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Transient Distortions of the South Atlantic Anomaly Radiation Environments Driven by Large-Scale Electric Fields

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Energetic electrons in Earth's inner radiation belt pose significant hazards to spacecraft systems, with the strongest radiation in low-Earth orbit (LEO) mostly confined to the South Atlantic Anomaly (SAA). Once considered stable, the inner belt is now understood to respond dynamically to both natural and anthropogenic influences. Using data from the low-Earth orbit Macau Science Satellite-1 mission, we report the first observations of abrupt, short-duration electron flux enhancements outside the traditional SAA region. These enhancements signify transient distortions of the SAA, induced by large-scale westward electric field perturbations and further modulated by ultra-low frequency waves. Test-particle simulations successfully reproduce the observational features and provide new, stringent constraints on properties of the associated electric fields. These findings reveal the highly dynamic nature of the inner belt and demonstrate that radiation hazards to LEO spacecraft can extend beyond the traditional SAA boundaries.

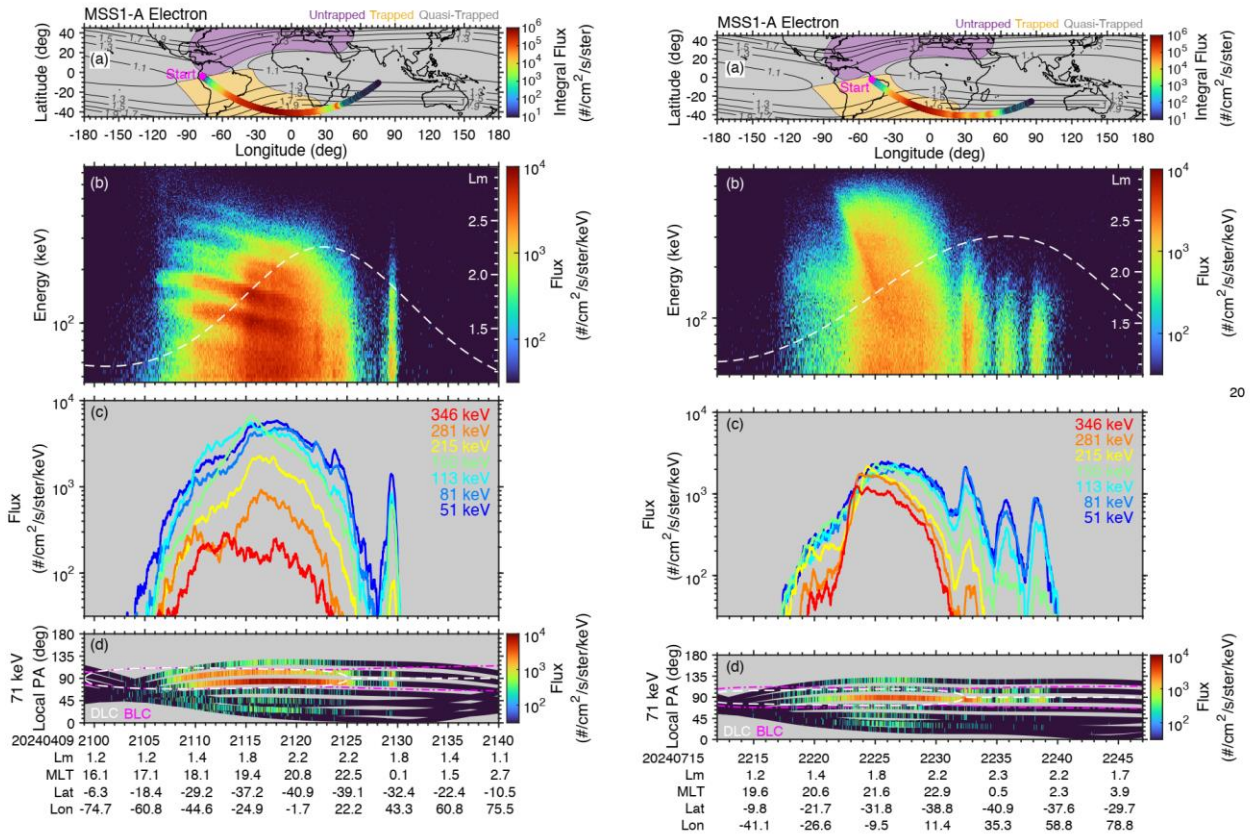

Figure 1. Two representative events observed by MSS-1A spacecraft, with electron flux enhancements inside and outside the South Atlantic Anomaly region.