Mini neutron monitor measurements at the Neumayer III station and on the German research vessel Polarstern

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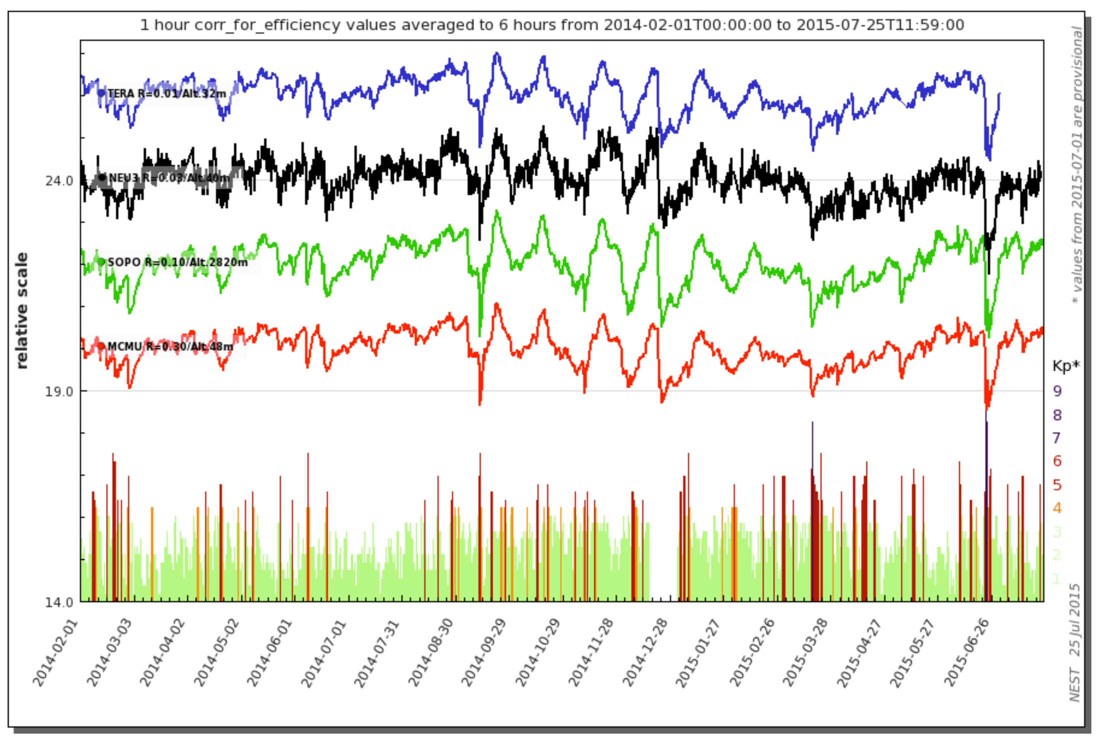
Abstract

Neutron monitors (NMs) are ground-based devices to measure the variation of cosmic ray intensities. They are reliable devices but difficult to install because of their size and weight. Therefore a portable mini NM (MNM) that can be installed as an autonomous station at any location that provides suitable conditions has been developed recently. The first continuous measuring MNMs are installed at Neumayer III and the German vessel Polarstern. They are providing scientific data since October 2012 and January 2014, respectively. NM measurements are influenced by the (variable) geomagnetic field and the atmospheric conditions. Thus, in order to interpret the data, a detailed knowledge of the instrument sensitivity with geomagnetic latitude (rigidity) and atmospheric pressure is essential. The rigidity dependence is determined experimentally by utilizing several latitude scans. The Polarstern was specially designed for working in the polar seas and sails usually twice a year in areas with rigidity ranges below 1 GV and above 10 GV. The results of different latitude scans from October 2012 to January 2015 will be presented and discussed in the framework of a yield function.

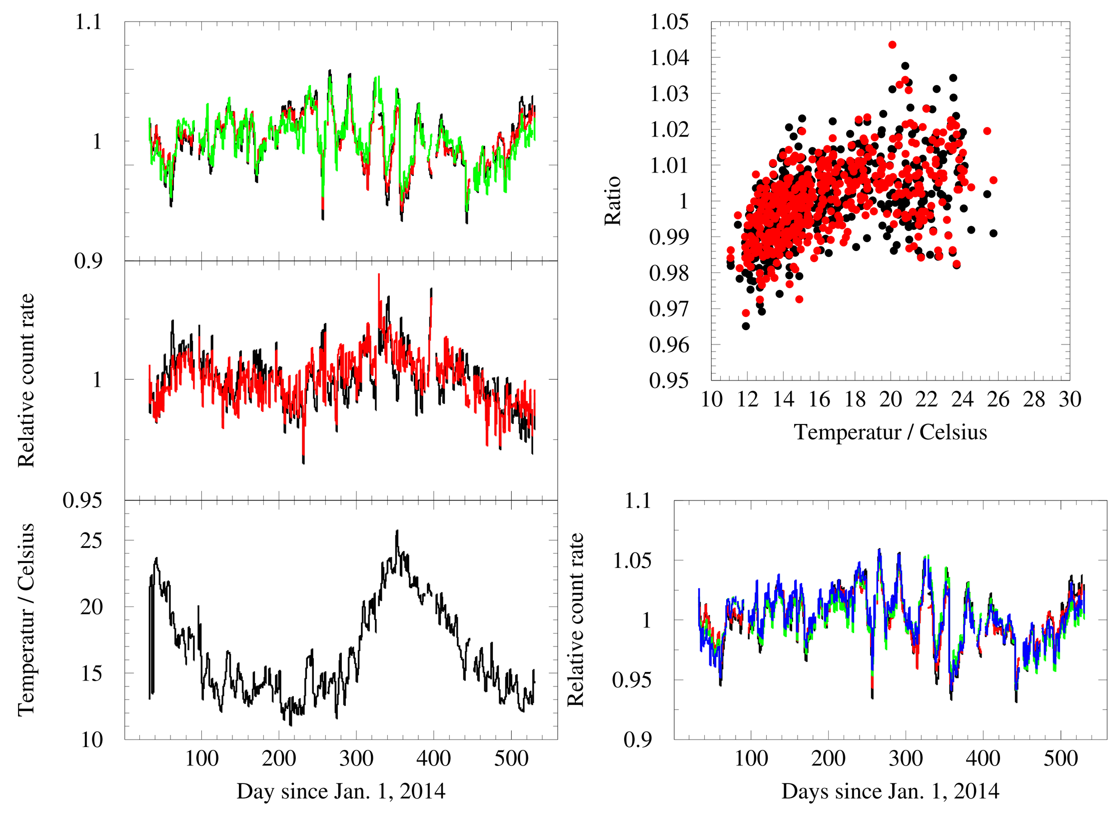
1 Introduction

Ground-based measurements of galactic cosmic rays (GCRs) have been performed since their discovery by Viktor Hess in 1912. Since the 1950s neutron monitors (NMs) are utilized for these kind of measurements [8, 9]. Because NMs are integral counters with a threshold energy defined by the minimum of the magnetic cutoff energy and the shielding by the atmosphere, several monitors have been installed world-wide. This should allow to determine the energy spectra of GCRs as well as solar energetic particles (SEPs) during Ground Level Enhancements. In order to extend the existing neutron monitor network, a lightweight mini neutron monitor has been developed [5]. This device is expected to achieve count rates of 1 count/second at sea level, allowing a statistical accuracy on the percent level by using hourly averages [5, 3]. The system has been setup as a mobile station that can be placed at almost any location in the world that can provide an office, power supply and internet access. In order to make the data easily accessible, they are provided to the neutron monitor database (NMDB, www.nmdb.eu). One of these devices was successfully installed in February 2014 at the German research station Neumayer III located at the Ekström Shelf Ice, Atka Bay, north-eastern Weddell Sea (70°40'S, 008°16'W), and another one is mounted on the German research vessel Polarstern (http://www.awi.de/en/infrastructure/ships/polarstern/).

2 Neumayer III measurements, long-term stability



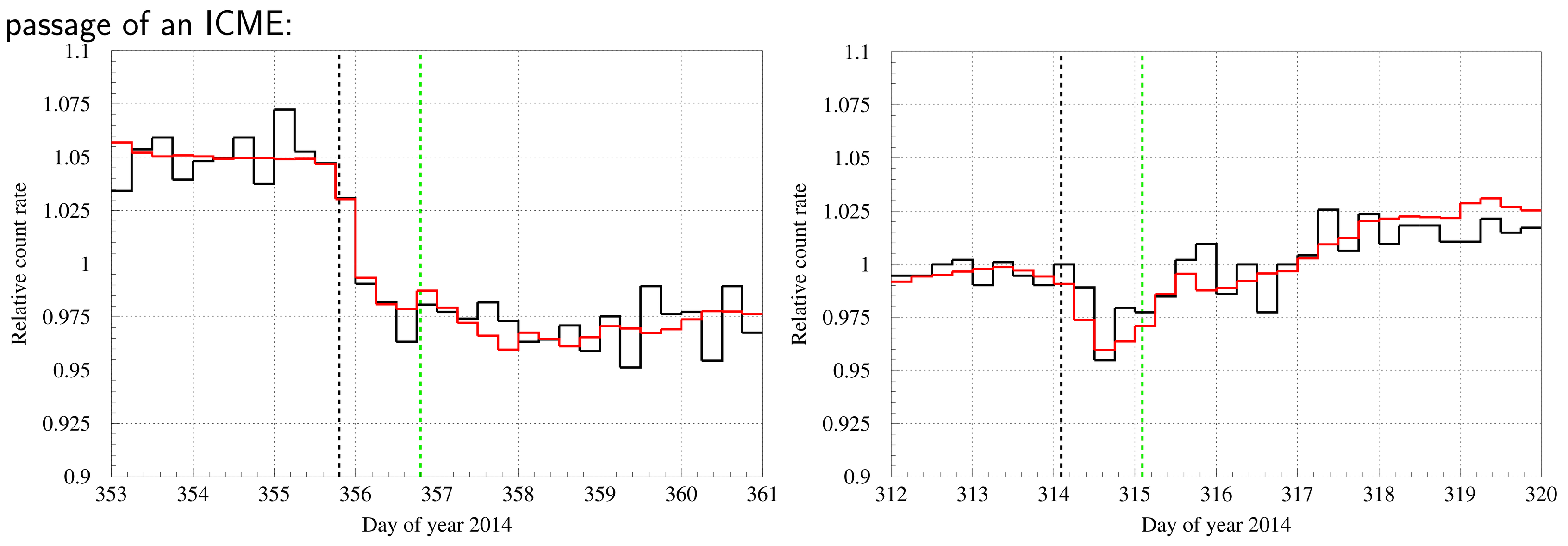
From top to bottom: 1h averages of the relative galactic cosmic ray intensity variation as measured by the neutron monitor at Terre Adelie, the mini neutron monitor at the Neumayer III station, the neutron monitor at South Pole and at McMurdo (from nest2.nmdb.eu). In order to indicate disturbed time periods, the 3h averaged K_p-values are plotted below.



Left: Daily averaged relative variation of the neutron monitors at South Pole (black curve), McMurdo (red curve) and Neumayer III (green curve). The middle panel shows the ratio of the Neumayer III monitor to the one at South Pole (black curve) and at McMurdo (red curve). The lower panel shows the temperature variation at the Neumayer III station. The upper right panel displays the daily averaged ratios as function of temperature. The temperature corrected time profile of the mini neutron monitor at Neumayer III is given by the blue curve in the lower right panel.

3 Sensitivity studies: Forbush decreases

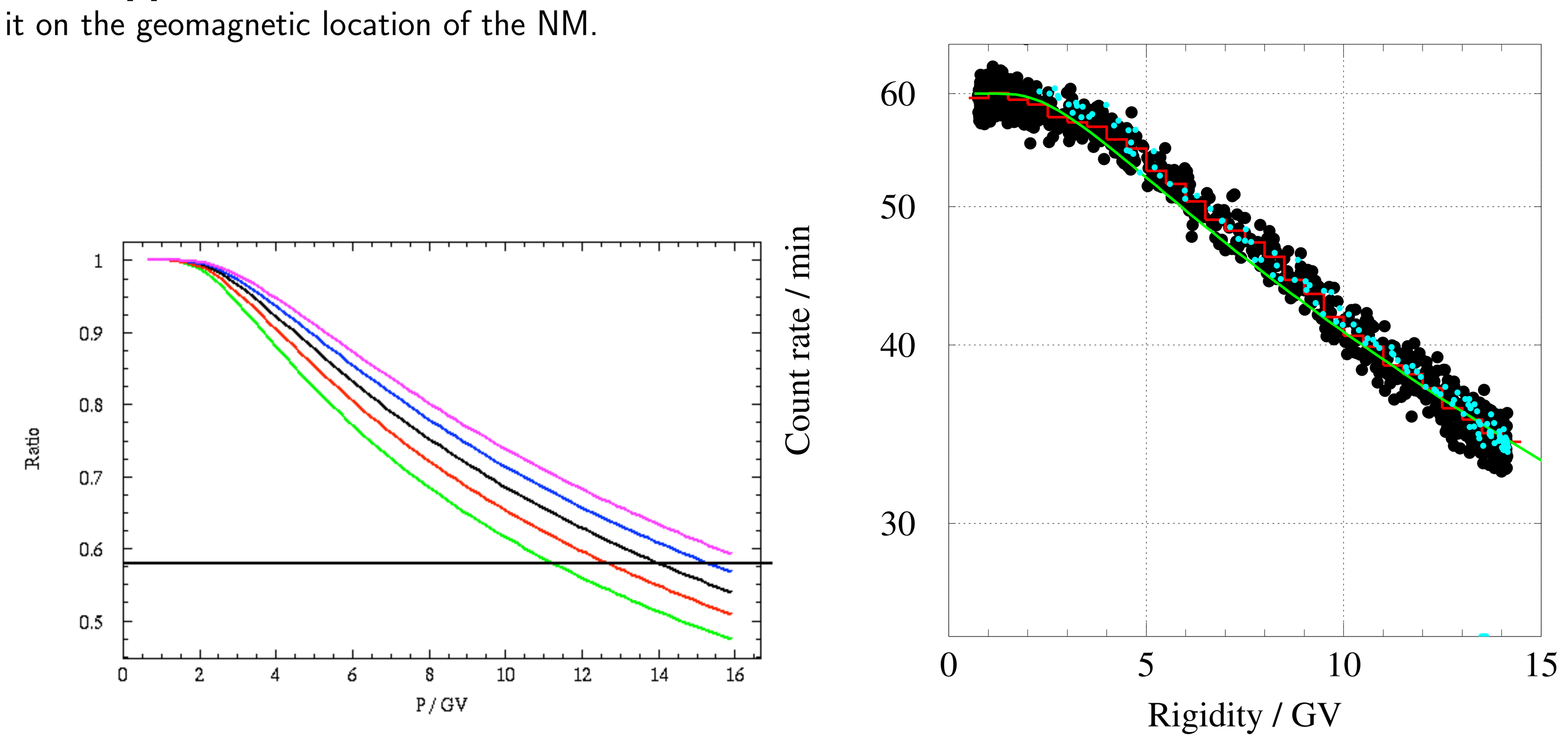
Forbush [2] as well as Hess and Demmlmair [4] were the first to observe short-term intensity decreases using ionization chambers, known as Forbush decreases (FDs). Using the ICME list from Richardson and Cane [7] for 2014, we identified 11 and 8 FDs for McMurdo and Neumayer III, respectively, that were associated to a passage of an ICME:



Forbush decreases observed by McMurdo (red curve) and Neumayer III (black curve) associated with the occurrence of a CME. Vertical lines indicate arrival times of the ICME, for details see [7]. While there is a significant amplitude of about 7% for the left event, an amplitude of 3% for the right event is only significant within 3 σ.

4 Latitude surveys of the Polarstern

Latitudinal surveys have been used in the past to determine the differential response function of a neutron monitor [1]. The intensity of GCRs entering the atmosphere strongly depends on the cut-off rigidity, and with it on the geomagnetic location of the NM.



Left: Model results of latitude surveys for different modulation potential varying from 400 to 1200 MV. The right panel displays the measured count rate variation during the 2012/2013 (black dots, and red line) and the 2015 (blue dots) latitude surveys. The green line represent the model results for a modulation potential of 570 MV. Note that all count rates and the model results are normalized to each other for rigidities below 1 GV.

5 Summary and Conclusion

Two modern mini neutron monitors were successfully installed, one in February 2014 at the German research station Neumayer III located at the Ekström Shelf Ice, Atka Bay, north-eastern Weddell Sea (70°40'S, 008°16'W) and another one on the German research vessel Polarstern (http://www.awi.de/en/infrastructure/ships/polarstern/).

- The comparison with other polar station indicate that a mini neutron monitor shows the same temporal variation and is therefore a valuable instrument in order to expand the existing network.
- The device can be used for the analysis of FDs that have an amplitude larger than about 3%.
- In addition the yield function of [6] is capable of describing the amplitude of the measured cosmic ray variation during the two latitude surveys of the Polarstern in 2012/2013 and in 2015.

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