The Cosmic Ray Intensity Between 1933-1965

K.G. McCracken[1], B. Heikkila[2]
(1) I.P.S.T., University of Maryland, College Park, MD 20742
(2) NASA/Goddard Space Flight Center, Greenbelt, Maryland

Abstract

The balloon borne measuremnts of Neher, and the cosmogenic ^{10}Be show that the GCR near 2 GeV/nucleon decreased by about 25% between 1933 and 1965. These data, and the Forbush ground level data are combined to yield the annual time dependence of the GCR. The characteristics of the qA<0 and qA>0 minima of 1944 and 1954, and the long term changes, are discussed.

1. Introduction

The time dependence of the cosmogenic isotope ^{10}Be recorded in polar ice indicates that there was a major decrease in the observed concentration between 1900 and 1965 [1]. The high altitude ionization measurements made by Neher between 1933 and 1965 [7] were used to verify that this was due to a decrease in the galactic cosmic ray (GCR) flux, as reported previously [3]. It is noted that Neher clearly recognised that there had been a major change in the GCR between the successive sunspot minima [7], however it appears that his discovery has been forgotten with the passage of time.

2. Methods

Figure 1A presents ionization data obtained throughout the period 1933-1965 at Bismarck, North Dakota, at a cutoff rigidity of 1.29 GV. Data are also given from the Fordney-Settle manned balloon flight of 1933 (cutoffs 1.73-1.93 GV), and from Saskatoon, Canada [5,6,7]. These data were chosen since the geomagnetic cutoff restricts the GCR to energies >700 MeV, making them directly comparable to the ^{10}Be data that has a response function that becomes significant about 700 MeV, and which peaks at 1.8 GeV [3,4]. Sunspot minima occurred in 1933, 1954, and 1965 , and it is clear from Figure 1A that the GCR >700 MeV decreased from each minimum to the next.

To further examine this result, Figure 1B displays the cross-correlation of the Neher data and the Mt.Washington neutron monitor (1.24 GV cutoff) between 1954 and 1965. The agreement is extremely good and it shows that the neutron

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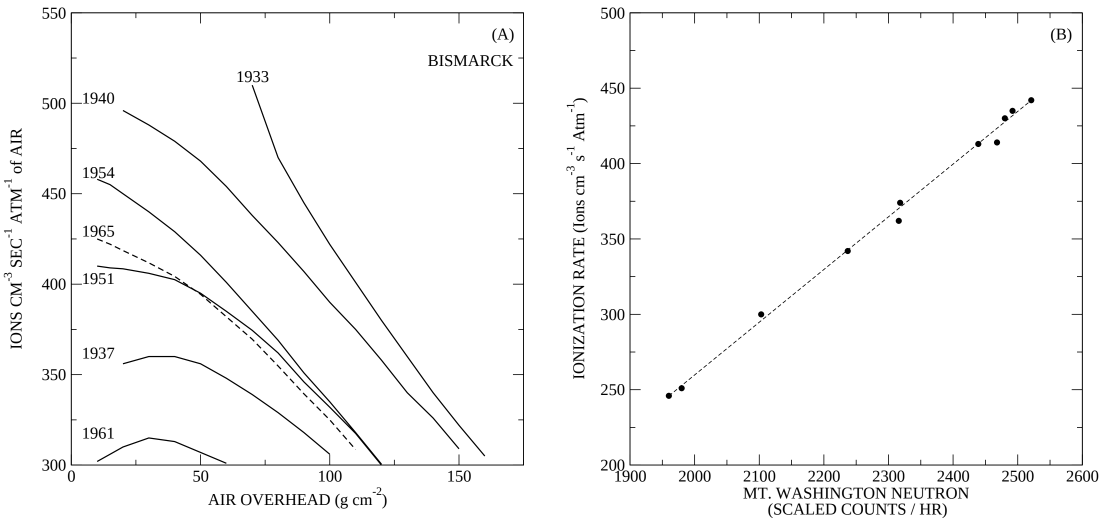

Fig. 1. **A.** Balloon measurements by V. Neher, 1933-65. **B.** Cross correlation between the ionization at 100g cm^{-2} and the Mt.Washington neutron monitor.

monitor counting rate decreased by 3% between 1954 and 1965. The neutron intensity at the five sunspot minima since 1954 has been essentially invariant, and this has been interpreted to indicate that there has been little change in the residual modulation since 1954. However, Figure 1B shows that the neutron monitor did see the small decrease in GCR flux between 1954 and 1965, that represented the end of the long term decline from 1933.

The data for 1933 in Figure 1A were from a manned balloon that flew between Akron, Ohio (1.73 GV) and Bridgeton, New Jersey (1.9 GV). Latitude surveys flown by Neher in 1938 and 1940 indicate that the ionization at Bismarck would have been approximately 3% higher than observed during the manned balloon flight. The 1933 flight carried a lead shielded ionization chamber flown by A.H. Compton, and there was concern that nuclear reactions in the shield of the Compton chamber had resulted in the observed ionization being erroneously high. At the end of his career, Neher considered this problem in the context of the flight of one of his ionization chambers on Mariner 2 [6]. He showed that the mass of the mid-course motors and other equipment representing up to 60g cm^{-2}; subtending a solid angle of 6.5% of 4π would result in an increase of $< 0.2\%$ in the observed ionization rate. This factor should be close to that applicable to the 1933 result for an atmospheric depth of 100g cm^{-2}. For the purposes of this paper, no correction was made for the cutoff, thereby probably overcompensating for the effects of mass on the balloon.

Neher used a set of calibration chambers for preflight calibration throughout the 32 year program [5,6,7], and inter-calibration accuracy was stated to be better than 1% [5]. This accuracy was repeatedly verified by making duplicate flights throughout the 32 year program. The long term decline in cosmogenic ^{10}Be gives independent verification of the long term decline in the GCR, and of the stability of Neher's calibrations. It is therefore proposed that the Neher data provides the most accurate record of the long term changes in the GCR, and therefore they have been used to synthesize the long term variation in GCR given in Figure 2.

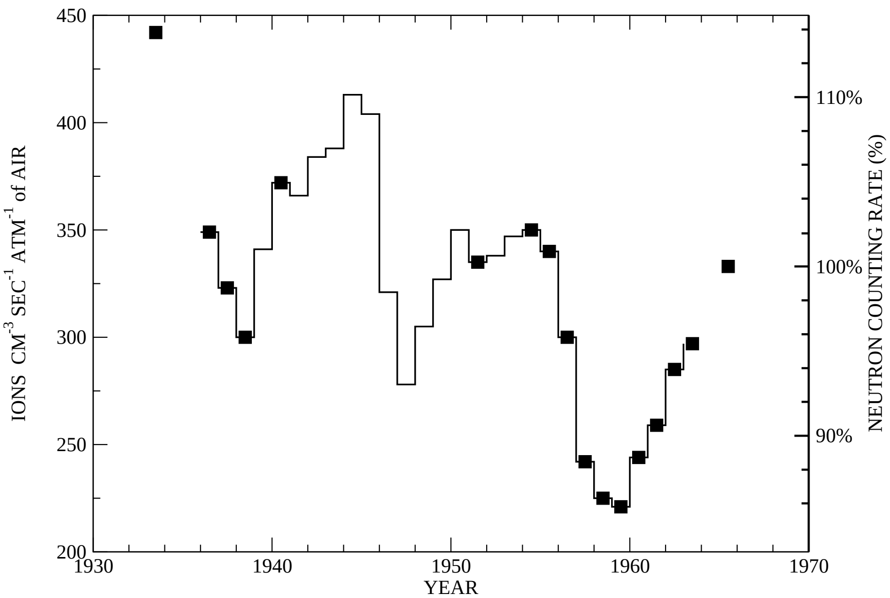

Fig. 2. The 100g cm^{-2} ionization rate, measured (black squares) and estimated (histogram), for 1933-65. The computed neutron monitor scale is on the right.

A latitude survey made by Neher in 1940 was first used to estimate the ionization that would have been observed at Bismarck in 1936 and 1937 (from observations at San Antonio, and Omaha, respectively) The synthesis then used the ground level ionization chamber data of Forbush [2] to interpolate between the spot measurements made by Neher. The presence of drifts in the Forbush data [2], and the small amplitude of the long term variations (5%), means that they are not as suitable as the Neher data for the investigation of long term changes, and furthermore, they did not commence until 1936. Using a linear regression to determine dN/dF, where N and F are the Neher and Forbush data, respectively, the spot Neher data were adjusted to a mean value for the year based upon the monthly variations of the Forbush data. Then a pro-rata interpolation was made using the Forbush annual data to estimate the Neher ionization for the years between his observations.

3. Discussion

Figure 2 shows that the ionization at 100g cm^{-2} at sunspot minimum decreased about 7% between 1933 and 1944; by a further 15% between 1944 and 1954; and then 3% to 1965. The Neher data indicate that the flat topped qA>0 event lasted from 1950 to 1955. While there are no Neher data to confirm the nature of the qA<0 event in 1944, the synthesis based on the Forbush data show that it was sharply defined. Solar activity after 1933 increased in a monotonic fashion, the peak annual group sunspot numbers being 120.6, 144.9, and 175.1, respectively. However, the long term changes in the residual modulation during a solar cycle were poorly correlated with solar activity. Thus while the steadily increasing activity in solar cycles 1933-44 and 1944-54 resulted in large long term decreases in the GCR (7% and 15%), the most active cycle of all (1954-65) only resulted in a 3% long term decrease.

Figure 1B indicates that the percentage variation in the Neher ionization data is 2.37 times that in the neutron monitor data. This was used to compute the neutron monitor scale given on the right hand side of Figure 2. This shows that the long term change between the sunspot minima of 1933 and 1965 was equivalent to a 13% decrease in the counting rate of a ground level neutron monitor.

4. Conclusions

The foregoing has shown that: (1)The Neher high altitude ionization data show that the GCR flux at sunspot minimum decreased in a monotonic manner from 1933 to 1965; (2) The observed changes are consistent with the observed decrease in the concentrations of cosmogenic ^{10}Be; (3) the Neher and Forbush data provide a synthesis of the high altitude ionization for the full period 1933-1965 that shows that the ionization rate at 100g cm^{-2} decreased by 7%, 15%, and 3% between the successive sunspot minima; and (4) the long term changes between sunspot minima are not well correlated with the solar activity during the sunspot cycle.

5. References

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