

GEOMAGNETICALLY INDUCED CURRENTS DURING THE SSC OF THE OCTOBER 2024 GEOMAGNETIC STORM IN EUROPE

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Introduction

This study investigates the sudden impulse (SI) associated with the 10 October 2024 magnetic storm by tracking the propagation of the interplanetary shock (IP shock). We employ a multi-instrument approach to examine the effects of solar disturbances on the magnetosphere, ionosphere, and ground-based systems. This work contributes to understanding how geomagnetically induced currents (GICs) are related to interplanetary shock geometry and identifies the conditions under which these phenomena may pose significant risks to modern technological infrastructure.

Shock Inclination and Magnetopause position $(\theta, \phi) = (8^\circ, 6^\circ)$

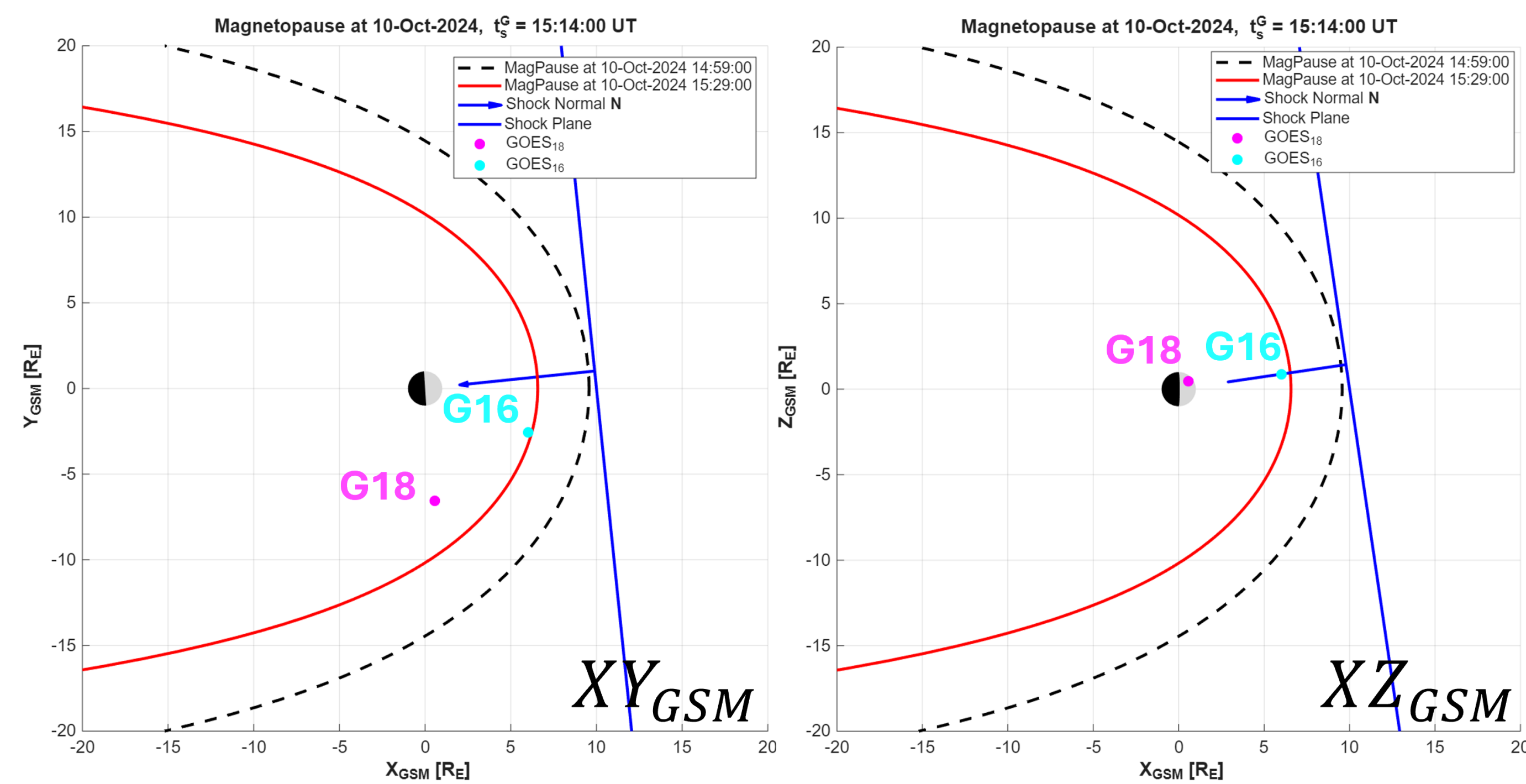


Figure 1: Magnetopause position (Shue et al., 1998) 15 minutes before (dashed) and after (red) the shock arrival at GOES. The left panel shows the XY_{GSM} plane and the right panel shows the XZ_{GSM} plane. The shock plane and its normal vector, evaluated at the point closest to Earth, are shown in blue. The positions of GOES-16 and GOES-18 are indicated in cyan and pink, respectively. The interplanetary shock normal was estimated using the Rankine-Hugoniot conditions and the four-spacecraft method with data from WIND, DSCOVR, ARTEMIS-P2, and GOES-16.

Ionospheric Disturbance Fields - Araki Model

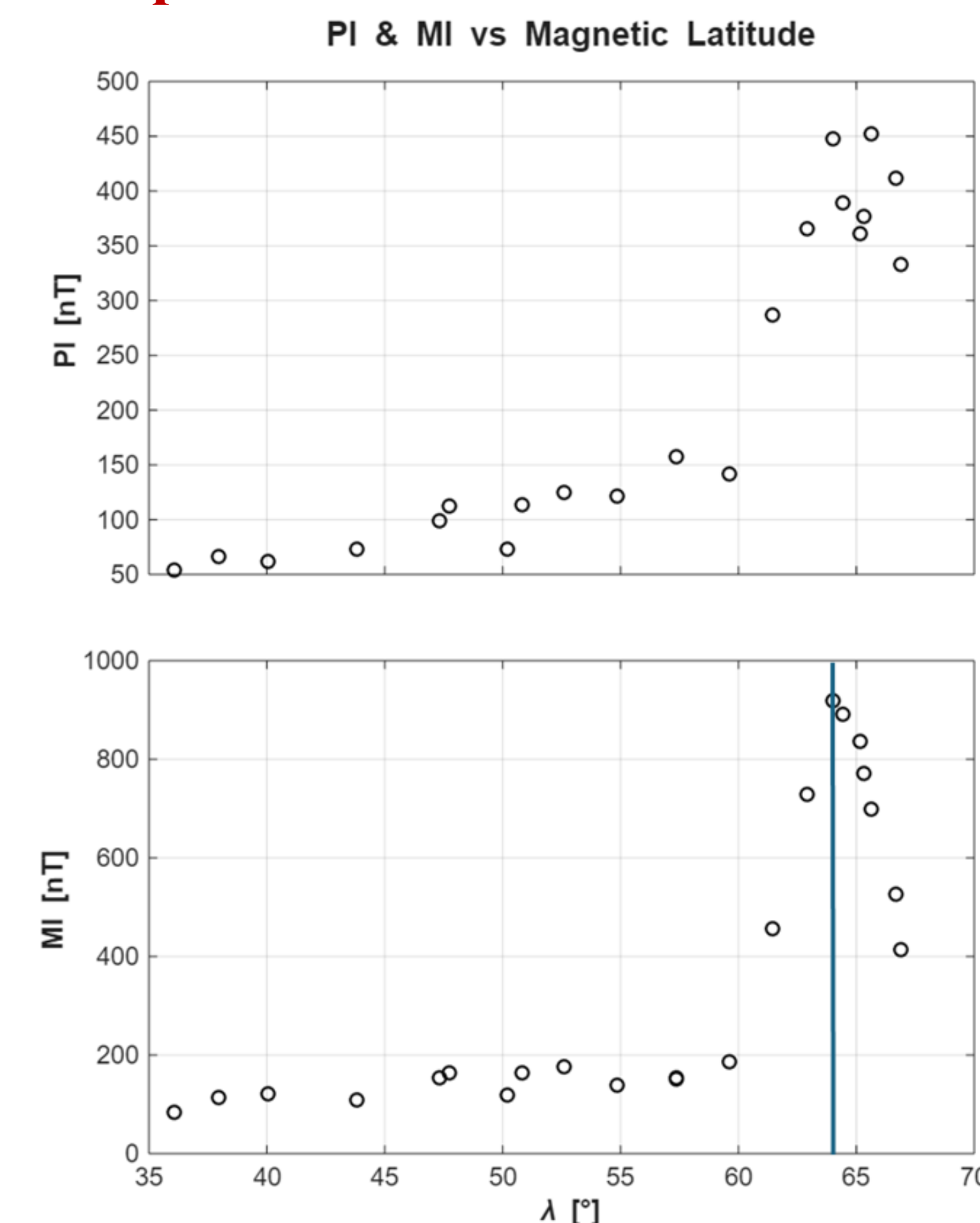


Figure 4: Disturbance field analysis. PI (top) and MI (bottom) associated with the sudden impulse as a function of magnetic latitude. From EMMA data, the magnetospheric contribution was subtracted by taking the means of the two steady states before and after the shock. The peak probably may be due to ULF resonance boost.

Magnetospheric Observations

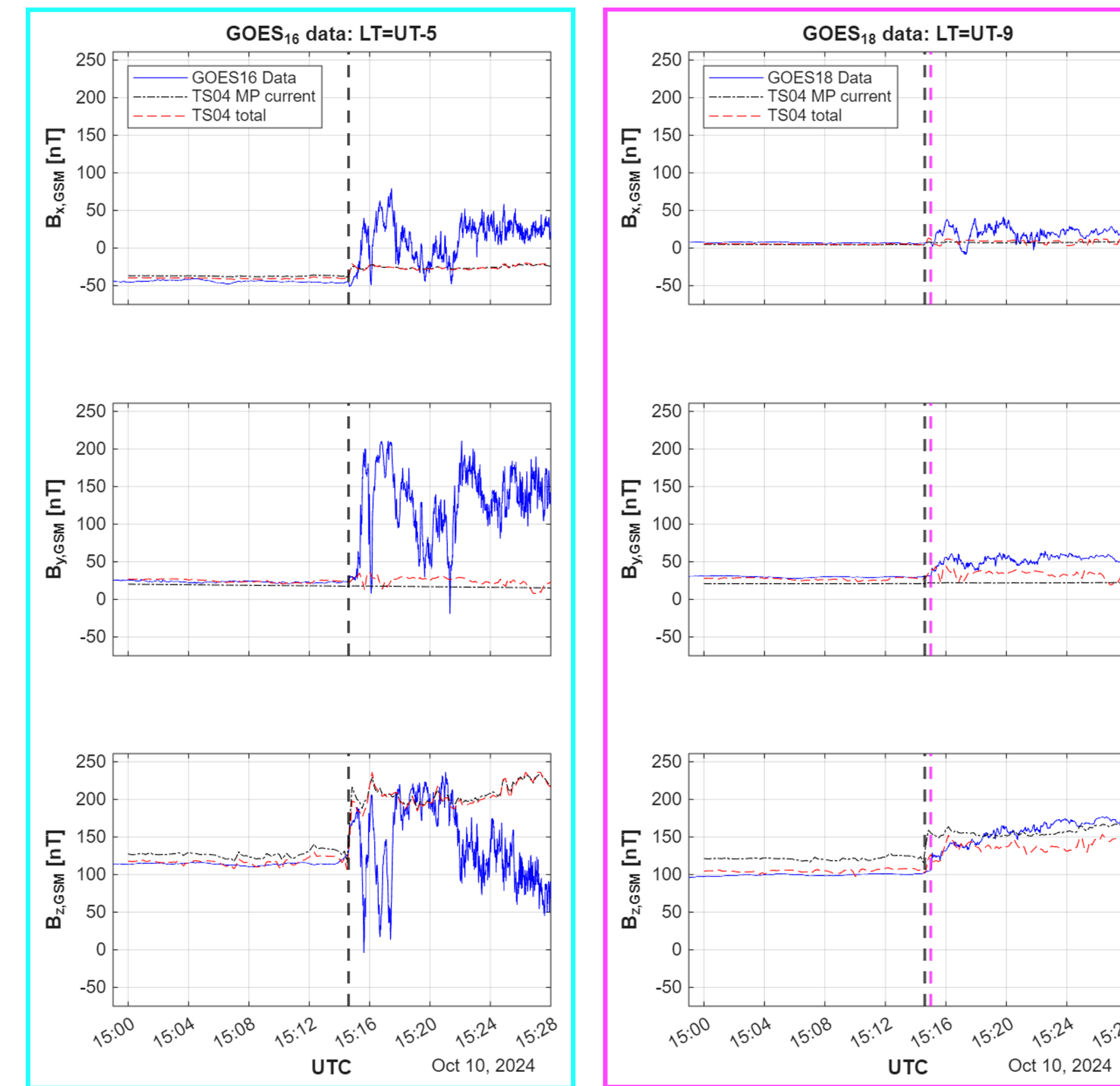


Figure 2: Magnetospheric magnetic field measured by GOES-16 (left, cyan) and GOES-18 (right, pink), compared with TS04 model predictions. From top to bottom, the B_x , B_y , and B_z components in the GSM reference frame are shown. The blue lines represent the measured data, while the red and black dashed lines correspond to the TS04 model results including all magnetospheric current systems and only the magnetopause current, respectively. The vertical dashed lines mark the shock arrival at the GOES satellites, observed at $t_s^G = 15:14$ UT.

Geomagnetically Induced Electric Field (GIE)

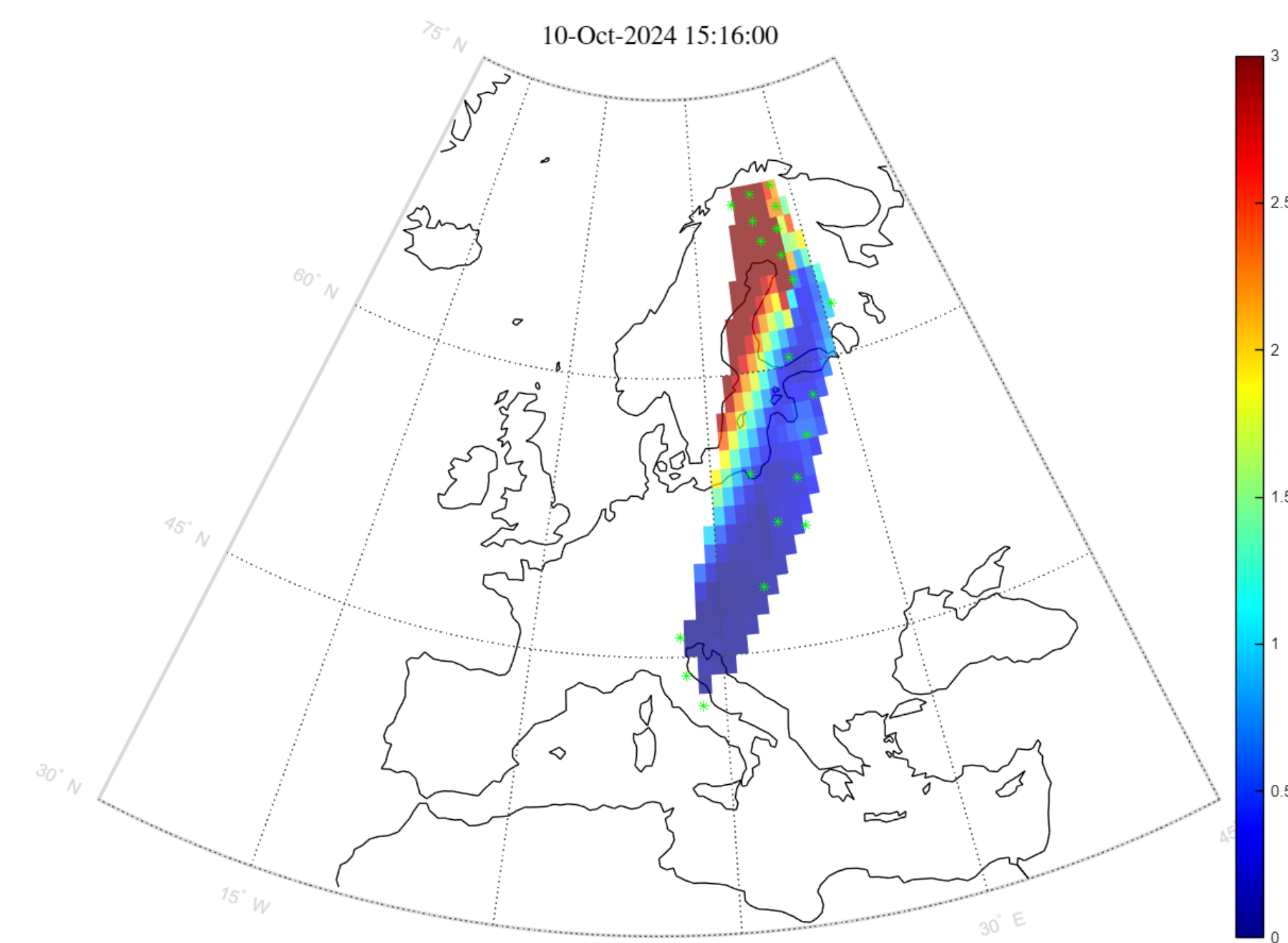


Figure 5: GIE variation of the Main Impulse over EMMA stations. The GIE was computed by using MAIGIC model (Piersanti et al., 2019).

Ground Observations

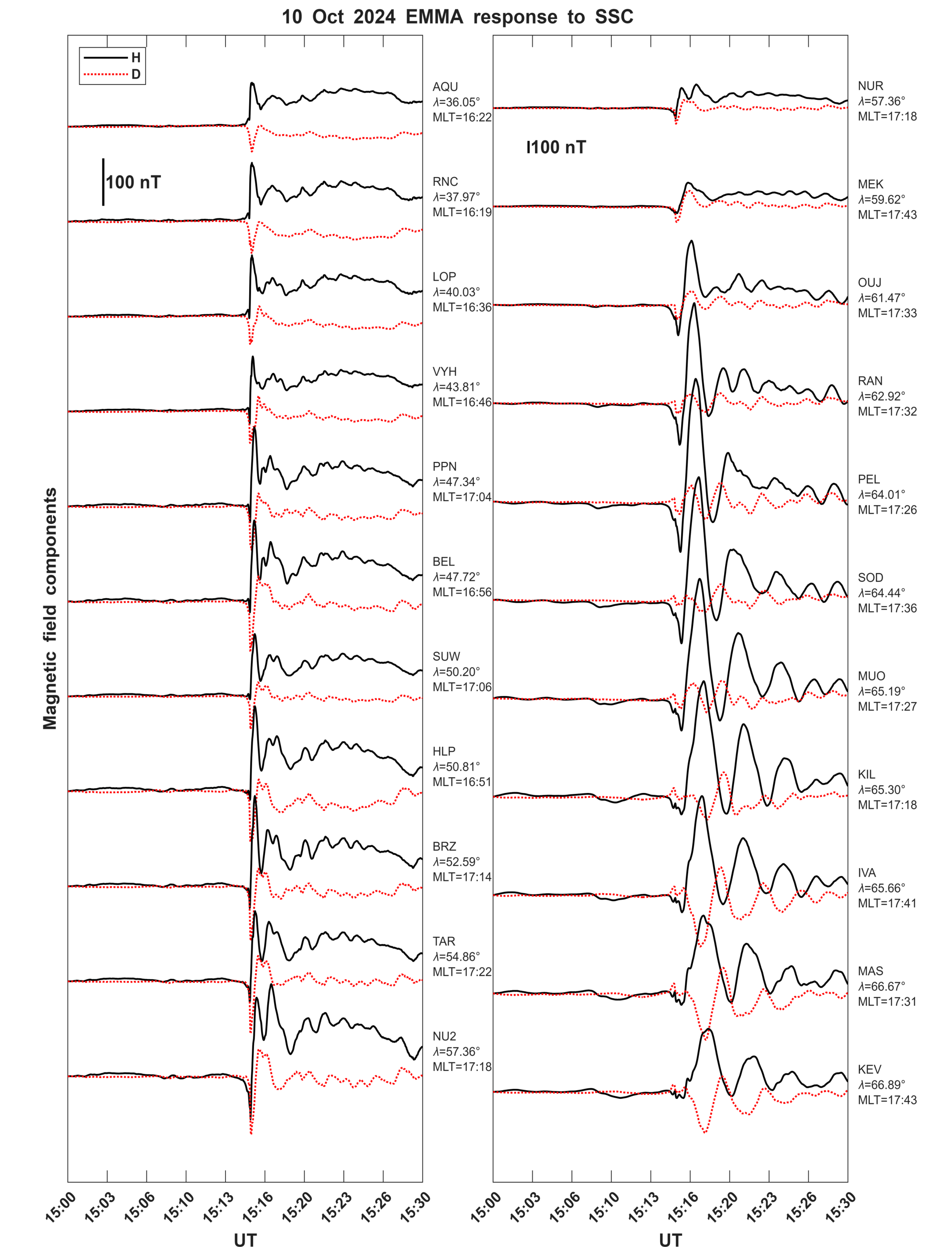


Figure 3: EMMA ground magnetometer stations, ordered by ascending magnetic latitude from top-left to bottom-right. The H component (positive northward) and the D component (positive eastward) of the magnetic field are shown in black and red, respectively.

Conclusions

- The inclination of the interplanetary shock (IPs) leads to an impact that is primarily centered and slightly northward within the magnetosphere.
- High-latitude ground measurements reveal strong ULF activity superimposed on the sudden impulse (SI), resulting in an enhancement of the disturbance field at these latitudes.
- The results are consistent with Piersanti et al. (2025), indicating that geomagnetically induced currents (GICs) depend on both ionospheric and magnetospheric current systems.
- ULF waves can amplify the GIC response at ground level.
- The origin of the observed ULF waves is under investigation and may be related to magnetospheric cavity modes, although further analysis is required.

References:
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