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Testing the Geomagnetic Axial Dipole hypothesis at the South Atlantic Anomaly region

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A robust reconstruction of geomagnetic field intensity requires careful evaluation of spatial sampling strategies and latitude reduction methods, especially in regions strongly influenced by non-dipolar field components. In this work, we systematically investigate the statistical stability and spatial and temporal sensitivity of regional geomagnetic intensity estimates as a function of three fundamental variables: the radius of the spatial region used to represent a point of interest, the number of sites sampled within the region of interest and the number of independent site samples. Using the global geomagnetic field models CHAOS-8.1 and COV-OBS.x2, we simulated controlled statistical experiments in which field intensity values are randomly sampled in circular regions centered on previously defined locations of interest. Five locations were analyzed, including two fixed points (Paris and São Paulo cities) and three time-varying reference points associated with the minimum, maximum and average values of the paleosecular variation index (P_i). The statistical performance of the regional estimates was quantified using the normalized root-mean-square (RMS) error, calculated relative to the local reference intensity at a specific epoch. Five approaches were tested: (i) without latitude correction; (ii) latitude correction considering only the axial dipole term (g_1^0); (iii) latitude correction including the axial dipole and quadrupole terms ($g_1^0 + g_2^0$); (iv) latitude correction including axial dipole, quadrupole and octupole terms ($g_1^0 + g_2^0 + g_3^0$); and (v) the eccentric dipole (ED) approximation. Our results show that the sampling radius is the dominant parameter in controlling the error. The effectiveness of the latitude corrections strongly depends on the region and epoch analyzed. Axial latitude corrections perform better in contexts close to a dipolar configuration, while no latitude correction or ED approach are more effective in regions dominated by non-dipolar contributions, such as the South Atlantic Anomaly (SAA).