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U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Environmental Research Laboratories

A Computer Processing Method
for Real-Time Magnetometer Observations

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Space
Environment
Laboratory
BOULDER,
COLORADO
May 1975

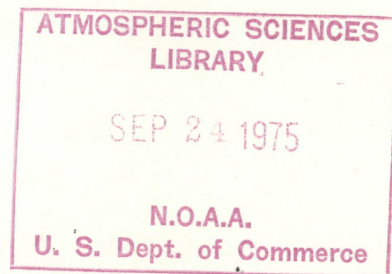
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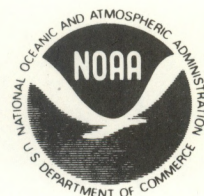
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A COMPUTER PROCESSING METHOD FOR REAL-TIME MAGNETOMETER OBSERVATIONS

Larry J. Gardner* and Charles E. Hornback

A computer method has been developed for estimating the K-indices and gamma deviations of a ground-based magnetometer. The results give automated, real-time observations that are suitable for operational applications.

1. INTRODUCTION

The Space Environment Services Center (SESC) is no longer operated 24 hours a day, so some method of automating the magnetometer output during unmanned periods had to be developed in order to satisfy Air Force real-time operational requirements.

The problem in developing such methods is in establishing an accurate, useable diurnal curve, or baseline, from which the deviations must be made, (Joselyn, 1970). (For a complete description of how the K-index is scaled, see Bartels, 1957). The current technique is to estimate subjectively the diurnal curve and the deviations from it.

From our point of view the simplest approach was to use a readily available computer (XDS 930) which can be accessed by telephone. Three methods were tried, but only one compared well with the subjective method.

2. PREVIOUS METHODS

Joselyn (1970) developed a method for providing a geomagnetic index from a computer. The method takes the standard deviations between 2-minute and 60-minute averages, then relates J , the logarithm of the standard deviations, to the K-index. Her results show a rather large spread in the correlation of J to K , e.g., $J = 0.6$, K ranges from 0 to 4. This is too large a range for practical applications required by the Air Force.

A second method we tried used a computer program with a fixed diurnal curve. The curve was determined from averaging several observed, quiet days. This method did not work because drifts in the magnetometer output gave values that did not compare well with the subjective values.

A third method, described in the next section, is the only one we know that has proved satisfactory.

3. K-INDEX AND DEVIATION COMPUTER PROCESS

The process used for generating K-indices and magnetic deviations from a quiet-day curve assumes the following: 1) The quiet-day curve can be approximated by straight lines for each 3-hour interval during the day and shifted so as to intersect the actual data value at the beginning of the 3-hour interval, and 2) the magnetometers are stable during a 3-hour interval.

The quiet-day curve was obtained by averaging the actual magnetometer traces over 7 very magnetically quiet days, and approximating the curve by straight line segments.

Each magnetometer signal is sampled 10 times per second and filtered by a program that is equivalent to passing an electric signal through a low-pass RC-type circuit whose time constant is 10 seconds. The signals are then sub-sampled each 5 seconds and the maximum plus and minus deviations are measured from the quiet-day value which is calculated from the quiet-day curve for each minute and assumed to be constant for 1 minute. Figure 1 shows an arbitrary magnetometer trace. The deviations measured are indicated by the arrows. The quiet-day curve approximations are shown by the dotted lines.

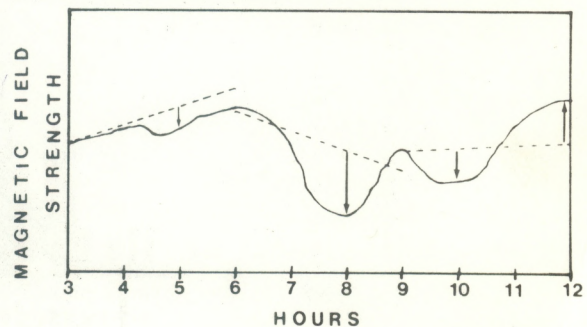


Figure 1. Arbitrary magnetometer trace showing quiet-day curve segments (dotted lines) and calculated deviations (arrows).

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At the beginning of a 3-hour interval, the following operations occur: 1) The line slope of the quiet-day curve for the previous 3-hour interval is adjusted (as explained later) in a manner depending on the measured deviations during that interval; 2) the line slope of the quiet-day curve for the present 3-hour interval is selected, and 3) this selected slope is shifted so that the initial value of the quiet-day curve is equal to the measured signal value at the beginning of the 3-hour interval. The quiet-day curve value is then calculated for each minute during the 3-hour interval. At 5-second intervals, the deviation of the signal from the quiet-day value is measured and the maximum and minimum deviations are calculated continuously for the 3-hour interval. Each minute, the running K-index is calculated from the total deviation by linear interpolation of a table of K-index vs. deviation values. At the end of the 3-hour interval, the final K-index and deviation values are stored. The values are flagged if more than ten 5-second intervals were missed during the 3-hour interval. The time associated with the values is the ending time for the interval, e.g., the values at 0600 UT are for the interval 0300-0600 UT. The slope of the quiet-day curve is adjusted by 1 gamma/3 hours in the positive direction if the magnitude of the maximum deviation is greater than the magnitude of the minimum deviation, and *vice versa*; hence, the calculated quiet-day curve continually adjusts to the slope of the observed trace in a gradual manner to allow for long-period variations (such as seasonal) in the quiet-day curve.

Each minute, the data for the previous time interval and those accumulated in the present interval are prepared for a display which can be accessed from the XDS 930 computer with a teletype. Figure 2 is an example of this display.

```
TMO TIME; 1975/02/28 18:28
MAG 18 DK=3.1, 23G; DK=2.0, 10G
HK=2.1, 10G; HK=0.8, 5G
```

Figure 2. Computer teletype display of magnetometer D and H components for 1828 UT, 28 February 1975. G is gammas. K is K-index. The first column of data is for the previous 3-hour period and the second column is for the current 3-hour period.

4. RESULTS

Figures 3 through 5 show the comparisons between computer and subjective estimates of both gamma deviations and K-indices.

Figure 3 shows that the computer estimates of the gamma deviations are within:

- ± 1 gamma of the subjective 22% of the time,
- ± 5 gamma of the subjective 53% of the time,
- ± 10 gamma of the subjective 82% of the time,
- ± 20 gamma of the subjective 96% of the time,

and between +27 and -39 gamma of the subjective 100% of the time.

Figure 4 shows that the computer estimates of the K-indices are within:

- ±0 of the subjective 62% of the time,
- ±1 of the subjective 93% of the time,

and between +1 and -2 of the subjective 100% of the time.

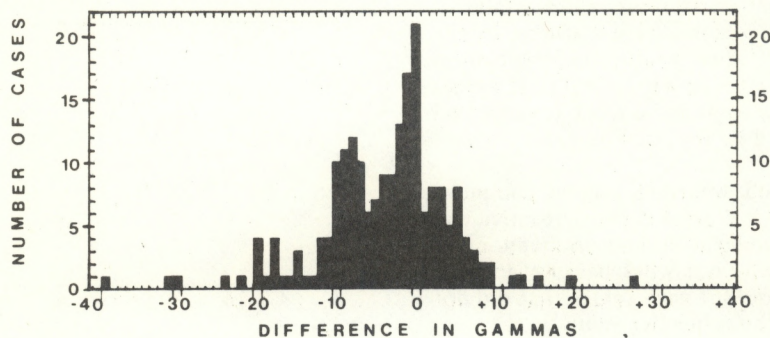


Figure 3. Distribution of differences in gammas between computer and subjective methods.

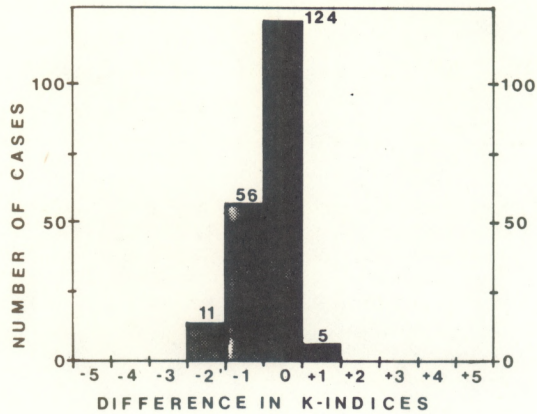


Figure 4. Distribution of differences in K-indices between computer and subjective methods.

Figure 5 shows the difference in gammas between the two methods for each 3-hour K-period. The maximum average difference for any 3-hour period was 7 gammas.

The above data were for 5 November through 5 December, 1974 and were for 196 cases. These results are considered to be quite adequate for real-time, operational use. In fact the variation seen in the comparisons could easily be on the same order as variations due to different observers using the subjective method.

In operational applications, no differentiation is made between the three components of the geomagnetic field insofar as reporting deviations from the quiet-day curve are concerned, i.e., the component with the greatest 3-hour deviation determines the K-index for that period. Therefore no such differentiation has been made in the above comparisons.

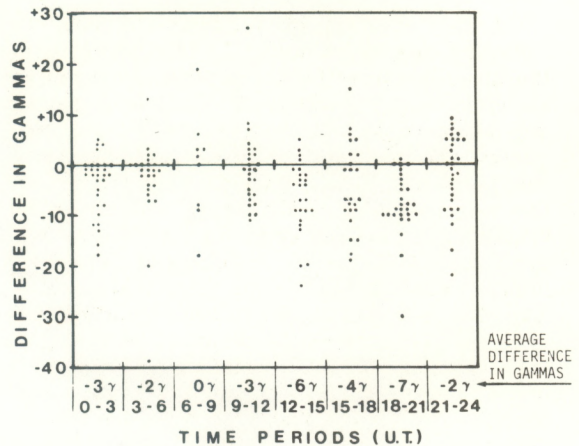


Figure 5. Distribution of the differences in gammas between the computer and subjective methods, with averages for each 3-hour period.

5. ACKNOWLEDGMENTS

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We would also like to thank Mr. Gary Heckman for his critical review of this paper. We thank Mr. Mark Sandoval for preparing the illustrations.

6. REFERENCES

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- Joselyn, J. A. (1970), A real-time index of geomagnetic activity, *J. Geophys. Res.*, 75, 2777-2780.