Space Weather Study with Global Muon Detector Network (GMDN). C. Kato[1] (for GMDN Collaboration), [1]Physics Department, Shinshu University, Matsumoto, 390-8621, Japan.

As indicated by the name, GMDN observes cosmic ray (CR) muons. Observation have been performed by multi-directional muon detectors located at Nagoya (Japan), Hobart (Australia), SãoMartinho (Brazil), and Kuwait City (Kuwait). GMDN started its operation in 2006. We recently added one more station at Syowa base in the Antarctic in 2018. After this expansion, GMDN is sometimes described as GMDN+. Viewing directions of GMDN+ outside the magnetosphere are shown in figure 1[1]. GMDN is monitoring almost all the sky. All sky monitoring is essential for precise measurement of the CR anisotropy, and GMDN is designed for this. Atmospheric effects are precisely corrected by a newly developed method[2].

The energy range of primary CRs measured by

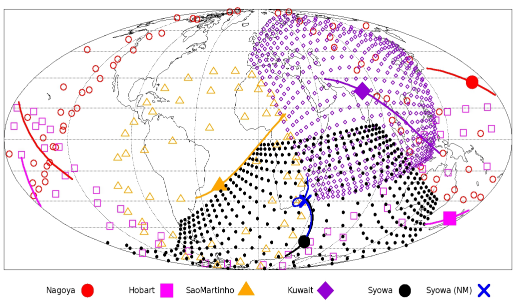

Figure 1 Asymptotic viewing directions of the GMDN and MD+NM at Syowa Station corrected for the magnetic deflection of CR orbits in the magnetosphere. Each small symbol shows the asymptotic direction of primary GCR having the median primary rigidity (P_m) observed in each directional channel, while each large solid symbol indicates the viewing direction of the vertical channel in ea. A large cross symbol indicates a viewing direction of Syowa NM. The track through each solid symbol represents the spread of viewing directions corresponding to the central 80% of the rigidity response.

GMDN is about 60 GeV, which is nearly an order of magnitude higher than neutron monitors (NMs). The better response to higher energy region has several advantages.

High energy CRs from an interplanetary coronal mass ejection (ICME) travel to the upstream Earth with the speed of light, overtaking the ICME and shock ahead and carrying advanced information of the storm as a CR precursor. The longer mean free path of pitch angle scattering for higher energy CRs enables us to get this information with a longer leading time which is an important issue in space weather forecasting. We have shown that more than 80% of severe geomagnetic storms are accompanied by cosmic ray precursors, observed on average 7.2 hours in advance of the storm sudden commencement (SSC) [3][4].

GMDN also has a better response to the larger scale magnetic structure of a CME extending over ~0.1 AU comparable to CR's Larmor radius. This is significant because it implies that kinetic anisotropies (such as $\mathbf{B} \times \nabla n$ anisotropy) are responding to the large-scale structure of the solar wind disturbance. Multiple CME events have been analyzed and the structure of the magnetic flux ropes (MFRs) was studied [5][6]. The most recent analysis was for the so called stealth CME in 2018[7], which was a rather small CME event but caused a large geomagnetic storm. Contribution of GMDN observation to understanding the characteristics of the MFR was demonstrated.

Solar cycle 25 started after a long quiet solar minimum period. We are expecting that GMDN can observe more space weather events within the next decade gaining new insight about space weather events by complementary analysis with NMs and other observational data.

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