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Evaluation of a new paleosecular variation activity index as a diagnostic tool for geomagnetic field variations

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Geomagnetic indices like Dst, K and A, have been used since the early twentieth century to characterize activity in the external part of the modern geomagnetic field and as a diagnostic for space weather. These indices reflect regional and global activity and serve as a proxy for associated physical processes. However, no such tools are yet available for the internal geomagnetic field driven by the geodynamo in Earth's liquid outer core. To some extent this reflects limited spatial and temporal sampling for longer timescales associated with paleomagnetic secular variation, but recent efforts in both paleomagnetic data gathering and modeling activity suggest that longer term characterization of the internal geomagnetic weather/climate and its variability would be useful. Specifically, we propose an index for activity in paleosecular variation, useful as both a local and global measure of field stability during so-called normal secular variation and as a means of identifying more extreme behavior associated with geomagnetic excursions and reversals.

To date, geomagnetic excursions have been identified by virtual geomagnetic poles (VGPs) deviating more than some conventional limit from the geographic pole (often 45 degrees), and/or by periods of significant intensity drops below some critical value, for example 50% of the present-day field. We seek to establish a quantitative definition of excursions in paleomagnetic records by searching for synchronous directional deviations and lows in relative paleointensity. We combine paleointensity variations with deviations from the expected geocentric axial dipole (GAD) inclination in a single parameter, which we call the paleosecular variation (PSV) activity index. This new diagnostic can be used on any geomagnetic time series (individual data records, model predictions, spherical harmonic coefficients, etc.) to characterize the level of paleosecular variation activity, find excursions, or even study incipient reversals. Currently reversals can only be detected after they have occurred. A baseline for the new index is established using modern and Holocene geomagnetic field data and models to analyze "normal" variability. We extend our analyses to the 100 ka interval where several excursions have been identified. We discuss the diminished or absent signatures of excursions in some records, the apparent transgressive behavior of detected excursions, and implications for transitional field behavior. The absence of specific excursions in some sediment records is attributed to smoothing by the sedimentary remanence acquisition process and low sedimentation rates. Overall PSV activity index is inversely correlated with dipole moment, indicating stronger impacts of non-axial-dipole secular variations during periods of low axial dipole strength. Excursional events found with the PSV activity index are analyzed in the context of global probability density functions for VGP positions. We studied the appearance of VGP clusters of the excursions to find the common characteristics of these instabilities, including the non-axial dipole features of the geomagnetic field. A better understanding of geomagnetic excursions will aid attempts to predict when such events might occur in the future.