Geomagnetic jerks observed in geomagnetic observatory data over Southern Africa between 2017 and 2023

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ABSTRACT

Southern Africa is located in the eastern region of the South Atlantic Anomaly. There is a high gradient of temporal and spatial geomagnetic field variations in this region. A study of geomagnetic jerks in Southern Africa during the period of 2017 – 2023 was conducted using ground data from four magnetic observatories, Hermanus (HER), Tsumeb (TSU), Hartebeesthoek (HBK), and Keetmanshoop (KMH). we observed rapid core field fluctuations especially in the X and Z field components during the study period and confirmed the 2020 and 2021 jerks in all observatories.

INTRODUCTION

The Earth's magnetic field is vital for both natural phenomena and human activities, enabling navigation with compasses and safeguarding our planet from solar wind intrusion. Geomagnetic jerks, abrupt changes in the linear secular variation of Earth's magnetic field, have garnered significant scientific attention. These events, often characterized by sudden shifts in geomagnetic field components, are primarily generated in the Earth's core, as discussed by Courtillot et al. (1978).

Leveraging the world recognized CHAOS-7 model (Finlay et al., 2020), we processed the data to visually represent changes in defined regions of interest. The results, presented in figure 1, highlight the locations of four geomagnetic observatories in Southern Africa and emphasize the transformation patterns observed around them. Figure 2 show the long-term change of geomagnetic field in X, Y, Z and F field components at four magnetic observatories, HER, HBK, TSU and KMH. The plotted data are annual mean values that were calculated from 1-min data recorded in one year.

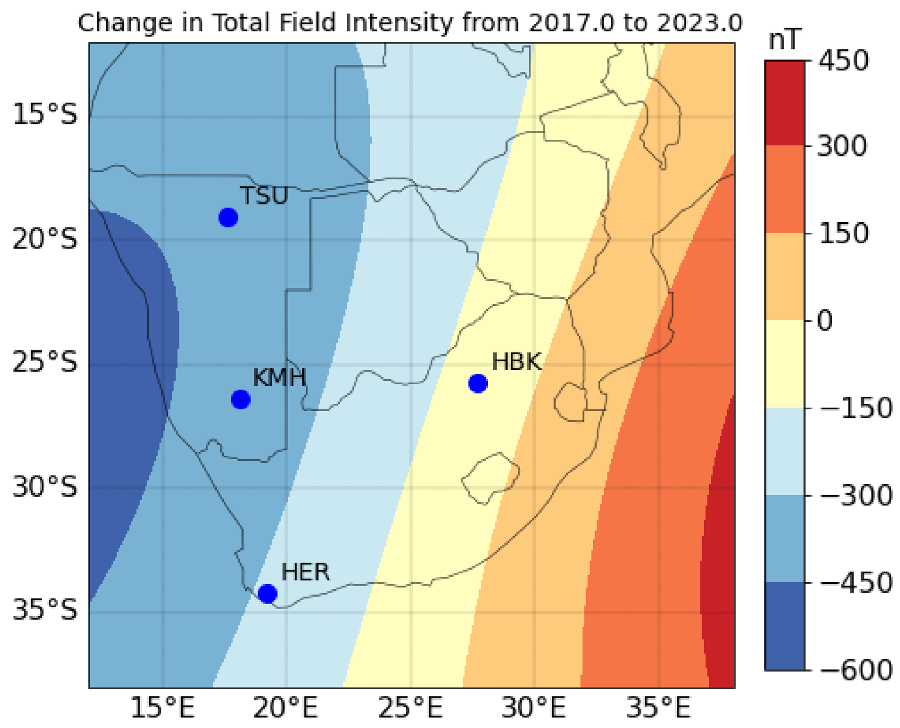

Figure 1: Change in total field intensity from 2017.0 to 2023.0, where the blue dots show the locations of the Southern African magnetic observatories, HER, HBK, TSU and KMH. The global model CHAOS-7 was used to calculate the field change in the total field intensity.

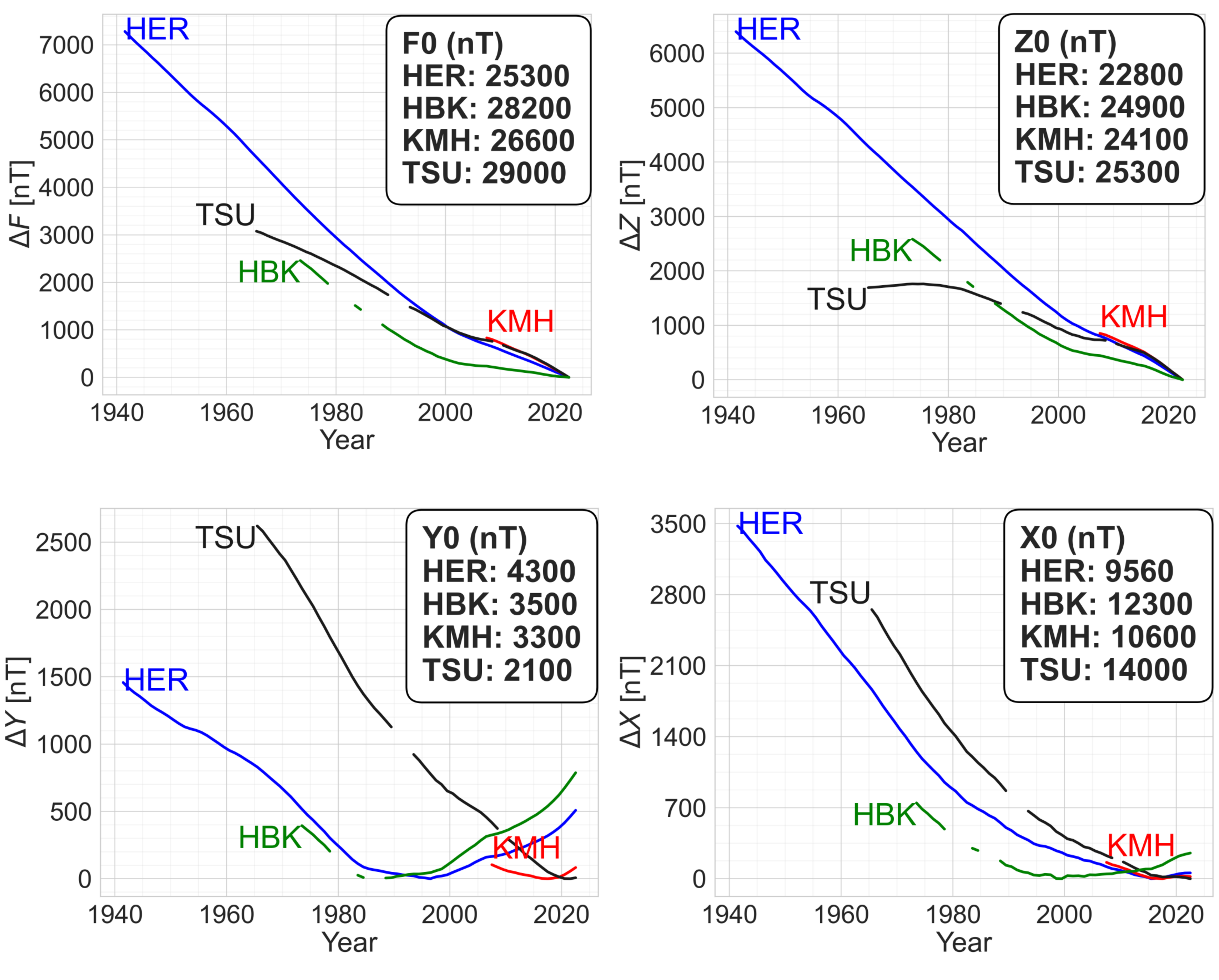

Figure 2: Long-term changes of X, Y, Z and F field components at four magnetic observatories in Southern Africa, HER, HBK, TSU and KMH between 1940 and 2022. On the Y-axis, ΔX, ΔY, ΔZ and ΔF are the differences between the main field values of X, Y, Z and F and their respective minimum values (X0, Y0, Z0 and F0) over the entire period of data availability.

DATA AND METHODOLOGY

This study utilizes six and half year of geomagnetic data from four Southern African observatories (HER, TSU, HBK, KMH) to investigate geomagnetic jerks. We analyzed data from Southern African observatories (HER, TSU, HBK and KMH) using 1-min data, selecting quiet nighttime periods 09:00PM to 04:00AM LT, $Kp \leq 2$, $|Dst| \leq 20\,nT/h$ or $|dDst/dt| \leq 3\,nT/h$ e.g., Saba *et al*. (1997), $|dRc/dt| \leq 3\,nT/h$. Monthly mean data were calculated. We calculated secular variation values to identify geomagnetic jerks using $dB/dt = [B(t+6) - B(t-6)]/1\,year$ *[1], B = (X, Y or Z)* where the unit of t is month, Chulliat et al. (2010) method and Maus (2010) mf7 model. Secular Variation was determined as the annual difference of monthly averages, allowing identification of long-term trends without smoothing. We derived results for the study period 2017 - 2023 using data from 2017.0 to 2023.5.

RESULTS

Our analysis of secular variation data from 2017 to 2023 reveals some earlier reported geomagnetic jerks, observed as sudden shifts in field components' linear secular variation. Figure 3 displays X, Y, and Z component results with CHAOS-7 predictions. Piecewise linear fits estimate secular variation change rates directly from time series data, optimized using an iterative method.

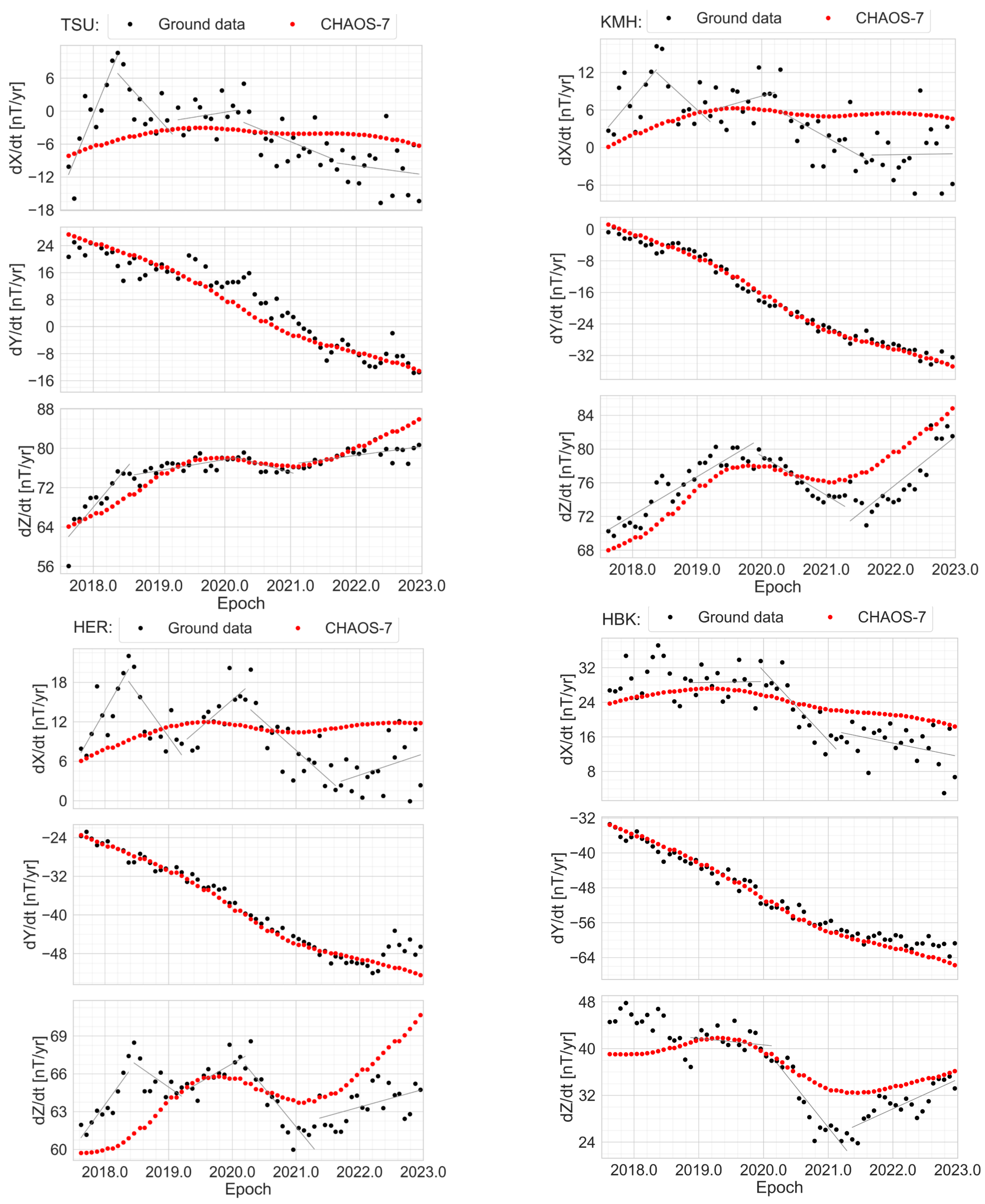

Figure 3: Shows TSU, KMH, HER, and HBK observatories X, Y, and Z secular variation (2017.5 – 2023.0) with black dots indicating annual field changes calculated at the centre of each month. The red dots represents CHAOS-7 global field model for comparison, while piecewise linear fits estimate secular acceleration.

CONCLUSION

Our study has shown that the Earth's magnetic field strength is still decreasing in the western region of Southern Africa (Mandea et al., 2007). This is confirmed by the high rate of decrease in the Z component, reaching more than 80 nT/year in 2023, at the magnetic observatories, TSU and KMH. However, the strength of other components X and Y has start increasing, slowing the rate of decrease of the total field intensity strength in the region. Rapid Southern African core field fluctuations were observed, with confirmation of the 2018 jerk on X and Z components (Figure 3) by Li et al. (2023). The 2020 jerk at HER and KMH (figure 3) is evident in X and Z components, reported by Pavon-Carrascon et al. (2021). The 2021 jerk appears as a V-shaped pattern in X and Z components across all observatories and in the CHAOS-7 model in the Z component.

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