SOLAR PROTON EVENTS DURING THE RISING PHASE OF SOLAR CYCLE 22;†
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Interest in solar energetic particles (SEPs), also called solar cosmic rays, comes mainly from
three directions: (1) the concern about radiation hazards to humans [1] and electronics [2] in
deep space (away from the protection of the Earth's magnetic field), (2) their effects on the Earth
and the near-earth environment [3], and (3) studies of their fossil records in extraterrestrial matter
[4]. Comparisons of the fluxes of energetic solar particles measured recently in space with those
inferred from lunar data do not show any major differences between modern (last few decades) and
ancient (last ~10^4-10^7 years) SEPs, although both data sets are far from complete [5]. Progress
in improving the ancient record is discussed elsewhere at this conference [6-8]. We present new
results for contemporary SEPs and discuss their implications.

The “modern” record goes back less than five decades for indirect measurements and since
the early 1960s for direct measurements in space [9]. Since 1954 until now, the Sun has gone
through only about 3.4 “11-year” cycles of solar activity, with solar cycle 19 starting in 1954 and
the current cycle (22) commencing in October 1986. Compilations of the fluxes of solar protons are
few. Only about 200 solar particle events since 1956 are in these compilations
through the fluences of solar protons as integrated over these events, there are some major disagreements.
The solar-proton fluxes during solar cycle 19 inferred from ^22Na and ^55Fe in lunar rocks [10] are
much higher than those by other indirect methods [9, 11]. More recent satellite measurements of
solar proton fluxes often disagree, cf. [2], such as the event-integrated fluxes of solar protons
above 30 MeV usually being much higher in Feynman et al. [11] than those in Goswami et al. [12]
Few solar-proton-flux compilations have been published for events since 1987. The current
solar cycle is of great interest as the Sun has been very active and there have been a large number
of big solar particle events during the last two years, including six during the second half of 1989
with many particles >0.5 GeV detected as ground level events (GLEs) with neutron monitors [13].
The GLE of 29 September 1989 was the largest since the huge one of 23 February 1956 [13]. It
appears that the present solar cycle 22 will be like solar cycle 19, during which the Sun was very
active and the fluxes of solar protons were very high [5, 6].

We report results from the Los Alamos Charged Particle Analyzer (CPA) instrument on a
satellite in geosynchronous orbit. Similar Los Alamos CPA instruments have made observations
of energetic particles since 1976. The satellite’s spin axis is normal to the Earth’s surface, and
protons are measured in the satellite’s equatorial plane every 256 ms with two sets of detectors [14].
The HiP detector monitors protons with energies of ~0.1–0.6 MeV. The HiP detector uses three
detectors in a telescope configuration to measure protons from ~0.02 to 160 MeV with 16 differential
energy channels having energy thresholds nominally logarithmically spaced from 0.4 to 147 MeV.
A magnet eliminates signals from electrons with energies below ~1 MeV, and there is an active
guard scintillator to reject signals from energetic particles that arrive from directions away from
the telescope’s front aperture, which has a half angle of ~6.5°. Numerical simulations are being
done for the HiP detector to more accurately determine its response to protons of various energies
from different directions. These calculations and other calibrations are not final, but preliminary
results indicate for the HiP channel 10 (E>9 MeV) that ~0.02 counts/minute is equivalent to a
flux of 10 protons/(cm^2 s sr). We also plan to compare our measurements during 1976–1986 with
those reported by others [11, 12].

Measurements by the HiP detector on spacecraft 1984–129 since the beginning of solar cycle
22 (October 1986) have been compiled for protons with energies from 9 MeV to ~160 MeV. (There
are relatively very few solar protons with energies above 160 MeV.) The proton fluxes from daily
averages for 1989 and 1990 are shown in Figs. 1–4 for energies >9 MeV and >60 MeV. The first two
years of this cycle had low solar-proton fluxes, typical of other solar cycles [11]. The count rates in
the >60 MeV channel during periods of no solar-particle events are due to the galactic cosmic rays
and vary systematically with solar activity, diminishing with increasing solar activity. Adopting
the threshold of 10 protons/(cm^2 s sr) used by Shea and Smart [9] for Ep>10 MeV in their compilation
for earlier solar-proton events, there were no such events during the first 12 months of solar cycle
22 (October 1986 – September 1987), 4 during the next year, 24 during the third year, and 19
during the fourth year. There are many more solar-proton events above this proton-flux threshold
during the first four years of the current solar cycle (47) than for the same period of any of the
three previous cycles, which had 20–25 of such events [9].

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The measurements show that the years 1989 and 1990 had much solar-energetic-particle activity. In 1989, the events in August through October (days 220-300) had many high-energy (>60 MeV) protons, consistent with the strong GLEs [15], while the events in March 1989 and most of those in 1990 were fairly soft. The total fluence of solar protons >10 MeV integrated over these two years is quite high, \( >10^{10} \) protons/cm\(^2\), similar to the integrals over all 11-years of solar cycles 20 or 21 [5,6]. We will report integral fluxes for >10, >30, and >60 MeV for these and other events observed by our CPA instruments after finishing the calibrations. It appears that solar cycle 22 is like cycle 19, with many intense, hard events. These recent SEP events with hard spectra will help to make the average modern spectral shape harder and thus more like that determined from the ancient record [5,6]. Such intense, hard events as seen in the second half of 1989, and which could possibly occur for another 6-7 years [11], could produce significant short-lived radioactivities in meteorites that fall during the next decade. New falls should be counted quickly to look for 78-day \(^{56}\)Co made by \(^{56}\)Fe(p,n)\(^{56}\)Co reactions, as was seen in the small Salem meteorite [15], which fell in May 1981 (near the time of maximum activity for solar cycle 21).


Figs. 1 – 4: Daily averaged count rates of solar protons with energies above 9 MeV for 1989 (top left) and 1990 (top right) and above 60 MeV for 1989 (bottom left) and 1990 (bottom right)