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The Effect of the Heliospheric Diffusion Tensor on 26-Day Recurrent Cosmic-Ray Variations

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Abstract: A linear relationship between the observed 26-day recurrent cosmic-ray intensity variations and the global latitudinal gradient was first reported by Zhang (1997, ApJ, 488). Burger and Hitge (2004, ApJL, 617) used a three-dimensional steady-state numerical modulation model and showed that a Fisk-type (Fisk 1996, JGR, 101) heliospheric magnetic field (HMF) can in principle explain these observations, at least at high latitudes. Burger and Engelbrecht (2006, AGU Fall meeting abstracts SH53B-1505) used a refinement of the Fisk-Parker hybrid HMF model by Kruger (2006, MSc dissertation, North-West University) to study these 26-day recurrent variations in more detail with the same modulation code. They reported that a single second-order fit to the amplitude of the recurrent variations as function of latitudinal gradient gives better results than a first-order fit and that there is a difference in the amplitudes for high- and for low rigidities at the same the latitudinal gradient. In the ecliptic at 1 AU the amplitude of the recurrent variations at high rigidity is larger during $qA > 0$ polarity epochs than during $qA < 0$ epochs, in agreement with observational results (Richardson et al. 1999, JGR, 104). In the present study we use two types of diffusion tensors and study their effect on 26-day recurrent variations. In both cases we use the same analytical expressions for the parallel mean free path (MFP) (Teufel and Schlickeiser 2002, A&A, 393) and the drift coefficient (Burger et al. 2000, JGR, 105), but different forms for the perpendicular MFP. We also show that in the transformation from field-aligned- to spherical coordinates, a slightly different result from that of Kobylinski (2001, ASR, 27) is obtained. For the first diffusion tensor, the perpendicular MFP has the same spatial dependence as the parallel MFP, but a flatter rigidity dependence (Burger et al. 2000). For the second case, we use the analytical expression for the perpendicular MFP derived by Shalchi et al. (2004, ApJ, 604) for the nonlinear guiding center model (NLGC) of Matthaeus et al. (2003, ApJ, 590). Using the first diffusion tensor, we find that when decreasing (increasing) parallel and/or perpendicular MFPs, the latitudinal gradient and the amplitude of the recurrent cosmic-ray variations are increased (decreased). When drifts are scaled down, the latitudinal gradient and the amplitude of the recurrent cosmic-ray variations are also decreased. A key new result is obtained when we use the second diffusion tensor with the NLGC perpendicular MFP for protons: Previously we found that in the ecliptic at 1 AU the amplitude of the recurrent variations is larger during $qA > 0$ polarity epochs than during $qA < 0$ epochs, but only at high rigidity (Burger and Engelbrecht 2006). With the NLGC perpendicular MFP, the (almost) linear relationship between the 26-day recurrent cosmic-ray variations and the global latitudinal gradient now also occurs for low rigidity protons at Earth. This means that the observational results of Richardson et al. (1999) can be qualitatively explained at all rigidities by a Fisk-type HMF.