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Measurement of Secondary Cosmic Ray Neutrons at High-Mountain Altitude

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In this paper, the influence of the environmental parameters that might affect the energy spectrum of the neutrons of the secondary cosmic rays (CRs) measured at high-mountain altitude is discussed. These neutrons are produced by the multiple interactions of primary CRs (mainly protons) with nuclei in the Earth's atmosphere (mainly oxygen and nitrogen). The energy distribution of those secondary neutrons predominately includes an evaporation peak at about 1-2 MeV originating from highly excited residual nuclei produced after intra-nuclear cascades, and a cascade peak at about 100 MeV that is due to a broad minimum in neutron cross sections in air at high energies. These neutrons contribute most to the cosmic radiation dose of air crew at typical flight levels (FL 350-390) with about 3 – 4 μSv/h, expressed in terms of neutron ambient dose equivalent rate, dH*(10)/dt. The secondary neutron spectra in the atmosphere do not include many thermal neutrons at energies below several eV. In contrast, close to the Earth's ground surface many more thermal and epithermal neutrons (with energies below 10 keV) are present, due to albedo neutrons backscattered from the ground. The number of albedo neutrons is for example determined by soil moisture and snow cover.
To investigate this effect, since 2004 an extended range Bonner sphere spectrometer (ERBSS) with 16 measuring channels has been operated at the Environmental Research Station "UFS Schneefernerhaus" (2,650 m a.s.l.) close to the summit of the Zugspitze Mountain, Germany. This spectrometer allows continuos measurement of the energy spectrum of neutrons from the secondary CRs. Gained data allow the quantification of any variations in the whole neutron energy range from a few meV up to GeV. The resulting time-dependent spectra have been folded with proper fluence-to-dose conversion functions and values for H*(10) have been calculated as a function of time. In the time period from 2006 to 2017 the resulting H*(10) dose rates varied between 57 nSv/h and 73 nSv/h depending on solar activity and snow conditions.
With the time series of the deduced neutron spectra, it is possible to investigate the effect of the solar activity cycle, ground level enhancement (GLE) events, Forbush decrease (FD), atmospheric pressure as well as snow in the environment, and soil moisture.