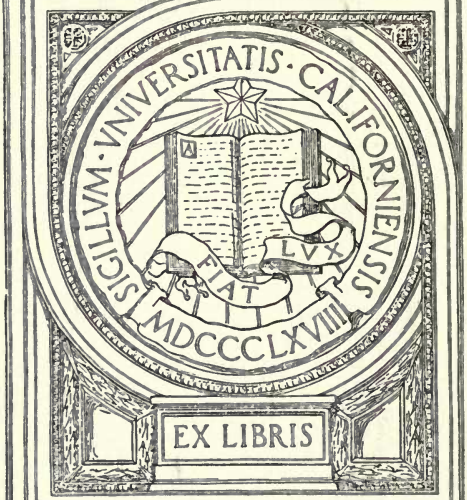

GROUND TEMPERATURE OBSERVATIONS

AT MANILA.

1896-1902.

By Rev. Fr. JOSÉ ALGUÉ, S. J.,

DIRECTOR OF PHILIPPINE WEATHER BUREAU.

March 19, 1902.

MANILA:
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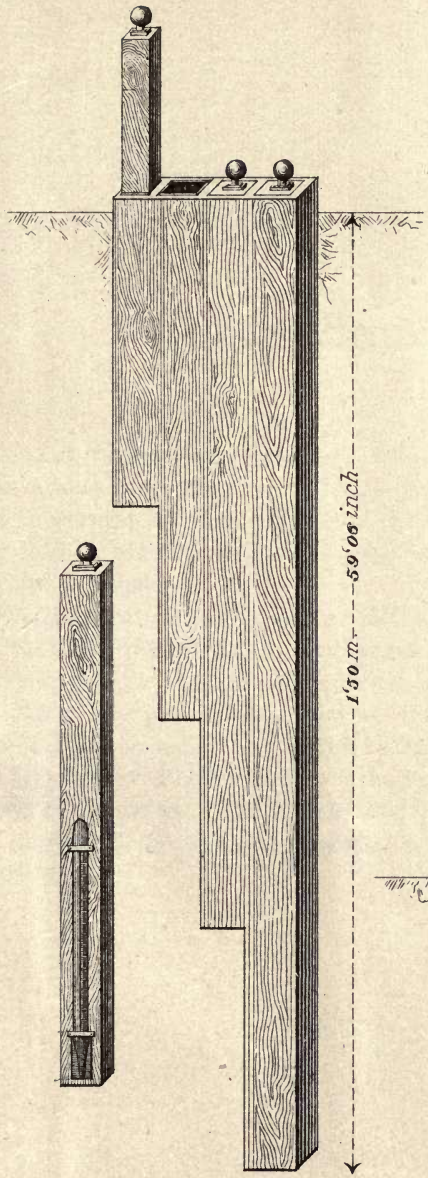


Fig.I

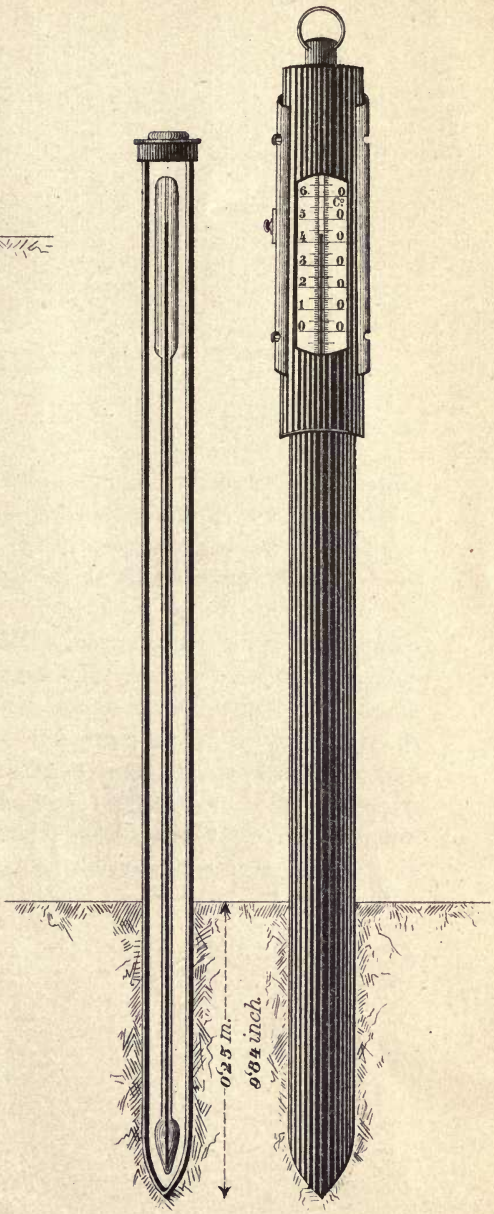


Fig.II

INTRODUCTION.

Ground temperature has been little studied, though the existing observations prove that the material gathered is quite as interesting as that concerning the temperature of the atmosphere and of the sea, and may lead to conclusions just as practical as that derived from the sea and the atmosphere.

The temperature of the ground is the most regular as to distribution and the most conservative in its changes. The subsoil of Manila is probably changing its thermic conductivity, as under the surface of the earth the water changes its level during the year, about 5 feet; that is, from a depth of about 4 to 8 feet. Underground temperature has been regularly observed in Manila since the year 1895 with four thermometers placed 59.06 inches, 29.53 inches, 17.72 inches, and 13.78 inches below the surface of the ground. Position of thermometers may be seen in Figure I.

TABLE I.

Day.	Hour.	May, 1901.			November, 1901.			February, 1902.		
		9.84 inches. 0.m25.	34.37 inches. 1m.	Air.	9.34 inches. 0.m25.	39.37 inches. 1m.	Air.	9.37 inches. 0.m25.	39.37 inches. 1m.	Air.
1	8 a. m	31.4	32.5	30.1	27.8	**29.2**	26.6	26.0	27.5	24.0
2	do	31.5	32.5	29.4	29.8	28.9	23.9	26.7	27.5	**24.6**
3	do	32.0	32.5	28.6	27.4	29.2	25.6	**26.8**	**27.8**	24.5
4	do	32.2	32.6	29.1	26.9	28.9	**23.3**	26.0	**27.8**	24.2
5	do	33.0	**32.4**	30.2	26.9	28.9	23.7	26.0	27.7	23.7
6	do	**33.5**	32.7	30.6	26.6	28.9	24.0	24.9	27.6	20.7
7	do	33.0	32.7	29.8	26.8	28.7	25.1	25.0	27.6	23.3
8	do	31.8	33.0	30.9	**25.9**	28.5	24.5	25.3	27.6	23.6
9	do	-------	-------	**31.2**	26.7	28.3	26.4	25.0	27.4	22.9
10	do	-------	-------	30.4	26.7	**28.0**	25.9	24.4	27.3	22.9
11	do	-------	**34.0**	30.9	27.7	28.4	**28.8**	24.4	27.4	22.9
12	do	31.4	33.0	28.3	27.7	28.3	27.3	25.0	27.3	23.4
13	do	31.6	33.0	29.2	27.8	28.4	26.2	25.4	27.3	23.9
14	do	31.1	33.0	29.3	26.8	28.4	26.2	25.0	27.1	23.3
15	do	30.2	32.8	**26.7**	27.3	28.5	27.1	24.9	27.2	23.2
16	do	30.2	33.0	27.9	27.2	28.4	26.8	23.8	27.1	**19.6**
17	do	**29.4**	33.0	28.8	27.5	28.5	27.4	23.7	27.2	20.4
18	do	**29.4**	**32.4**	27.8	27.6	28.4	24.7	23.7	27.0	20.8
19	do	-------	-------	29.3	27.6	28.5	25.3	23.8	27.0	21.6
20	do	30.9	32.4	28.9	27.3	28.5	25.6	23.7	26.9	20.9
21	do	31.7	32.8	30.1	27.8	28.6	26.5	23.9	26.9	22.3
22	do	31.8	32.8	28.7	**27.9**	28.7	26.1	**23.2**	26.8	20.6
23	do	31.8	32.8	28.9	**27.9**	28.8	27.7	23.4	26.8	20.6
24	do	32.2	32.8	30.2	**27.9**	28.8	26.8	23.6	26.8	20.7
25	do	32.0	33.0	30.3	26.6	28.6	23.9	23.9	26.9	22.8
26	do	31.6	32.8	29.3	26.9	28.6	25.5	23.9	**26.7**	21.6
27	do	31.4	33.6	29.8	27.1	28.7	25.7	23.5	26.8	22.2
28	do	31.0	32.8	27.8	27.4	28.5	25.7	25.1	26.8	23.7
29	do	31.1	33.0	29.9	27.8	28.5	26.6	-------	-------	-------
30	do	30.6	32.8	28.8	27.3	28.7	26.1	-------	-------	-------
31	do	31.0	33.0	28.6	-------	-------	-------	-------	-------	-------
Mean		31.3	32.8	29.3	27.3	28.6	25.8	24.6	27.2	22.5

TABLE II.

Day.	Hour.	February.				May.			
		1896.		1897.		1896.		1897.	
		59.06 inches. 1.m50.	Air.	59.06 inches. 1.m50.	Air.	59.06 inches. 1.m50.	Air.	59.06 inches. 1.m50.	Air.
1	8 a. m	28.2	24.4	27.9	24.5	30.3	27.8	**29.6**	29.8
2	do	**27.6**	**21.7**	27.9	23.7	30.3	29.5	29.8	29.4
3	do	28.2	25.4	27.6	24.3	30.2	27.7	29.7	29.9
4	do	28.0	24.2	27.8	24.1	30.1	28.8	29.7	30.0
5	do	28.2	25.0	28.0	26.1	30.0	26.2	29.8	30.2
6	do	28.0	**27.0**	27.6	23.7	30.2	**25.5**	29.7	28.6
7	do	28.2	24.8	**28.6**	25.1	30.2	28.6	29.7	29.4
8	do	28.2	24.9	27.9	25.2	30.2	29.5	29.7	29.6
9	do	28.0	25.9	28.0	24.6	30.1	28.6	**29.6**	31.3
10	do	28.3	23.1	27.8	25.1	**30.4**	27.6	-------	29.6
11	do	28.2	25.0	28.0	25.6	30.2	27.1	30.0	29.5
12	do	28.3	24.8	28.0	24.7	30.1	27.4	29.9	30.2
13	do	28.2	24.2	27.6	24.1	30.0	27.2	30.0	30.9
14	do	28.2	24.3	27.8	25.2	30.0	26.1	29.9	30.6
15	do	28.2	22.9	28.0	**22.4**	30.0	26.3	30.0	30.8
16	do	28.0	25.5	28.0	24.5	29.9	27.9	30.3	30.1
17	do	28.3	23.9	27.8	25.0	**28.8**	26.4	30.2	28.1
18	do	28.4	22.7	27.7	23.5	30.0	26.7	30.2	**31.5**
19	do	28.5	24.7	**27.5**	23.6	29.8	27.3	30.3	30.8
20	do	28.5	23.2	27.8	26.8	29.8	27.2	**30.5**	29.3
21	do	28.3	23.7	28.0	**27.2**	30.0	26.0	30.2	28.6
22	do	28.5	24.0	28.0	24.6	29.6	26.0	30.2	29.5
23	do	28.0	25.1	27.9	25.5	29.8	26.3	30.0	30.0
24	do	**28.7**	23.9	28.2	24.3	30.0	27.2	30.3	30.5
25	do	28.4	24.6	-------	23.7	29.7	29.3	30.2	30.0
26	do	28.5	24.2	27.9	25.0	29.8	**30.0**	30.2	29.9
27	do	28.4	23.7	27.7	24.5	29.8	29.4	**30.5**	27.2
28	do	28.4	23.8	28.5	25.3	29.6	29.7	30.2	27.1
29	do	28.5	22.8	-------	-------	29.8	29.6	30.2	**26.3**
30	do	-------	-------	-------	-------	29.9	28.9	30.4	28.6
31	do	-------	-------	-------	-------	29.8	28.9	30.2	30.1
Mean		28.3	24.3	27.9	24.7	29.9	27.8	30.0	29.6

TABLE III.—*Extremes of the underground (19.68 inches = ½ meter) temperature in Manila during the year 1901, taken from self-recording thermographs.*

Day.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	**28.7**	**27.8**	26.7	**26.1**	27.8	21.8	30.7	26.0	34.5	28.6	34.2	28.3	32.9	**28.2**	29.7	25.3	26.1	24.6	28.1	**26.2**	**27.0**	**22.5**	**25.7**	21.3
2	28.4	27.5	26.7	**26.1**	26.7	21.4	**29.7**	25.7	34.8	28.7	34.9	28.6	**33.1**	27.9	27.5	24.9	26.5	24.3	26.2	25.2	24.0	22.4	23.6	**21.5**
3	28.1	27.0	26.8	**26.1**	26.4	22.2	29.9	25.8	34.7	29.1	33.7	29.3	32.4	28.0	29.6	24.7	29.5	24.7	25.1	22.4	26.8	22.1	22.9	21.3
4	27.8	26.8	26.4	24.1	25.8	21.7	31.3	25.7	35.6	29.2	35.5	29.7	32.3	27.6	------	------	**25.9**	25.0	25.4	22.7	22.8	21.3	23.0	20.8
5	27.6	26.6	27.4	24.0	27.3	21.0	30.5	25.4	36.4	30.1	**35.7**	29.8	32.7	27.2	30.4	24.8	26.9	24.5	27.8	22.6	22.7	21.1	21.5	19.9
6	27.4	26.4	26.8	23.8	25.9	**20.6**	31.4	**25.1**	36.5	30.9	34.9	**29.9**	31.8	26.9	29.9	24.6	26.3	24.3	28.4	23.2	22.3	20.9	19.9	18.9
7	27.3	26.4	28.2	23.5	26.6	20.7	31.7	25.5	36.8	31.1	35.0	29.3	32.3	26.8	28.3	24.9	26.1	24.3	29.5	23.7	22.9	20.8	**18.9**	18.3
8	27.4	26.6	27.4	23.7	26.9	21.3	32.4	26.8	**37.1**	31.0	32.3	28.9	32.1	26.7	30.7	24.9	27.9	**23.9**	29.7	24.5	**21.7**	**20.5**	21.0	17.9
9	27.6	26.6	28.2	24.4	27.4	22.2	32.6	26.3	36.5	31.3	32.3	28.7	32.5	26.9	28.3	25.1	28.1	24.3	29.8	24.2	23.4	**20.5**	21.2	18.6
10	27.4	26.5	28.9	24.7	**24.6**	22.6	32.5	27.0	36.2	31.6	33.2	28.0	32.9	27.0	28.4	25.1	28.9	24.1	29.2	24.3	24.5	**20.5**	23.0	19.1
11	27.5	26.6	28.6	25.2	27.4	22.4	33.8	27.9	**37.1**	31.6	33.0	28.0	33.0	27.1	28.7	24.7	29.4	24.4	30.1	24.4	25.0	20.7	22.6	19.9
12	27.6	26.8	28.1	24.3	28.5	23.1	33.2	27.6	35.7	**31.7**	32.7	27.6	29.9	26.6	**25.9**	24.2	30.0	24.8	**30.2**	24.3	25.5	21.2	24.1	20.1
13	27.7	26.8	27.6	24.0	28.8	23.3	33.6	27.4	36.0	30.2	**28.9**	26.6	29.6	26.3	27.9	23.8	30.6	25.3	27.5	24.7	26.1	21.5	23.9	20.3
14	27.6	26.7	28.2	23.8	28.4	23.0	33.8	28.4	35.6	29.8	32.0	26.4	31.3	26.0	27.2	23.7	30.2	25.2	**24.0**	**21.7**	24.3	21.3	24.7	19.3
15	27.6	26.6	28.6	23.8	29.2	23.4	34.4	28.4	35.0	29.4	32.1	**26.2**	30.6	25.7	28.7	23.7	30.7	25.5	24.4	21.8	25.7	21.3	22.1	18.5
16	27.5	26.4	29.2	24.3	29.1	23.4	33.5	28.6	**31.3**	28.6	32.8	26.9	31.0	25.6	26.5	23.7	31.0	25.4	------	------	25.2	21.2	22.5	18.1
17	27.3	26.2	28.9	24.3	29.0	23.0	34.3	28.3	32.1	28.1	32.4	27.4	31.6	25.8	28.1	**23.5**	30.9	25.1	------	------	25.0	21.3	22.1	18.1
18	27.6	25.9	28.4	24.6	27.8	23.1	34.5	28.3	32.2	27.7	31.6	27.4	31.1	26.0	27.7	23.6	31.2	25.7	------	------	24.3	21.3	22.5	17.9
19	27.8	26.3	29.2	24.8	29.5	23.5	35.0	28.7	32.6	**27.5**	33.1	27.2	32.0	26.2	26.8	24.1	31.6	26.3	26.4	23.8	23.7	21.5	22.5	18.1
20	27.9	26.4	28.6	24.7	29.4	23.7	35.7	29.6	33.1	28.0	33.4	27.3	28.8	26.0	28.4	24.1	31.4	26.0	27.5	23.5	25.6	21.4	22.1	17.7
21	28.1	26.7	29.5	24.5	29.3	24.0	35.6	29.5	34.2	28.5	32.9	27.5	**26.7**	25.1	27.1	24.3	30.6	26.3	27.1	23.5	25.2	21.6	21.9	17.4
22	27.9	26.4	29.2	25.0	29.1	23.7	35.3	29.9	34.4	28.7	33.4	27.8	30.8	**24.6**	28.9	24.4	30.8	26.0	26.0	24.2	26.5	21.5	21.8	**17.2**
23	27.4	26.6	**29.8**	24.7	29.5	23.6	35.8	30.4	34.6	29.1	33.1	27.5	31.7	25.3	29.1	24.4	30.5	26.2	24.4	23.2	26.4	21.9	22.3	18.2
24	27.9	26.4	29.5	24.4	29.9	24.7	35.9	29.9	35.5	29.5	29.2	26.8	29.7	25.7	29.2	24.5	31.4	26.0	27.1	22.7	26.7	22.1	22.6	18.8
25	27.7	26.3	26.7	23.1	30.1	24.5	36.1	29.9	35.1	29.4	31.4	26.4	30.6	25.8	29.8	25.0	31.0	26.4	26.3	23.3	23.2	21.3	23.6	19.2
26	27.7	26.1	26.6	22.8	31.1	25.5	**36.7**	30.3	34.7	29.1	32.5	26.4	32.0	25.7	------	------	29.6	26.4	27.4	23.3	25.2	21.2	23.7	19.4
27	27.6	26.1	**25.6**	22.9	31.0	25.9	36.0	**30.6**	32.9	28.9	32.8	27.0	32.0	26.2	31.0	------	31.5	26.1	28.1	23.5	25.6	21.2	23.9	19.3
28	**26.7**	25.6	27.4	**22.5**	32.0	26.6	33.2	29.8	33.7	28.5	33.0	27.1	28.7	25.8	**31.2**	25.5	31.7	26.1	26.6	23.2	25.1	21.5	23.5	19.6

29	27.1	**25.4**	------	------	31.5	**27.5**	35.0	28.7	34.5	28.4	32.3	27.2	29.3	25.7	28.2	**25.9**	**31.9**	26.4	27.6	22.9	26.0	21.8	23.8	19.3
30	26.8	25.7	------	------	**32.7**	27.2	34.9	28.0	34.3	28.1	33.7	27.8	30.7	24.9	28.0	25.2	31.5	**26.8**	25.6	23.2	24.9	21.4	22.4	18.9
31	26.9	25.7	------	------	32.1	26.6	------	------	33.8	27.9	------	------	30.9	25.1	27.4	24.8	------	------	26.4	22.8	------	------	23.1	18.6
Mean	27.6	26.5	28.0	24.3	28.7	23.4	33.6	28.0	34.8	29.6	33.3	27.8	31.2	26.3	28.6	24.6	29.7	25.3	27.2	23.5	24.4	21.4	22.7	19.1
	27.05		26.15		26.05		30.80		32.20		30.55		28.75		26.60		27.50		25.35		22.90		20.90	

Observations were regularly taken at 8 a. m., at noon, and at 4 p. m.

Later on, three more underground thermometers, at the depth of 9.84, 19.68, and 39.37 inches, were also observed. Position of thermometers as per Figure II. Finally, two self-registering underground thermographs were set in operation recording the temperature at 19.69 inches and 39.38 inches below the ground.

Temperature at the depth of 9.84 inches offers no special interest except that the oscillation is less than that of the ground temperature and changes are undergone more slowly.

At a depth of 19.78 inches the variation of temperature is still less, but it is also affected by the air temperature. At 39.38 inches underground the thermic variations are much less and affected only at large by the air temperature. Finally, at 59.15 inches the underground temperature undergoes about the same variations as that at the depth of 39.38 inches, as may be deduced by comparing Tables I and II.

The above conclusions are shown by comparing Tables I, II, and III.

This comparison, and a general survey of the data, gives rise also to the following general results shown in Table IV:

TABLE IV.—*Air and underground extreme temperatures in Manila.*

Year.	Month.	Hour.	Position of thermometers.	Highest.	Lowest.	Difference.
				° C.	° C.	° C.
1896	February	8 a. m	In the air	27.0	21.7	5.3
1896	do	do	At 13.78 inches	29.7	28.0	1.7
1896	do	do	At 17.72 inches	29.5	28.0	1.5
1896	do	do	At 29.53 inches	29.0	28.0	1.0
1896	do	do	At 59.06 inches	28.7	27.6	1.1
1897	do	do	In the air	27.2	22.4	4.8
1897	do	do	At 13.78 inches	29.5	27.5	2.0
1897	do	do	At 17.72 inches	28.9	27.2	1.7
1897	do	do	At 29.53 inches	29.2	27.8	1.4
1897	do	do	At 59.06 inches	28.6	27.5	1.1
1901	do	do	In the air	24.8	20.3	4.5
1901	do	do	At 9.84 inches	26.6	24.0	2.6
1901	do	do	At 19.68 inches	27.8	26.7	1.1
1901	do	do	At 39.37 inches	27.9	27.2	0.7
1902	do	do	In the air	24.6	19.6	5.0
1902	do	do	At 9.84 inches	26.8	23.2	3.4
1902	do	do	At 39.37 inches	27.8	26.7	1.1
1896	May	do	In the air	29.7	25.5	4.2
1896	do	do	At 13.78 inches	33.3	27.7	5.6
1896	do	do	At 17.72 inches	32.4	28.6	3.8
1896	do	do	At 29.53 inches	31.5	29.8	1.7
1896	do	do	At 59.06 inches	30.4	28.8	1.6
1897	do	do	In the air	31.5	27.1	4.4
1897	do	do	At 13.78 inches	33.3	30.8	2.5
1897	do	do	At 17.72 inches	32.3	31.2	1.1
1897	do	do	At 29.53 inches	31.4	29.9	1.5
1897	do	do	At 59.06 inches	30.5	29.6	0.9
1901	do	do	In the air	31.2	26.7	4.5
1901	do	do	At 9.84 inches	33.5	29.4	4.1
1901	do	do	At 39.37 inches	34.0	32.4	1.6

TABLE IV.—*Air and underground extreme temperatures in Manila*—Continued.

Year.	Month.	Hour.	Position of thermometers.	Highest.	Lowest.	Difference.
				° C.	° C.	° C.
1896	October	8 a. m	In the air	28.6	24.4	4.2
1896	do	do	At 13.78 inches	30.1	28.2	1.9
1896	do	do	At 17.72 inches	29.6	28.9	0.7
1896	do	do	At 29.53 inches	30.0	28.9	1.1
1896	do	do	At 59.06 inches	29.4	29.0	0.4
1901	November	do	In the air	28.8	23.3	5.5
1901	do	do	At 9.84 inches	27.9	25.9	2.0
1901	do	do	At 19.68 inches	29.1	27.7	1.4
1901	do	do	At 39.37 inches	29.2	28.0	1.2

Changes in the air temperature during one month are quite similar through the whole year in cold months, as February; in temperate months, as October and November, and in the warmest months, as May. By taking, then, the mean changes for similar depths, we shall have the following results in Table V:

TABLE V.—*Change of temperature during one month at 8 a. m.*

Position.	° C.
In the air	4.7
Underground at 9.84 inches	3.0
Underground at 13.78 inches	2.7
Underground at 17.72 inches	1.76
Underground at 19.68 inches	1.3
Underground at 29.53 inches	1.2
Underground at 39.37 inches	1.1
Underground at 59.06 inches	1.0

From the ground to 19.68 inches below the change is decided, but farther down it is very small. If we calculated from the above data the change corresponding to different depths, every 10 inches, we would have:

TABLE VI.—*Change of temperature during one month.*

Position.	° C.	△
Above the ground	4.70	1.75
Underground 10 inches	2.95	
Underground 20 inches	1.28	1.67
Underground 30 inches	1.18	0.10
Underground 40 inches	1.08	0.10
Underground 50 inches	1.00	0.08
Underground 60 inches	0.91	0.09

It is then understood that during the year changes of underground temperature below 20 inches can not be very great. We will study specially the variations at 39.37 inches. From the records of the underground thermograph we take the following data given in Table VII:

TABLE VII.—*Mean underground temperature at the depth of 1 meter (39.37 inches) in Manila during the year 1901, taken at midnight.*

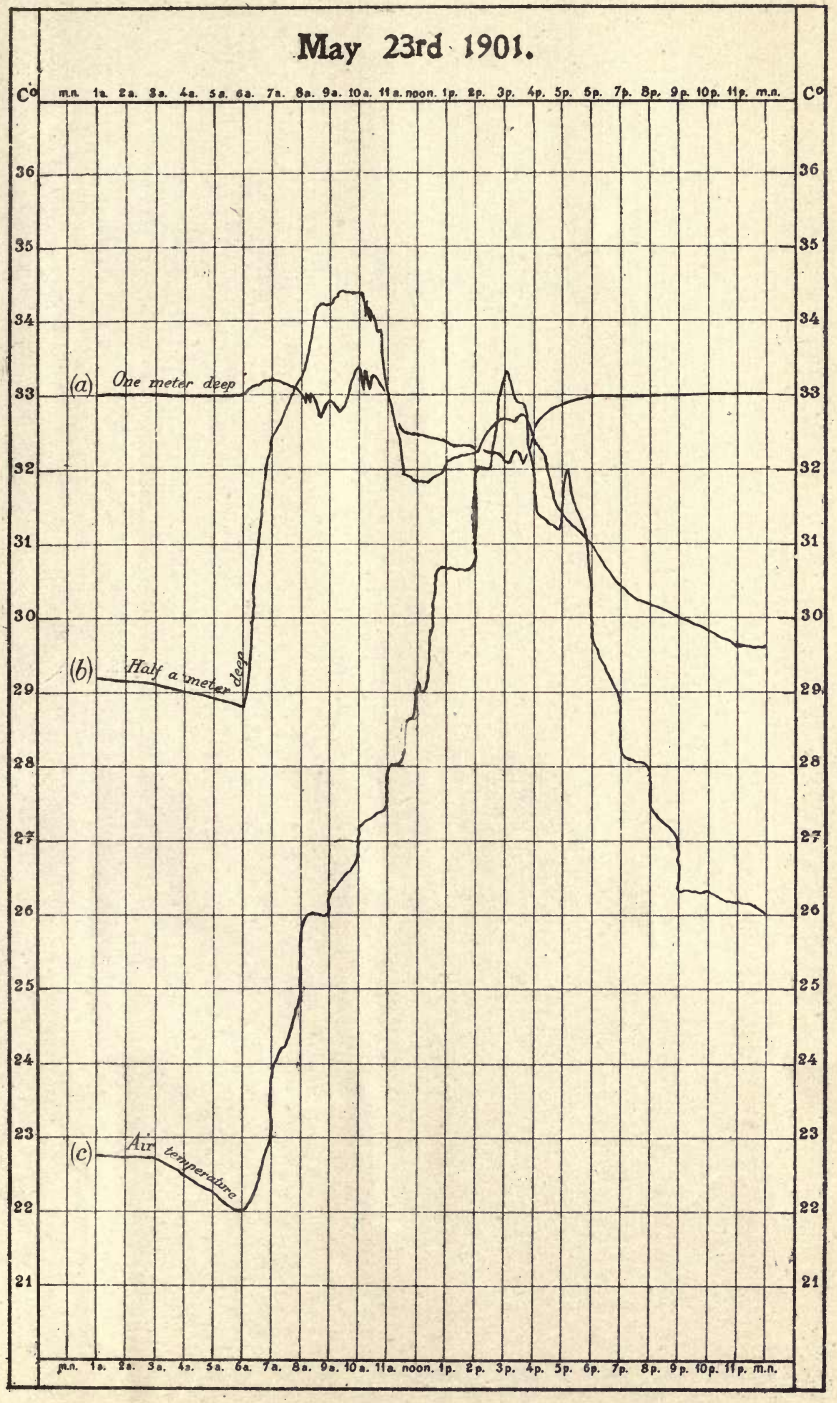
Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	28.0	28.0	29.2	31.0	33.1	32.9	32.1	**31.1**	------	**30.9**	29.7	**28.8**
2	28.0	28.0	29.2	31.1	33.1	32.9	32.1	**31.1**	30.7	**30.9**	29.5	**28.8**
3	28.0	27.9	29.2	31.0	33.1	33.0	32.2	**31.1**	30.6	30.2	**29.8**	28.7
4	27.9	**28.3**	29.1	**30.9**	33.2	33.0	32.1	**31.1**	30.5	30.1	29.2	**28.8**
5	**27.8**	28.0	29.1	**30.9**	33.4	33.1	32.1	30.9	30.4	30.1	29.1	28.2
6	**27.8**	28.0	29.0	31.1	33.4	33.1	32.2	30.9	**30.1**	30.0	28.9	27.8
7	28.3	28.0	28.9	31.2	33.7	33.1	32.2	30.9	30.4	30.1	28.8	27.9
8	28.4	28.0	**28.8**	31.0	33.8	33.1	32.1	30.8	30.3	30.1	28.6	27.7
9	28.4	27.8	28.9	31.2	33.9	**33.2**	32.2	30.9	30.2	30.1	28.6	27.3
10	28.3	27.9	28.9	31.3	33.9	32.9	**32.3**	30.9	30.2	30.1	28.4	27.5
11	28.4	27.8	29.0	31.4	**34.1**	32.9	32.1	30.8	30.3	30.1	28.5	27.7
12	28.5	27.8	29.0	31.6	**34.1**	32.8	32.1	30.7	30.3	30.1	28.5	27.8
13	28.5	27.9	29.1	31.9	33.9	32.7	32.1	30.7	30.4	30.1	28.4	27.9
14	28.6	28.0	29.1	32.2	33.9	32.4	32.0	30.4	30.5	**29.4**	28.4	27.9
15	28.6	27.8	29.2	32.2	33.9	32.4	31.9	30.3	30.5	29.9	28.4	27.7
16	28.6	27.8	29.4	32.3	33.4	32.5	31.9	30.2	30.9	30.0	28.2	28.1
17	28.5	**27.7**	29.6	32.4	33.3	32.3	31.9	30.3	31.0	29.9	28.4	28.0
18	**28.8**	27.9	29.7	32.4	33.1	32.3	31.9	**30.1**	31.0	29.7	**27.3**	27.9
19	28.7	28.0	29.8	32.5	33.2	32.3	31.9	30.4	31.1	**29.4**	27.6	27.9
20	28.7	28.1	29.8	32.7	**32.8**	32.2	31.8	30.5	31.1	------	------	27.8
21	28.7	28.2	29.8	32.9	32.9	32.3	31.7	30.5	31.1	29.9	------	27.8
22	28.5	28.2	29.9	32.8	32.9	32.4	31.9	30.4	30.9	29.9	28.8	27.4
23	28.5	**28.3**	29.9	33.0	32.9	32.5	31.9	30.4	31.0	29.8	28.8	**27.0**
24	28.4	**28.3**	30.1	33.1	32.9	**32.1**	31.9	30.6	31.1	29.9	28.7	27.2
25	28.5	**28.3**	30.2	33.3	32.9	32.2	31.9	30.7	31.0	29.8	28.8	27.3
26	28.5	------	30.3	33.4	32.9	32.2	31.8	30.4	31.1	29.7	28.9	27.2
27	28.4	------	30.4	**33.6**	32.9	**32.1**	31.9	30.2	31.1	29.9	28.8	27.3
28	28.2	28.2	30.6	33.4	33.0	**32.1**	------	30.8	31.2	29.9	28.5	27.4
29	**27.8**	------	30.8	33.1	33.0	32.3	31.2	30.9	**31.3**	29.8	28.7	27.5
30	**27.8**	------	**30.9**	33.1	32.9	32.4	**31.1**	30.8	31.1	29.6	28.6	27.4
31	**27.8**	------	**30.9**	------	32.9	------	**31.1**	30.8	------	29.9	------	27.1
Mean	28.3	28.0	29.6	32.1	33.3	32.6	31.9	30.7	30.7	30.0	28.7	27.8

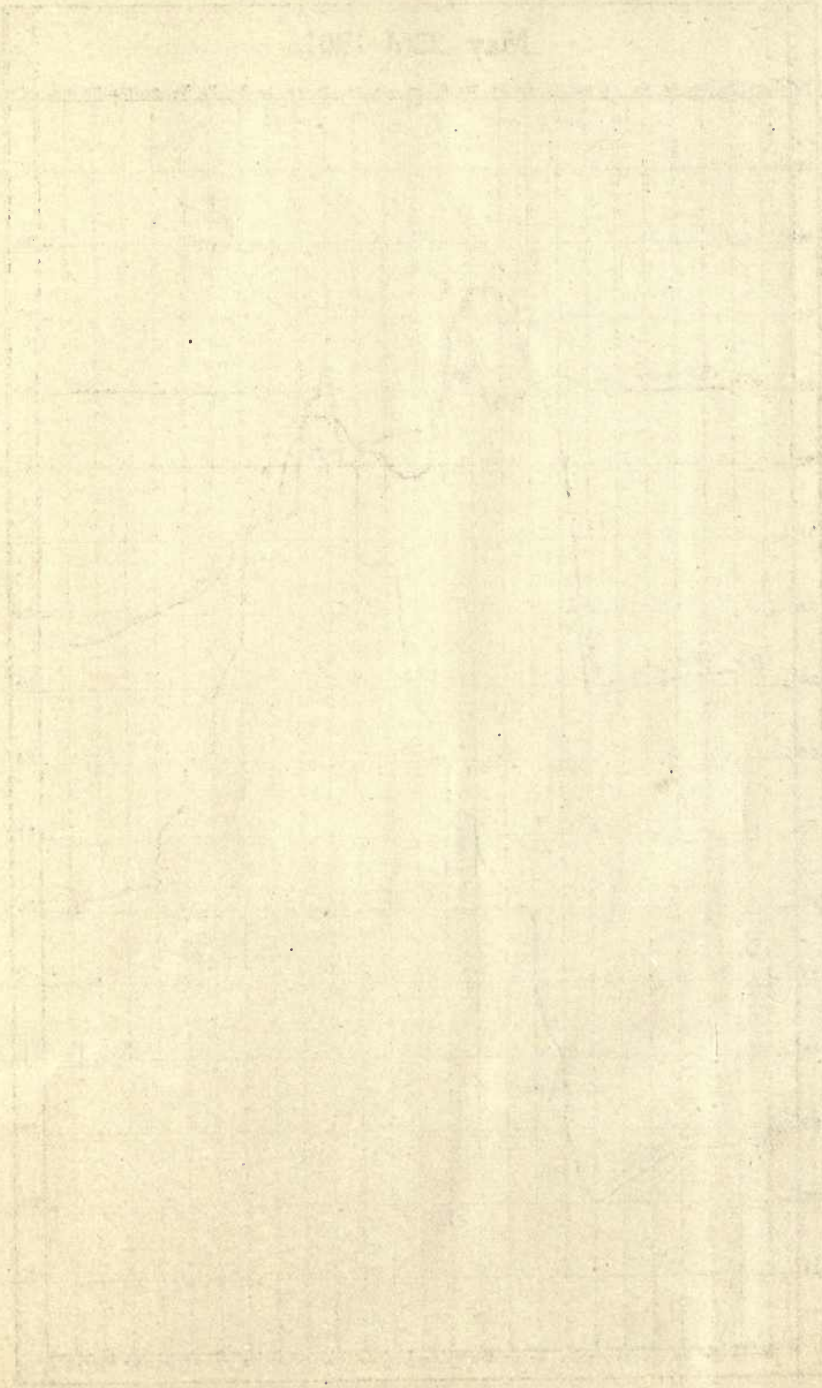
TABLE VIII.—*Mean underground temperature at the depth of 1 meter (39.38 inches) in Manila during January and February, 1902, taken from thermographs at midnight.*

Days.	Jan., 1 meter.	Feb., 1 meter.	Days.	Jan., 1 meter.	Feb., 1 meter.
1	27.3	27.7	11	27.1	27.4
2	27.1	27.9	12	27.0	27.7
3	27.3	27.9	13	27.1	27.6
4	27.3	28.0	14	27.1	27.6
5	27.5	28.0	15	27.1	27.7
6	27.3	**28.1**	16	**26.8**	27.7
7	27.3	28.0	17	27.0	27.5
8	27.2	28.0	18	27.1	27.5
9	27.1	27.3	19	27.1	27.6
10	27.0	27.8	20	27.1	27.6

AIR AND UNDER GROUND TEMPERATURES IN MANILA

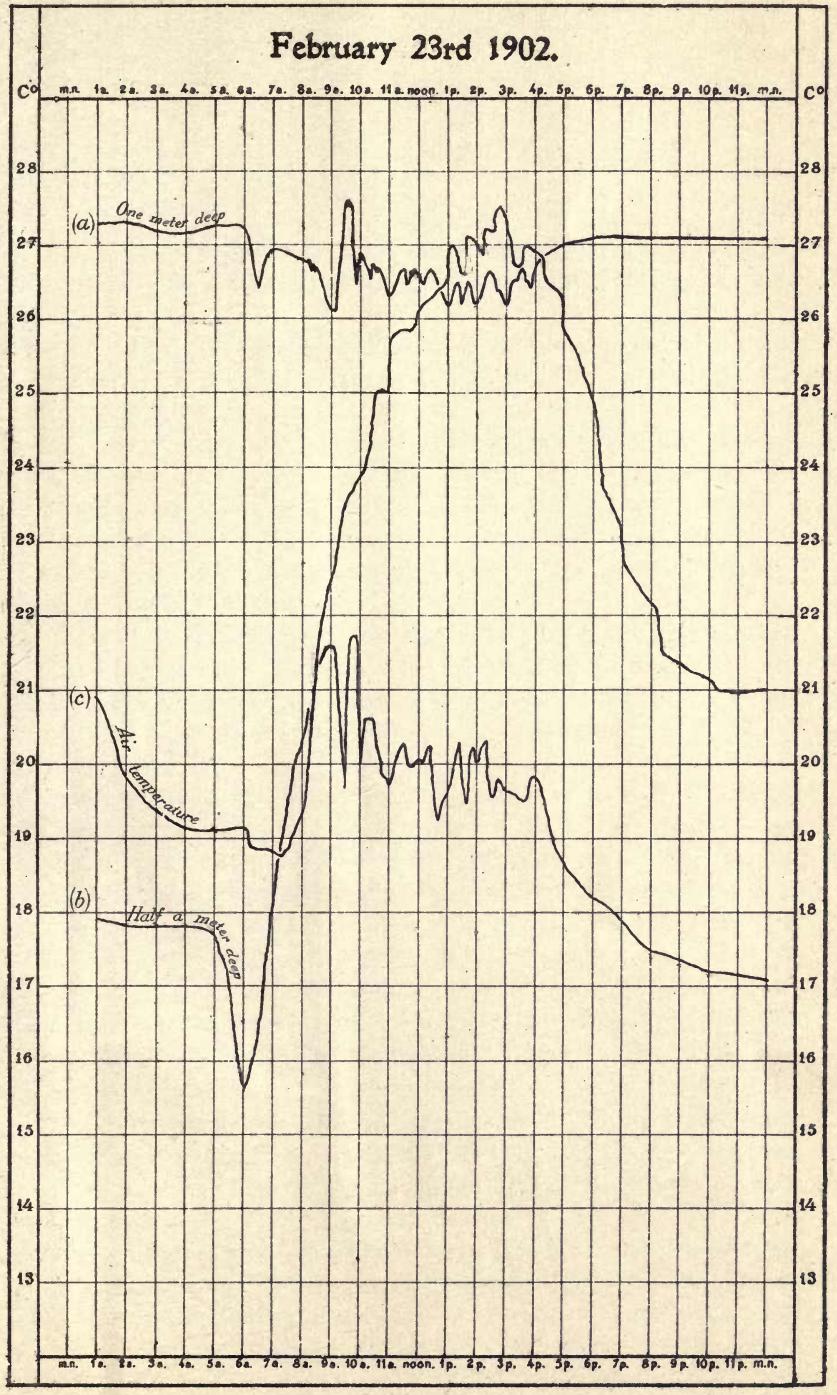
Plate I





AIR AND UNDER GROUND TEMPERATURES IN MANILA

Plate II



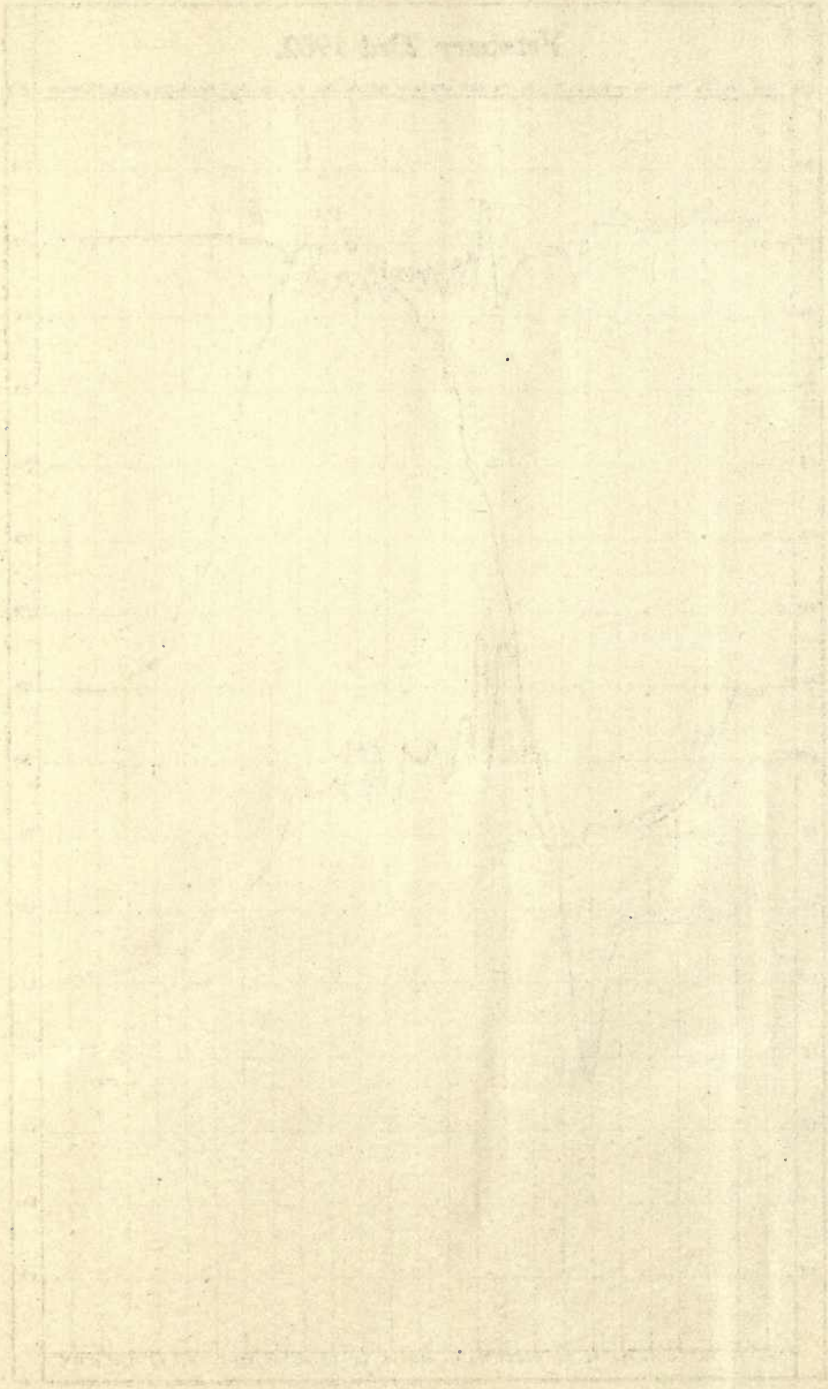


TABLE VIII.—*Mean underground temperature, etc.*—Continued.

Days.	Jan., 1 meter.	Feb., 1 meter.	Days.	Jan., 1 meter.	Feb., 1 meter.
21	27.2	27.5	28	27.3	27.0
22	27.5	27.4	29	27.4	----
23	27.6	27.2	30	27.5	----
24	27.6	27.0	31	27.6	----
25	27.8	26.8	Mean	27.3	27.6
26	27.8	26.9			
27	27.2	27.0			

During the night there is no variation of temperature, and the midnight record may be well taken as the mean temperature during the preceding day.

Table VII shows: First, that oscillation of temperature for one month ranges between 1.0° C. in January and August and 2.7° in April, the average change being 1.5 for each month.

Second, that the highest mean underground temperature during January and February, 1902, was lower than during January and February, 1901, because December, 1901, was colder than December, 1900, and colder days prevailed in January and February, 1902, than during the same months of 1901. Mean change during January and February, 1902, amounts to 1.1° C.

Plates I and II will illustrate the range of the air and underground temperature in one day. They are a reproduction of the diagrams from the thermographs. Plate I corresponds to an ordinary day in the warmest month and Plate II represents the range of temperature on an extraordinarily cold day.

Generally speaking, the plates show: First, that in the cool season underground temperature at half a meter, or 19 inches, ranges lower than the air temperature and at 1 meter (39 inches) oscillates around the maximum temperature at the air. Second, that in the warmest days the temperature under 19.69 inches from the ground ranges higher than the air temperature, and at 1 meter, or 39.38 inches, oscillates also around the highest temperature on the ground. Curves (*a*) and (*b*) in Plate I may be taken as a type of the thermic variation underground in the average days during the whole year. Curve (*b*) in Plate II is entirely extraordinary, as the deflection from 5 to 6 a. m. is unique in the diagrams for the whole year 1901 and part of 1902. Third, temperature at 39.38 inches is steady from sunset to sunrise, and at 19.68 inches from midnight to sunrise. Fourth, the maximum occurs about 10 a. m. both at 39.38 inches and at 19.68 inches, from 6 a. m. at both depths. Changes become more accentuated at 19.68 inches, the rise of temperature being very remarkable after 6 a. m. This may clearly explain why at 8 a. m. underground temperature at 19.68 inches is constantly higher than the air temperature, even during the cool season. Fifth, underground temperature is lower during the warmest hours above the ground.

GENERAL FEATURES OF THE UNDERGROUND TEMPERATURE AT 19.68 INCHES.

An accurate survey of the data in the diagrams and of Tables III and IV and of the curves of Plates I and II may give ground to establish the following facts about the temperature 19.68 inches below the ground in Manila.

First, the minimum of the year falls in December and the maximum in May.

Second, the minimum of the day, as a rule, occurs at 6 a. m., a secondary minimum being registered about noon. The maximum falls about 10 a. m.

Third, the daily oscillation ranges from 3° to 6° C., the greatest oscillation being registered in April and the smallest in the coldest months.

Fourth, temperature is nearly constant from midnight to 6 a. m.

GENERAL FEATURES OF THE UNDERGROUND TEMPERATURE AT 39.38 INCHES IN MANILA.

A close examination of the data and of Tables I, II, IV, V, VI, and VII, and of Plates I and II, confirms the following conclusions:

First, the minimum temperature, as a rule, falls in December, and the maximum in May.

Second, the absolute maximum in the year 1901 was registered on the 12th of May and the minimum on December 23.

Third, a large oscillation takes place from about 6 a. m. to 10 a. m., then a slight descent follows up to 11 a. m. From January to May temperature perseveres low to about 4 p. m., to rise again slightly till 5 p. m., and then remains steady all the night through till 6 a. m. next day.

Fourth, during the year the mean underground temperature oscillates between the mean annual maximum of the air temperature, but never rising so high, and the mean annual, but never descending so low. The mean annual maximum is 36.2° C., and the mean annual 26.8°.

Fifth, from June to September the hour of rising in the afternoon gradually recedes from 4 p. m., and from October to December gradually approaches to 4 p. m., the rest of the year being about 4 p. m., as stated before.

Sixth, the greatest change in twenty-four hours, 1.0° C., occurred on the 1st of March, 1901. The greatest change in one month, 2.7° C., was recorded in April and November, 1901.

"All these data," we may say with one distinguished meteorologist, Rev. Fr. L. Obenbach, S. J., commenting on his own data, "form very interesting knowledge for inquisitive minds, but would hardly be worth the time and trouble they have cost were it not for the fact that, brought into connection with certain theories advanced by medical science, they acquire an importance which few would suspect, but which the sanitary

authorities and the medical profession in general will not be slow in recognizing, and perhaps (such is our hope) they may assist in further clearing up and developing this matter which may one day stand side by side in importance with such theories as disinfection and sterilization."

Professor Pettenkofer, of Munich, a man of the highest reputation, at one time ascribed a powerful influence in the diffusion of cholera to the ground water of a locality where that disease was prevalent, shallow, porous soils affording, according to him, special facilities for the reception, development, and distribution of the so-called cholera germs.

Mr. Ernest Hart expressed the opinion that cholera, like enteric fever, cholera nostras, or cholerine, becomes much more virulent when the ground temperature at 4 feet reaches the critical point of 56° F. As this occurs most readily when the level of subsoil water is low, the significance of Pettenkofer's theory is at once evident. The fluctuation of subsoil water may have a secondary influence, but beyond this it has no significance.

Systematic observations at the meteorological observatory of Manchester, England, have convinced Dr. John Tatham, at one time medical officer of that city, and then medical superintendent of statistics at Somerset House, that in accordance with views held by Dr. Edward Ballard, F. R. S., when the temperature at the depth of 4 feet below the surface reached 56° F., infantile diarrhea may be expected to become epidemic in the city. This critical, or "temperature optimum," holds good for enteric fever and cholera as well as for diarrhea. This seemingly wonderful dependence between the prevalence of contagious diseases and the temperature 4 feet below ground is easily explained.

Contagious diseases, according to the best authorities, are propagated by minute vegetable organisms belonging to the class of *shizomycetes,* the third of the groups proposed by Mägeli. They are fission fungi, which produce putrefactive processes. They are very small, ranging from 0.001 mm. to 0.005 mm. Comparing them with a drop of water one twenty-fifth of an inch in diameter, we may say that 1,000 must be placed in a line to reach across, and that such a drop would contain 525,000,000 individuals. Their shapes vary from that of a minute sphere to that of a straight, curved, or twisted cylinder. Their growth is very rapid and propagation takes place by means of division. As the immediate result of nutrition, an elongation of the cell takes place, then its division into parts, this process being repeated and continued until hundreds of thousands are produced. It has been observed that a bacterium may divide once every half hour. At this rate the sum total of all new individuals will run into millions within the short space of twenty-four hours.

These pestilential broods swarm in the air, in the water, and enter the ground. Many of them have been recognized as the germs of disease. We know of a cholera, a typhus, a smallpox bacillus, and of many others besides, producing as many specific diseases. All these germs must

undergo modification or development after they leave the body of an infected person, and this is best done in the ground under certain conditions of temperature and moisture. The life of a bacillus depends on a certain amount of heat and water; so does its development. For each species of bacillus there is a *certain* amount of moisture and a *certain* temperature necessary; this temperature has been styled the critical, or *temperature optimum.*

To sum up all that is so far known regarding this matter, we will take Dr. Edward Ballard as our authority. He considers the following facts as well established. The subsoil temperature is, of all meteorological factors, by far the most effective element in the causation of diarrheal prevalence. He constructed for London and many other towns in the Kingdom a large number of charts showing, week by week, for many years the earth temperature at a depth of 1 foot from the surface, and at a depth of 4 feet also; each chart showing, in addition, the diarrheal mortality of the corresponding weeks. The general results shown by these charts are as follows:

1. The summer rise of diarrheal mortality does not commence until the mean temperature recorded by the 4-foot thermometer has risen to somewhere near 56° F., no matter what may have been the temperature prevailing in the atmosphere previous to that time, or recorded by the 1-foot thermometer.

2. The maximum diarrheal mortality of the year is usually observed in the week in which the temperature recorded by the 4-foot thermometer attains its weekly maximum.

3. The decline of diarrheal mortality coincides with the decline of this temperature at 4 feet below the surface, and since the change of ground temperature is not as rapid as is that of the atmospheric temperature, the epidemic may continue long after the atmosphere has been cooled down.

4. Atmospheric temperature exerts little, if any, influence on the prevalence of diarrhea until the 4-foot subsoil thermometer has risen to 56° F.; then its influence is apparent, but it is a subsidiary one. Minert, of Dresden, another great authority, holds the same views in an article on "cholera infantum."

This short exposition of a matter at once very interesting and highly practical will, we trust, serve to induce others to take up observations both on ground temperature and the prevalence of contagious diseases. Much remains to be done, and the sooner a start is made the sooner can we hope to deduce facts which may be of immense value to the whole of mankind.[1]

In Manila underground temperature never falls so low as in higher latitudes, and the subsoil thermometer at 4 feet is always higher than 56° F., or 13.33° C.; nevertheless changes in the subsoil may exert

[1]Ground Temperature Observations, Omaha, St. Ignatius College, 1900-1901, p. 10.

influence in the prevalence of disease also in Manila. In Table IX we compare the extremes of temperature at 19.68 inches and at 39.38 inches, and in the air, with the percentage of plague rats published in the Monthly Report of the Board of Health for the Philippine Islands and the City of Manila, for December, 1901.

TABLE IX.—*Relation between the air and underground temperatures and the per cent of plague rats in Manila, December, 1901.*

Day.	Underground temperature.						Air temperature.			Per cent of plague rats.
	One-half meter.			One meter.						
	Min.	Max.	Δ Max.-Min.	Min.	Max.	Δ Max.-Min.	Min.	Max.	Δ Max.-Min.	
	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	
1	21.3	**25.7**	4.4	27.8	**29.0**	1.2	22.2	**31.8**	9.6	3.08
2	21.4	23.7	2.3	27.9	28.8	0.9	22.2	28.8	6.6	0.93
3	21.2	23.0	1.8	28.0	28.8	0.8	22.4	27.4	5.0	0.00
4	20.9	23.1	2.2	27.8	28.9	1.1	22.6	28.4	5.8	0.66
5	20.3	21.6	1.3	27.8	28.6	0.8	20.7	25.3	4.6	1.37
6	18.9	19.6	0.7	27.5	28.2	0.7	19.1	23.2	4.1	1.68
7 [1]	18.1	18.8	0.7	27.4	28.1	0.7	20.3	23.5	3.2	0.69
8	18.6	21.0	2.4	27.3	28.0	0.7	20.6	28.4	7.8	8.57
9	19.3	21.0	1.7	26.5	27.4	0.9	22.6	31.4	8.8	1.27
10	19.1	23.0	3.9	26.6	27.6	1.0	22.2	31.4	9.2	0.00
11	19.8	22.7	2.8	26.7	27.7	1.0	22.7	30.5	7.8	1.38
12	20.1	24.0	3.9	26.9	28.0	1.1	22.1	30.3	8.2	0.84
13	20.4	24.0	3.6	26.8	28.0	1.2	21.9	31.0	9.1	0.54
14 [2]	19.3	24.6	4.3	26.8	28.2	1.4	19.9	29.1	9.2	0.00
15	18.5	22.0	3.5	26.6	27.9	1.3	18.2	27.4	9.2	0.56
16	18.6	22.7	4.1	26.8	28.0	1.2	16.6	28.5	11.9	1.63
17	18.1	22.1	4.0	27.1	28.3	1.2	19.8	28.6	8.8	0.84
18	18.6	22.5	3.9	27.1	28.2	1.1	18.3	28.6	10.3	2.17
19	18.1	22.5	4.4	27.9	28.2	0.3	19.7	30.1	10.4	1.66
20	17.6	22.1	4.5	27.8	27.9	0.1	17.6	29.3	11.7	1.35
21	17.4	22.0	4.6	26.7	27.8	1.1	17.8	30.4	12.6	1.78
22	**17.2**	21.8	4.6	26.5	27.5	1.0	**17.4**	29.3	11.9	0.00
23	18.3	22.4	4.1	**26.2**	27.6	1.4	20.5	31.2	10.7	1.55
24	18.7	22.6	3.9	**26.2**	27.4	0.8	20.6	31.4	10.8	1.06
25	19.2	23.6	4.4	26.5	27.7	1.2	21.2	20.8	9.6	
26	19.4	23.8	4.4	26.5	27.8	1.3	20.1	31.6	11.5	2.27
27	19.3	24.0	4.7	26.6	27.7	1.1	20.3	30.7	10.4	0.00
28	19.6	23.5	3.9	26.7	27.6	1.0	21.3	30.2	8.9	0.55
29	19.4	23.8	4.4	26.5	27.7	1.2	20.3	**31.8**	11.5	1.21
30	19.1	22.4	3.3	26.3	27.4	1.1	20.4	31.0	10.6	1.96
31	18.5	23.2	4.7	26.4	27.4	1.0	19.3	31.7	12.4	4.30
Mean										1.33

[1] Maximum mean relative humidity.
[2] Minimum mean relative humidity.

It seems that in Manila the mean subsoil temperature at 39.38 inches, and below, is constantly higher than the mean overground temperature, which is also the case in temperate zones during the winter months. This can be clearly shown by comparing underground temperatures in Manila and in two other stations in the Temperate Zone, one in the Northern and another in the Southern Hemisphere.

Mean air and underground temperature in Manila, Cleveland (Ohio), and Sidney (Australia).

Month.	Manila, 1901. (Lat. 14° 34′ 42″ N.)					Cleveland, 1900. (Lat. 41° 30′ N.)			Month.	Sidney, 1893. (Lat. 33° 51′ 41″ S.)				
	Air.	19.68 inches.	Δ	39.38 inches.	Δ	Air.	48 inches.	Δ		Air.	30 inches.	Δ	60 inches.	Δ
	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.		° C.	° C.	° C.	° C.	° C.
January	25.3	27.05	2.20	28.3	3.0	—1.11	5.39	6.50	July	11.56	13.00	1.44	14.56	3.00
February	25.2	26.15	1.13	28.0	2.8	—4.72	5.39	10.11	August	12.89	12.83	—0.06	13.56	0.67
March	26.6	26.05	—0.55	29.6	3.0	—3.22	4.83	8.05	September	15.22	13.72	—1.50	14.61	—0.61
April	28.4	30.80	2.40	32.1	3.7	7.94	8.11	0.17	October	17.89	16.11	—1.78	16.50	—1.34
May	28.9	32.20	4.11	33.3	4.4	16.06	11.94	—4.12	November	19.61	16.78	—2.83	16.67	—2.94
June	28.3	30.55	2.52	32.6	4.3	20.00	16.72	—3.28	December	20.94	17.17	—3.77	17.50	—3.44
July	27.6	28.75	1.69	31.9	4.3	22.78	19.61	—3.17	January	20.72	17.44	—3.28	17.78	—2.94
August	26.8	28.60	1.80	30.7	3.9	21.33	21.11	—0.22	February	21.17	19.11	—2.06	19.00	—2.17
September	27.7	27.50	—0.20	30.7	3.0	19.44	20.72	1.28	March	19.78	19.00	—0.78	19.06	—0.59
October	27.0	25.35	—1.65	30.0	3.0	16.72	18.28	1.56	April	16.67	17.39	0.72	18.11	1.44
November	26.4	22.90	—3.50	28.7	2.3	5.11	14.14	9.06	May	14.61	15.50	0.89	16.94	2.33
December	25.0	20.90	—4.10	27.8	2.8	—0.44	9.44	9.88	June	12.22	13.56	1.34	15.11	2.89