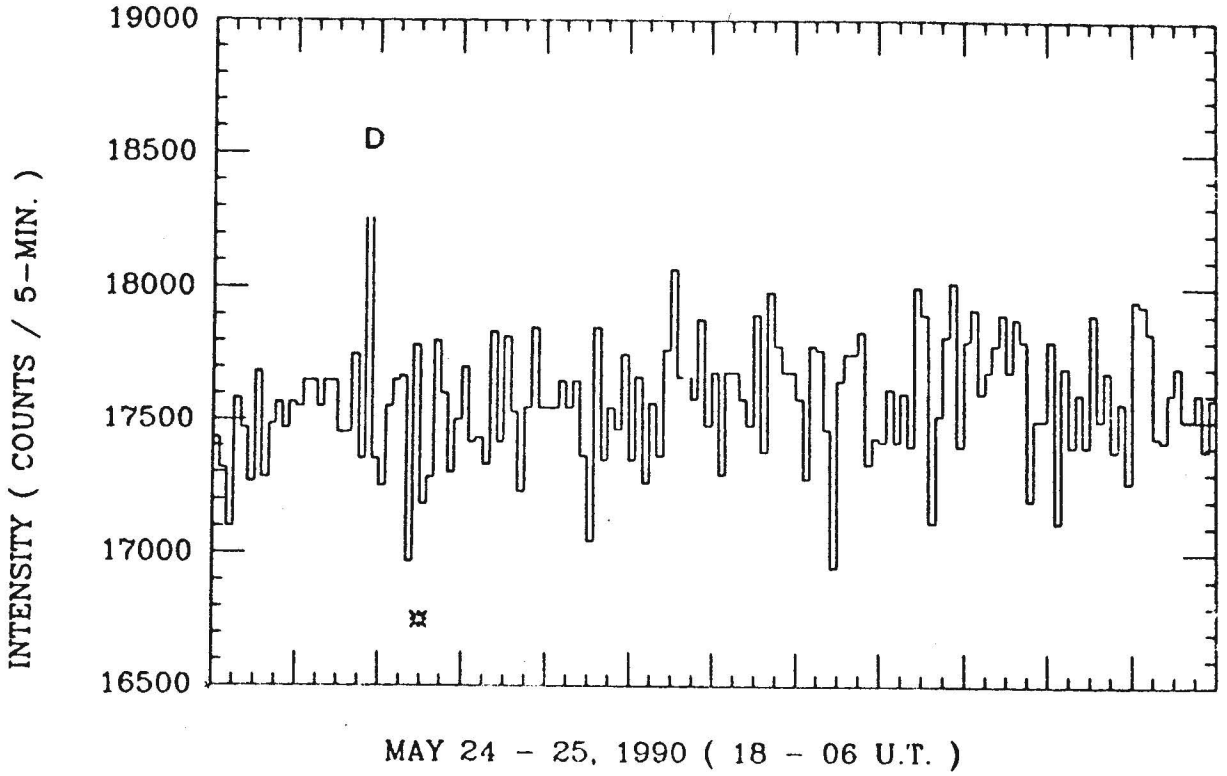

Fig. 11. Pressure-corrected 6 - NM - 64 intensity detected at 'Los Cerrillos' (Santiago, Chile) from May 24 (18 U.T.) to 25 (06 U.T.), 1990 on 5-min base. Solar flare start-time is denoted by star symbol.

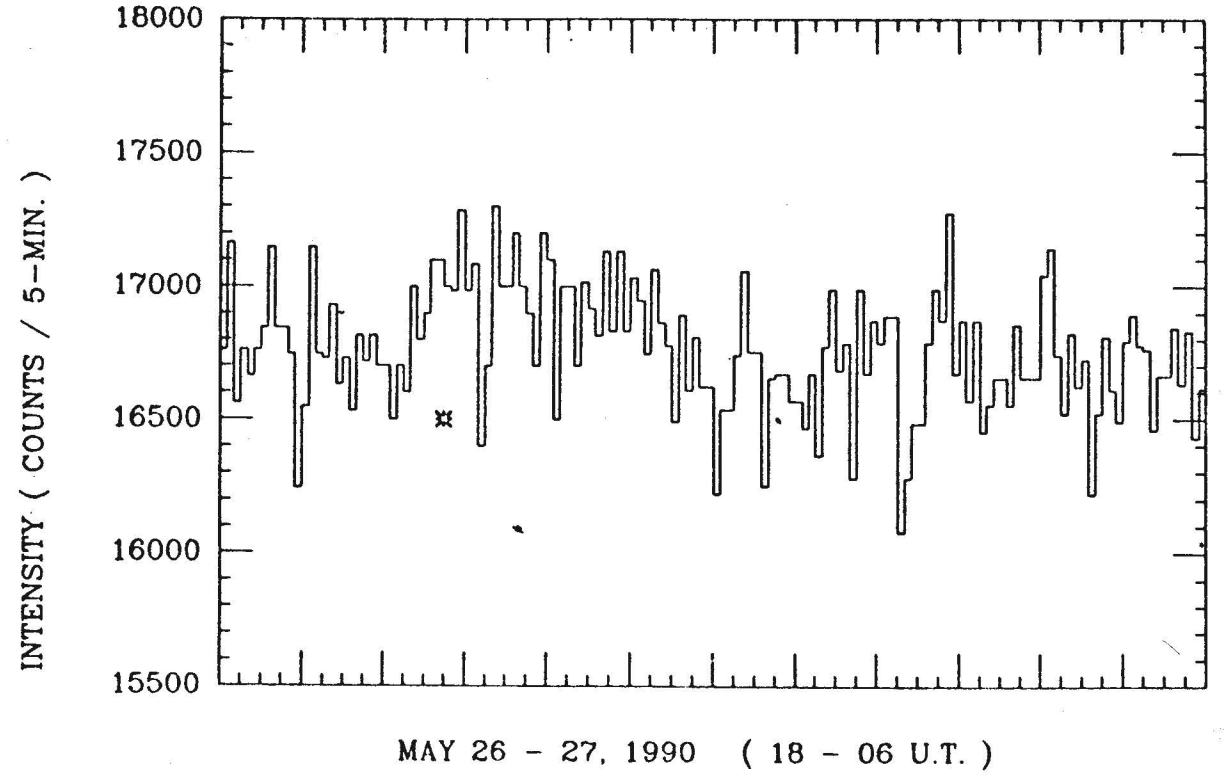

Fig. 12. Pressure-corrected 6 - NM - 64 intensity detected at 'Los Cerrillos' (Santiago, Chile) from May 26 (18 U.T.) to 27 (06 U.T.), 1990 on 5-min base. Solar flare start-time is denoted by star symbol.

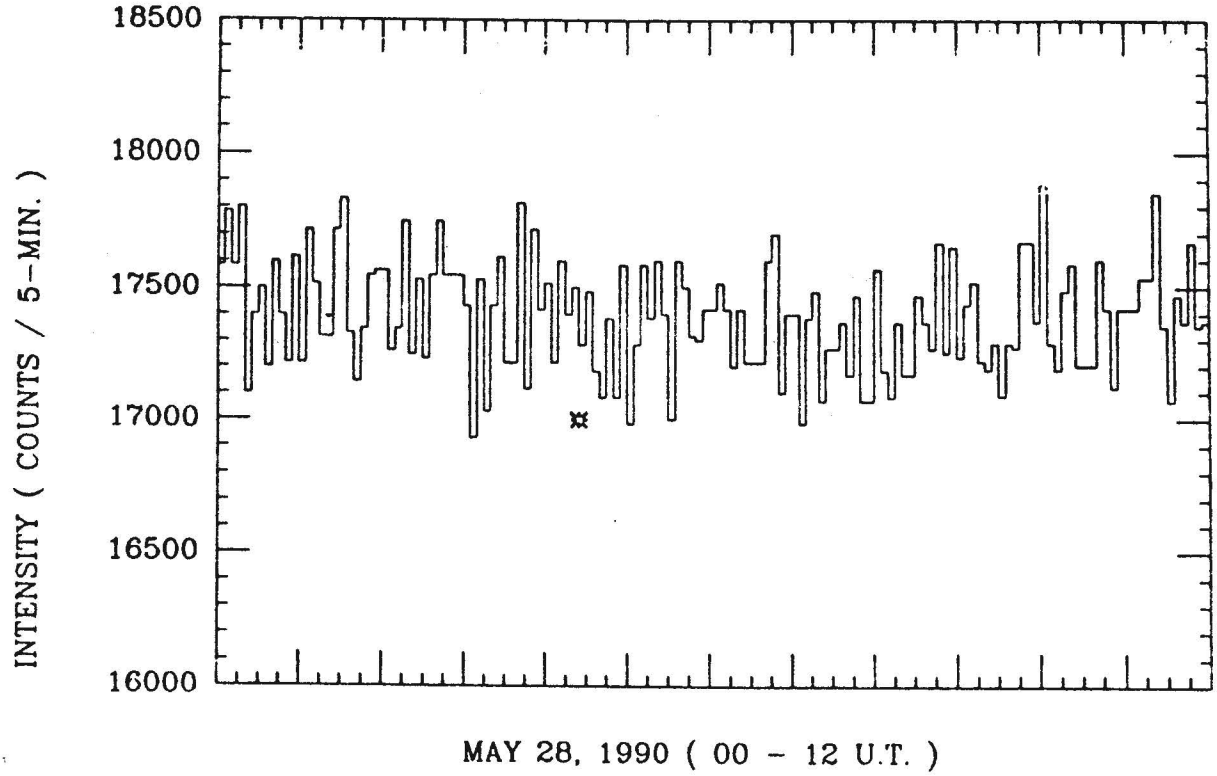

Fig. 13. Pressure-corrected 6 - NM - 64 intensity detected at 'Los Cerrillos' (Santiago, Chile) for May 28, 1990 from 00 U.T. to 12 U.T. on 5-min base. Solar flare start-time is denoted by star symbol.

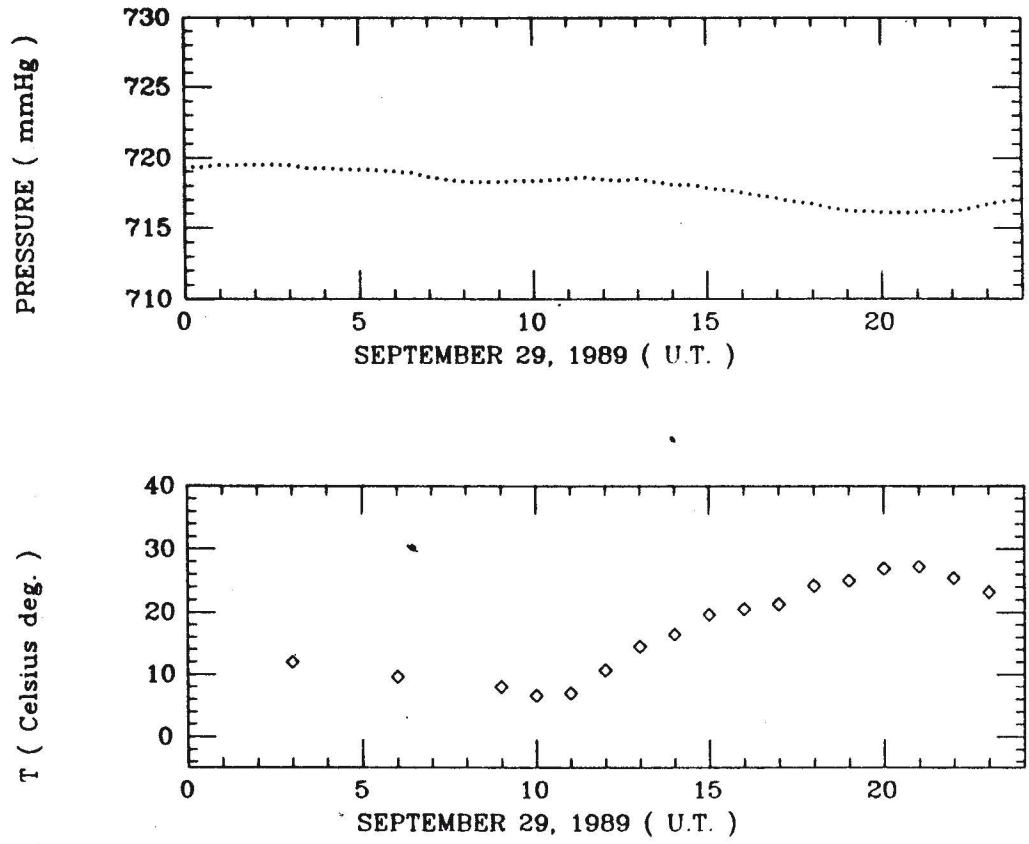

Fig. 14. Atmospheric pressure (upper panel) and ground temperature (lower panel) registered at 'Los Cerrillos' during September 29, 1989.

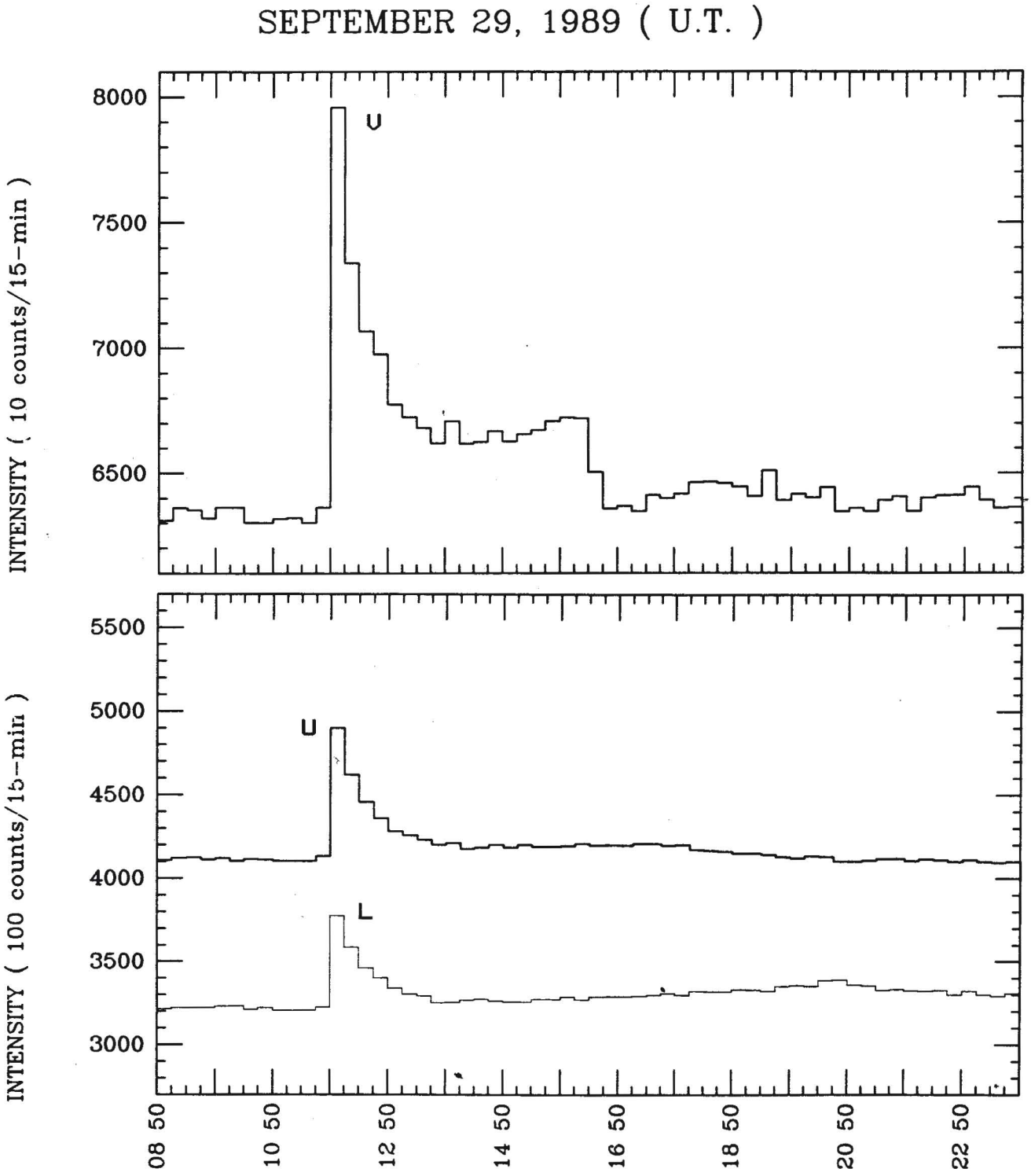

Fig. 15. Muon data registered at 'Los Cerrillos' during the September 29, 1989 GLE event. L, U and V symbols stand for lower level, upper level and vertical cubical coincidences.

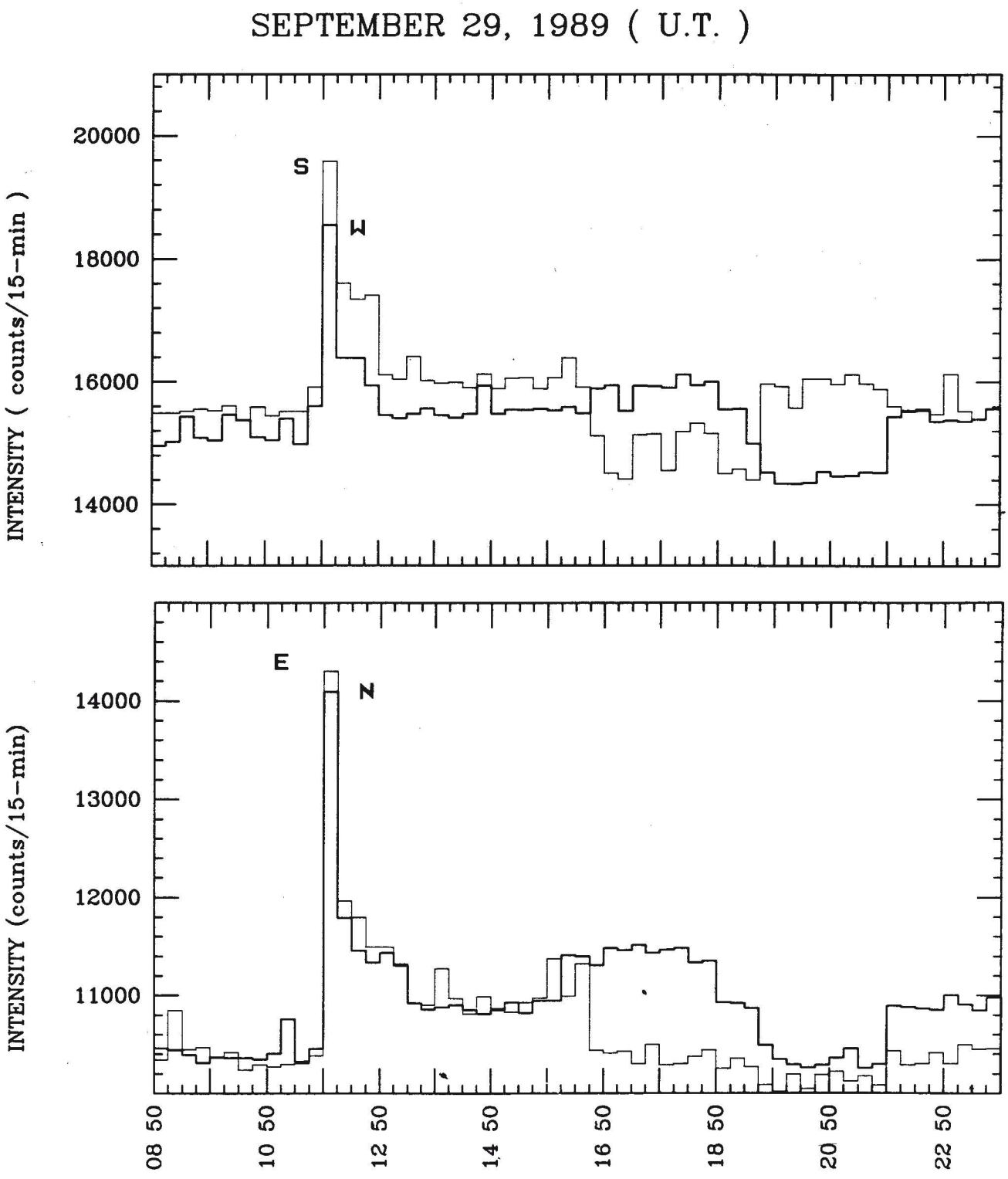

Fig. 16. As in Fig. 15 for the north (N), east (E), south (S) and west (W) channels.

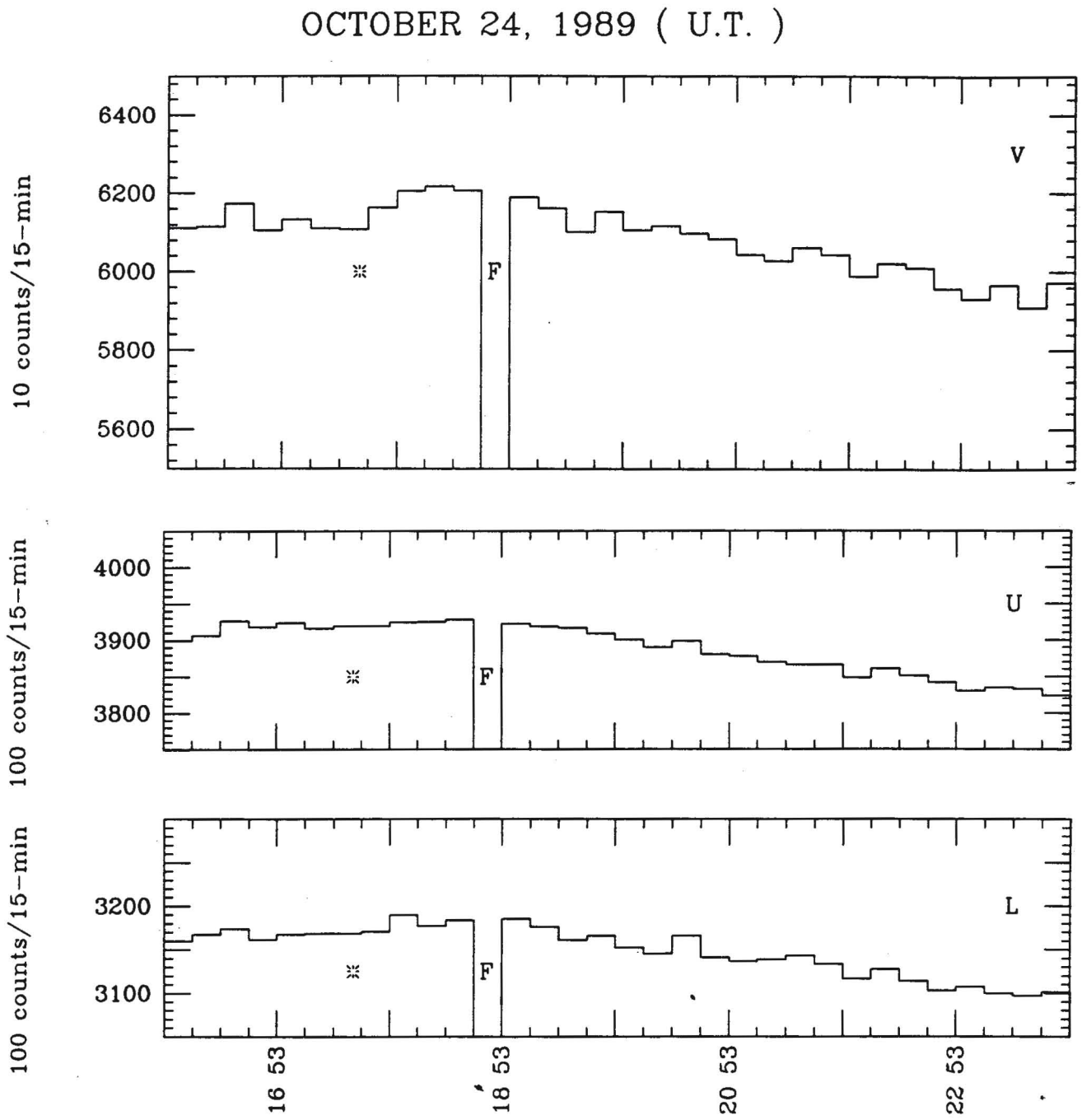

Fig. 17. Muon data registered at 'Los Cerrillos' during the October 24, 1989 GLE event. Symbols are as in Fig. 15; 'F' stands for instrumental failure.

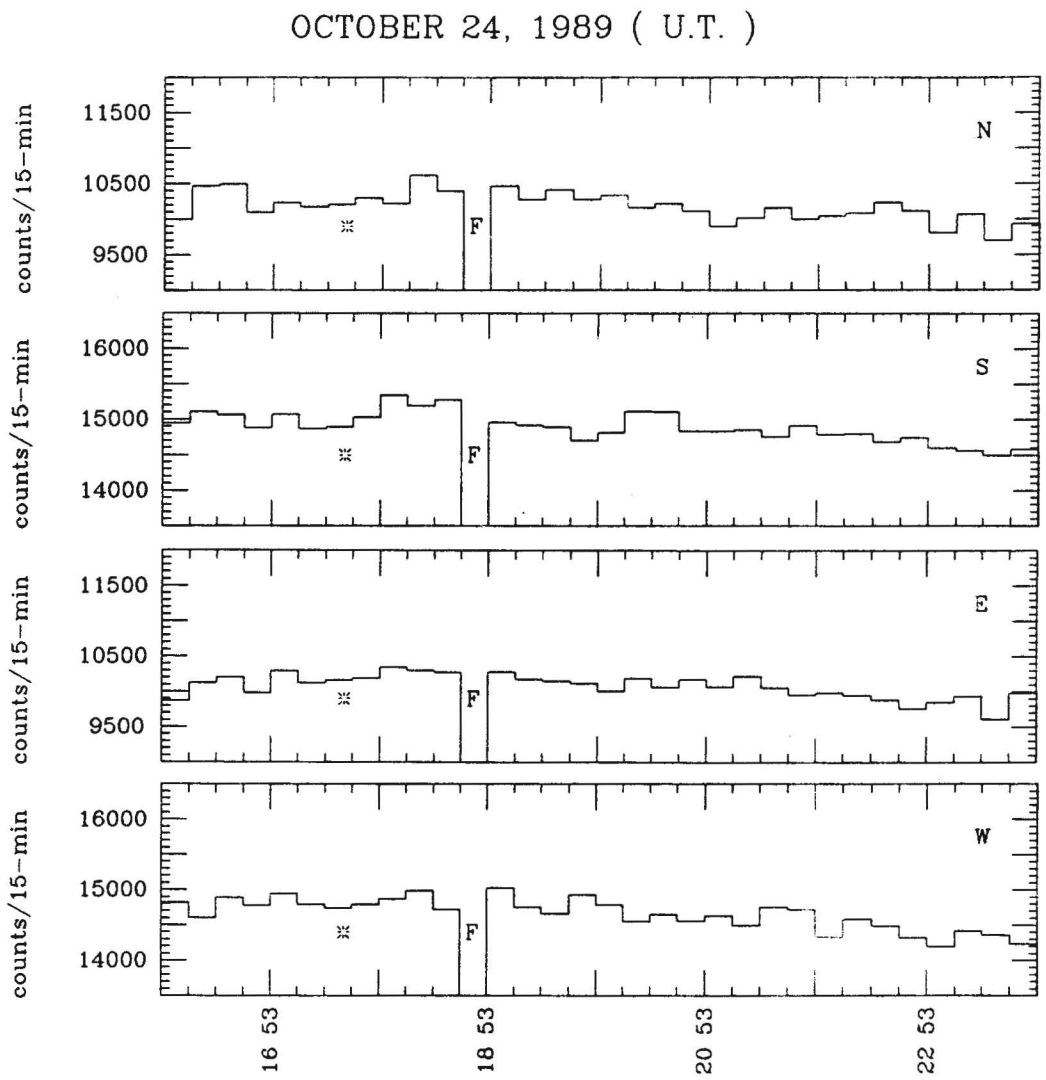

Fig. 18. As in Fig. 17 for the north (N), south (S), east (E) and west (W) channels.

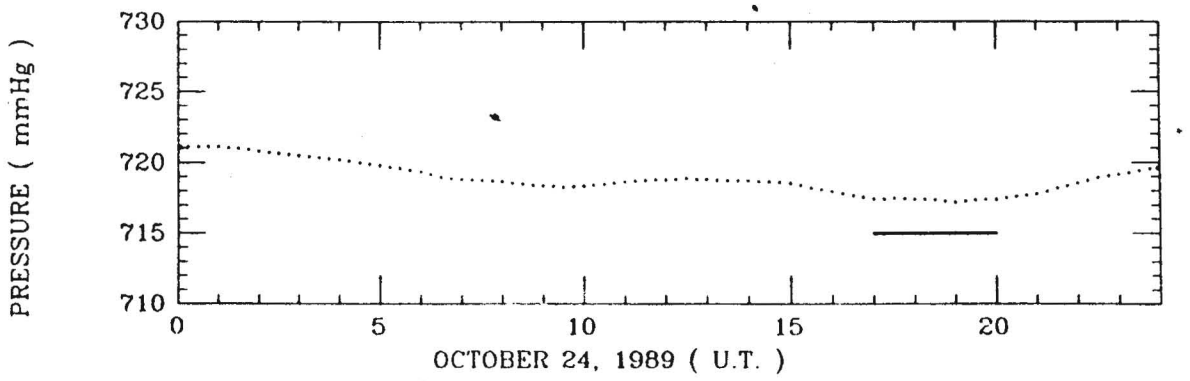

Fig. 19. Atmospheric pressure registered at 'Los Cerrillos' during October 24, 1989.

16 illustrates the temporal trend for the coincidence counts in the N, S, E and W channels (intensity increases are about 36%, 26%, 39% and 22%, respectively).

Finally, Figures 17 and 18 report the October 24, 1989 event. A possible increase in the V channel is found, particularly if we take into account the nearly constant level of the atmospheric pressure registered in the 17-20 U.T. interval (see the bar in Figure 19).

CONCLUSIONS

After a pause of more than thirty years, the solar activity has shown its capability to accelerate ions at energies above 10GeV. Many unsolved problems on solar particle emissivity and associated effects are rediscovered (Storini, 1990; Storini *et al.*, 1991). To improve research studies in this field multi-station GLE information is required. Efforts for archivial and exchange data events have been started by the Geophysics Laboratory of HANSCOM (AFB, Mass. - USA) in the early eighties (Shea *et al.*, 1979; Shea *et al.*, 1985; Shea *et al.*, 1987; Shea, 1990). As soon as possible, Los Cerrillos revised data will be sent there, to integrate the world-wide GLE data base for the 1989 and 1990 years.

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