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Ground-based measurements of cosmic ray spectrum during Forbush decreases

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Strong shocks propagating in the interplanetary medium sweep out energetic cosmic rays, and this effect is known as a Forbush decrease of the cosmic ray intensity. Studying the cosmic ray spectrum during the times of Forbush decreases would provide a tool for probing large scale interplanetary irregularities. However, since the Forbush decreases are short transient phenomena, there is lack of information on detailed direct measurements of the cosmic ray spectrum, especially in the high energy range. Here we analyze the spectrum indirectly, using simultaneous continuous cosmic ray measurements at the ground, in two nearby sites in Finland: by a neutron monitor in Oulu, and by a muon scintillator detector in Pyhäsalmi. We showed that the shock, which sweeps out particles of all energies at the fast active phase of the Forbush decrease, soon becomes transparent for high energy particles, leading to a faster recovery of more energetic cosmic rays. In some cases we observed a post-increase of cosmic rays in the muon data (the cosmic ray level at a late recovery phase exceeds the pre-increase level). Using a detailed computation of the specific yield function for both neutron monitor and muon detector, we estimated the cosmic ray spectrum during major Forbush decreases in 2003-2005. We discussed some implications of the present study in terms of the shocks' development and interaction with cosmic rays.