R006-P46
ポスター 1：11/25　AM1/AM2（9:15-12:35）

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Spatiotemporal Evolution of the Storm-Time Ring Current Inferred from Low-Latitude Geomagnetic Observations

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The spatiotemporal evolution of the ring current during geomagnetic storms is fundamental to understanding the magnetospheric current system and overall magnetospheric dynamics. Previous studies have examined the ring current intensity and its magnetic local time (MLT) asymmetry mainly through geomagnetic indices such as SYM-H/ASY-H and SMR. In this study, we use geomagnetic field data from a dense global network of low-latitude observatories ($|\mathrm{MLAT}| = 10 - 30^\circ$) to investigate the temporal development of the storm-time partial ring current. We focus on two superstorms that occurred in 2024 and compare their features with those of other intense and moderate storms.

The analysis is based on geomagnetic data from 14 low-latitude INTERMAGNET observatories. From the horizontal component, we subtract the quiet-time baseline and the diurnal variation (Sq). Using the residuals, we construct UT − MLT maps binned at 3 h in UT and 2 h in MLT. These maps are then processed with harmonic fitting in the MLT direction.

Our results show that the partial ring current initially expands from midnight (00 MLT) toward the noon − dusk sector (12 − 18 MLT) during the main phase, followed by a shift toward noon (12 MLT) in the early recovery phase. This progression likely reflects plasma injection from the midnight sector, subsequent westward drift of energetic ions, and eventual escape through the dayside magnetopause. The observed spatiotemporal evolution indicates that open drift paths of ring current ions persist even during the recovery phase. We further compare the characteristics of superstorms with those of intense storms (SYM-H minima between − 100 and − 200 nT) and moderate storms (SYM-H minima $>$ − 100 nT) to clarify similarities and differences in ring current ion dynamics and the associated partial ring current system.