Proc. NIPR Symp. Upper Atmos. Phys., 10, 64–68, 1997

CORRELATIONS OF *AKR* INDEX WITH *Kp* AND *Dst* INDICES

Takeshi MURATA[1], Hiroshi MATSUMOTO[2], Hirotsugu KOJIMA[2] and Toshihiko IYEMORI[3]

[1]*Ehime University, 3, Bunkyo-cho, Matsuyama 790*
[2]*Radio Atmospheric Science Center, Kyoto University, Uji 611*
[3]*Data Analysis Center for Geomagnetism and Space Magnetism, Kyoto University, Kyoto 606*

Abstract: After initial observations of Auroral Kilometric Radiation (AKR), their associations with substorms had been intensively investigated during 1970's. Herein we extend these studies and propose a new index available for substorm studies, named the *AKR* index. We define the *AKR* index by the power flux of *AKR* normalized to a reference distance from the Earth. The *AKR* index is found to show good correlations with *Kp* and *Dst* indices for weak magnetic disturbances. The *AKR* index tends to saturate for moderate and severe disturbance.

1. Introduction

The GEOTAIL Plasma Wave Instrument (PWI) (MATSUMOTO *et al.*, 1994) has observed a variety of plasma waves including Auroral Kilometric Radiation (AKR). Various studies so far have discussed the time-dependent *AKR* emissions associated with magnetospheric substorms. GURNETT (1974) and KAISER and ALEXANDER (1977) pointed out a close relation between *AKR* and auroral electrojet (*AE*) index. In spite of their successful results, the association of *AKR* emissions with magnetospheric substorms has not been explicitly studied since them. Generally, empirical evidence has suggested that a sudden enhancement of *AKR* could be a clear signature of substorm onsets. MURATA *et al.* (1995) defined substorm onsets using *AKR* sudden enhancements. However, the relation between the *AKR* sudden onsets and the magnetospheric substorm onsets identified by other signatures such as Pi 2 pulsation has been still unclear. In this paper we propose a new index called the *AKR* index for use in substorm studies, to examine the relationship between this index with other two indices, *Kp* and *Dst* indices.

2. Definition of *AKR* Index

Figure 1 represents a dynamic spectrum (0–800 kHz) of *AKR* and other plasma waves observed by GEOTAIL. The GEOTAIL/PWI team has observed the *AKR* with the Sweep Frequency Analyzer (SFA). The frequency sweep time is 8 s, so we obtain the 8 s value of *AKR* power flux.

We define the *AKR* index by the power flux of the observed *AKR* normalized to

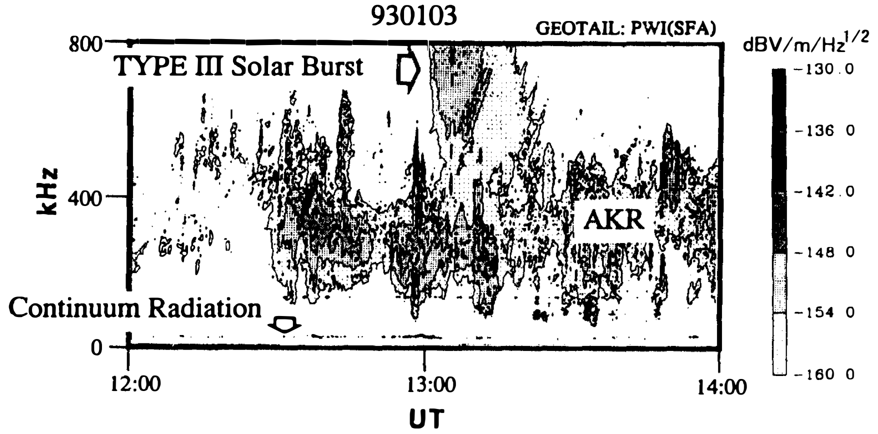

Fig. 1. Dynamic spectra of AKR electric field observed with Sweep Frequency Analyzer onboard GEOTAIL spacecraft on 3 January 1993.

a reference distance from the Earth. In formatting the *AKR* index we remove the dependence on the satellite position. We first apply the following normalization equation to the observed signals:

$$E_0 = E(r)\,\frac{r}{r_0}\ \mathrm{V/m/\sqrt{Hz}}\,, \tag{1}$$

where r is the distance from the Earth to the spacecraft, $E(r)$ and E_0 represent the amplitude of the observed and normalized electric field of *AKR* respectively, and the suffix 0 denotes the parameter at the reference distance ($r_0 = 25\ R_E$ in the present study). Then we integrate the normalized power flux over the frequency from 50 kHz ($=f_l$) to 800 kHz ($=f_h$):

$$\frac{\int_{f_l}^{f_h} E_0^2\, df}{f_h - f_l}\ \mathrm{V^2/m^2/Hz}\,. \tag{2}$$

We define the *AKR* index ε by the logarithmic *AKR* power flux (dBV/m /$\sqrt{\text{Hz}}$).

The noise level of the SFA detector onboard GEOTAIL is about -180 dBV/m/$\sqrt{\text{Hz}}$. When GEOTAIL is located at the largest apogee, the noise level becomes -160 dBV/m/$\sqrt{\text{Hz}}$ after the normalization with eq. (1). We exclude signals smaller than -160 dBV/m/$\sqrt{\text{Hz}}$ from the integration in eq. (2).

The present frequency range (between 50 kHz and 800 kHz) is reasonable since most of the *AKR* power fluxes appear in this frequency range. In this range, however, we occasionally observe TYPE III solar bursts (Fig. 1). Thus, at strong TYPE III solar burst periods, the *AKR* index is contaminated by solar bursts.

3. *AKR* Index Correlated with *Kp* and *Dst* Indices

Our attempt is to prove that the *AKR* index is a useful index. One of the greatest interests is the result of its comparisons with *Kp* and *Dst* indices. The latter two indices are frequently referred to in the study for a long-term activity of the magnetosphere. Note that the *Kp* index is usually provided every three hours and

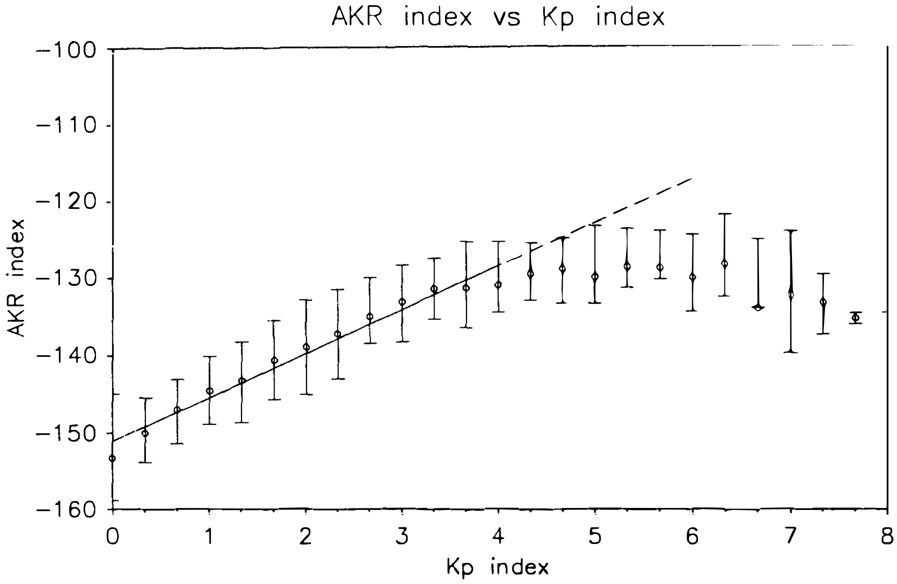

Fig. 2. Correlation of AKR index with Kp index statistically averaged over one year (from January 1993 to December 1993). The vertical line at each Kp value represents the standard deviation of logarithmic AKR index value. The straight line in the figure represents the least square fit calculated from the plots for Kp less than 4. This line is given as $\varepsilon = -151.0 + 5.65\,Kp$.

the *Dst* every one hour.

Figure 2 indicates the *AKR* index *vs.* *Kp* index plots for one year (from January 1993 to December 1993). We used three-hour average of the *AKR* index for the direct comparison with the *Kp* index. The vertical lines are the standard deviations of the *AKR* index at each *Kp* value. The *AKR* index is proportional to the *Kp* index when the *Kp* is smaller than 4. The straight line in the figure represents the least square fit calculated from the plots for $Kp < 4$. This line is given as $\varepsilon = -151.0 + 5.65\,Kp$ where ε represents the *AKR* index. When the *Kp* is greater than 4, however, we find no strong dependence of the *AKR* index on the *Kp* index.

Figure 3 shows scatter plots of the *AKR* index against the *Dst* index during the same interval as in Fig. 2. We again find a linear relation between the *AKR* and *Dst* indices when the *Dst* value is between is -50 and 0. (Note that the *Dst* becomes greater as the geomagnetic disturbance becomes smaller.) At severe ($Dst < -50$) or weak ($Dst > 0$) disturbance period, we see no strong dependence of *AKR* on the *Dst* index. This reminds us of the similar tendency between the *AKR* and the *Kp* index in Fig. 2.

It is notable that the value of the *AKR* index at the turnover points in Fig. 2 ($Kp = 4$) and in Fig. 3 ($Dst = -50$) are about -132 dBV/m/$\sqrt{\text{Hz}}$. These coincidences remind us of the studies by VOOTS *et al.* (1977) and GALLAGHER and D'ANGELO (1981). VOOTS *et al.* pointed out in their statistical study that two different stages exist in the correlation between the *AKR* power flux and the *AE* index. GALLAGHER and D'ANGELO investigated the correlation of *AKR* power flux with a variety of the solar wind parameters. They found that the solar wind velocity shows a good parallelism with the *AKR* power and is divided into two levels. The

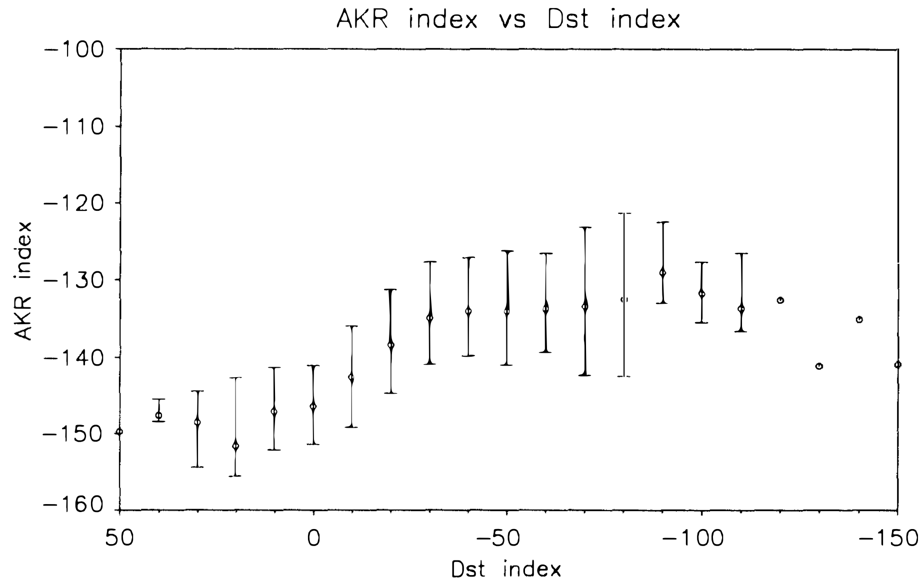

Fig. 3. Correlation of AKR index with Dst index statistically averaged over one year (from January 1993 to December 1993). The vertical line at each Dst value represents the standard deviation of logarithmic AKR index value.

turnover points in the both studies coincide each other (the *AKR* power at the turnover point is -132 dBV/m/$\sqrt{\text{Hz}}$ if normalized to $r=25$ R_E from the Earth). Taking account of these results, GALLAGHER and D'ANGELO concluded that the solar wind velocity controls both *AKR* emissions and geomagnetic activities. The present result shows a good agreement with their conclusions.

4. Summary and Discussions

The close relationship between Auroral Kilometric Radiation (AKR) and magnetospheric substorms has been pointed out in its early studies (*e.g.*, GURNETT, 1974). Even though GURNETT demonstrated "*AKR* as an indicator available for substorm studies", *AKR* has rarely been used practically as an index. *AKR* is observed by GEOTAIL for most of the time in the magnetotail, and the upper frequency limit of the intense *AKR* is usually lower than 800 kHz (GURNETT, 1991), which is the upper frequency of the SFA. These conditions enabled us to propose the *AKR* index as a new practical index.

We defined the *AKR* index by the *AKR* power flux normalized to a certain distance (25 R_E) from the Earth. In order to demonstrate the utility of the *AKR* index for substorm studies, we compared the *AKR* index with *Kp* and *Dst* indices. At the low geomagnetic activity period, the *AKR* index shows a linear relationship with the geomagnetic indices of *Kp* and *Dst*. These useful results imply a straightforward adequacy of *AKR* index as a substitute for the geomagnetic indices.

The *Kp* index becomes greater and the *Dst* index becomes smaller during high activity periods, whereas the *AKR* index tends to saturate contrary to the linear relationship at the low activity period. *AKR* is excited with the growth of the electron cyclotron maser instability resonanced with the electrons precipitating into the auroral region. These electrons come from the tail plasma sheet and are accelerated in the inverted-V potential (GURNETT, 1974; BENSON and CALVERT, 1979). The inverted-V potential is believed to be formed through wave-particle interactions with precipitating electrons. Thus, the growth of the potential is saturated when a large amount of particles precipitate at the severe disturbance period. This possibly causes the saturation of the *AKR* index at the high activity period. We need further investigations of the saturation process through the direct comparison between the *AKR* index and particle precipitations observed in the ionosphere.

Acknowledgments

The first author (T. M.) is grateful to all the members of PWI team GEOTAIL spacecraft, especially to I. NAGANO, K. HASHIMOTO, R. R. ANDERSON, M. TSUTSUI, T. OKADA, and Y. OMURA. The first author thanks Y. KAMIDE for his suggestions.

References

BENSON, R. F. and CALVERT, W. (1979): ISIS 1 observations at the source of auroral kilometric radiation. Geophys. Res. Lett., **6**, 479–483.

GALLAGHER, D. L. and D'ANGELO, N. (1981): Correlations between solar wind parameters and auroral kilometric radiation intensity. Geophys. Res. Lett., **8**, 1087–1089.

GURNETT, D. A. (1974): The Earth as a radio source: Terrestrial kilometric radiation. J. Geophys. Res., **79**, 4227–4238.

GURNETT, D. A. (1991): Auroral plasma waves. Auroral Physics, ed. by C.-I. MENG *et al.* Cambridge, Cambridge Univ. Press, 241–253.

KAISER, M. L. and ALEXANDER, J. K. (1977): Relationship between auroral substorms and the occurrence of terrestrial kilometric radiation. J. Geophys. Res., **82**, 5283–5286.

MATSUMOTO, H., NAGANO, I., ANDERSON, R. R., KOJIMA, H., HASHIMOTO, K., TSUTSUI, M., OKADA, T., KIMURA, I., OMURA, Y. and OKADA, M. (1994): Plasma wave observations with GEOTAIL spacecraft. J. Geomagn. Geoelectr., **46**, 59–95.

MURATA, T., MATSUMOTO, H., KOJIMA, H., FUJITA, A., NAGAI, T., YAMAMOTO, T. and ANDERSON, R. R. (1995): Estimation of tail reconnection lines by AKR onsets and plasmoid entries observed with GEOTAIL spacecraft. Geophys. Res. Lett., **22**, 1849–1852.

VOOTS, G. R., GURNETT, D. A. and AKASOFU, S.-I. (1977): Auroral kilometric radiation as an indicator of auroral magnetic disturbances. J. Geophys. Res., **82**, 2259–2266.

(Received March 25, 1996; Revised manuscript accepted July 12, 1996)