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On the Diurnal Variation of Air-Earth Current at Kakioka.
(First report)

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Abstract

Diurnal variations of air-earth current obtained by indirect method at a small farm village, Kakioka, are given, and they are compared with the similar results observed in suburb of Tokyo.

Visual observations of electric conductivity of air were carried out[1] every five days during the year 1945 at Kakioka magnetic observatory. The instrument used was a Gerdien's aspiration type constructed by the workshop of the observatory, and the electrometer was so adjusted that it has such a high sensibility as 0.5 volts per division in order to finish in six minutes both observations of positive and negative conductivity. Hourly values were obtained by averaging observed values in six minutes before and after the corresponding hours. The number of days of observations in all were 71, and they were carried out independently on meteorological conditions.

As the potential gradient was continuously recorded at Kakioka, it was possible to obtain hourly values of it from the recordings on the corresponding days of conductivity observation.

From these data, air-earth current i was calculated by the following formula
$$i = (\lambda_+ + \lambda_-) E,$$
where λ_+ and λ_- are positive and negative conductivity of air respectively, and E is potential gradient of the earth's electric field.

Kakioka is a small farm village of which population is about 5.000, situated at 60 km north-east ward from Tokyo, and it is surrounded almost by rice-fields and woodlands. The nearest town populating 15,000 is found at 12 km east ward, and there is no large industrial work in the circle area of diameter of 40 km with it's center at Kakioka.

The values of air-earth current at Tanashi which were observed by T. Aoki and K. Kato[2],[3] are given to compare with those at Kakioka. They did not observed air-earth current directly but calculated it from λ and E as the case of Kakioka, and only difference at Tanashi is that λ was obtained from observed ion

number and it's mobility.

Tanashi is situated in the western suburb of Tokyo, therefore it is considered that any effect of pollution on conductivity of air will be larger at Tanashi than at Kakioka.

Hourly mean values of air-earth current for each month at Kakioka obtained from whole days of obsevation are given in Table 1, giving the numbers of observed days in the second line from the bottom.

Table. 1. Mean hourly values of air-earth current for each month for all days of observationat Kakioka. ($\times 10^{-16}$ Amp/cm²)

Month \ Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1	1.46	1.74	0.79	2.52	1.04	1.25	2.27	1.45	1.18	0.66	3.55	2.06	1.64
2	1.35	1.93	2.04	1.78	1.34	1.79	2.14	1.29	1.09	0.67	2.37	2.87	1.72
3	1.64	1.56	2.28	1.26	1.06	1.68	2.96	1.25	1.24	1·67	3.28	2.57	1.79
4	1.89	2.22	1.41	1.20	0.77	2.08	1.76	1.27	1.49	1.55	3.45	2.09	1.77
5	1.60	1.87	2.04	1.11	0.45	2.16	3.66	1.80	1.29	1.48	3.59	2.61	1.97
6	1.48	1.72	3.02	2.10	0.96	2.63	5.03	1.51	1.37	1.26	1.86	1.34	2.02
7	1.34	1.29	1.26	2.59	1.50	2.30	2.96	0.86	2.83	1.66	1.19	1.07	1.74
8	1.25	1.42	1.40	1.39	1.31	-13.37	2.34	0.93	2.53	1.90	3.73	1.24	0.50
9	1.12	1.18	1.44	1.75	1.50	-37.62	1.06	0.67	1.77	2.42	2.18	1.53	1.75
10	1.43	1.00	0.23	0.68	1.22	1.21	1.64	1.00	1.91	-2.54	1.84	1.75	0.91
11	1.19	1.29	1.13	0.70	0.98	0.96	1.12	0.93	1.29	-0.95	1.43	1.38	0.95
12	1.04	0.83	0.39	0.65	1.05	0.76	1.13	0.83	1.21	-0.97	1.36	1.54	0.82
13	0.84	0.84	-0.26	0.56	0.69	0.73	1.04	0.68	1.04	-1.18	1.20	1.30	0.63
14	1.05	1.31	1.24	0.62	0.69	0.81	1.35	0.74	0.90	-5.60	1.52	1.66	0.44
15	1.22	2.47	1.66	0.85	0.76	0.70	1.39	0.75	0.82	-10.30	1.61	1.42	0.28
16	1.02	2.12	0.79	0.84	0.86	0.83	0.59	0.71	0.93	0.92	0.96	1.71	1.02
17	1.09	1.09	0.71	1.07	1.58	0.92	6.11	0.76	2.66	0.67	0.33	1.87	1.57
18	0.77	2.27	0.89	10.55	0.54	-5.89	3.60	0.85	1.05	0.02	0.86	1.33	1.40
19	0.68	-0.54	0.33	0.68	0.77	0.89	1.26	0.74	0.89	1.05	2.21	1.46	0.87
20	-0.55	2.42	1.12	0.93	0.67	8.78	1.07	0.88	0.72	2.84	2.77	2.52	2.01
21	-0.48	1.63	0.67	1.25	0.38	4.89	0.72	0.79	0.98	0.01	0.67	1.98	1.12
22	1.39	1.81	0.13	1.58	0.53	1.30	1.86	0.71	1.17	1.24	1.75	2.15	1.30
23	1.05	2.81	1.33	1.83	0.71	1.12	1.91	1.02	0.90	3.31	2.13	2.36	1.71
24	-1.53	1.86	1.07	1.81	0.64	1.59	1.29	1.20	1.19	1.25	2.01	1.86	1.19
No. of days obsered	7	6	6	5	6	6	6	5	6	6	6	6	71
Mean	0.94	1.61	0.99	1.69	0.93	0.94	2.10	0.97	1.36	0.09	1.98	1.81	1.27

In Table 2 and 3, we find monthly mean hourly values deduced from calm days for Kakioka and Tanashi respectively, showing in the second line from base in Table 2 the number of adopted calm days at the former. It gives at most 6 days in September and only one day in March, accordingly it seems difficult to conclude that they represent the average diurnal variation of calm day for each month, although, they might give at least general tendency of the change. They are again represented graphically in A and B of Fig. 1.

Seasonal variations of diurnal change for both stations are given in Fig. 2. They

Table. 2. Mean hourly values of air-earth current of calm days observed for each month at Kakioka. ($\times 10^{-16}$ Amp/cm^2)

Month \ Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1	1.73	1.99	0.98	2.52	1.02	1.24	2.32	1.45	1.18	1.74	1.52	2.06	1.65
2	1.66	1.99	1.05	1.78	1.27	1.88	2.18	1.29	1.09	1.65	1.24	2.86	1.66
3	1.73	1.57	2.04	1.26	1.48	1.29	1.47	1.25	1.24	2.15	1.48	2.57	1.63
4	2.21	2.03	1.37	1.20	1.14	1.62	1.04	1.27	1.49	2.98	1.42	2.09	1.65
5	1.87	1.92	2.06	1.11	0.79	1.34	1.01	1.80	1.29	2.07	1.61	2.61	1.62
6	1.61	1.52	2.06	2.10	1.17	1.56	1.31	1.51	1.37	1.26	1.44	1.34	1.52
7	1.20	1.29	0.86	2.59	1.61	1.55	1.53	0.86	2.83	—	1.55	1.07	1.54
8	1.62	1.47	0.58	1.39	1.06	1.28	2.16	0.93	2.53	2.63	2.68	1.24	1.63
9	1.37	1.00	0.88	1.73	0.85	1.17	0.78	0.67	1.77	2.38	2.06	1.53	1.60
10	1.46	1.07	0.96	0.68	1.20	0.77	1.80	1.00	1.91	2.03	1.88	1.95	1.65
11	1.27	1.41	1.20	0.70	1.02	1.05	1.15	0.93	1.29	1.33	1.58	1.43	1.20
12	0.99	0.90	0.47	0.65	1.04	0.72	1.23	0.83	1.21	1.52	1.31	1.57	1.04
13	0.72	0.81	0.70	0.57	0.94	0.70	1.11	1.04	1.35	1.21	1.00	0.90
14	1.06	1.04	0.81	0.62	0.76	0.77	1.48	0.74	0.90	1.02	1.82	1.36	1.03
15	1.18	1.65	1.34	0.85	0.80	0.70	1.55	0.75	0.82	1.17	1.98	1.52	1·19
16	0.89	1.08	1.04	0.84	0.83	0.89	1.29	0.71	0.93	1.52	1.29	1.97	1.10
17	0.97	1.11	0.46	1.07	0.83	0.70	1.86	0.76	2.66	0.66	1.17	1.87	1.18
18	0.87	0.97	0.99	0.94	1.32	0.88	1.30	0.85	1.05	1.25	1.20	1.33	1.08
19	0.78	1.14	1.02	0.68	0.97	0.70	1.45	0.74	0.89	1.16	0.95	1.46	0.99
20	0.85	1.16	0.70	0.93	0.80	1.52	1.15	0.88	0.72	1.23	1.00	2.52	1.16
21	1.27	1.44	1.21	1.25	0.64	0.90	1.36	0.79	0.98	1.20	1.62	1.98	1.22
22	1.57	1.75	0.81	1.58	0.80	1.25	1.87	0.71	1.17	1.67	1.71	2.15	1.42
23	1.46	2.13	1.19	1.83	0.89	1.27	1.74	1.02	0.90	1.89	1.89	2.36	1.55
24	1.31	2.00	1.01	1.81	1.14	1.24	1.36	1.20	1.19	1.72	1.41	1.86	1.44
No. of. days observed	4	5	1	5	4	3	5	5	6	3	3	5	49
Mean	1.33	1.44	1.07	1.29	1.01	1.12	1.47	0.97	1.36	1.63	1.55	1.82	1.34

Table. 3. Mean hourly values of air-earth current of calm days observed for each month at Tanashi. ($\times 10^{-16}$ Amp/cm^2)

Month \ Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1	1.10	1.15	1.04	0.78	1.08	0.43	0.36	0.41	0.67	0.98	1.08	1.68	0.87
2	1.09	1.06	0.98	0.84	0.70	0.51	0.27	0.41	0.72	1.20	1.11	1.50	0.87
3	1.10	1.10	0.93	0.94	0.71	0.51	0.31	0.48	0.88	1.27	1.13	1.49	0.90
4	1.10	0.88	0.92	0.88	0.68	0.49	0.37	0.50	0.92	1.38	1.31	1.59	0.92
5	1.05	0.96	1.00	0.88	0.68	0.59	0.37	0.53	1.04	1.45	1.20	1.66	0.94
6	0.91	0.89	1.03	0.77	0.76	0.56	0.52	0.57	1.04	1.34	1.27	1.53	0.91
7	0.84	0.78	0.94	0.81	0.83	0.57	0.62	0.69	1.15	1.25	1.04	1.33	0.89
8	0.79	0.90	0.98	1.00	0.88	0.62	0.67	0.81	1.38	1.38	1.11	1.03	0.99
9	0.80	1.01	1.39	1.08	0.84	0.64	0.76	1.07	1.62	1.40	1.27	1.28	1.16
10	0.94	0.82	1.24	0.94	0.77	0.55	0.71	1.04	1.25	1.21	1.50	1.50	1.08
11	0.71	0.84	1.12	0.88	0.62	0.51	0.59	1.00	1.31	1.04	1.24	1.24	0.94
12	0.67	0.61	1.03	0.79	0.48	0.43	0.49	0.85	1.00	0.85	1.17	1.26	0.79
13	0.63	0.51	0.88	0.58	0.42	0.43	0.51	0.80	0.66	0.77	1.11	1.25	0.69
14	0.55	0.51	0.84	0.55	0.49	0.39	0.41	0.67	0.55	0.75	1.02	1.09	0.63
15	0.61	0.56	0.72	0.44	0.47	0.39	0.47	0.63	0.57	0.73	0.90	0.95	0.61
16	0.54	0.60	0.75	0.52	0.46	0.34	0.49	0.59	0.57	0.71	0.78	0.77	0.59
17	0.52	0.60	0.78	0.60	0.55	0.38	0.50	0.53	0.59	0.65	0.75	0.75	0.60
18	0.41	0.54	0.81	0.54	0.57	0.42	0.52	0.42	0.46	0.64	0.60	0.62	0.58
19	0.41	0.60	0.73	0.51	0.44	0.41	0.42	0.36	0.40	0.56	0.66	0.83	0.55

Month Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
20	0.41	0.74	0.78	0.54	0.47	0.45	0.39	0.38	0.41	0.54	0.62	1.04	0.58
21	0.54	0.93	0.81	0.58	0.49	0.36	0.36	0.36	0.39	0.65	0.69	1.46	0.65
22	0.53	1.01	0.81	0.60	0.45	0.45	0.36	0.36	0.43	0.80	0.79	1.52	0.71
23	0.68	1.16	0.97	0.74	0.45	0.44	0.34	0.34	0.43	1.00	0.88	1.64	0.79
24	0.84	1.14	1.13	0.76	0.50	0.42	0.49	0.37	0.46	0.99	0.94	1.61	0.80
Mean	0.76	0.84	0.96	0.76	0.61	0.48	0.48	0.60	0.77	0.97	1.03	1.32	0.80
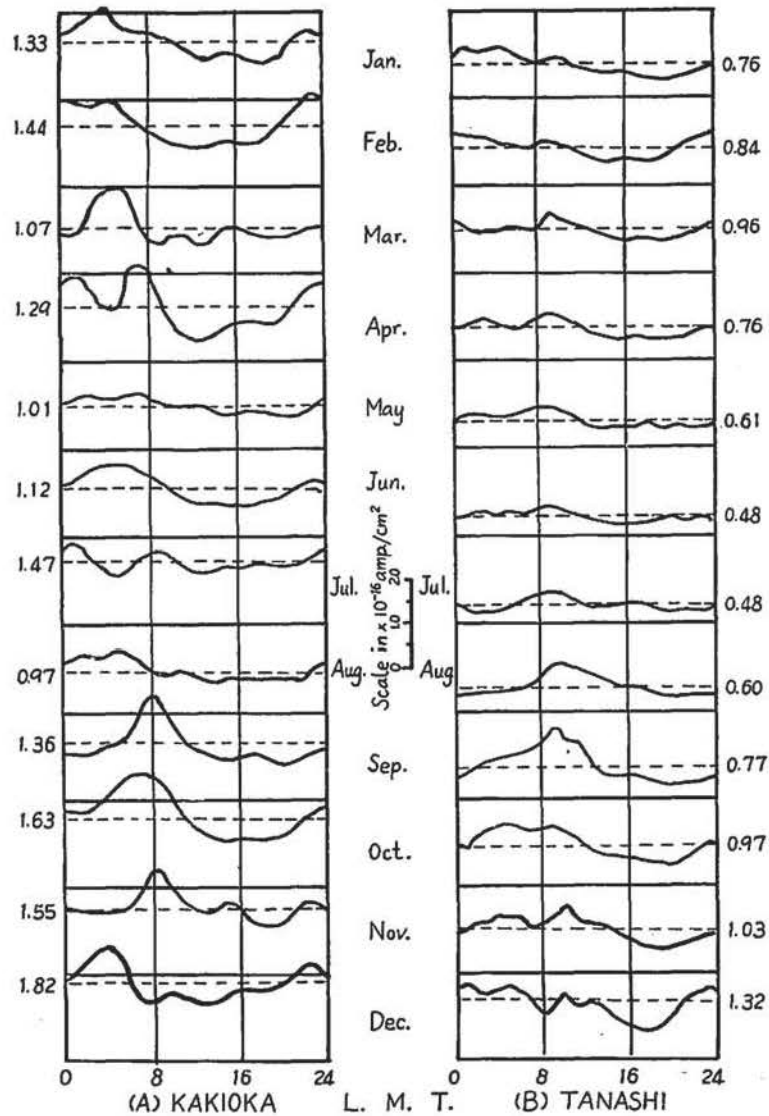
Fig. 1 Mean hourly values of air-earth current on calm
days for each month

run similarly in spring, summer and autumm, at each station, while the change is
different in winter at Kakioka. This characteristics of seasonal variation is also
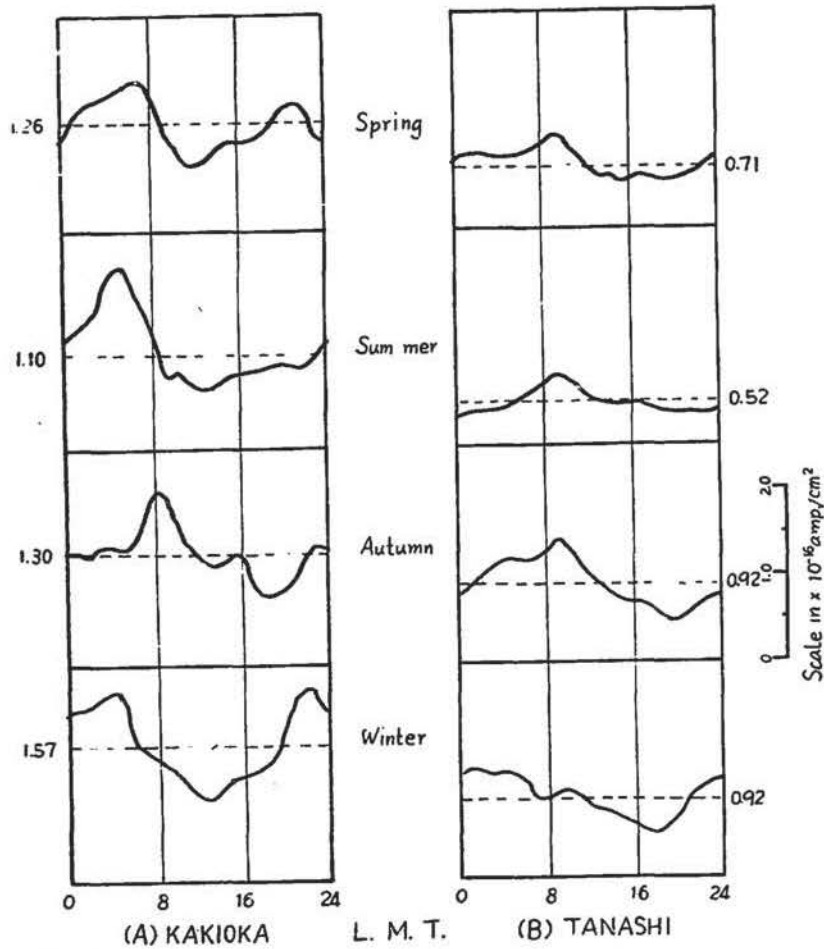found at Tanashi, and it is notable that the amplitude of the former is double

Fig. 2. Mean hourly values of air-earth current on calm days for each season.

that of the latter.

In Table 4 and in Fig. 3, we give diurnal variations of air-earth current at Kakioka, which are grouped according to meteorological conditions such as perfect fine, fine, cloudy and mist or fog, but thunderly and raining hours are omitted, because it is difficult to read complex variation of potential gradient on records. It may be worthy to notice that diurnal change for each weather has almost the same type of variation.

Table. 4. Mean hourly values of air-earth current for various weathers. at Kakioka. ($\times 10^{-16}$ amp/cm^2)

Weather Hour	Perfect fine	Fine	Cloudy	Fog or Mist
1	2.18(24)	1.35(14)	1.64(15)	2.27(6)
2	2.31(23)	1.46(13)	1.53(16)	2.06(7)
3	2.21(23)	1.93(11)	1.87(15)	2.29(8)
4	2.36(24)	1.74(8)	1.76(15)	1.88(14)
5	2.37(23)	1.30(6)	2.36(17)	2.89(13)

Hour \ Weather	Perfect fine	Fine	Cloudy	Fog or Mist
6	1.83(18)	1.23(6)	1.57(16)	2.18(20)
7	1.56(17)	1.42(3)	2.34(19)	2.22(19)
8	1.45(18)	2.21(5)	2.02(18)	1.89(18)
9	1.58(18)	1.01(6)	1.44(18)	1.48(18)
10	1.27(19)	1.48(12)	1.51(28)	1.59(9)
11	1.25(19)	1.17(11)	1.09(28)	1.56(9)
12	0.98(18)	1.20(12)	1.12(29)	1.03(9)
13	0.91(17)	0.87(14)	1.03(27)	0.89(9)
14	1.07(17)	1.01(12)	1.13(28)	0.87(7)
15	1.23(19)	1.33(13)	1.14(25)	1.23(7)
16	1.28(19)	1.05(12)	1.03(21)	0.94(7)
17	1.12(19)	0.88(11)	1.79(19)	0.96(4)
18	1.26(18)	0.99(13)	1.08(19)	0.81(2)
19	1.02(23)	0.66(9)	0.95(19)	1.34(2)
20	1.64(22)	0.87(10)	1.46(19)	0.84(2)
21	1.99(24)	0.93(10)	1.34(19)	1.36(2)
22	1.67(22)	1.04(10)	1.49(18)	1.79(3)
23	2.13(22)	1.21(11)	1.66(19)	2.18(3)
24	1.53(21)	1.18(12)	1.57(17)	1.85(6)
Mean	1.59(487)	1.23(244)	1.49(484)	1.60(204)

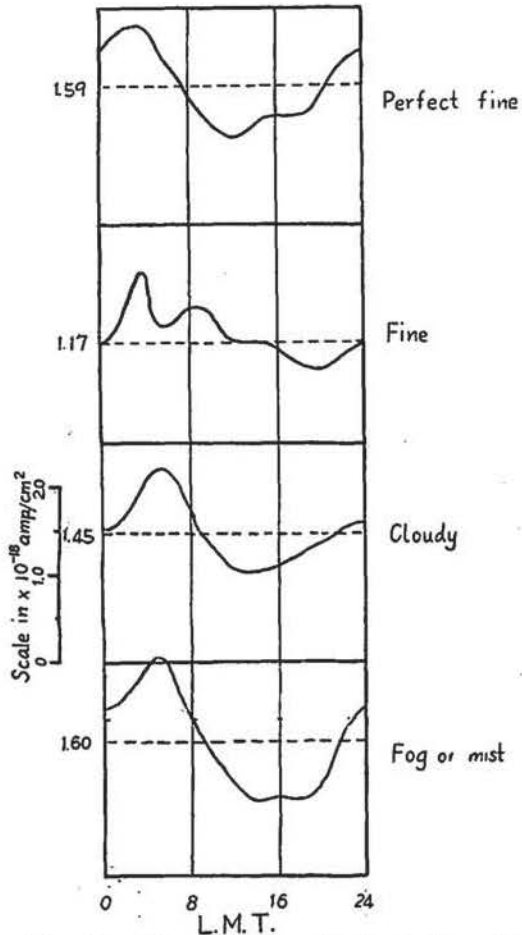Numbers of adopted samples are given in brackets.

Fig. 3. Mean hourly values of air-earth current for various weather at Kakioka.

Lastly, Fig. 4 gives diurnal variations of air-earth current and potential gradient at both stations, the former was represented in full line and the latter in dotted line.

Potential gradient at the above two stations change in similar manner in the cause of day and the amplitudes of the two show almost the same, while in air-earth current appreciable difference is found between the two stations before 10^h, though after that hour they take almost the same variation except in hours from 14^h to 18.^{h}

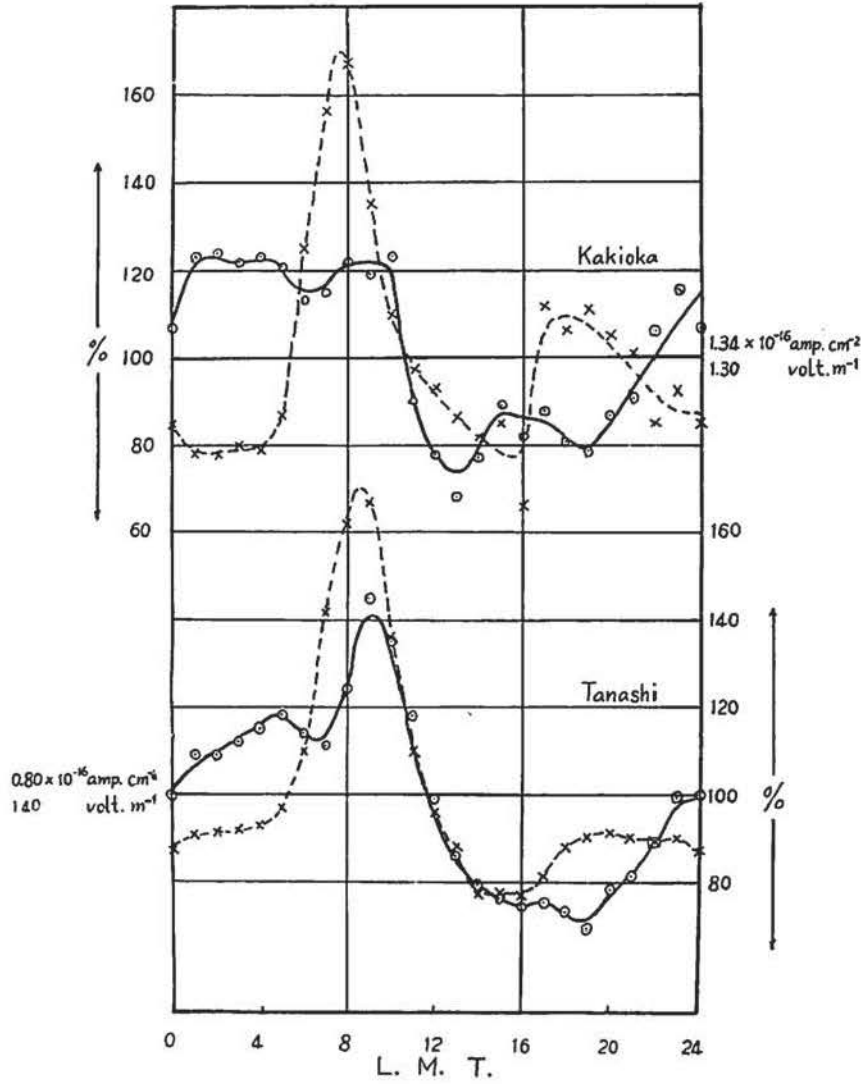Some discussion on these variations will be seen in the second report.

Fig6. 4 Diurnal variations of air-earth current (full line) and
potential gradient (dotted line) at Kakioka and Tanashi.

Reterence

(1) Report of the Kakioka Magnetic Observatory (1941-1945), Geoelectricity
(2) Aoki, T. and Kato K. : Atmospheric conductivity at Tokyo,
       Bulletin of the Institute of Electrics Experiment Vol. 17 No. 1. (1952)
(3) Aoki, T. : Researches of Atmospheric Electricity (Part 1) , Reseaches of
       the Electrotechncal Laboratory No. 494 (1948).