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How Well Can a Footpoint Tracking Method Estimate the Magnetic Helicity Influx during a Magnetic Flux Emergence?

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As shown by Demoulin and Berger (2003), the magnetic helicity flux through the solar surface into the solar atmosphere can be exactly calculated if we can trace the motion of footpoints with infinite temporal and spatial resolutions. When there is a magnetic flux transport across the solar surface, the horizontal velocity of footpoints becomes infinite at the polarity inversion line, but the surface integral yielding the helicity flux does not diverge. In practical application, a finite temporal and spatial resolution causes an underestimate of the magnetic helicity flux when a magnetic flux emerges from below the surface. In this paper, we consider emergence of simple two- and half-dimensional magnetic flux ropes and calculate the supremum of the magnitude of the helicity influx that can be estimated from footpoint tracking, per unit length in the invariant direction. The results depend on the ratio of the resolvable length scale and the flux rope diameter. For a Gold-Hoyle flux rope, in which all field lines are uniformly twisted, the observationally estimated helicity influx would be about 90% of the real influx when the ratio is 0.01 and about 45% when the ratio is 0.1. For Lundquist flux ropes, the errors to be incurred by observational estimation would be smaller than the case of the Gold-Hoyle flux rope, but could be as large as 30%. Our calculation suggests that the error in the helicity influx estimate is at least half of the real value or even larger when small scale magnetic structures emerge into the solar atmosphere.