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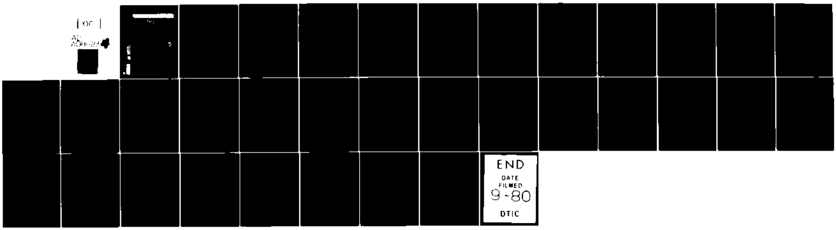

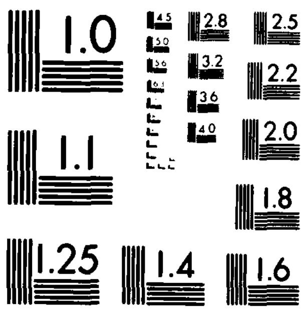

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

AFGWC/TN — 80/002

GEOMAGNETIC INDEX CALCULATION AND USE AT AFGWC

BY

CAPT ROBERT D. PROCHASKA

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APR 1980

UNITED STATES AIR FORCE
AIR WEATHER SERVICE (MAC)
AIR FORCE GLOBAL WEATHER CENTRAL
OFFUTT AFB NE 68113

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At Air Force Global Weather Central (AFGWC) we use several geomagnetic indices to specify the state of the magnetosphere. In this paper I introduce the indices of geomagnetic activity most commonly in use by DOD agencies. I discuss the procedures used at AFGWC to compute the indices and briefly describe the uses of each one.

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Preface

People who are unfamiliar with geomagnetic activity frequently have difficulty finding an understandable explanation of the indices of geomagnetic activity. The people of AFGWC's Space Environmental Support Branch compute several indices of this activity. New members of the branch and staff meteorologists at user locations normally are unfamiliar with geomagnetism. This report is designed as an instructional aid for them.

I compiled this material for use in the Space Environmental Technical Training courses which I have written. This paper is tutorial in approach with exercises in computing various indices included. The answers to the exercises form the appendix. The material is correct as of December, 1979. Since this report was designed for classroom use, it will not necessarily be revised if operational procedures change. This report may be retained for future reference but should not be used in lieu of operating instructions.

Many members of the Space Environmental Support Branch and Space Systems section of AFGWC contributed suggestions and recommendations to improve this report. I especially want to thank Major Vern Patterson for his critical review of the paper which led to several significant improvements in its content.

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INTRODUCTION

The operation of several units in the Department of Defense are affected by geomagnetic disturbances. The effects of the disturbances include increased atmospheric drag on spacecraft due to heating of the earth's atmosphere and degraded high latitude communications due to ionospheric disturbances. Geomagnetic observations are taken at several locations. Air Force Global Weather Central personnel use them to compute various indices of a geomagnetic disturbance to meet the requirements of Department of Defense customers.

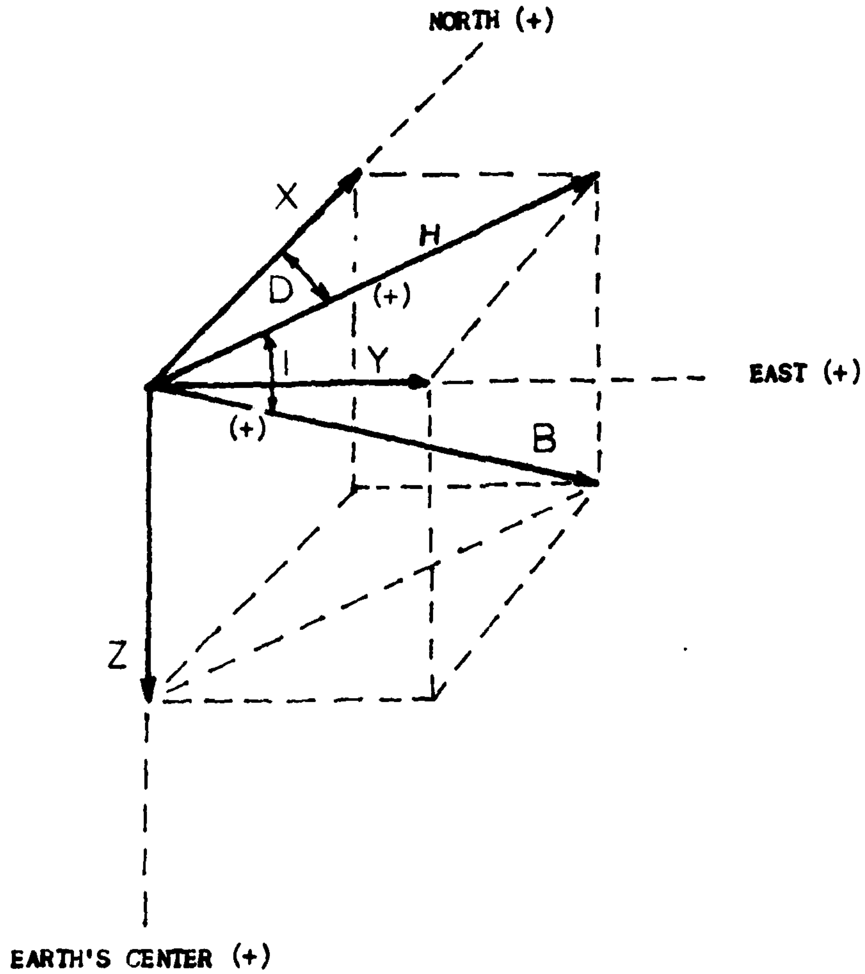
GEOMAGNETIC FIELD STRENGTH MEASUREMENTS

Geomagnetic field strength measurements are made using an instrument called a magnetometer. The magnetometer makes continuous measurements of the instantaneous geomagnetic field strength along three mutually perpendicular axes. Figure 1 displays the conventional directions of the axes, and the H, D, and Z set or the X, Y, and Z set of axes are the most common axes chosen*. The output of each sensor is recorded on strip-charts (see figure 2). Geomagnetic field strength is specified in units called gammas. The readout on the strip-charts for a sensor is in units of chart divisions, where each chart division represents a certain number of gammas on the axis of that sensor. At observing sites manned by Air Weather Service (AWS) personnel, the observations are made and encoded in units tenths of chart divisions and all work at these observing sites are in units of chart divisions. The observers leave the conversion to units of gammas to Air Force Global Weather Central (AFGWC).

The basic observing period for geomagnetic disturbance measurements is three hours long. The first observing period of the day begins at 00:00:00 universal time (UT or zulu, Z) and ends at 02:59:59 UT. Thus there are eight observing periods each day. A disturbance which occurred at 0143Z is included in the 0300Z (00:00:00 UT to 02:59:59 UT) observation. Observatories in the real-time network of magnetometers monitored by AFGWC (Table 1) divide each observing period into two 90 minute sections.

---

*Air Weather Service operated magnetometers only measure geomagnetic field strengths along two axes, the H and Z. It is common practice in Air Weather Service to refer to the three sensors as "X", "Y", and Z. The "X" and "Y" sensors are, in reality, two sensitivities of the horizontal component measurement. The sensors are parallel, with the one called "Y" recording the values at higher sensitivity than the "X" sensor. The assumption made in not measuring three independent components is that a disturbance will not affect the geomagnetic field strength only along one axis. This assumption, while not precisely correct, is true virtually 100% of the time.



D=DECLINATION
H=HORIZONTAL INTENSITY
B=TOTAL INTENSITY
I=INCLINATION

Z=VERTICAL COMPONENT
X=NORTH COMPONENT
Y=EAST COMPONENT

Figure 1. Geodetic elements of the geomagnetic field.

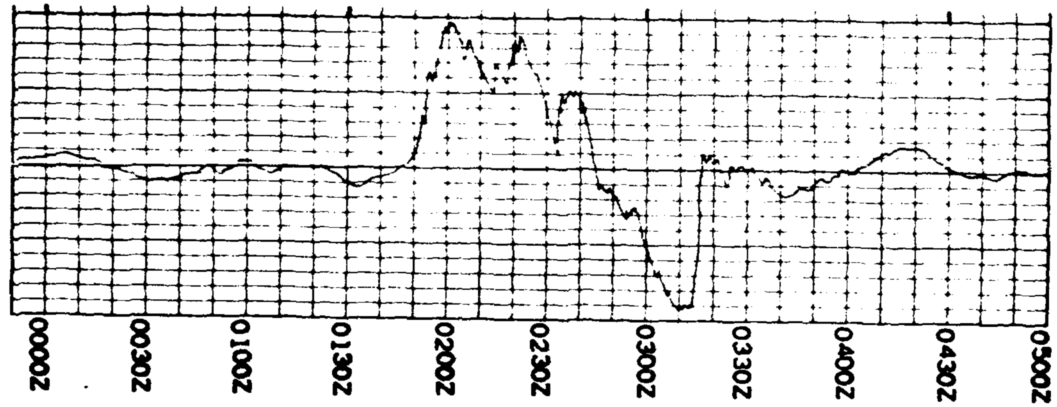


Figure 2. Simulated output for one sensor from a magnetometer. A real trace is recorded on stripchart paper with ten times as many divisions as shown here.

Each magnetometer observation gives the left and right extent of the strip-chart trace made during the observing period (see figure 2). Technically, this observation represents the change of geomagnetic field intensity from the quiet day curve (QDC) along each axis, where the QDC is caused by currents due to the apparent motion of the quiet sun (Sq) and moon (L). In practice, of the observing locations used at AFGWC only Boulder has a significant QDC. The analyst (or computer for automated reports) at Boulder removes the QDC prior to transmitting the observation; for all other observing locations monitored by AFGWC the QDC is so small that it is ignored.

AWS (and cooperating) observatories transmit their 90 minute observations in GEMAG code (figure 3). Each observation gives the furthest left (maximum intensity) and furthest right (minimum intensity) value of the trace for each of the three sensors during the 90 minutes. These observations are the basis for calculated indices of geomagnetic disturbances.

Three Hour, Single Station Indices

The basic index of the disturbance of the geomagnetic field is the AMPLITUDE, a. This index is the magnitude of the largest disturbance (from the QDC) of any sensor measured by a magnetometer during a three hour observing period. It is specified in units of gammas (units of magnetic intensity).

AFGWC personnel calculate an amplitude for each reporting period for each station listed in Table 1. They combine two consecutive GEMAG reports by taking the larger of the two maxima and the smaller of the two minima. This combination is the values which would be reported in a three hour GEMAG which covered the same two consecutive 90 minute periods. The difference between the maximum and minimum intensity for a sensor is the disturbance level in units of tenths of chart divisions. AFGWC personnel convert this value to the RANGE, R, in units of gammas (using Table 2). The largest range for the three hour period is the amplitude for that period.

Table 1. Magnetic observatories used by AFGWC

Observatory	Station Number	Geographic Lat	Geographic Long	Geomagnetic Lat	Geomagnetic Long
Boulder, Colorado	72469	40 08N	105 14W	+49.0	316.5E
College Observatory, Fairbanks, Alaska	25602	64 52N	147 50W	+64.6	256.5E
Goose Bay, Labador, Canada	71816	55 20N	60 30W	+60.5	11.9E
Loring AFB, Maine	72712	46 57N	67 53W	+58.5	1.5E
Thule, Greenland	04205	77 29N	69 10W	+88.0	5.7E
RAF Upper Heyford, England	03655	51 56N	1 15W	+50.7	79.1E

Table 2. Conversion Factors from Chart Divisions to Deflection
(difference is chart divisions) *(conversion factor) = (range in gammas)

Observatory	1st Sensor	2nd Sensor	3rd Sensor
Boulder	10.0	10.0	*
College	80.5	80.4	81.5
Goose Bay	125.0	20.0	100.0
Loring	125.0	12.5	50.0
Thule	50.0	10.0	20.0
Upper Heyford	50.0	12.5	50.0

* sensor not used/not available

```
GEMAG
IIIII  YMMDD  3GGgg  4S/NN
11111  20MN1  30MX1  40MN2  50MX2  60MN3  70MX3  99999
22222  20MN1  30MX1  40MN2  50MX2  60MN3  70MX3  99999
```

IIIII = station number

YMMDD = year/month/day; e.g., 1 Apr 1979 is 90401

GGgg = hour/minute of the end of the observation period

s = report status (9 = data valid for 90 minutes ending at GGgg)

11111 = this line is for 90 minutes ending at GGgg

22222 = this line is for 90 minutes just prior to 11111 line and is optional. If used, omit the 99999 group at the end of the previous (11111) line.

MN1 = Minimum pen deflection on sensor 1

MX1 = Maximum pen deflection on sensor 1

MN2/MX2 = minimum/amximum for sensor 2

MN3/MX3 = minimum/maximum for sensor 3

a. GEMAG Code

```
MAGTR  IIIII  DDHH/  GGG11  99999
```

IIIII = station number

DDHH = day/hour of start of 3 hour period

GGG = amplitude, a

NOTE: K index is normally appended to this message as a plain language comment.

b. MAGTR Code

Figure 3. Geomagnetic Observing Codes. These codes are used for real-time reports of geomagnetic observations.

Amplitude is a linear index of geomagnetic disturbance level. An amplitude of 50 represents a geomagnetic disturbance (in gammas) twice as severe as that represented by a 25.

Amplitude is strongly dependent on the observatory location in geomagnetic coordinates. Instruments located in auroral latitudes react most strongly, and those near 30° north or south react least strongly to a disturbance of the worldwide geomagnetic field. You must remove the geomagnetic latitude dependence of the amplitudes before you can compare observations from different observatories.

In 1938, the K scale was adopted for the observatory at Niemegk (near Potsdam, GDR) as a quasi-logarithmic index of geomagnetic activity. The values chosen gave a reasonable distribution of frequency of occurrance across the scale from zero (very quiet) to nine (violently disturbed). All observatories could not use the same scale to convert amplitude to K, the "LOGARITHMIC" AMPLITUDE; otherwise auroral stations would show much greater K values than would lower latitude stations for the same storm. So to get a conversion from a to K for some stations we remove the geomagnetic latitude dependence. The 1938 data for any particular station was compared to that from Niemegk to get the same frequency of occurrance of K in each category at each station. As new observatories are established their amplitude values are compared to calibrated observatories [7]. Table 3 is used to convert a to K for the observatories which report to AFGWC in real-time.

Since the K-index is based on a single station, it represents regional (longitude) conditions and will include local variations in geomagnetic activity, including the Sq and L variations. A possible index to express the geomagnetic disturbance on a worldwide scale might be a simple average of the K indices from several (or all available) stations. However, the K index is not linear, so a simple average would not be useful even if we had a uniform geographic distribution of observatories. The first step to a planetary index is to compute a single station "equivalent" index.

Table 3. a to K conversion

K	Boulder	College	Loring	Goose Bay	Thule	Upper Heyford	K
0	0–4	0–24	0–7	0–16	0–9	0–5	0
1	5–9	25–49	8–14	17–32	10–19	6–11	1
2	10–19	50–99	15–29	33–64	20–39	12–24	2
3	20–39	100–199	30–59	65–129	40–79	25–49	3
4	40–69	200–349	60–104	130–227	80–139	50–84	4
5	70–119	350–599	105–179	228–389	140–239	85–149	5
6	120–199	600–999	180–299	390–649	240–399	150–249	6
7	200–329	1000–1649	300–494	650–1072	400–659	250–399	7
8	330–499	1650–2499	495–749	1073–1624	660–999	400–599	8
9	over 500	over 2500	over 750	over 1625	over 1000	over 600	9

Note: a is in units of gammas, K is dimensionless

The EQUIVALENT AMPLITUDE, a_K, is a linear, single-station, three hour index which has had the geomagnetic latitude dependence removed. The international way of determining a_K is to use Table 4, converting the amplitude to K and K to the equivalent amplitude. AT AFGWC, the analyst converts amplitude directly to equivalent amplitude, dividing each station's amplitude by a latitude dependent factor (see Table 5). Since a_K is linear and station-independent, various a_K values can be averaged for several time periods to get other indices; e.g., the a_K values during a geomagnetic disturbance can be averaged to determine the severity of the disturbance.

EXERCISE 1. Using Tables 1-3 and 5, figure 3, and the following reports:

```
GEMAG
71816  90403  31030  49/12
11111  20449  30403  40497  50215  60406  70337
22222  20452  30444  40528  50474  60335  70328  99999
GEMAG
71816  90403  31200  49/06
11111  20///  30///  40488  50467  60330  70329  99999
```

complete the following:

station name: ____________________

date of reports: ____________________

0730Z - 1030Z amplitude = ____________________

0730Z - 1030Z K index = ____________________

0900Z - 1200Z amplitude = ____________________

0900Z - 1200Z K index = ____________________

0900Z - 1200Z equivalent amplitude = ____________________

EXERCISE 2. MAGTR is a code which is used by Boulder to report a/K values directly. Use figure 3 to interpret the following report.

MAGTR 72469 1215/ 22711 99999

station: Boulder Day ____________________

Time: ____________Z to ____________Z, a = ____________, K = ____________

Table 4. Equivalent Amplitude for a Given K Value

K	0	1	2	3	4	5	6	7	8	9
a_K	0	3	7	15	27	48	80	140	240	400

Table 5. Equivalent Amplitude Conversion Factors
(a) - (conversion factor) = a_K

Observatory	Factor (gammas)
Boulder	2.0
College	10.0
Goose Bay	6.5
Loring	3.0
Thule	4.0
Upper Heyford	2.4

Daily/Planetary Indices

The indices which we have examined this far are valid only for one station and they are valid during a particular three hour period. We will now examine indices used to specify geomagnetic activity level on a daily and/or planetary scale.

The EQUIVALENT DAILY AMPLITUDE, A_K, specifies the geomagnetic activity level for a particular station on a particular day. A_K is obtained by averaging the chosen station's eight a_K values for that day. Since a_K is independent of the station's geomagnetic latitude, A_K can be used to compare the daily geomagnetic activity at various observatories. When discussing A_K values for various observatories, it is common practice to replace the subscript K with a two letter subcript to identify the station. For example, the A_K for Fredricksburg, Virginia is normally denoted as A_{FR} (called A-FRED by NOAA personnel at Boulder). Since A_K is linear, we can average several days worth to get weekly, monthly, or even yearly values of the average disturbance at that station. Any one station index does not specify the worldwide level of distribution of the geomagnetic field, so we will next examine the so-called planetary indices, indices of worldwide geomagnetic activity.

All planetary indices of geomagnetic activity are computed by averaging selected single station indices. Ideally, one should use a large number of stations which are evenly distributed about the globe. In practice, a small number of observations taken at selected locations are used. By averaging the a_K values from twelve specific stations (see Table 6), the personnel of the International Service for Geomagnetic Indices determine the EQUIVALENT PLANETARY AMPLITUDE, ap. This value represents the official value of the activity of the entire geomagnetic field for the three hours. However, this index is not available in real time and so is not routinely used by AFGWC. Personnel at AFGWC normally refer to it as the Göttingen ap.

Table 6. Magnetic observatories selected for determining Göttingen A_p

Symbol	Observatory	Geographic Lat	Geographic Long	Geomagnetic Lat	Geomagnetic Long
Le	Lerwick, Shetland Islands	60 08N	358 49E	+62.5	88.6
Lo	Lovo, Sweden	59 21N	17 50E	+58.1	105.8
Si	Sitka, Alaska	57 04N	224 40E	+60.0	275.4
Rs	Rude Skov, Denmark	55 51N	12 27E	+55.8	98.5
Es	Eskdalemuir, Scotland	55 19N	356 48E	+58.5	82.9
Me	Meanook, Alberta, Canada	54 37N	246 40E	+61.8	301.0
Wn	Wingst, West Germany	53 45N	9 04E	+54.5	94.0
Wi	Witteveen, Netherlands	52 49N	6 40E	+54.2	91.0
Ha	Hartland, Devon, England	51 00N	355 31E	+54.6	79.0
Ag	Agincourt, Ontario, Canada	43 47N	280 44E	+55.0	347.0
Fr	Fredericksburg, Virginia	38 12N	282 38E	+49.6	349.9
Am	Amberley, New Zealand	43 09S	172 43E	-47.7	252.5

AFGWC personnel use a network of real time stations (Table 1) to simulate the EQUIVALENT PLANETARY AMPLITUDE, ap. They average the a_K values for five of these stations (excluding Thule) to get a value which very closely approximates a_p and which at AFGWC is called ap. In the remainder of this discussion I will refer to the AFGWC value as a_p, although my comments are more precisely correct for the Göttingen value. a_p, a linear index, ranges from zero to well over one hundred.

Thule, like other polar cap stations, is excluded from planetary calculations because it has a poor correlation to worldwide disturbances. Polar stations respond very strongly to disturbances of the geomagnetic field which affect only the polar regions. They respond less strongly to worldwide disturbances than do auroral stations. Thus, they are excluded from planetary calculations, as they would bias the calculated index away from the "planetary" value.

The "LOGARITHMIC" EQUIVALENT PLANETARY AMPLITUDE, K_p, is a three hour value of geomagnetic activity for the entire earth, using a quasi-logarithmic scale. K_p values range from 0 to 9 in 28 steps; i.e., 0, 0+, 1-, 1, 1+,...7+, 8-, 8, 8+, 9-, 9. At AFGWC, the conversion from ap to K_p is made using Table 7.

The specification of the total planetary level of geomagnetic activity during a 24-hour period is an average of the eight ap values for that period. The resultant index is the DAILY EQUIVALENT PLANETARY AMPLITUDE, A_p. At AFGWC the classification of geomagnetic disturbances is based on the Ap and the plain language descriptions listed in Table 8. Again, as with a_p, the official value is the Göttingen Ap, calculated from the stations listed in Table 6, while AFGWC calculates a similar value using the real time reporting stations.

Table 7. Minimum a_p Threshold for a Given K_p value

ap	Kp	ap	Kp	ap	Kp
0	0	15	3	80	6
2	0+	18	3+	94	6+
3	1-	22	4-	111	7-
4	1	27	4	132	7
5	1+	32	4+	154	7+
6	2-	39	5-	179	8-
7	2	48	5	207	8
9	2+	56	5+	236	8+
12	3-	67	6-	300	9-
				400	9

Table 8. Plain Language A_p Description

Condition	Minimum Ap
Quiet	0
Unsettled	7
Active	15
Minor Storm	30
Major Storm	50

EXERCISE 3. Given the following amplitudes (in gammas)

End Time	02/00	02/03	02/06	02/09	02/12	02/15	02/18	02/21	02/24
Station									
Loring	1	0	12	3	90	870	210	90	180
College	15	20	50	30	550	4000	2300	650	1100
Goose Bay	13	13	33	52	358	2275	1073	455	942
Boulder	0	0	10	4	70	520	90	50	100
Upper Heyford	3	1	14	3	60	528	156	120	204

Complete the following:

End Time	02/00	02/03	02/06	02/09	02/12	02/15	02/18	02/21	02/24
Station									
Loring a_K									
College a_K									
Goose Bay a_K									
Boulder a_K									
Upper Heyford a_K									
ap									
Kp									

What is the A_K for College for day 02? For Goose Bay?

What is the A_p for the day (02)?

EXERCISE 4. Encode the Boulder MAGTR for the time period ending 02/1800Z, using the data from Exercise 3.

EXERCISE 5. URSI (International Radio Science Union) observatories transmit daily summaries of their K index values and the A_K value for that day using the code UMAGE (figure 4). Use the data from exercise 3 to encode a UMAGE for Loring from 01/21Z to 02/21Z, and one for Upper Heyford from 02/00Z to 02/24Z (indicates SSC of 02/0315Z for both stations). Since Loring and Upper Heyford are AWS stations, they do not calculate the indices included in the UMAGE reports.

UMAGE IIIII JJTTa bbkkk kkkkk cHHmm dHHmm eeeee

IIIII = station number

JJTT = day/hour of start of 24 hour period reported

a = check sum last digit (this is the last digit of the sum of the 2-b and 8-k values)

bb = last two digits of A_K for day JJ (use // or XX if not available)

k = K index, one for each 3-hour period beginning at JJTT

c = special phenomenon

1 = storm end
2 = bay (PSC)
3 = typical crochet
4 = provisional figures
6 = gradual storm beginning
7 = SSC
8 = very marked SSC

HHmm = time of special phenomenon

Optional Groups

d = 5 means special phenomenon of H- component minimum

eeeee = intensity of H-component minimum in gammas

Figure 4. UMAGE Code Breakdown

Other Geomagnetic Indices

There are several other indices of geomagnetic activity. Indeed, each geomagnetic index (including those previously discussed) was developed for a particular use, and the relationship between indices is generally not a simple one. The people who use a particular index often have a strong bias toward that index as "the" indicator of geomagnetic activity; I will avoid any indorsement of a particular index. I will now briefly introduce the more generally accepted geomagnetic indices which are not commonly used by DOD agencies.

The K_P index may be obtained from K without the computation of a_K. By removing the longitudinal, or local time, variation effect and the seasonal effect from a K index, you can obtain the STANDARDIZED K index, K_S. K_P is the average of the K_S values from the 12 stations used to compute A_P. K_P, by the way, is due to a combination of high and low latitude effects and the correlation between it and some other geomagnetic indices (like AE and Dst below) is not a simple relationship. K_P is published in the so-called musical-note format shown in Figure 5.

The magnetic character Figure, C, is a subjectively obtained index for a 24 hour interval. Each participating observatory evaluates its daily magnetograms and assigns one of three values: zero for quiet, one for moderately disturbed, or two for very disturbed. An average of the contributing stations, to the nearest tenth of a value, is called C_i. Variations of this index include Cp, which is based on conversion from Ap, and C9, which ranges from 0 to 9. Ap and C_I are published in the format of Figure 6.

Quantitative studies use indices which measure the disturbance by region. Dst and AE are the most commonly used of these indices. The storm time disturbance index, Dst, is the longitudinal average depression of the low latitude horizontal component in units of gammas. This index is approximately proportional to the total kinetic energy of the particles which are injected and trapped in the radiation belts during the main phase of the geomagnetic storm. The AURORAL ELECTROJECT index, AE,

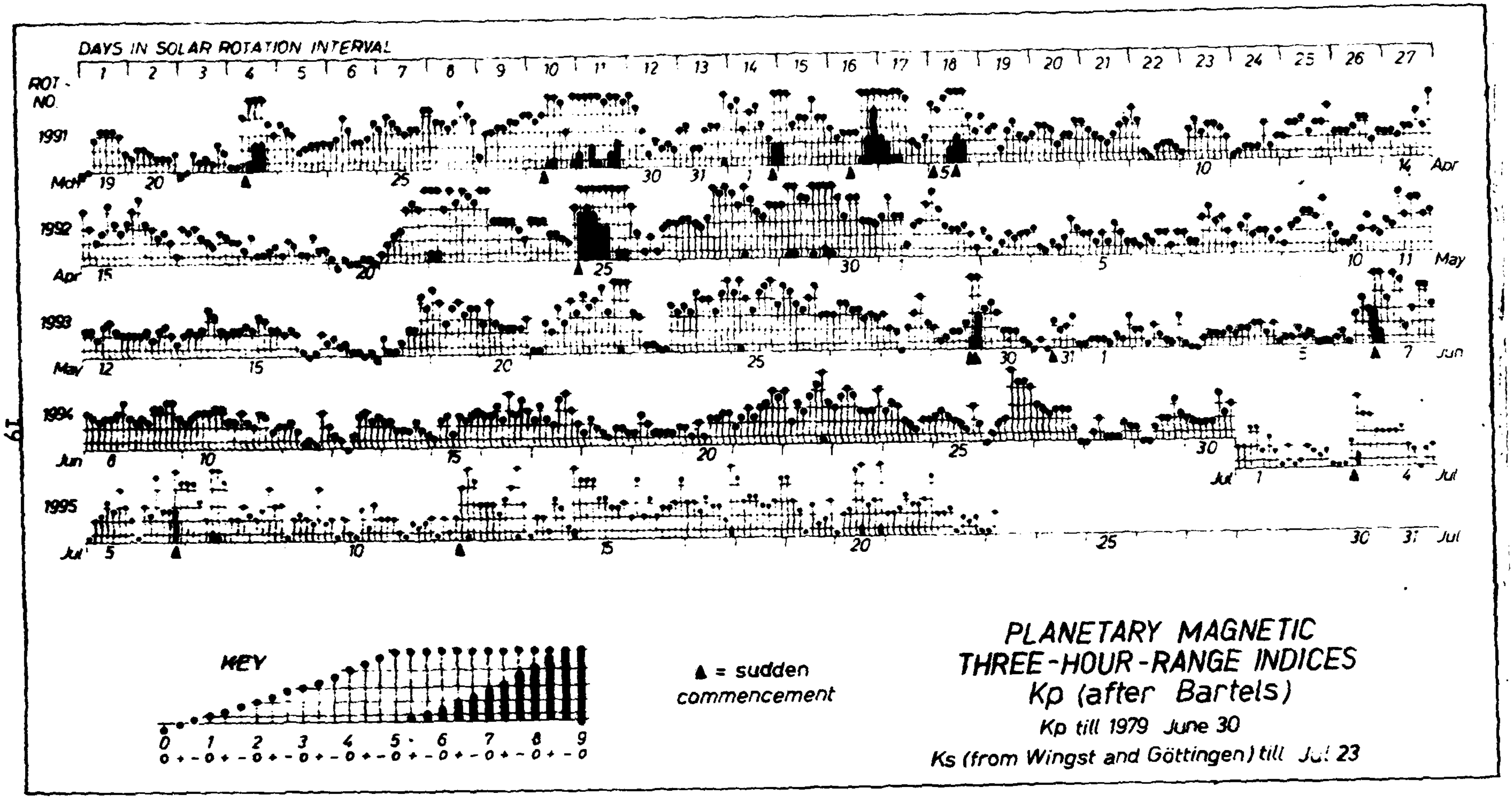


Figure 5. Musical note diagram of K_p

IUGG: ASSOCIATION OF GEOMAGNETISM AND AERONOMY

(International Service of Geomagnetic Indices)

International quiet and disturbed days:

Quietest Days 1 -5: 17 16 6 31 3
Quietest Days:6-10: 10A 4A 5A 8A 13A

Most Disturbed Days 1-5: 22 25 24 26 19

GEOMAGNETIC PLANETARY INDICES

Three-hourly: Kp; Daily: Ap and Cp

May 1979

	1 2 3 4	5 6 7 8	Sum	Ap	Cp
1	3+4+3+3+	1+3-3o4o	25+	18	1.0
2	5-4-3-2+	2+3-2o1o	21+	14	0.8
3	2+2-1-1+	2o2-2o2o	14-	6	0.3
4	2+1o1-1+	1o2-3o2+	13+	7	0.3
5	2o2o1+2o	1+3-2o1+	15-	7	0.3
6	1+1o2-1+	2o2o1o2o	12+	6	0.3
7	2o1+1+3o	4-3-3o2o	19o	11	0.6
8	1o2+3o2-	2o2o1+2o	15+	8	0.4
9	1o2+3-3+	3+3o4o2+	22o	14	0.8
10	2-1o1o1+	2o3o2o2-	14-	7	0.3
11	3-2+4+3o	4o4o3o3+	27-	19	1.0
12	2+2+2-3-	3o2+2o2o	18+	9	0.5
13	2o2o2+2-	2+3-2o1+	16+	8	0.4
14	2o2+2o2+	4-3+2+2o	20o	11	0.6
15	2+2+3-2+	3+3o2+2+	21-	11	0.6
16	2o2+2o1-	0+1-2o1+	11+	5	0.2
17	2-1o1+1-	1-0+1-0o	6+	3	0.1
18	2-1-1-1+	2+2+4+4-	17o	11	0.6
19	5-4o3-4-	4o3+4-4-	30-	24	1.1
20	3-4o3-2+	2+2+2+3o	22-	13	0.7
21	1-1-3-2o	4-3-4o3+	20-	13	0.7
22	4+4-4-5-	3+5o5+5o	35o	36	1.4
23	3+3o1o1o	1-1-4-3+	17-	11	0.6
24	4-3+4-4o	4o3+4+5o	31+	27	1.2
25	4+5+4o3+	4+5-5o4-	35-	34	1.4
26	5-4+3+3+	4o5-3o3o	30+	25	1.2
27	3o4-4-3+	3+3-3o3-	25+	17	0.9
28	3o2o2-0+	2o3o4o2+	18+	11	0.6
29	2o1o1+2-	2-2+6-7o	23-	30	1.3
30	3+4-3o2-	2-2-1o1-	17-	10	0.6
31	0+1o0+2+	2-2o3-1-	11o	6	0.3
			Mean	14	0.68

Preliminary ssc: 29 d 18 h 50 m
29 d 20 h 58 m 31 d 09 h 31 m

Figure 6. Gottingen A_p/C_p Summary

is a monitor of the intensity of the auroral electroject, based on horizontal magnetic component measurements taken by a set of auroral zone magnetic stations. The set of stations should be uniformly disturbed in longitude to cancel the local time dependence of the index. Dst is typically specified with hourly time resolution while AE normally is specified with two to five minute resolution. [1]

USE OF GEOMAGNETIC INDICES

The three hour, single station indices (a, K, a_K) were designed for use in classifying short-lived activity in a small area. The amplitude, because of its dependence on geomagnetic latitude, is of use only in comparing various observation periods at the same station. The equivalent amplitude a_K, and the K-index are used to compare observations at various locations, as the geomagnetic latitude dependence of each has been removed. The K-index ranges only from zero to nine while the a_K value can reach a few hundred; the K-index is more commonly used than a_K. Small (spatial) scale disturbances of the geomagnetic field which typically last one to four hours are called substorms; the K-index is widely used when substorms are examined.

The equivalent daily amplitude, A_K is used to classify the activity level on various days at a single station. Since eight 3-hour a_K values are averaged, the effect of an individual substorm is minimized, and the primary factor classified by A_K is the overall character of the geomagnetic field at that location. Using the appropriate A_K indices, we can compare the severity of a particular geomagnetic storm as seen at various locations, or compare the geomagnetic activity of various days as observed at a single location.

We use multi-station indices to specify the overall state of the magnetosphere. The equivalent planetary amplitude, ap, and its logarithmic version, Kp, define which phase of a geomagnetic storm (a major disturbance of the magnetosphere) is in progress during a particular time period. Typically the largest K_p values, occur during the main phase of a storm, while slowly declining K_p values occur during the recovery phase. The daily equivalent planetary amplitude, Ap, is used to classify the overall intensity of a geomagnetic storm (see Table 8).

AURORAL OVAL INDEX Q_E

The index Q is a measure of the size of the polar cap and the auroral oval around it. Q, the polar range index, varies with the intensity of the ionospheric currents which flow across the polar cap. Stronger polar cap currents will produce a larger auroral oval. Q is a quasi-logarithmic index which can be computed only for observatories located poleward of 58° geomagnetic latitude (see Table 9). Q is a 15 minute index based on variations of the horizontal magnetic field strength (vector H in Figure 1). It is a short-term index and reacts very strongly to geomagnetic substorms.

AFGWC personnel do not compute Q, but use an equivalent Q index, Q_E, to monitor the auroral oval size and location. They analyze the equatorward boundary of the diffuse aurora seen on DMSP imagery, specifying the location and time of occurrence. Computerized analysis of precipitating electron measurements taken by DMSP also results in the location and time of auroral occurrences due to those particles. These times and locations, in Corrected Geomagnetic coordinates [10] are used to specify the Q value which would have caused that auroral oval extent. AFGWC personnel use the Q_E values with Whalen's auroral oval plotter [10] to monitor auroral and polar disturbances.

Table 9. Upper Range Limit in Gammas Defining Q Values

Q	0	1	2	3	4	5	6	7	8	9	10
Upper Limit	10	20	40	80	140	240	400	660	1000	1500	2200

Table 10. Geomagnetic Indices used at AFGWC

Index	Time Scale	Spatial Scale	Comments
a	3 hour	local	
K	3 hour	local	Pseudo-logarithmic
a_K	3 hour	local	Geomagnetic Latitude Independent
A_K	24 hour	local	Geomagnetic Latitude Independent
ap	3 hour	planetary	
Kp	3 hour	planetary	Pseudo-logarithmic
Ap	24 hour	planetary	
Q	15 minute	polar cap	Not used directly, but inferred from auroral observations

SUMMARY

Geomagnetic activity indices are measures of the level of disturbance of the geomagnetic field. Magnetometer observations are local measurements of geomagnetic disturbances. AFGWC personnel use the measurements from a network of observing locations to calculate the indices K, a_K, a_P, K_P and A_P (see figure 7). DoD personnel use these and the indices A_K and Q_E to monitor terrestial magnetospheric activity. Comparison of appropriate indices reveals the short and long term, local and worldwide scale and severity of a geomagnetic disturbance (see Table 10).

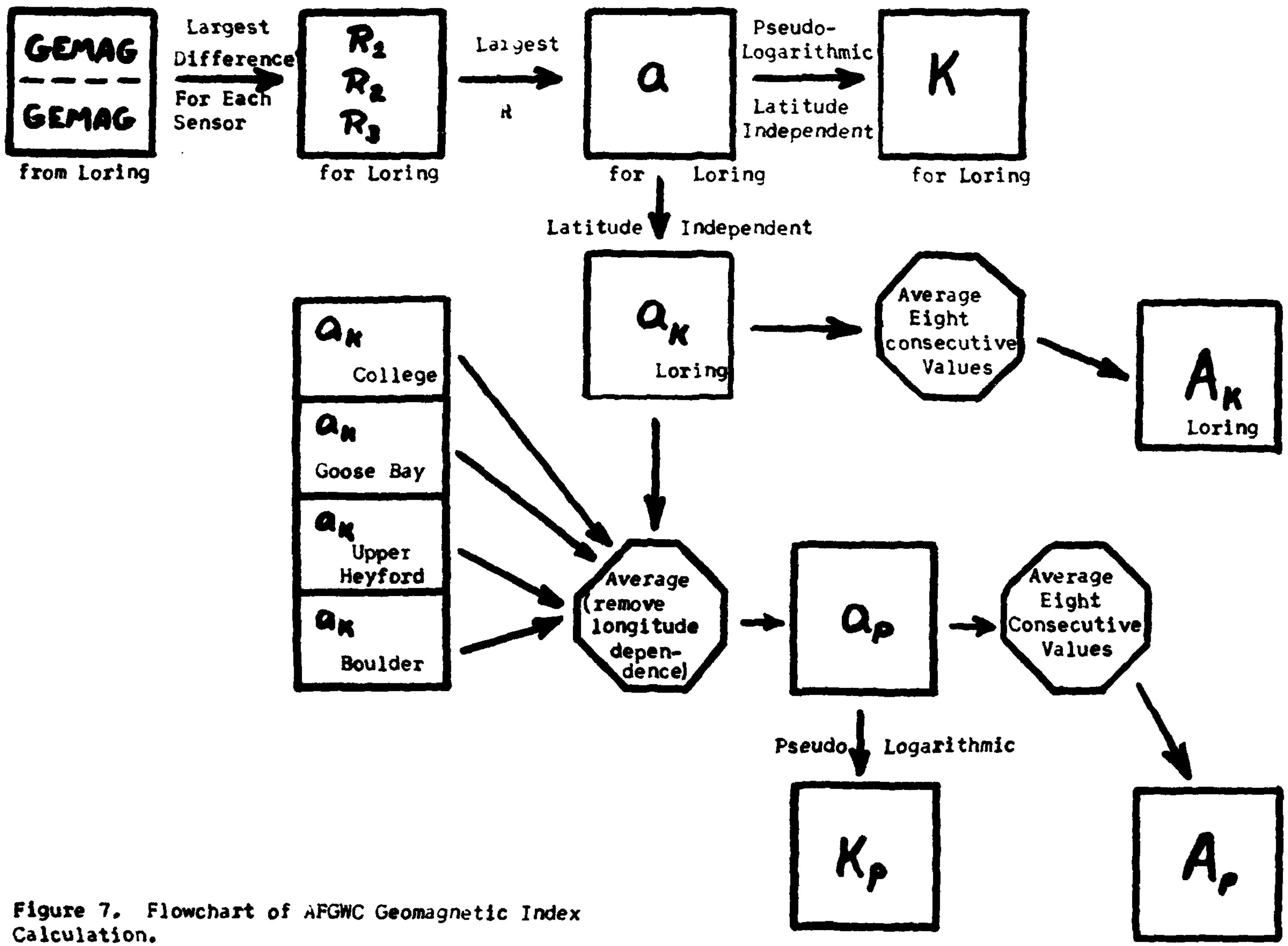


Figure 7. Flowchart of AFGWC Geomagnetic Index Calculation.

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APPENDIX

Answers to Exercises

Exercise 1

Station 71816 - Goose Bay Labrador

Date of Report - 90503 - 3 April 1979

TIME PERIOD	X-MAX	X-MIN	Y-MAX	Y-MIN	Z-MAX	Z-MIN
0730-0900Z	44.9	40.3	49.7	21.5	40.6	33.7
0900-1030Z	45.2	44.4	52.8	47.8	33.5	32.8
1030-1200Z	N/R	N/R	48.8	46.7	33.0	32.8

N/R indicates none reported

TIME PERIOD	Range (Chart Divisions)			Range (Gammas)		
	X	Y	Z	X	Y	Z
0730-1030Z	4.9	31.3	7.8	612.5	626.0	780.0
0900-1200Z	*	6.1	0.7	*	122.0	70.0

TIME PERIOD	Amplitude	K	Equivalent Amplitude
0730-1030Z	780	7	120
0900-1200Z	122	3	18.8

Exercise 2

Day 12th of Month
Time period 1500Z to 1800Z
a = 227
K = 7

Exercise 3 (values to nearest whole number)

End Time	02/00	02/03	02/06	02/09	02/12	02/15	02/18	02/21	02/24
Station									
Loring	0	0	4	1	30	290	70	30	60
College	1	2	5	3	55	400	230	65	110
Goose Bay	2	2	5	8	55	350	165	70	145
Boulder	0	0	5	2	35	260	45	25	50
Upper Heyford	1	0	6	1	25	220	65	50	85
ap	1	1	5	3	40	304	115	48	90
Kp	0	0	1+	1-	5-	9-	7-	5	6

$A_{College}$ = 109 $A_{Goose\ Bay}$ = 100 A_p = 76

Exercise 4

MAGTR 72469 0215/ 04511 99999

Exercise 5

UMAGE 72712 01214 XX001 04964 70315
UMAGE 03655 02002 56020 48656 70315