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CNA QUIET DAY CURVES AND THEIR SIDEREAL TIME DEPENDENCE

Takashi ARAKI[1] and Natsuo SATO[2]

[1]*Faculty of Education, Hirosaki University, 1, Bunkyo-cho, Hirosaki 036*
[2]*National Institute of Polar Research, 9–10, Kaga 1-chome, Itabashi-ku, Tokyo 173*

Abstract: This paper presents a method of obtaining a riometer quiet day curve (QDC) of the correct shape, after modifying the technique of inflection point method proposed by R. J. ARMSTRONG *et al.* (Planet. Space Sci., **25**, 1193, 1977) with Fourier analysis using computer assisted programing of the data. This method was applied to 30 MHz riometer data observed at Tjörnes (from 8 September 1984 to 30 September 1986) and Husafell (from 15 August 1985 to 31 August 1986) in Iceland. The QDCs are usefull in studying the diurnal, seasonal and solar cycle variations of average ionospheric absorption level.

1. Introduction

Studies of the ionospheric radio-wave absorption have been carried out for many years using riometers, or relative ionosphereic opacity meters (LUSIGNAN, 1960; BASLER; 1963). Riometers are primarily used in the study of discrete absorption events such as sudden cosmic noise absorption, aurorally associated absorption, and polar cap absorption. In these studies, the absolute base-line levels on quiet days are relatively unimportant, so that the necessary quiet day levels are usually derived by dealing with only a few geomagnetically quiet days during the month in which the event occurs. For the statistical studies of ionospheric absorption, however, the absolute values of quiet day curves must be computed at least one year of data. In this case, errors in the quiet day levels are quite important and may influence the results considerably.

It is assumed that the unabsorbed noise power observed with the antenna oriented in a given direction in space is constant for a short time. The variation of this incident noise power, as the fixed antenna system scans across the sky owing to the earths rotation, is defined to be the 'quiet day curve: QDC' for the system. Quiet day curves for a given system must be based on the actual data recorded by that system. The usual technique is to scale the daily charts for a sufficiently long period of time, transfer these values to the proper sidereal time (ST), and compare all values for a given sidereal hour (CHIVERS and PRESCOTT, 1967; HEISLLER and HOWER, 1967). The highest 'reliable' values for each hour comprise the lowerly value on the quiet day curve. This technique assumes that the highest values correspond to a condition of zero absorption and that no recording drifts and no interference in equipment have occurred during the period. The determination of the QDC has involved the plotting of the sidereal time dependence of the received signal followed by a visual estimation of the QDC or a calculation using a percentage criterion. The choise of the percentile value involves a certain amount of arbitrariness and appears to be based on a qualitative consistency with visual estimates.

ARMSTRONG *et al.* (1977) proposed that, rather than using an arbitrary percentage value, a better definition of the quiet day value for a given sidereal time interval (BIN) would be to use the value corresponding to the inflection point on the high-signal side of the peak of the data for that interval.

This paper describes a computer technique for determining QDCs, based on the inflection point idea proposed by ARMSTRONG *et al.* (1977), and also its application to cosmic noise data observed at Tjörnes (66.20°N, 17.12°W in geographic coordinate) and Husafell (64.67°N, 21.03°W in geographic coordinate) in Iceland.

2. Data Processing

The definition of the quiet day value for a given sidereal time (ST) is shown in Fig. 1 (ARMSTRONG *et al.*, 1977; KRISHNASWAMY *et al.*, 1985). It is the *dB* value corresponding to the inflection point on the high-signal side of the measured cosmic radio noise. This value is calculated for each sidereal time bin and a raw QDC is obtained.

The inflection point is mathematically the point where number of data points show a local maximum with respect to the absorption level. Therefore, the adoption of this criterion is equivalent to assuming that the quiet day point is that point on the high-signal side of the peak at which the distribution of signal values decreases most rapidly with increasing signal level. This interpretation makes the physical significance of the method clearer and provides a relatively objective operational defenition of the QDC which is also easy to implement with a computer. Thus, it has the potential of contributing to the standardization of data analysis in riometry.

Figure 2 is a flow chart indicating the main steps in the procedure, starting with the cosmic noise measurements recorded by a riometer and ending with the printout of the scatterplot and/or writing the QDC values to the line printer.

Assuming the riometer output is in volts and the QDC is ultimately desired on a *dB* scale, there are two possible ways of processing the data: (1) the entire analysis can

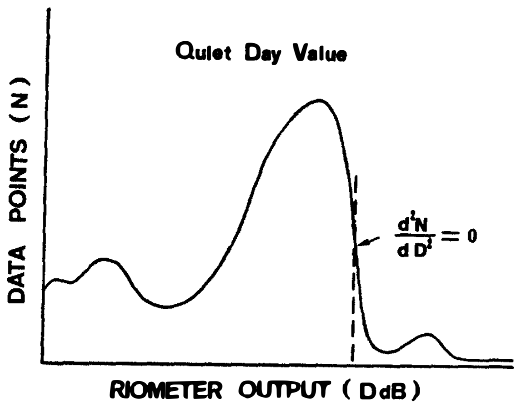

Fig. 1. Definition of the quiet day value for data points at a given sidereal time according to the inflection point criterion. This figure is essentially the same as Fig. 2 in ARMSTRONG *et al. (1977).*

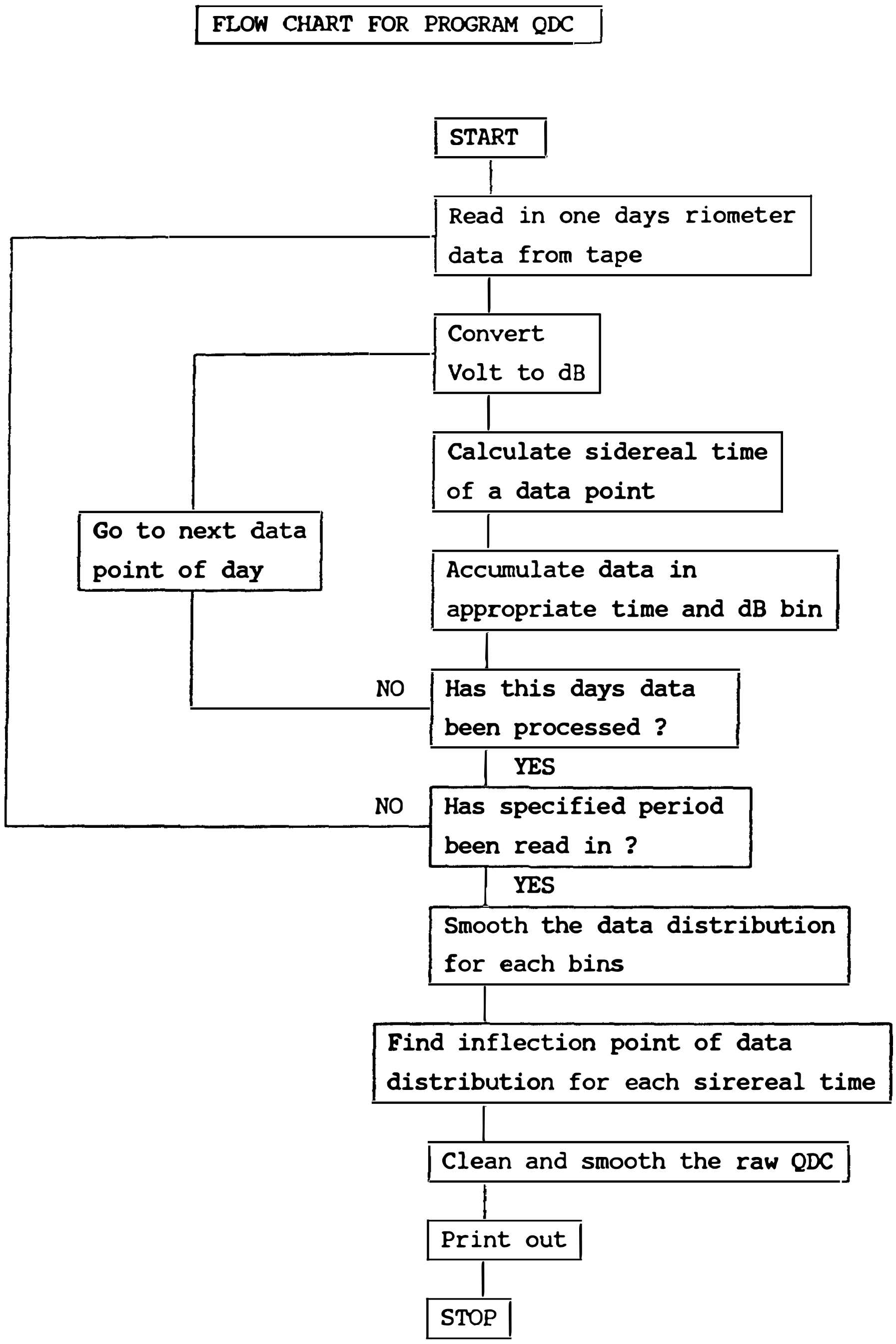

Fig. 2. Flow chart showing the major steps in the Inflection Point Method for obtaining the quiet day curve (QDC) from riometer data.

be done with voltage values and the conversion to *dB* done at the last step or (2) the riometer output can be converted to *dB* first and entire analysis can be done with the *dB* values. These two ways may not be equivalent since conversion from volts to *dB* involves a non-linear transformation which may change the location of the inflection point.

In the present processing, we are concerned with the latter case. For a riometer, the *dB* value is related to the recorded voltage value by

$$dB = 10\ \mathrm{Log}_{10}\ V = 4.34\ \mathrm{Ln}\ V$$

Actually, we use the next equation.

$$dB = 4.34\ \mathrm{Ln}\ (5/2048 * I)$$

where I is the integral number.

Each data point with its time in UT is fed into the computer. The corresponding sidereal time is calculated and the data are grouped into 10 min intervals in sidereal time. When all the data are read in, the data points are then distributed in 144 boxes, in sidereal time. The interval of 10 min was chosen because this was the interval of one record block size of a digital tape.

The quiet day curve was determined anew for each month readings.

In Fig. 3 the observed cosmic noise level is plotted as a function of *dB* and sidereal time.

The scatterplot gives a more direct and immediate visual impression of the data distribution in a gray-scale pattern. The ordinate gives the riometer noise level in *dB*. Thus, each dot represents the noise level for the particular sidereal time interval. The number of data points is indicated by the density of dot printed at each *dB*-sidereal time intersection.

In Fig. 4, the number of data points is indicated at each *dB*-sidereal time bin intersection for the particular interval (10 minutes) of *dB* and sidereal time, and is smoothed by fourier analysis. The quiet day points were determined using by the techniques of inflection point method for each time bins. The locus of these quiet day points in the *dB*-sidereal time plane is the raw QDC. This curve is somewhat irregular and spiky, caused by quantitative differences in the noise level between adjacent sidereal time bins.

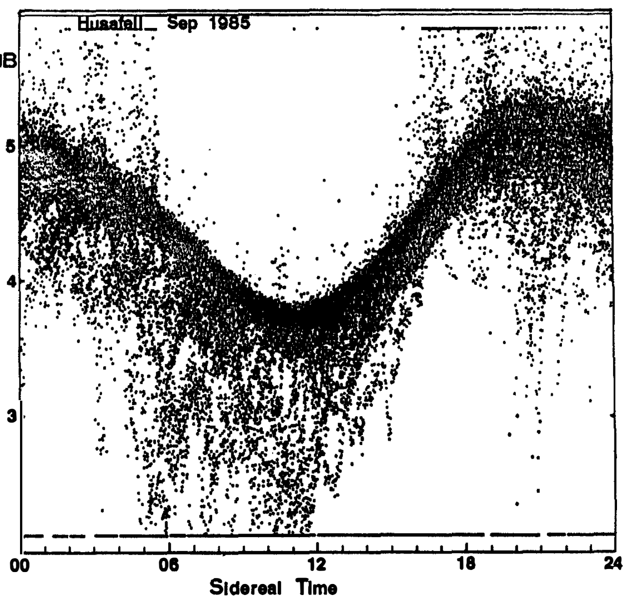

Fig. 3. Scatter plot generated by the program for Husafell, September 1985 data with the sidereal time bins. The absorption and interference features can be seen.

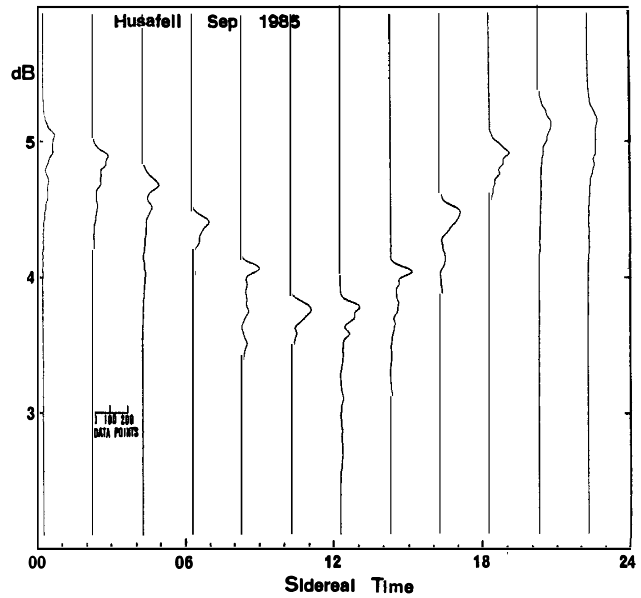

Fig. 4. Examples of actual noise level values at different sidereal times with the corresponding inflection points determined by the program. Each profile shows a measure of the number of data points in a 1/1200 dB interval and a 10 minute bin around the indicated sidereal time (ST).

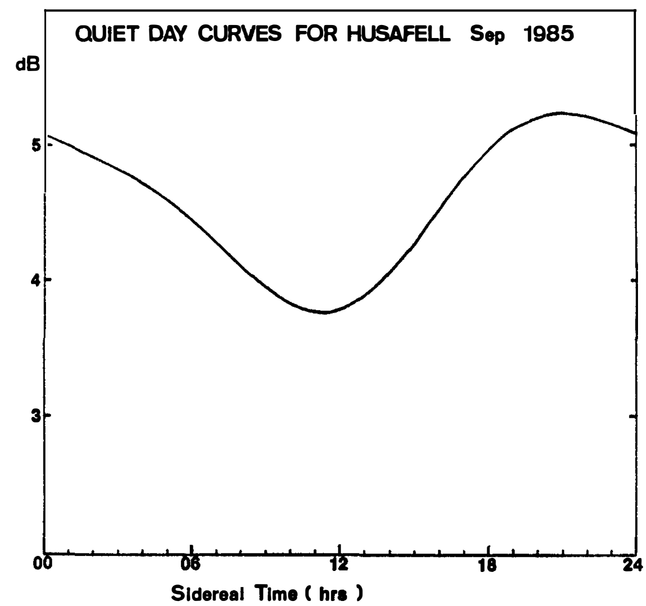

Fig. 5. Quiet day curve computed using the observed dB values for the data set. Fourier analysis was used for data smoothing.

Figure 5 shows the final corrected quiet day curve which is filtered to smooth out these irregularities by the technique of fourier analysis.

Quiet day curves have been calculated individually for each month during the one year and are shown in Fig. 6a, b for Husafell and Tjörnes, respectively. These monthly curves actually define a "quiet day curve" as a function of sidereal time and season.

It is clear from Fig. 6a, b that the QDCs show almost the same variation with a

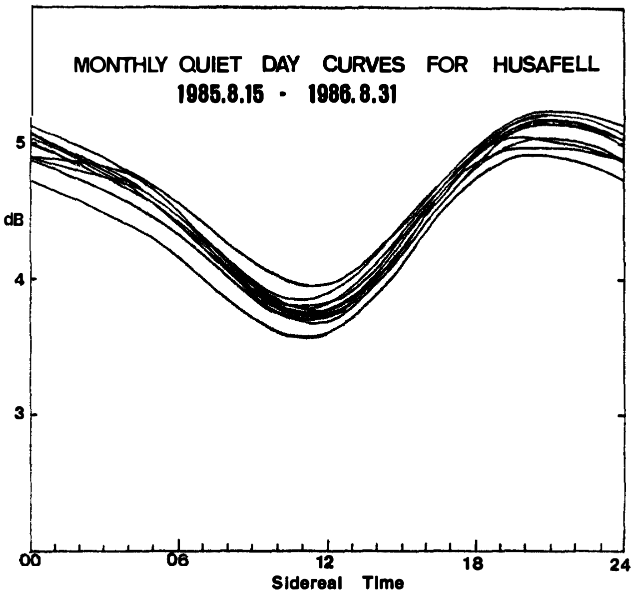

Fig. 6a. Monthly QDCs for Husafell between 1985 and 1986.

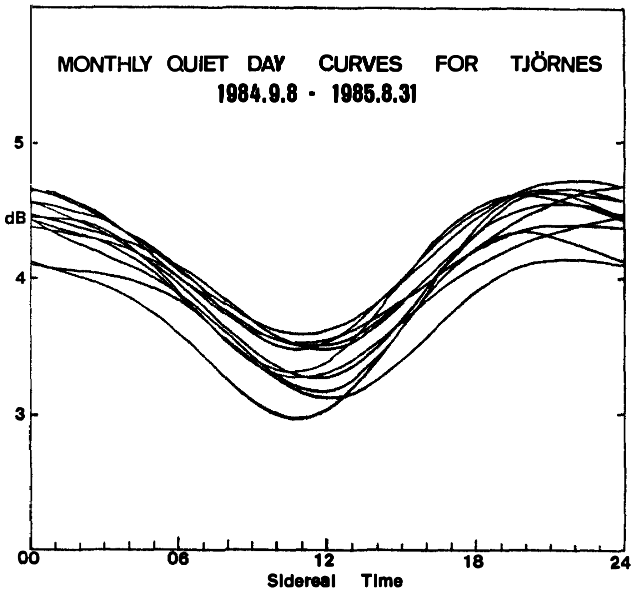

Fig. 6b. Monthly QDCs for Tjörnes between 1984 and 1985.

minimum at 11h ST and a maximum at 21h ST for both stations, and the Max-Min difference is in the range of 1.2–1.6 dB.

Although all the curves show similar features as a whole, there are differences in the amplitudes and the levels of the curves. In order to find any seasonal variations, QDC values at specific sidereal time (1800) are plotted in Fig. 7. It is found from Fig. 7 that the monthly levels of QDC for Husafell are settled within ± 0.1 dB, while they fluctuate by the amplitude of over ± 0.8 dB for Tjörnes. The above difference seems to be caused by a geographical effect: Husafell lies inland, while Tjörnes is on the seaside. On the coast, there are so much interference radio noise that double peaks appear on the high-signal side of the data, which might cause a larger fluctuation in the QDC for Tjörnes.

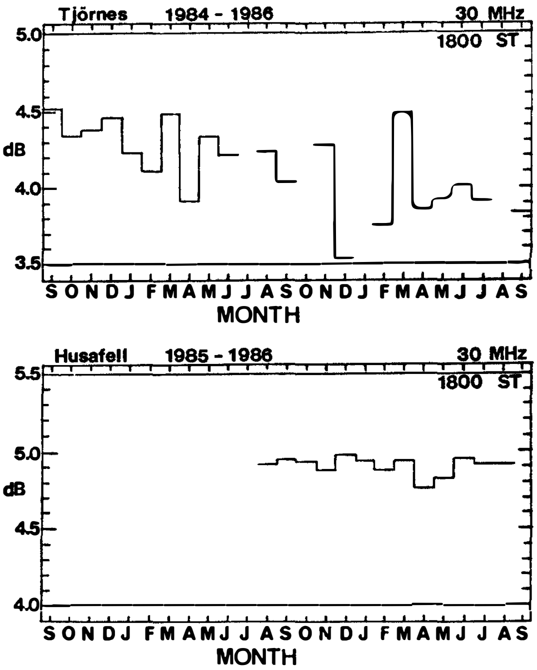

Fig. 7. Quiet day curve levels for Tjörnes and Husafell at a sidereal time of 1800 hours, as a function of the month.

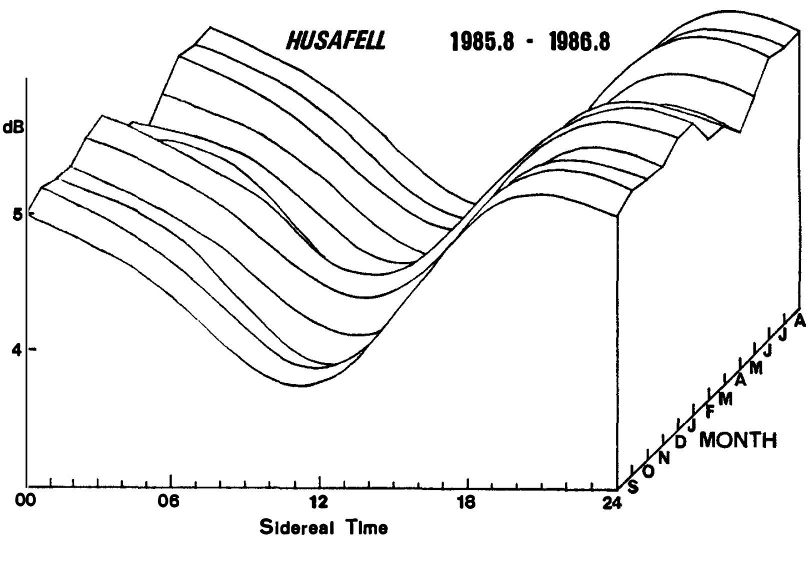

Fig. 8. Example of a "quiet day surface".

Figure 8 is an example of a "quiet day surface" formed by combining the monthly QDCs for Husafell shown in Fig. 6a. Given the radio sky brightness distribution and the riometer frequency, this surface is uniquely defined by the geographical latitude of the station, the riometer antenna pattern, and the diurnal and seasonal variations of the "quiet" ionosphere over the riometer site at the operating frequency. A similar plot can be produced for Tjörnes by combining the curves in Fig. 6b.

3. Summary and Conclusion

The inflection point method has been applied to 30 MHz riometer data observed at Tjörnes (66.20°N, 17.12°W in geographic coordinate) and Husafell (64.67°N, 21.03°W in geographic coordinate) in Iceland for determining QDC.

The data analyzed are periods of 8 September 1984 to 30 September 1986 at Tjörnes and 15 August 1985 to 31 August 1986 at Husafell, respectively.

The main features for the diurnal and seasonal variations of the QDC are summarized as follows;

1) The QDCs show almost the same daily variation with a minimum at 11h ST and a maximum at 21h ST for the both stations, and the Max-Min difference is in the range of 1.2–1.6 dB.
2) The monthly levels of the QDC for Husafell are settled within ± 0.1 dB, while they fluctuate by the ± 0.8 dB for Tjörnes. The difference seems to be caused by a geographical effect.

In order to confirm the effect, a more precise computer analysis is desirable with another stations data.

Acknowledgments

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