Implementing Badhwar-O'Neill Galactic Cosmic Ray Model for the Analysis of Space Radiation Exposure

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For the analysis of radiation risks to astronauts and planning exploratory space missions, accurate energy spectrum of galactic cosmic radiation (GCR) is necessary. Characterization of the ionizing radiation environment is challenging because the interplanetary plasma and radiation fields are modulated by solar disturbances and the radiation doses received by astronauts in interplanetary space are likewise influenced. A model of the Badhwar-O'Neill 2011 (BO11) GCR environment, which is represented by GCR deceleration potential Φ, has been derived by utilizing all of the GCR measurements from balloons, satellites, and the newer NASA Advanced Composition Explorer (ACE).   In the BO11 model, the solar modulation level is derived from the mean international sunspot numbers with time-delay, which has been calibrated with actual flight instrument measurements to produce better GCR flux data fit during solar minima. GCR fluxes provided by the BO11 model were compared with various spacecraft measurements at 1 AU, and further comparisons were made for the tissue equivalent proportional counters measurements at low Earth orbits using the high-charge and energy transport (HZETRN) code and various GCR models. For the comparison of the absorbed dose and dose equivalent calculations with the measurements by Radiation Assessment Detector (RAD) at Gale crater on Mars[1], the intensities and energies of GCR entering the heliosphere were calculated by using the BO11 model, which accounts for time-dependent attenuation of the local interstellar spectrum of each element. The BO11 model, which has emphasized for the last 24 solar minima, showed in relatively good agreement with the RAD data for the first 200 sols, but it was resulted in to be less well during near the solar maximum of solar cycle 24 due to subtleties in the changing heliospheric conditions. By performing the error analysis of the BO11 model and the optimization in reducing overall uncertainty, the resultant BO13 model corrects the fit at solar maxima as well as being accurate at solar minima. The BO13 model is implemented to the NASA Space Cancer Risk model for the assessment of radiation risks. Overall cumulative probability distribution of solar modulation parameters represents the percentile rank of the average interplanetary GCR environment, and the probabilistic radiation risks can be assessed for various levels of GCR environment to support mission design and operational planning for future manned space exploration missions.

[1]Kim, M.-H. Y., et al. (2014), Comparison of Martian surface ionizing radiation measurements from MSL-RAD with Badhwar-O'Neill 2011/HZETRN model calculations, J. Geophys. Res. Planets, 119, doi:10.1002/2013JE004549.