

# ON THE NON-CYCLIC CHANGE.

BY L. STEINER.

In the following paragraphs is given a short account of the investigations, which I have made, concerning the non-cyclic change. Although the investigations are of a somewhat fragmentary character, yet it seemed worth while to publish the results, as they contribute something, at least, to our knowledge of this non-cyclic change.

1. The non-cyclic change, as defined by Doctor Chree,<sup>1</sup> is the difference of the two consecutive midnight-values of the magnetic elements on a quiet day. Instead of taking the difference of the midnight-values, I have taken the difference of the daily means on two consecutive quiet days. I have chosen the observations at the magnetic observatories of the United States Coast and Geodetic Survey, the uniformity in the selection of the quiet days for the different places being thus, I assumed, best secured. The geographical positions of these places are:

	Latitude (North)	Longitude (West of Greenwich)
Sitka.....	57 03	135 20
Baldwin.....	38 47	95 10
Cheltenham.....	38 44	76 51
Honolulu.....	21 19	158 04
Vieques, Porto Rico.....	18 09	65 26 (old location.)

In Table I are given the mean values of the differences of the daily means on two consecutive quiet days, noted by a \* in the publications.<sup>2</sup>  $\Delta D$ ,  $\Delta H$ ,  $\Delta V$  are these differences, respectively, in declination, horizontal intensity and in vertical intensity, east declination being taken as positive. The data not available to me were kindly supplied by Mr. R. L. Faris. What strikes one most, is the general constancy of sign (and in general, too, its amount for the same station) of  $\Delta H$  (+) and of  $\Delta V$  (-); the sign and amount of  $\Delta D$  is very changeable.

<sup>1</sup> *Studies in Terrestrial Magnetism*, London, 1912, pp. 23-32.

<sup>2</sup> HAZARD: *Results of Observations, etc., Coast & Geodetic Survey*.

TABLE I.

Year	SITKA			BALDWIN			CHELTENHAM			HONOLULU			VIEQUES		
	$\Delta D$	$\Delta H$	$\Delta V$	$\Delta D$	$\Delta H$	$\Delta V$	$\Delta D$	$\Delta H$	$\Delta V$	$\Delta D$	$\Delta H$	$\Delta V$	$\Delta D$	$\Delta H$	$\Delta V$
1901	.103	$\gamma$	$\gamma$	.060	$\gamma$	$\gamma$	.004	$\gamma$	$\gamma^3$	.084	$\gamma$	$\gamma$	.038	$\gamma$	$\gamma$
02	+	+0.9	.....	.049	-0.2	.....	-.044	+1.0	0.0	-.084	+1.1	.....	+	.....	.....
03	+	+1.0	.....	.020	+1.4	.....	.058	+1.9	-0.8	.050	+1.9	.....	+	+2.3	.....
04	+	+1.3	.....	.079	+1.6	.....	.032	+1.8	-1.2	.030	+1.3	.....	+	+1.2	.....
05	-	.181	0.0	-.040	+2.2	-0.6	+.004	+1.8	-1.2	.082	+2.2	-0.4	-	+2.1	+0.8
06	+	+1.4	-0.7	-.064	+1.5	-1.3	-.071	+1.5	-1.3	.042	+2.7	-0.3	-	+0.4	-0.4
07	+	+2.4	-0.5	+.006	+2.2	-0.4	+.042	+1.6	-1.0	+.006	+2.0	-0.7	+	+0.4	-0.4
08	+	.045	+0.2	+.003	+1.8	-0.5	+.014	+1.7	-1.3	+.034	+2.4	-0.7	+	+3.2	-0.4
09	+	.072	+0.8	+.045	+2.2	-1.1	+.010	+2.2	-0.8	+.038	+1.7	-0.3	-	+2.1	-0.5
10	-	.061	-0.7	.....	.....	.....	+.033	+2.4	-0.7	+.045	+2.5	-1.0	-	+2.7	-0.3
11	-	.089	-0.3	.....	.....	.....	+.032	+0.8	-0.5	+.032	+1.9	+0.1	-	+0.9	-0.7
12	-	.070	-0.5	.....	.....	.....	+.040	+1.4	-1.1	+.040	+2.5	-1.5	-	+1.7	-0.1

<sup>1</sup> Observations began in July, 1901.

TABLE II.

Stations and Years	$\Delta D$			$\Delta H$			$\Delta V$				
	+	0	-	Years	+	0	-	Years	+	0	-
Sitka, 1902-'12	243 (41)	56 (9)	291 (50)	1902-'12	400 (63)	87 (13)	152 (24)	1905-'12	164 (35)	78 (17)	225 (48)
Baldwin, 1901-'09	227 (45)	63 (13)	210 (42)	1901-'09	316 (63)	53 (11)	130 (26)	1905-'09	97 (37)	27 (11)	134 (52)
Cheltenham, 1901-'12	295 (46)	93 (14)	257 (40)	1901-'12	406 (63)	75 (12)	158 (25)	1901-'12	169 (27)	94 (15)	359 (58)
Honolulu, 1902-'12	290 (46)	91 (14)	245 (40)	1902-'12	400 (64)	61 (10)	165 (26)	1905-'12	168 (35)	66 (14)	250 (51)
Vieques, 1903-'12	241 (42)	86 (15)	249 (43)	1903-'12	363 (63)	39 (7)	169 (30)	1905-'12	183 (38)	60 (12)	236 (50)

In Table II is given the distribution of the signs of the differences. The numbers in parentheses give the same distribution when the total number is equal to 100.

Table III contains the differences of the daily means (for horizontal and for vertical intensity) on each two consecutive quiet days (magnetic character 0.0 to 1.1) for Pola, Potsdam, O'gyalla for a few years. At Pola for  $\Delta V$  there were taken those consecutive quiet days in which the daily amplitude was less than the mean daily amplitude for the month.

The distribution of signs in percentages, and the total number of dates, are contained in Table IV.

TABLE III.

Year	POLA		POTSDAM		O'GYALLA	
	$\Delta H$	$\Delta V$	$\Delta H$	$\Delta V$	$\Delta H$	$\Delta V$
1903	$\gamma$ +2.6	$\gamma$ -0.7	$\gamma$ +1.6	$\gamma$ +0.1	$\gamma$ .....	$\gamma$ .....
4	1.8	+0.4	+2.3	-0.8	.....	.....
5	2.5	-0.5	+1.6	-1.5	.....	.....
6	1.7	-0.8	+1.6	-0.8	+3.0	+0.4
7	2.6	-0.3	+2.7	-1.3	+1.4	-1.5
8	1.7	-0.6	.....	.....	+3.0	-0.9
9	2.1	-0.1	.....	.....	.....	.....

TABLE IV.

Station	$\Delta H$				$\Delta V$			
	+	0	-	Total No. of dates	+	0	-	Total No. of dates
Pola, 1903-'09	71	1	28	567	45	1	54	795
Potsdam, 1903-'07	86	0	14	50	27	2	71	164
O'gyalla, 1906-'08	76	2	22	46	38	4	58	290

Some attempts with Tokyo, Manila, and Mauritius did not give as definite a result, but throughout there is a tendency for the plus sign in  $\Delta H$ , and the minus sign in  $\Delta V$ .

From the two consecutive midnight values on calm days, exhibited in the Preface of the "Bulletin des Observations," we have for Zikawei (east declination positive):

Year	$\Delta D$	$\Delta H$	$\Delta V$
1904	+0.17	+2.9	-1.8
1905	.01	1.8	2.8
1906	.04	3.2	0.9
1907	.02	2.6	0.2

In all these cases there is a strong tendency to give + a sign for  $\Delta H$ , and a - sign for  $\Delta V$ .

Although the above calculations embrace only a few years, yet they show the general tendency towards regularity of the differences of daily means on two consecutive quiet days.

2. If on two consecutive quiet days we form the difference for every hour, we get what we may consider as the "non-cyclic" change for the different hours. Forming the difference of every hour and diminishing these differences by the difference of the daily mean values on these two consecutive quiet days, we get the diurnal inequality of the non-cyclic change. This diurnal inequality shows how the difference of the daily means on the two consecutive quiet days originated.

Proceeding in this way my expectation of finding a regular daily inequality has not been entirely fulfilled. Although there was a tendency to regularity, I could not get a definite result. But things changed when I separated those pairs of consecutive quiet days, whose differences were positive, from those with negative differences. And I found a regular inequality, which may be expressed as follows:

From the morning hours (about 7<sup>h</sup>-9<sup>h</sup> a. m.) to the afternoon hours (4<sup>h</sup>-6<sup>h</sup> p. m.) the differences are of the same sign as the difference of the daily means; during the night hours they are of contrary sign. Or, in other words, if the difference of the daily means on two consecutive quiet days is  $\begin{cases} \text{positive} \\ \text{negative,} \end{cases}$  then the differences from morning (about 7<sup>h</sup>-9<sup>h</sup> a. m.) till afternoon (about 4<sup>h</sup>-6<sup>h</sup> p. m.) are  $\begin{cases} \text{greater} \\ \text{less,} \end{cases}$  and during the night (about 6<sup>h</sup> p. m. to 7<sup>h</sup> a. m.) they are  $\begin{cases} \text{less} \\ \text{greater,} \end{cases}$  than the difference of the daily means.

This rule holds good for the declination as well as for the horizontal and vertical intensity. For Sitka (probably on account of the disturbances, which play here a greater part) the rule is not so conspicuous in all the years, as for the other stations of the Coast and Geodetic Survey, to which the investigations apply.

As a sample, I give in Table V the results for Baldwin in 1907. In the second column we find the mean value of the differences on two consecutive quiet days, in the third column the number of those pairs of days, from which the results have been derived. The daily inequality values given in Table V are smoothed-out values, obtained by the formula  $\frac{a+2b+c}{4}$

My investigations so far do not show a definite difference in this inequality at different places, but more exhaustive researches may disclose them. There remains the possibility that the inequality, stated above, may be only a consequence of the fact that, in general, the elements are changing more during the day time than during the night.

3. The daily amplitude in the diurnal inequality gives, in general, a hint about the character of a day in such sense, that on disturbed days the amplitude is larger. Proceeding from this remark, I took the observational data for Pavlovsk and divided the days into two classes, viz.: those in which the amplitude is less or equal (class *a*), and those in which it is greater than the average daily amplitude of the month (class *b*). In case very great disturbances have taken place on some days, the average daily amplitude of the month has been corrected by omitting these highly disturbed days. But such corrections, in most cases, did not considerably affect the mean monthly amplitude given in the publications.<sup>3</sup> Calculating the differences of the daily means on such two consecutive days, we form two groups of these differences. In the first group (*A*), we put the differences of all the consecutive days belonging to class *a*; in the second group (*B*), we put the differences of all other consecutive days belonging either both to class *b*, or the one to class *a*, the other to class *b*. In this way

<sup>3</sup> *Annales de l'Observatoire Physique Central Nicolas.*

we have obtained the results for the horizontal intensity ( $\Delta H$ ) and the vertical intensity ( $\Delta V$ ), exhibited in Table VI. Some very large disturbances have been excluded and sometimes the difference between the first day of a month and the last of the preceding month has been omitted.

The mean differences in Table VI show a very peculiar character. Comparing columns 5 and 9 for  $\Delta H$ , 13 and 17 for  $\Delta V$ , we see that the differences in group *A* have the opposite sign to those in group *B* (except  $\Delta V$  in 1898). The differences in group *A* have the same sign that has been found for the non-cyclic variation on quiet days. This opposite character of groups *A* and *B* illustrates the fact already mentioned and discussed by Chree (*Studies in Terrestrial Magnetism*, pp. 29-31) that the non-cyclic change on disturbed days is of opposite sign to that on quiet days. Taking into account that in the majority of cases disturbances tend to diminish *H* and increase *V*, this seems quite natural. The return from the disturbed values to the former undisturbed values takes place, in general, in the form of quiet days, and thus the differences of the daily means on two consecutive quiet and two consecutive disturbed days must generally be opposite in sign. In this conception what we consider as "non-cyclic" change on quiet days might be considered what Doctor van Bemmelen called "Magnetische Nachstörung."

The method we followed for Pavlovsk, when applied to other stations, does not always give such definite results as above. Thus, for instance, some attempts made with the observational data of Greenwich show for the horizontal intensity (1897-1906) that although there is a tendency to give positive differences for the group *A* and negative for *B*, this rule does not hold for every year. Potsdam gives results similar to those of Pavlovsk, but the investigations have only been made for two years (1905-1906). The results are:

	1905	1906
	$\gamma$	$\gamma$
$\Delta H$ , group <i>A</i>	+1.9	+1.3
" <i>B</i>	-1.0	-0.9
$\Delta V$ , group <i>A</i>	-0.8	-0.5
" <i>B</i>	+0.6	+0.3

TABLE V. Baldwin, 1907.

		1h	2	3	4	5	6	7	8	9	10	11	Noon	13h	14	15	16	17	18	19	20	21	22	23	24
	'	'	'	'	'	'	'	'	'	'	'	'	'	'	'	'	'	'	'	'	'	'	'	'	'
	'	'	'	'	'	'	'	'	'	'	'	'	'	'	'	'	'	'	'	'	'	'	'	'	'
$\Delta D$	+34	-11	-08	-06	+01	+03	+10	+12	+10	+25	+38	+21	+18	+06	-04	-05	+02	00	-12	-19	-21	-25	-25	-25	-22
$\Delta D$	-28	+24	+18	+13	+15	+10	+03	+04	+03	+02	-01	-08	-23	-41	-46	-33	-14	-02	+03	+09	+15	+16	+16	+20	+24
$\gamma$	51	14	15	17	17	14	10	07	00	+01	+26	+34	+24	+28	+21	+14	+08	+02	00	-03	-07	10	-04	15	13
$\Delta H$	+3.8	-2.7	+2.6	+2.9	+3.4	+1.7	+1.1	-0.2	-2.0	-4.7	-9.2	-9.0	-6.9	-4.0	-2.9	-2.2	+0.1	+2.4	+4.0	+4.7	+4.4	+4.6	+4.8	+3.9	3.3
$\Delta V$	+3.5	+2.1	+1.6	+1.7	+1.4	+0.9	-0.5	+0.2	+1.7	+3.4	+4.9	+5.5	+5.3	+2.3	+2.3	-0.1	-0.2	-0.6	-0.9	-1.4	-2.0	-1.5	-2.0	-2.3	2.3
$\Delta V$	4.6	+2.9	+2.9	+2.6	+2.3	+1.7	+0.8	+0.2	-0.5	-1.2	-1.8	-2.7	-3.6	-3.5	-2.3	-1.4	-1.3	-1.1	-0.5	+0.2	+1.0	+1.8	+2.1	+2.1	+2.3

TABLE VI. Pavlovsk.

Year.	$\Delta H$ , GROUP A				$\Delta H$ , GROUP B				$\Delta V$ , GROUP A				$\Delta V$ , GROUP B			
	Distribution of signs.			Mean of Differences.	Distribution of signs.			Mean of Differences.	Distribution of signs.			Mean of Differences.	Distribution of signs.			Mean of Differences.
	+	0	—		+	0	—		+	0	—		+	0	—	
1897	65	14	28	$\gamma$ +1.40	119	22	114	$\gamma$ — .67	46	32	72	$\gamma$ — .41	94	16	96	$\gamma$ + .73
98	76	12	24	+1.38	116	25	113	— .50	42	32	75	— .56	108	18	80	— .14
99	87	10	21	+1.30	115	28	102	— .33	48	38	72	— .27	90	19	70	+ .18
1900	80	12	28	+0.93	112	28	101	— .51	57	36	83	— .41	68	32	78	+ .30
01	88	17	39	+0.90	72	25	105	— .65	42	43	77	— .45	81	30	81	+ .21
02	71	37	45	+0.44	88	28	87	— .36	58	47	83	— .29	70	35	63	+ .32
03	81	15	36	+1.27	100	24	101	— .67	50	30	78	— .42	78	28	89	+ .22
04	86	14	39	+1.22	116	22	86	— .70	44	43	93	— .58	80	23	70	+ .42
05	65	12	28	+1.58	118	19	116	— .81	39	23	84	— .86	94	21	96	+ .42
06	62	19	27	+1.03	119	13	118	— .63	31	34	68	— .51	96	32	95	+ .27

We are aware that putting in the same group  $B$ , the pairs of days  $ba$  (consisting of one day of class  $a$  and a precedent day of class  $b$ ) with those formed by two consecutive days of class  $b$  and with the pairs of days  $ab$  (a day of class  $b$  and the precedent day of class  $a$ ) impairs our above reasoning since the day group  $ba$  might, according to the above assumption, rather be put in group  $A$ . But the number of these pairs ( $ba$ ) in comparison with those of  $bb$  and  $ab$  is small, and our interpretation of the opposite signs of groups  $A$  and  $B$  will, in the main, be correct.