

Long-term Statistical Analysis of Auroral Kilometric Radiation Observed by Geotail: Applied Automated Detection Technique

*Haruto Yamanaka¹, Yasumasa Kasaba¹, Satoshi Kurita², Hirotsugu Kojima², Fuminori Tsuchiya¹, Hiroaki Misawa¹

1. Graduate School of Science, Tohoku University, 2. RISH, Kyoto University

Auroral Kilometric Radiation (AKR) is the most intense radio emission from Earth, generated by cyclotron resonance of high-energy electrons on auroral magnetic field lines. AKR intensity correlates with auroral field-aligned current, and its frequency corresponds to the emission altitude (cyclotron frequency of the source), making it a good indicator of the total amount of auroral electrons and acceleration altitude. For long-term statistical analysis, including solar activity effects, high-quality data from the Plasma Wave Instrument (PWI) on the Geotail satellite, spanning ~30 years (September 1992–June 2022), provides a suitable dataset. The AKR frequency range (~tens of kHz to 500–600 kHz) overlaps with Solar Type-III bursts. For long-term statistical analysis, it is desirable to automatically remove these bursts. Automated detection is effective as it eliminates subjectivity and reduces the statistical analysis burden.

Other long-lived satellite covering this range is Wind (1994–). Although mainly in the solar wind near L1 and not always ideal for nightside AKR, Waters et al. (2021) statistically analyzed AKR using the automatic elimination method of Solar type-III bursts, leveraging the fact that the temporal variation of the Solar type-III burst is smaller than that of AKR. Their method used the standard deviation of electric field fluctuations over a 3-sec (~1-spin) interval using the Z-axis (spin-axis parallel antenna).

We tried to apply this method to Geotail data. From 1992–1994, Geotail mainly observed the magnetotail, while post-1994, it followed an elliptical orbit at 10–30 Re near the equatorial plane. This trajectory is ideal for long-term AKR study (though post-1994, local time and magnetic latitude correlate with season). AKR is observed using the PWI Sweep Frequency Analyzer (SFA), covering a few Hz to 800 kHz. However, adapting the Wind method to Geotail was a challenge: (1) Geotail lacks a spin-axis-parallel antenna. Since its spin axis is north-south, spin-phase variations affect electric field measurements. (2) The SFA operates in five bands, with Band-5 (100–800 kHz) best suited for AKR observation. However, its frequency sweep takes 8-sec, so data at a specific frequency is acquired only every 8-sec, limiting short-timescale variability detection.

To detect Solar Type-III bursts in Geotail PWI/SFA data, we propose a hybrid approach combining two criteria: (A) Low temporal variability: To suppress spin-induced fluctuations, we average data over 24-sec (3 data of 8-sec period, corresponding to 8 spin periods) and set a standard deviation threshold over this interval (e.g., ± 3 samples, 162-sec). The longer time window compared to Wind should be noted. (B) Low frequency variability: Solar Type-III bursts are broadband with relatively uniform intensity; thus, the standard deviation across frequency is also used as a threshold (frequency width under investigation). As of February 2025, preliminary trials show that this method effectively identifies and removes Solar Type-III bursts. While not achieving a 100% detection rate, it appears sufficient for AKR statistical analysis.

AKR intensity and frequency variations have been analyzed over timescales from days to few years. Previous studies have highlighted (1) local time and magnetic latitude radiation patterns and their dependence on magnetospheric activity and (2) relationships between AKR intensity and frequency,

Earth's rotational axis tilt relative to the solar wind, and seasonal variations—key factors in auroral electron flux and acceleration electric fields. Using the Geotail dataset, covering three solar cycles, we plan to extend these studies to longer timescales, incorporating solar activity dependence. This presentation will discuss our initial results.

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