Cosmic ray modulation and radiation dose of aircrews during possible grand solar minimum

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After surprising September 2017 flares, the Sun is exhibiting very low activity, and it is likely to be continued as well as in the case of the past grand solar minima. The cosmic-ray modulation, which is the variation of the galactic cosmic ray (GCR) spectrum caused by the heliospheric environmental change, is basically anti-correlated with the solar activity. In the recent weak solar cycle, we thus expect that the flux of GCRs is getting higher than that in the previous solar cycles, leading to the increase in the radiation exposure in the space and atmosphere. In order to quantitatively evaluate the possible solar modulation of GCRs and resultant radiation exposure at flight altitude, we have developed the time-dependent and three-dimensional model of the cosmic-ray modulation. Our model can give the flux of GCRs anywhere in the heliosphere by assuming the variation of the solar wind speed, the strength of the heliospheric magnetic field (HMF), and its tilt angle. We solve the gradient-curvature drift motion of GCRs in the HMF, and therefore reproduce the 22-year variation of the cosmic-ray modulation. We also calculate the neutron monitor counting rate and the radiation dose of aircrews at flight altitude, by the air-shower simulation performed by PHITS (Particle and Heavy Ion Transport code System). In our previous study [1], we calculated the radiation dose at a flight altitude during the coming solar cycle by assuming the variation of the solar wind speed and the strength of the HMF expressed by sinusoidal curve, and obtained that an annual radiation dose of aircrews in 5 years around the next solar minimum will be up to ~19% higher than that at the last cycle. In this study, we predict the new model of the heliospheric environmental change on the basis of a prediction model for the sunspot number. We show our latest quantitative predictions of the cosmic-ray modulation and the radiation dose at a flight altitude during possible Grand Minimum considering the new model for the heliospheric environmental change.

[1] S. Miyake, R. Kataoka, and T. Sato, Space Weather, 15, 589-605, 2017.

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