Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PEM25-09 Room:202 Time:May 25 11:15-11:30

Average features of interplanetary shocks observed with the Global Muon Detector Network (GMDN)

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It has been well established that the short term decreases of galactic cosmic ray (GCR) isotropic intensity (or GCR density) at the Earth, called 'Forbush decreases' (Fds), are mostly caused by the interplanetary shocks passing the Earth. The GCR spatial distribution which reflects the magnetic structure and geometry of the shock causing Fd can be deduced from the observation of three dimensional GCR anisotropy associated with Fds, because the first order anisotropy arises from the diffusion and drift of GCRs which are proportional to the spatial gradient of GCR density in the Fd.

Deriving the dynamic variation of GCR anisotropy during the Fd observed with a single detector, however, has been difficult because the traditional analyses based on the diurnal variation of GCR intensity provide only the daily mean equatorial anisotropy. The present GMDN consisting of four multi-directional muon detectors in Nagoya (Japan), Hobart (Australia), São Martinho (Brazil) and Kuwait city (Kuwait) started operation in 2006 and successfully observed dynamic variations of GCR anisotropy associated with major Fd events (Okazaki *et al.*, 2008; Kuwabara *et al.*, 2009; Fushishita *et al.*, 2010; Rockenbach *et al.*, 2014).

In this presentation, we analyze the average features of GCR density gradient associated with interplanetary shocks identified by the Storm Sudden Commencement (SSC) onset recorded at the Earth between 2006 and 2014. About 100 SSC events classified into two groups arising from coronal hole and flare are analyzed. From the first order anisotropy corrected for the solar wind convection and Compton-Getting effect arising from Earth's orbital motion around the Sun, we deduce the three dimensional density gradient on hourly basis for each SSC event. We then derive the average temporal variation by superposing variations at the SSC onset timing. We find clear enhancements of radial and latitudinal density gradients after the SSC implying the geometry of low GCR density region in Fds behind the shock front. We also discuss the difference in average features in events caused by shocks arising from coronal holes and flares.

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Keywords: density gradient of galactic cosmic rays, Forbush decrease, solar modulation, interplanetary shock, solar flare, coronal hole