



Random Walk and Trapping of Interplanetary Magnetic Field Lines: Global Simulation, Magnetic Connectivity, and Implications for Solar Energetic Particles

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The random walk of magnetic field lines is an important ingredient in understanding how the connectivity of the magnetic field affects the spatial transport and diffusion of charged particles. As solar energetic particles (SEPs) propagate away from near-solar sources, they interact with the fluctuating magnetic field, which modifies their distributions. We develop a formalism in which the differential equation describing the field line random walk contains both effects due to localized magnetic displacements and a non-stochastic contribution from the large-scale expansion. We use this formalism together with a global magnetohydrodynamic simulation of the inner-heliospheric solar wind, which includes a turbulence transport model, to estimate the diffusive spreading of magnetic field lines that originate in different regions of the solar atmosphere. We first use this model to quantify field line spreading at 1 au, starting from a localized solar source region, and find rms angular spreads of about 20 – 60 degrees. In the second instance, we use the model to estimate the size of the source regions from which field lines observed at 1 au may have originated, thus quantifying the uncertainty in calculations of magnetic connectivity; the angular uncertainty is estimated to be about 20 degrees. Finally, we estimate the filamentation distance, i.e., the heliocentric distance up to which field lines originating in magnetic islands can remain strongly trapped in filamentary structures. We emphasize the key role of slab-like fluctuations in the transition from filamentary to more diffusive transport at greater heliocentric distances. This research has been supported in part by grant RTA6280002 from Thailand Science Research and Innovation and the Parker Solar Probe mission under the ISOIS project (contract NNN06AA01C) and a subcontract to University of Delaware from Princeton University (SUB0000165). MLG acknowledges support from the Parker Solar Probe FIELDS MAG team. Additional support is acknowledged from the NASA LWS program (NNX17AB79G) and the HSR program (80NSSC18K1210 & 80NSSC18K1648).

