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Time dependence of multiple geomagnetic surface intensity minima

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The present-day geomagnetic field is characterized by a region of weak intensity over the South Atlantic, known as the South Atlantic Anomaly (SAA). Over the past few hundred years, there is evidence for possible persistence of the SAA. In addition, another less pronounced surface intensity minimum has appeared below the West Pacific, known as the West Pacific Anomaly (WPA). Since 2008, the SAA has split with a new local minimum appearing in Africa. This split introduces a challenge for characterizing the time dependence of a pair of minima, particularly in terms of their respective areas.

In this work, we propose a new topological algorithm to calculate the time dependent areas and centers of complex field configurations with multiple local surface intensity minima enclosed by the same threshold value. The algorithm relies on the identification of saddle points, which further enables the subdivision of the SAA area into sub-regions associated with different minima. In addition, the analysis considers contours of null intensity gradient, which do not require setting an arbitrary threshold value.

Based on the analysis of a modern geomagnetic field model, we find that the sub-region area associated with the weaker South American minimum decreases, whereas that of the African minimum increases. Both minima drift westward with negligible north-south displacement. The global minimum is located at a lower latitude than both local minima. The proposed method can be applied to paleo-magnetic field models, in which more complex patterns are observed.

In addition, analysis of the distribution of the null meridional intensity gradient over the period 1000–1950 reveals localized hemispheric asymmetry with relatively subdued activity in the Pacific hemisphere and stronger variability in the Atlantic, particularly in the Southern Hemisphere. The null intensity azimuthal gradient exhibits an order-2 signature suggestive of mantle control on the geomagnetic field.