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Is there an instrumental drift in the counting rate of some high latitude neutron monitors?

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Abstract

For the last six decades the neutron monitors have provided a continuous string of very reliable data to the heliophysics community. Although neutron monitors are not the primary source of data for the galactic cosmic rays, these data serve as a baseline reference for the data collected by the detectors on board the satellites and deep space probes, far away from earth orbit. The pressure corrected hourly data are available from the World Data Centers. These data have been used to derive deep insights pertaining to the electromagnetic states of the heliosphere and the modes of transport of energetic charged particles in the tangled interplanetary magnetic fields. We present evidence that some of the high latitude neutron monitors are undergoing long-term drifts in their baselines. In particular, we argue that there is no physical basis to justify the observed long-term downward trend in the baseline of the South Pole neutron monitor. The real reason may have to do with its maintenance at a distant location with challenging logistics and an improper normalization of its data after the 26 months break in the 1970s.

Keywords: High latitude neutron monitors; Long-term counting rate drift; Global network; Galactic cosmic rays; Sunspot cycles

1. Introduction

The global network of neutron monitors (NMs) have provided data to the heliophysics community for over 60 years to study the time variations of the galactic cosmic ray (GCR) intensity. Simpson recommended a standard NM for worldwide use during the International Geophysical Year (IGY, 1957–58). Later, Carmichael designed the higher counting rate super monitor (NM64) for community use during the year of the Quiet Sun (IQSY, 1964–1965). The present network consists of a mix of both types of geometries. They are located at sites ranging from sea-level to mountain altitudes with the vertical geomagnetic/atmospheric cut-off rigidity (*Ro*/*Ra*) ranging from 1 GV at high latitudes to 17 GV at the geomagnetic equator; their total number today is less than half at the peak period. For historical details, the reader is referred to Simpson (2000) and Hatton (1971).

NM data have been used extensively for the time variation studies ranging from minutes to decades. The short-term studies involve energetic particles of solar origin in MeV to tens of GeV range (Heber and Klecker, 2010), related to the solar flares and the Coronal Mass Ejections (CMEs). Earlier studies (McCracken, 1962) led to the discovery of the spiral configuration of the interplanetary magnetic field (IMF). Later studies led to the discovery of the solar neutrons (Debrunner et al., 1983; Muraki, 2009). The data were also used to make several important discoveries about the characteristic features of the onset and the recovery phases of the 11-year modulation of GCR intensity related to the sunspot cycles (Ahluwalia, 1994, and references therein).

The recovery phase of GCR modulation for a sunspot number (SSN) cycle contains important information about the transport modes of the energetic charged particles in the tangled IMF that pervades the heliosphere. The modulation

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exhibits a 22-year periodicity (Hale cycle). Ahluwalia (1980) showed that during a negative ($A < 0$) cycle when the magnetic field in the solar northern hemisphere points into the sun, the recovery takes twice as long as for an even ($A > 0$) cycle when the solar magnetic field in the northern hemisphere points away from sun; GCR intensity recovers to a broad maximum for $A > 0$ and to an inverted "V"-like maximum for $A < 0$ cycle. This empirical finding was explained later in terms of the helio-latitudinal drifts of the positive charges in an inhomogeneous Parker (1958) IMF spiral (Kota and Jokipii, 1983). For $A > 0$, GCR protons drift down from the high latitudes towards the heliographic equator and out along the warped heliospheric current sheet (HCS). When the solar polar field turns negative (as in 1958–1969 and 1981–1990) the protons drift inwards along HCS and out to the higher helio-latitudes. The access path to earth orbit is shorter in the first case, leading to a more rapid GCR recovery at earth orbit. Webber and Lockwood (1988) and Ahluwalia (1994) drew attention to the fact that the recovery during a positive cycle is to a lower level than for a negative cycle; for NMs the difference is ~1.5% and for the shielded ion chambers (ICs) ~0.3% (Ahluwalia, 1997); the physical cause of this difference in the recovery levels is not understood yet, but the pattern has been observed to repeat for the last two Hale cycles (1954–1996).

The pivotal role played by the time variations of IMF intensity B in modulating GCR flux in the heliosphere is now well appreciated (Barouch and Burlaga, 1975; Ahluwalia, 1992; Perko and Burlaga, 1992; Burlaga and Ness, 1998; Cane et al., 1999). For example, Ahluwalia (2000) showed that the systematic GCR flux changes near the solar minima (residual modulation) during 1963–1998 correspond to systematic inverse changes in B.

Although NMs are not the primary source of data for GCRs (e.g. there exists a global network of directional muon telescopes deployed at the surface and underground sites), they serve as a baseline reference for the data collected by the detectors on board the satellites and deep space probes. The pressure corrected hourly NM data are available from the World Data Centers. The detectors are characterized by a median rigidity of response (Rm) to the GCR rigidity spectrum, 50% of a detector counting rate is contributed by GCR rigidities below Rm (Ahluwalia and Fikani, 2007).

McComas et al. (2006) infer that the structure of the heliosphere during the decay phase of the sunspot cycle 23 is significantly different from that observed for cycles 21 and 22; cycle 23 started in May 1996 and the monthly mean SSN is zero for August 2009. The measurements made at the Wilcox Solar Observatory indicate that solar polar field strength for cycle 23 is only half as large as for previous three cycles (Schatten, 2005), leading to a monotonic decline of B at earth orbit after 2006, reaching ~3 nT in 2009 the lowest value of B ever recorded since in situ measurements began in October 1963. It is not surprising that cycle 23 GCR recovery observed by the global network of NMs has exceeded the level in 1996 by a significant amount (>1.5%), upsetting the pattern for the $A < 0$ cycles seen previously in 1965 and 1987 (Ahluwalia et al., 2010; Ahluwalia and Ygbuhay, 2011). The stability of a NM count rate baseline is a pre-requisite for the success of investigations of the long-term systematic trends (often small) in the data. Sadly, several NMs are observed to undergo long-term drifts of unknown cause(s) in their baselines. Here we examine the case of some high latitude NMs in the American zone.

2. Global neutron monitor data

To investigate the long-term change in the level of GCR intensity measured by a NM, it is very important to ensure that the detector is not undergoing a long-term drift in its operation from whatever cause(s). For this purpose, we compare the baselines of the global network of NMs with the NM at Climax (CL/NM). It has operated continuously, at the same site, at an altitude of 3000 m, since 1950 (see Table 1 in Pyle, 1993). It is of IGY design, with two sections of six tubes each. To keep its counting rate level stable to within ±0.25% (private communication from late J.A. Simpson), a great care is taken to maintain the stability of atmospheric pressure measurements.

Although $Ro \sim 3$ GV at Climax, the monitor is 16% more sensitive to modulation (because of its altitude) than the sea-level monitor at Deep River (DR/NM) with a (lower) atmospheric cut-off rigidity of 1.1 GV (Ahluwalia and Wilson, 1996). Also, the Ro value for CL/NM has been relatively stable for a very long time (Smart et al., 2000); it changed from 3.06 GV in 1965 to 2.93 in 1995, an inconsequential change in the present context. So, CL/NM is an ideal reference instrument to test other detectors against for the long-term stability of their baselines; the day-to-day stability of NMs is not tested in this paper.

Fig. 1 shows a plot of the monthly mean hourly rate (monthly average of hourly pressure corrected values) for CL/NM for January 1951 to November 2006; the rate is normalized to 100% in May 1965. The smoothed SSNs are also plotted in the diagram. The period covers four complete solar cycles (19–22) and parts of the other two (18 and 23) as well as five epochs of solar polar field reversals, marked by the vertical dashed lines drawn through the middle of the epochs. After November 2006, CL/NM data is available till December 2008 but is unprocessed for a lack of support to its PI, Clifford Lopate. Ahluwalia et al. (2010) discuss the time variations observed in the two datasets and their relationships.

A comparison of the monthly mean hourly rates of CL/NM ($Rm = 11$ GV) with several other NMs of the global network are shown below for 1951–2009; in each case the data are normalized to 100% in May 1965. Fig. 2a compares Oulu (Finland) and Climax monthly averages for the available NM data; $Rm = 16$ GV for OU/NM. The two data strings track each other quite well.