Fig. 1. Magnetic field fluctuations at a low-latitude magnetometer station (SHIP). The rapid fluctuation $\delta B_{\text{SH}}(t)/|B|$ (blue line) highlighted towards the 100-day period (dashed line) until in April 2001 and is associated with a storm sudden commencement.

Fig. 2. The 99th percentile of $|\delta B_{\text{SH}}(t)/|B||$ for each site. Contours indicate computed geomagnetic CSC-magnitudes.

Fig. 3. Magnitude field fluctuations at a low-latitude magnetometer station (SHIP). The rapid fluctuation $\delta B_{\text{SH}}(t)/|B|$ (blue line) highlighted towards the 100-day period (dashed line) until in April 2001 and is associated with a storm sudden commencement.

Fig. 4. The 99th percentile of $|\delta B_{\text{SH}}(t)/|B||$ for each site. Contours indicate computed geomagnetic CSC-magnitudes.

Fig. 5. Predicting Extreme $|dB/dt|$ from Discretely Sected Directions, Seasons, or Magnetic Local Times

The strong dependence of occurrence likelihood on covariates (direction, MLT, month, etc.) validates the assumption of an identical distribution in Eq. 1. Models that take into account covariate effects may yield more accurate results since they explain more of the variability in the data by setting thresholds that vary with the covariate (see Fig. 1). The following example – an ocean wave height analysis method (eq. 1) – applies to peaks of $\delta B_{\text{SH}}(t)/|B|$ in discrete directional sectors, but is readily adapted to seasonal or calendar time analysis.

Given a non-intersecting directional sectors (or seasons, etc.), not necessarily of equal size, we determine a sufficiently high threshold, $u_i$, in each sector, $i$. We then identify thresholds for each grid sector.

In each sector, we fit (by ML estimation) parameters of the complementary principal Gaussian distribution of $\delta B_{\text{SH}}(t)/|B|$ conditional on exceeding $u_i$, given by

$$ P(x > u_i | x_i = 0) = \left(1 - \frac{1}{\sqrt{2\pi}} \int_{u_i}^{\infty} e^{-x^2/2} dx \right) $$

where $x_i$ denotes a measure in sector $i$, and $x_i = 0$. The variation of $u_i$, $\sigma_i$, and $\nu_i$ for each site is plotted in Fig. 5 as direction sector and CSC magnitude. In each sector, we determine the complementary principal Gaussian distribution conditional on exceeding the highest threshold, $u_{max} = \max(u_i)$, $i = 1, \ldots, k$. The omnidirectional distribution may then be reconstructed as a weighted sum of complementary distributions in the sector. When $n(\text{years})$ may then be calculated for a range of return levels $x_0$ from

$$ P(x > x_0 | x_{max}) = \left(1 - \frac{1}{\sqrt{2\pi}} \int_{x_0}^{\infty} e^{-x^2/2} dx \right) $$

where $x_{max}$ is the total number of cluster peaks in the $i$th sector, and is the total number of samples. The resulting return period analysis plot for $x_0$ at GISM is presented in Fig. 6, where the colors (blue) – represents the omnidirectional profile (Eq. 5) reconstructed from directional sector distributions (dotted-dashed line) [from Eq. 1]. The return levels are significantly smaller than those obtained by Eq. 2 fitting to all data regardless of direction (dark). This is typical for sites below 40° GSM latitude as illustrated in Fig. 6a, which compares 100-year return levels for all sites using the directional sector reconstruction method (Eq. 5) [blue] with those obtained using Eq. 2 ignoring direction (dark). The differences, presented in Fig. 6b, indicate that reconstructing the GISM from directional sector definitionsa often leads to higher return value estimates at mid to high latitudes.

6: Summary

- Predictions of extreme geomagnetic fluctuations are an important indicator of GIC risk.
- Using an archive of magnetograms from 125 sites worldwide, we predict the largest return levels for $(\delta B_{\text{SH}}(t)/|B|)$ exceeding 53° to 55° at GISM (magnetometer site) with a secondary peak near the geomagnetic poles.
- Occurrence probability strongly depends on local time, local time, month, and direction, and influenced by IMF orientation.
- Occurrence patterns match the known patterns of substorm expansions, Pc5 waves, sudden commencements, and high-latitude substorm events.
- The poor assumption of identically distributed peaks is addressed by fitting GP distributions to data discretely segregated by direction (or month, etc.).
- Return levels for 50-year return period reconstructed from discretely directional data yield lower return levels for absolute GIC magnitudes below 40° where there are strong anisotropic anisotropies, higher return levels above 40°.

7: Future Work

- An alternative to the direct sectoring approach requirements fitting GP parameters as continuous functions of covariates (direction, month, MLT, etc.) The predictive performance of these methods will be compared.
- We hypothesized that $(\delta B_{\text{SH}}(t)/|B|)$ occurrence rates are strongly dependent on the time-scale (di), particularly at lower latitudes. Future models will incorporate the full spectrum of temporal fluctuations of interest to GIC risk modeling.

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References


