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AURORAL KILOMETRIC RADIATION INTEGRATED POWER FLUX AS A PROXY FOR A_E

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ABSTRACT

We propose to use the integrated intensity of auroral kilometric radiation from Polar measurements as a proxy for the auroral electrojet index A_E in support of studies of the response of the magnetosphere and the geomagnetic tail to changes in magnetic activity. In addition to providing event timing information to understand the effects of perturbations and substorms, the resulting space-based auroral kilometric radiation index would be useful as an input to space weather efforts as an auroral activity metric.

INTRODUCTION

Auroral kilometric radiation is an intense, sporadic radio emission observed in the frequency range of a few hundred kHz. Voots *et al.* (1977) demonstrated the correlation between auroral kilometric radiation (AKR) intensity and A_E. This work was undertaken during an era in which it was demonstrated repeatedly that the radiation was directly linked to discrete auroral arcs and associated phenomena (Gurnett, 1974; Kurth *et al.*, 1975; Benediktov *et al.*, 1968; Huff *et al.*, 1988).

The use of magnetic indexes such as the auroral electrojet index has been an important means by which geophysical observations have been ordered in the past and it is reasonable that the rapid availability of such an index would be important for campaigns such as those initiated by the Interagency Consultative Group (IACG). However, A_E is derived from numerous individual ground magnetometers situated around the globe and the assembly of the required information often requires as much as two years. Hence, waiting for A_E becomes problematic for rapid progress. Given the known correlation between A_E and the intensity of AKR, it is reasonable to use this observable as a proxy for A_E, at least until the index is available.

Additionally, there is growing interest in space weather. Just as we are interested in current conditions as well as predictions of weather in the future, knowing the current or recent state of space weather is also useful. Again, for use prior to the availability of A_E, modelers in the space weather arena may be interested in utilizing records of the AKR intensity as a proxy.

With the commissioning of the Polar spacecraft and its Plasma Wave Investigation (PWI) in the spring of 1996, we now have a monitor for the AKR activity in position to observe the AKR over a majority of the time (except when the spacecraft is too close to Earth and, hence, shadowed by the high density regions of the magnetosphere). Hence, we propose herein to provide a proxy for A_E in the form of the integrated power flux of auroral kilometric radiation.

TECHNIQUE

Basic Computation

Voots *et al.* (1977) used the power flux of AKR in the 178-kHz channel of the IMP 6 plasma wave receiver for their study. We propose here, however, to utilize 86 narrowband channels in the Polar PWI (see Gurnett *et al.*, 1995 for a description of the PWI instrumentation) to integrate the power flux across the entire AKR bandwidth from 50 to 800 kHz. This will enable us to report a value which is indicative of the total power being emitted in the auroral radio spectrum and not subject to movement of the emission to higher or lower frequencies or changes in the emission bandwidth within this very liberal frequency range.

The integrated power flux P_I is computed in the following manner:

$$P_I=\left(\frac{R}{9R_E}\right)^2\sum_{i=M}^{N}P(f_i)\Delta f(f_i) \qquad (1)$$

Here, $P(f_i)$ is the power flux in units of W/m^{2}Hz measured in channel i, $\Delta f(f_i)$ is the portion of the spectrum in Hz represented by channel *i*, and *R* is the radial distance in Earth radii at which the measurement is made. *M* and *N* are the Polar PWI sweep frequency channel numbers covering the frequency range from 50 to 800 kHz. The factor multiplying the sum in the equation serves to normalize the value to the distance of 9 R_E which is approximately the Polar apoapsis. We define $\Delta f(f_i)$ as the difference in frequency between the midpoints between channels *i*+1 and *i* and channels *i*-1 and *i*.

Caveats

A number of caveats are required in order to utilize P_I as an index of magnetic activity. First, we have implied by integrating from 50 to 800 kHz that the only contributor to the spectrum in this frequency range is auroral kilometric radiation. In fact, type III solar radio bursts and escaping continuum radiation (Kurth *et al.*, 1981) are often observed in this frequency range. During the current period of solar minimum, very few type III bursts have been observed, but it would seem reasonable to attempt to correct for them especially when they become more frequent. For the moment, we simply plan to flag the data during type III's as being polluted. The continuum radiation is normally much less intense than AKR (Gurnett, 1995). It is unlikely that the continuum radiation will alter P_I by more than a few percent. Finally, it should be noted that we do not attempt to subtract the noise background from the individual power fluxes used in the computation. The result of this is that there will be an obvious noise floor to the signal. The fact that the sum is corrected for radial distance further means that the noise floor will be a function of radial distance, since the receiver noise is basically independent of distance. However, we submit that the magnitude of this effect is small and that the practical dynamic range of the integrated power flux is at least 10^3.

Another caveat is that the spacecraft must be within the illumination cone for AKR and not in the plasmasphere where plasma wave emissions can exist in the integrated frequency range. Voots *et al.* (1977) have shown that near the equatorial plane, especially on the dayside, the AKR is seldom observed because it is effectively shadowed by the high density plasmasphere. Currently, we are simply testing for periods during which $R > 5R_E$ when we believe the Polar spacecraft is free of both of these effects. Perhaps more detailed tests could be performed to ensure the maximum amount of observing time during an orbit is utilized, but by pushing too hard on such limits it may be that magnetospheric modifications in response to changing solar wind input could modify the shadow zones and introduce uncertainties in the utility of the index near the limits of the observation zone.

RESULTS

In the bottom panel of Figure 1 we show a frequency-time spectrogram from 3 June 1996 showing wave spectral density as a function of time (abscissa) and frequency (ordinate). The gray scale on the right shows the relationship between gray level and spectral density. Auroral kilometric radiation is seen predominantly between about 0700 and 1600 GMT between several tens of kHz and 400 kHz. Also in this frequency range are features associated with periapsis passages near 0300 and 2000 GMT. For example, the narrowband emission which rises from low frequencies to 300 to 500 kHz is at the upper hybrid resonance frequency; this band is a common plasma wave phenomenon in the plasmasphere. These features and the existence of the AKR shadow zone preclude the use of AKR as an index near periapsis.

In the middle panel of Figure 1 we have calculated one-minute averages of P_I. Thick horizontal bars indicate times when the spacecraft is within 5 R_E. The integrated power flux then corresponds to the AKR at the other times. The random bright pixels in the frequency range above 50 kHz are telemetry errors and were found to strongly influence the calculation of P_I. Therefore, we despiked the data by replacing elements of each spectrum which were a factor of ten higher in power flux than their nearest spectral neighbors by an average of the neighbors. Further, we checked to be sure that the P_I amplitude was not affected during times when there were no telemetry errors.

Since A_E is not yet available for the Polar era, we obtained Canopus magnetic indexes CU and CL (Rostoker *et al.*, 1995) for the time period in Figure 1 and plotted these in the upper panel. We have also plotted CU - CL since this is the method by which A_E is determined. Of course, the Canopus chain spans the range of longitudes only between about 220 and 247° longitude and is not able to fully replicate the response of a full global magnetometer chain at auroral latitudes. However, when Polar is beyond about 5 R_E, there is a reasonable correspondence between CU-CL and P_I. We hesitate to attempt extensive statistical analyses of the correlation because of the limited extent of this chain.

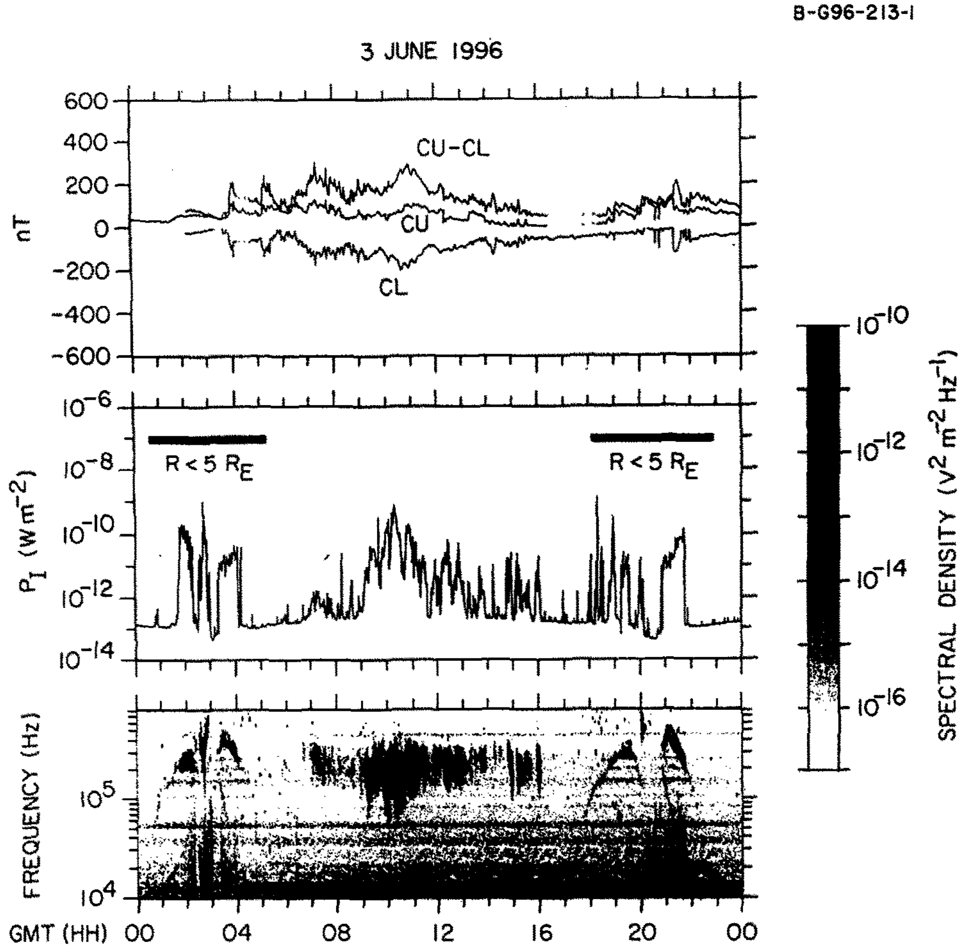

Figure 1: A frequency-time spectrogram highlighting auroral kilometric radiation (bottom), the computed integrated power flux P_I (middle) and Canadian magnetometer chain indexes CU, CL, and the derived CU - CL (top).

SUMMARY

We have formulated an integral of the AKR power flux to serve as a proxy for A_E. The primary motivation for the development of P_I as a magnetic disturbance index is as input to IACG campaigns, other ISTP studies, and to the space weather effort as an additional term in the state of the magnetosphere which may be useful in the development or testing of predictive models. We note that Murata *et al.* (1996) have developed a similar index based on Geotail observations of AKR. They integrate over the same spectral range, but there are some minor differences in the units in which the index is expressed. We plan to investigate a uniform approach to such an index so that both Geotail and Polar can contribute a comparable index.

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