

about 4° lower at the high altitudes. This lag of the self-register is a serious defect in all ascensional operations, and it should be carefully considered before drawing conclusions from such data. In this ascension the wet-bulb thermometer seems to have ceased to operate at the temperature  $-22^{\circ}$  C., and after that it actually read warmer than the dry-bulb thermometer. This shows the extreme unreliability of all direct measures of humidity at very low temperatures in the free air.

Besides giving us some interesting low temperature readings at several high elevations, these experiences show what should be avoided in several particulars, especially in starting up with a partially inflated balloon.

#### CLIMATOLOGY OF THE ISTHMUS OF PANAMA, INCLUDING THE TEMPERATURE, WINDS, BAROMETRIC PRESSURE, AND PRECIPITATION.<sup>1</sup>

By HENRY J. ABBOT, Brigadier General, U. S. A. (retired).

In his note on this subject dated Paris, June, 1882, Monsieur Cugnin enumerated the astronomical and physical conditions which produce important consequences as to local climate. The following are some of these conditions:

*General considerations.*—The geographical position of the Isthmus of Panama is about 9° north latitude. From this position it follows that at noon the sun is in the zenith twice a year; it is on the northern side between the 13th of April and the 29th of August. Its altitude above the north horizon on the day of the summer solstice is  $75^{\circ} 41'$  and its altitude above the south horizon at the winter solstice is  $57^{\circ} 24'$ . It transmits to the surface of the earth the maximum possible amount of heat on April 13 and August 29. The amount of heat coming from the sun is in proportion to the sine of the angle made by the solar rays with the horizon; that is to say, to the numbers 1.00, 0.97, and 0.84 at noon at the time of the maximum and at the two periods of summer and winter minima, respectively. This shows the very small differences in the quantity of heat received day by day during the entire year.

But the temperature of the air does not depend solely upon the quantity of heat coming from the sun, it is also necessary to consider the amount lost by radiation and the effects of many local conditions, and these may vary according to place and from one day to another. Among these conditions the motions of the atmosphere and the quantity of aqueous vapor are general and powerful factors.

Aqueous vapor is the great regulator of temperature, as it is less permeable than dry air to the waves of energy from the sun and still less so to those that radiate from the earth. Its influence in this direction is very important on the Isthmus of Panama because there is only a narrow strip of land between two great oceans, and consequently the relative humidity is always very high. By combining high temperatures with this high humidity there results an excessive absolute amount of moisture in the atmosphere.

In regard to the general motions of the air, it is well known that in consequence of the high temperature in the equatorial regions the air ascends; in consequence of this we should have constantly in the lower atmosphere north winds from the north, and south winds from the south, seeking to fill up the vacuum; but on account of the rotation of the earth from west to east, these directions become northeast and southwest. Nevertheless, there are circumstances, as we shall see further on, which modify this general law on the

<sup>1</sup>The original text of General Abbot's paper has, with his permission, been slightly modified by the Editor, so as to restrict this paper to the presentation of the climate of the Isthmus of Panama. The original data in metric measures has been compared as far as possible with published data, and has been converted into English measures by Mr. A. J. Henry, Chief of Division, who has also added an appendix containing figures not accessible to General Abbot.

Isthmus of Panama. Thus, the observations made daily at Colon, during the year 1881, at 6 a. m., 1 p. m. and 9 p. m. (fig. 1), show 55 per cent of winds from northeast and

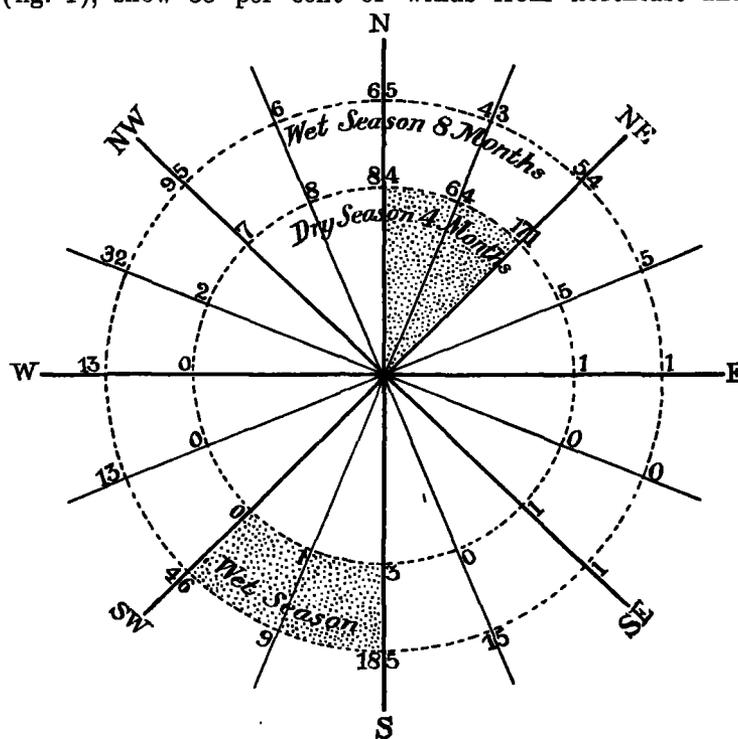


FIG. 1.—Wind rose at Colon for the year 1882. The figures give the total number of times each wind is recorded during the dry and wet seasons, respectively, at the 3 hours of daily observation. During the dry season 91 per cent of the recorded winds are from north and northeast. During the wet season 33 per cent of the recorded winds are from south and southeast.

northwest; 35 per cent between southeast and southwest, and 10 per cent from all other directions, including 1 per cent of calm. Nevertheless these percentages become, during the dry season (January, February, March, and April), 95 per cent from northeast and northwest, 91 per cent between northeast and north, 2 per cent southeast and southwest, and 3 per cent from all other directions, respectively: during the rainy season 36 per cent from the northeast and northwest; 91 per cent from southeast and southwest, of which 33 per cent between southwest and south, and 13 per cent from all other directions. That is to say, at Colon north winds prevailed during the dry season, but south winds were strongest during the rainy season; thus, these winds follow the sun as it carries northward the axis of the ascending layer of air.

In order to elucidate these facts one must remember that the geographic equator does not coincide with the thermal equator, which is the term applied to the curve that connects the points on all meridians where the annual maximum temperature is found (generally from  $26^{\circ}$  to  $30^{\circ}$  Centigrade). This thermal equator passes very near to the Isthmus of Panama, but a little to the south, on account of the great ocean current which carries thither the equatorial waters of the Atlantic, and consequently increases the temperature of the whole of Central America, commencing with the Isthmus. This is not to say, however, that the temperature there is ever very high, as we shall see later on. In a great measure, so far as concerns temperature, this ocean current neutralizes the effect of  $9^{\circ}$  of north latitude.

The axis of the ascending layer of air moves toward the north and retrogrades toward the south with the sun, oscillating in the course of a year, day by day, symmetrically across the thermal equator. This layer varies in thickness, from one place to another, according to the diverse local conditions, such as the configuration of the land, the dura-

tion and force of the prevailing winds, etc., but in general it is less than the distance between the extreme positions of the axis of the ascending layer.

On the whole, it follows from the above that the Isthmus of Panama is south of this entire layer for several days about the time of the summer solstice, and to the north of it for a greater number of days toward the time of the winter solstice, that is to say, that the ascending layer of warm air covers the Isthmus from the beginning of May to the end of June, and from the end of July to the beginning of December. This explains the winds observed at Colon, and many other facts concerning the climate of the region.

To sum up, the Isthmus of Panama is very near to the thermal equator, where the heat of the sun from one day to another, during the year, varies extremely little, and where it is conserved, so to speak, by a thick covering of aqueous vapor which is but slightly permeable during the day and still less so during the night. Thus, the temperature, which is determined in general by the difference between the heat received from the sun and that lost by radiation, should here have its maximum uniformity, either from day to night or from one season of the year to another.

In regard to precipitation, there are two well-marked seasons, the dry season, including the months of January, February, March, and April, and the rainy season comprising the remainder of the year. This latter season generally suffers an interruption of several days, after the summer solstice, when the rains diminish. Then the ascending layer is entirely to the north of the Isthmus.

*Temperature.*—The first Panama Canal Company made daily observations at Colon, Gamboa, and Naos, during the six years from 1882 to 1887, with maximum and minimum thermometers. The absolute maxima and minima for each month are found in the following tables. The means of these two temperatures have also been added; these, as will be seen below from the observations made by a self-registering thermometer, represent values which do not differ greatly on the Isthmus from the true means deduced from observations made every hour.

TABLE 1.—COLON.

*Absolute maximum temperatures.*

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1882	85.8	87.1	84.9	87.8	89.7	89.5	88.2	89.6	91.8	92.1	89.9	89.2	88.5
1883	88.9	87.8	88.2	89.2	89.6	89.6	89.2	89.6	88.9	88.9	89.2	86.0	88.7
1884	86.4	85.6	86.4	87.5	89.6	89.6	90.7	91.4	90.5	91.2	95.9	92.1	89.8
1885	90.3	90.7	90.7	89.2	92.1	90.7	90.3	91.4	92.8	94.3	.....	95.2	91.9
1886	88.2	89.8	88.2	89.8	89.9	89.2	89.2	89.9	96.1	95.7	94.6	95.2	89.2
1887	96.8	93.2	91.4	92.1	92.2	92.3	91.8	91.4	90.7	89.2	87.4	89.6	91.6
Means.	90.9	89.6	90.0	90.5	91.2	90.9	90.5	91.2	91.6	91.9	91.4	91.6	90.9

*Absolute minimum temperatures.*

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1882	71.6	69.1	70.2	68.0	68.7	69.4	68.7	68.1	66.2	66.6	66.2	66.6	67.8
1883	66.0	70.5	64.4	65.5	69.4	68.0	68.4	66.2	69.8	68.4	63.7	66.9	67.5
1884	65.8	67.6	64.4	66.2	64.4	65.8	67.6	59.4	57.6	76.3	70.7	66.2	66.0
1885	71.2	66.9	72.7	70.2	72.0	70.5	71.6	70.2	70.5	71.2	71.2	70.2	70.7
1886	65.6	71.6	67.1	71.6	69.1	70.5	69.4	69.4	68.7	69.1	67.3	65.8	68.7
1887	67.6	69.4	66.6	69.1	68.0	70.3	70.5	73.0	74.5	72.3	73.8	73.4	70.7
Means.	68.4	69.3	68.7	68.4	68.5	69.1	69.3	68.9	69.4	70.5	68.7	70.0	68.7

*Mean temperatures, 1882-1887.\**

.....	79.5	79.5	79.3	79.5	79.9	79.9	79.9	79.2	80.6	81.3	80.1	79.9	79.9
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*Departures of the monthly means from the annual.*

.....	-0.4	-0.4	-0.6	-0.4	0.0	0.0	0.0	-0.7	+0.7	+1.4	+0.2	0.0	.....
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\* Mean absolute maximum + mean absolute minimum ÷ 2.

TABLE 2.—GAMBOA.

*Absolute maximum temperatures.*

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1882	.....	.....	92.5	91.8	97.7	98.6	88.7	94.1	96.8	95.0	85.0	95.0	.....
1883	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1884	88.5	87.8	88.9	90.3	90.3	93.7	90.7	90.8	91.0	91.0	91.0	89.2	90.3
1885	88.2	89.0	90.3	94.3	97.5	95.4	91.4	89.9	93.6	98.9	92.1	91.0	92.1
1886	92.8	90.0	92.5	97.2	95.4	91.8	94.6	92.3	95.7	92.2	92.5	98.6	93.4
1887	91.4	90.0	92.8	91.8	96.4	93.6	98.0	91.4	91.8	93.9	93.2	91.8	92.3
Means.	90.3	89.6	90.7	93.0	95.5	97.5	91.8	91.4	94.3	93.4	92.8	91.4	92.5

*Absolute minimum temperatures.*

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1882	.....	.....	62.6	53.6	63.0	59.0	71.6	66.2	66.2	66.6	64.4	.....	.....
1883	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1884	60.4	59.0	58.6	61.2	65.8	66.6	68.0	65.8	66.9	65.8	66.2	59.0	63.7
1885	60.4	59.7	61.2	61.5	65.1	68.4	68.4	69.8	68.0	68.0	63.4	67.6	65.5
1886	58.6	60.4	61.5	65.5	68.0	68.4	66.9	68.7	67.6	60.8	67.6	68.0	64.8
1887	62.2	58.3	57.2	61.2	63.3	68.5	67.6	70.9	71.2	70.2	72.0	71.2	66.2
Means.	60.4	59.4	60.3	60.6	65.1	66.2	68.5	68.4	68.0	66.2	67.6	65.3	64.8

*Mean temperatures, 1882-1887.\**

.....	75.4	74.5	75.6	76.8	80.2	81.9	80.2	79.9	81.0	79.9	80.2	78.4	78.6
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*Departures of the monthly means from the annual.*

.....	-3.2	-4.1	-3.0	-1.8	+1.6	+3.3	+1.6	+1.3	+2.4	+1.3	+1.6	-0.2	.....
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\* Mean absolute maximum + mean absolute minimum ÷ 2.

TABLE 3.—NAOS.

*Absolute maximum temperatures.*

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1882	91.0	89.6	89.6	93.3	94.6	94.1	91.4	91.8	89.6	90.5	89.2	91.4	91.2
1883	90.7	89.6	92.8	95.4	96.1	.....	93.6	93.2	93.2	93.2	90.3	89.2	89.6
1884	91.4	91.0	92.8	92.8	92.8	94.6	96.1	95.7	95.7	91.4	93.9	91.4	93.2
1885	87.8	90.3	92.1	95.4	95.7	97.9	98.2	96.4	96.4	94.3	92.8	95.7	94.5
1886	89.6	92.8	96.4	97.5	96.1	97.2	97.2	95.4	95.4	.....	91.4	91.4	.....
1887	94.3	91.8	90.3	95.0	93.6	97.5	97.7	89.6	90.0	86.7	85.3	87.4	91.6
Means.	91.4	90.9	92.1	94.6	94.8	96.3	95.7	93.7	93.4	91.2	90.5	91.0	93.0

*Absolute minimum temperatures.*

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1882	69.8	68.4	68.0	68.0	67.1	71.6	71.6	72.3	73.4	73.0	68.0	71.6	70.2
1883	69.8	67.3	68.0	68.2	71.6	72.0	71.6	69.8	69.8	71.6	68.0	69.1	69.6
1884	68.2	66.2	65.9	69.8	69.8	72.0	69.8	71.6	69.8	69.8	69.8	66.2	68.9
1885	66.0	65.8	66.9	70.5	71.6	70.5	69.4	68.4	69.4	70.5	70.5	68.4	69.1
1886	66.6	69.1	67.3	71.2	70.2	70.2	69.4	69.4	69.4	.....	70.2	69.8	.....
1887	69.8	66.6	64.4	67.3	68.0	70.3	69.3	74.8	75.9	74.5	73.4	73.4	70.9
Means.	68.4	67.3	66.7	68.9	69.6	71.6	70.2	71.1	71.2	71.6	70.0	69.4	69.6

*Mean temperatures, 1882-1887.\**

.....	79.9	79.2	79.3	81.7	82.2	83.8	82.9	82.4	82.4	81.3	80.2	80.2	81.3
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*Departures of the monthly means from the annual.*

.....	-1.4	-2.1	-2.0	+0.4	+0.9	+2.5	+1.6	+1.1	+1.1	0.0	-1.1	-1.1	.....
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\* Mean absolute maximum + mean absolute minimum ÷ 2.

TABLE 4.—COLON.

Months.	Mean temperature.	Months.	Mean temperature.	Months.	Mean temperature.
January	79.7	May	80.6	September	79.2
February	79.2	June	80.2	October	78.0
March	80.1	July	80.4	November	78.6
April	81.1	August	79.3	December	79.7

The first Panama Canal Company also made daily observations at Colon during the year 1881, at 6 a. m., 1 p. m., and 9 p. m., for which place the monthly means are given below.

The annual mean was 79.7°. The absolute maximum, observed May 22, was 94.1°. The absolute minima, observed March 22 and 23, and September 29, were 67.8°.

In order to ascertain the diurnal variation M. Royer has recently made observations at Panama with a self-registering thermometer during nine months, five of which were in the rainy season and four in the dry season, and also at the Haut Chagres,<sup>1</sup> on the coast, during April. The results of these observations are as follows: The lowest temperature was 71.6°, on March 13, at 6 a. m., and March 15 at 6 a. m. and 6 p. m. The highest temperature, 89.8°, occurred May 13, at 4 p. m. Thus the extreme range was only 18.2°.

TABLE 5.—PANAMA.

Hourly mean temperature.

Hour.	Panama, 1897.			Panama, 1898.						Upper Chagres, 15 days, April, 1898.
	October, 13 days.	November, 19 days.	December, 19 days.	January, 21 days.	February, 18 days.	March, 27 days.	April, 10 days.	May, 24 days.	June, 19 days.	
Midnight	73.0	78.4	78.1	77.5	76.6	77.7	79.5	79.3	78.4	78.1
2 a. m.	73.6	78.1	77.9	77.0	75.9	76.8	78.1	78.5	77.9	75.0
4 a. m.	73.3	77.7	77.5	76.3	75.0	76.1	77.5	78.3	77.4	74.1
6 a. m.	73.9	77.7	77.2	76.1	74.5	75.4	77.4	77.9	77.0	73.6
7 a. m.	73.9	77.7	77.0	75.9	74.3	75.2	77.4	78.3	77.4	73.6
8 a. m.	73.1	77.4	77.0	76.1	74.6	75.6	77.6	78.6	78.6	74.6
10 a. m.	80.1	77.7	77.0	76.9	75.9	76.9	78.9	79.5	79.2	79.2
Noon	81.1	79.9	79.2	81.7	82.6	82.9	84.6	85.5	83.9	83.1
1 p. m.	80.1	79.5	79.5	82.9	83.5	83.9	85.9	86.9	83.9	84.4
2 p. m.	81.5	80.1	79.9	83.3	83.3	83.6	85.3	86.3	83.1	84.7
3 p. m.	81.3	80.9	79.9	83.3	83.3	84.6	85.3	86.3	83.9	84.7
4 p. m.	81.1	80.9	79.9	83.1	85.3	85.1	85.1	85.3	83.1	84.4
5 p. m.	80.6	80.1	79.7	82.4	84.7	85.3	84.2	84.4	81.9	84.2
6 p. m.	79.7	79.5	79.5	81.7	83.5	84.4	83.3	81.9	81.3	81.9
8 p. m.	78.6	79.5	79.5	79.5	80.1	81.3	81.1	80.6	80.1	79.3
10 p. m.	73.5	78.3	78.4	78.4	77.9	79.3	79.7	79.9	79.3	77.7
Mean of the twelve even hours only	79.5	78.8	78.4	79.1	79.2	79.9	81.1	80.7	80.0	78.7

serves always the same daily mean. The following figures taken from the last table will show this important difference in the two seasons by giving the values above and below the means for each month, and for the two seasons, respectively. The signs are so applied as to enable one to pass from actual observations to the monthly mean; i. e., mean — observed = departure; or, mean = observed + departure.

The hourly curves, fig. 2, show very distinctly the daily temperature to be expected at Panama in the rainy and in the dry seasons, as also the temperature in the interior during the dry season.

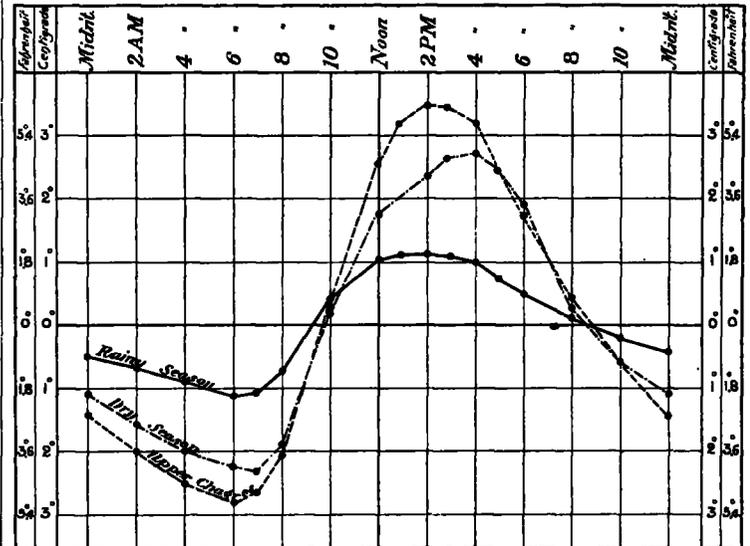


Fig. 2.—Hourly departures of mean temperatures. The zero line corresponds to 79.5° F. for the curve of rainy season; 79.8° F. for the curve of dry season; 78.7° F. for the curve of upper Chagres.

TABLE 6.—Departures from mean temperature.

Hour.	Panama, 1897.			Panama, 1898.						Means at Panama.		
	October, 13 days.	November, 19 days.	December, 19 days.	January, 21 days.	February, 18 days.	March, 27 days.	April, 10 days.	May, 24 days.	June, 19 days.	Upper Chagres, 15 days, April, 1898.	Dry season.	Wet season.
Midnight	+0.5	+0.4	+0.3	+1.6	+2.2	+2.2	+1.6	+1.4	+1.3	+1.6	+1.98	+0.86
2 a. m.	+0.9	+0.7	+0.5	+1.1	+1.1	+1.1	+1.6	+1.9	+2.1	+1.6	+2.35	+1.26
4 a. m.	+1.2	+1.1	+0.9	+1.3	+1.3	+1.3	+2.0	+2.4	+2.6	+2.0	+3.80	+1.89
6 a. m.	+1.3	+1.4	+1.3	+1.3	+1.3	+1.3	+2.7	+3.4	+3.0	+2.0	+4.12	+2.05
7 a. m.	+1.6	+1.3	+1.4	+1.3	+1.3	+1.3	+3.7	+4.4	+3.8	+2.8	+4.12	+1.96
8 a. m.	+1.4	+1.4	+1.4	+1.4	+1.4	+1.4	+4.7	+5.4	+4.8	+3.8	+4.43	+1.40
10 a. m.	+1.3	+1.3	+1.3	+1.3	+1.3	+1.3	+5.1	+5.8	+5.2	+4.2	+5.00	+1.88
Noon	+1.6	+1.3	+1.3	+1.3	+1.3	+1.3	+6.0	+6.7	+6.1	+5.1	+6.10	+1.80
1 p. m.	+2.4	+1.3	+1.3	+1.3	+1.3	+1.3	+6.9	+7.6	+7.0	+6.0	+6.95	+1.95
2 p. m.	+2.0	+1.3	+1.3	+1.3	+1.3	+1.3	+7.8	+8.5	+7.9	+6.9	+7.85	+1.98
3 p. m.	+1.3	+1.3	+1.3	+1.3	+1.3	+1.3	+8.8	+9.5	+8.9	+7.9	+8.85	+1.98
4 p. m.	+1.3	+1.3	+1.3	+1.3	+1.3	+1.3	+9.7	+10.4	+9.8	+8.8	+9.75	+1.98
5 p. m.	+1.1	+1.3	+1.3	+1.3	+1.3	+1.3	+10.6	+11.3	+10.7	+9.7	+10.65	+1.98
6 p. m.	+0.7	+0.9	+0.9	+0.9	+0.9	+0.9	+11.5	+12.2	+11.6	+10.6	+11.55	+1.98
8 p. m.	+0.4	+0.5	+0.4	+0.4	+0.4	+0.4	+12.4	+13.1	+12.5	+11.5	+12.45	+1.98
10 p. m.	0.0	0.0	0.0	+0.7	+1.3	+0.6	+1.4	+0.1	+0.7	+1.0	+0.88	+0.30
											+0.99	+0.33

These results, like those made for the first Panama Canal Company, given above, show the extraordinary uniformity of the mean monthly temperature, as also of that from day to day. Nevertheless a characteristic difference in the temperature from one hour to another during the rainy and dry seasons must be noted. In the former the more numerous clouds and the excess of relative humidity (which latter was observed at Colon in 1881 to be 86 per cent during the rainy season and 77 per cent during the dry season), obstruct the heat of the sun, and especially the radiation from the earth, and this causes the temperature to be not much higher during the day than during the night. On the other hand, during the dry season the sky is clearer, the relative humidity less, and the temperature rises during the day and falls at night, but pre-

<sup>1</sup> 77 feet above sea level.

In addition to the figures given above, the first Panama Canal Company made interesting daily observations of the temperature of the water at Colon and at Naos for four years; in the following table the monthly means will be found.

TABLE 7.—Water temperatures on the Atlantic coast at Colon.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1884	79.5	80.8	80.1	82.0	80.6	81.7	81.9	81.7	82.6	81.9	82.2	80.8	81.5
1885	79.5	80.8	80.4	82.0	84.0	82.9	82.0	80.1	79.9	79.9	79.2	78.8	80.7
1886	78.3	74.8	75.9	76.5	75.9	75.0	78.4	78.8	78.1	77.4	76.3	76.3	76.6
1887	78.3	71.8	71.8	73.8	74.5	82.6	78.1	86.2	87.3	86.4	85.3	85.3	80.2
1888	86.4	83.5	82.9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Means	78.7	77.7	78.2	77.4	78.8	80.6	81.4	81.7	82.0	81.4	80.9	79.9	79.9

Departures of the monthly means from the annual.

-1.2	-2.2	-1.7	-2.5	-1.1	+0.7	+1.5	+1.8	+2.1	+1.5	+1.0	0.0	.....
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TABLE 8.—Water temperatures on the Pacific coast at Naos.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1884	71.1	67.6	66.9	72.7	79.0	80.8	81.0	81.0	80.8	78.8	79.3	77.9	79.1
1885	71.1	67.6	66.9	72.7	77.7	77.9	77.4	76.8	77.4	77.0	76.6	76.1	74.5
1886	71.6	67.8	68.0	75.6	75.7	75.4	75.2	74.5	74.8	.....	.....	.....	73.2
1887	71.6	67.8	68.0	75.6	75.7	75.4	75.2	74.5	74.8	.....	.....	.....	73.2
1888	81.0	77.0	76.8	.....	78.4	79.2	77.9	83.5	85.8	84.2	83.7	83.1	82.2
Means	74.6	70.8	71.1	73.8	77.7	78.3	77.9	79.0	79.7	80.0	79.9	79.0	78.8

Departures of the monthly means from the annual.

-2.2	-5.8	-5.7	-3.0	+0.9	+1.5	+1.1	+2.2	+2.9	+3.2	+3.1	+2.2	.....
------	------	------	------	------	------	------	------	------	------	------	------	-------

In the rainy season the minimum temperature occurs at 6 a. m., and the maximum at 2 p. m. The total difference be-

tween these two extremes does not attain 5° F.; moreover between noon and 4 p. m. there is no perceptible change in the temperature.

In the dry season this difference between the minimum at 7 a. m. and the maximum at 3:30 p. m. increases to 9° F., but the duration of the extreme heat diminishes.

At the upper Chagres, in April, there occurs a difference of 11° between the minimum temperature at 6 a. m. and the maximum at 2:30 p. m. It appears that between 10 a. m. and 5 p. m. the heat is greater than at Panama, while on the other hand, between 11 p. m. and 8 a. m. it is less.

Finally, these characteristic variations, peculiar to seasons and places, are lost in the mean values, which are, at Panama, for the rainy season, 79.5° F., but for the dry season 80.5° F. These temperatures, which agree well with the observations of the first canal company, should not frighten one. Perhaps it will be objected that all these results relate only to thermometers that are protected from the direct rays of the sun, and have little to do with those experienced by anyone exposed out of doors without any shelter whatever. But there is nothing inaccurate in this appreciation of the climate of Panama if these figures be compared with those obtained by similar observations in other southern countries.

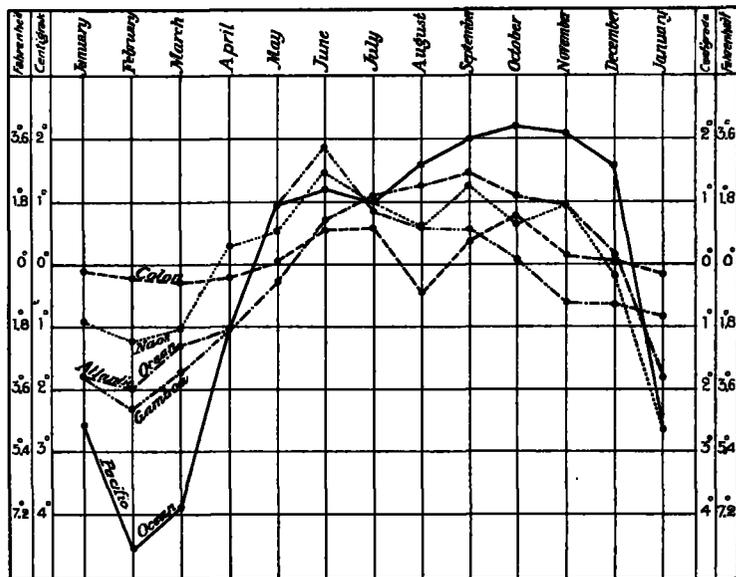


FIG. 3.—Monthly departures of mean temperatures. The zero line or normal temperature corresponds to 79.3° F. for the Atlantic Ocean; 76.1° F. for the Pacific Ocean; 79.8° F. for Colon; 81.3° F. for Naos; 78.6° F. Gamboa.

In the curves, fig. 3, where the mean monthly temperature of the air is also given, one may perceive the influence of the great marine current which carries the equatorial waters of the Atlantic to the Isthmus, as well as the action of the sun passing annually north and south of the zenith. The temperature of the Atlantic is generally higher than that of the Pacific by a maximum difference of about 9°, when the sun, in February, approaches the equinoctial line and the two seas are, respectively, colder than at any other season of the year. The minimum difference of 1.1°, in round numbers occurs after the sun has again passed that line in September, and leaves the air warmer than at any other season. It may also be noted that the mean annual temperature of the ocean at Colon (79.3°) is nearly the same as that of the air (79.9°), but that at Naos it is 5° colder (76.1° and 81.3°).

To summarize: The observations made at the Isthmus show that it is not the extreme temperatures that are to be feared. These temperatures are more favorable (under the reserve above-mentioned) than some experienced from time to time

in the United States, even at the north. The complete absence of frost and the great uniformity of climate afford valuable advantages. In tropical regions it is not the excessively high temperatures which increase the difficulties of out-door labor and construction, but those which remain permanently high and are accompanied by great humidity of the air and heavy rainfall, which latter will be considered later.

*Barometric pressures.*—Observations made during the year 1881 at Colon at 6 a. m., 1 p. m., and 9 p. m., show a very uniform pressure. The monthly means fell from a maximum of 29.941 in April to a minimum of 29.831 in November, the annual mean being 29.886. The absolute maximum of 30.016 occurred February 26 at 1 p. m., and the absolute minimum of 29.705, November 18 at 1 p. m., which give an extreme difference of 0.311. The pressure during the rainy season is a little lower than that during the dry season.

M. Royer has just added to our knowledge in regard to the barometric pressures by giving us the original records of the observations made during three months at Panama with his self-registering barometer. These data show the same marked regularity near the Pacific coast as at Colon, i. e., an extreme variation for the three months of 0.240, of which 0.094 was the normal hourly variation. The following are the monthly results:

TABLE 9.—Barometric pressures at Panama.

Months.	No. of days.	Monthly means.	Maxima.	Dates.	Minima.	Dates.	Extreme variations.
		Inches.	Inches.		Inches.		Inches.
Nov., 1897.....	27	29.986	30.115	3d, 10 a. m.	29.882	19th, 20th, 23d, 3 p. m.	0.23
Dec., 1897.....	31	29.997	30.095	6th, 10 a. m.	29.882	12th, 3 p. m.	0.21
Jan., 1898.....	28	29.996	30.123	3d, 9 a. m.	29.906	18th, 3 p. m.	0.23
Means.....		29.998	30.111		29.890		0.22

The curves showing the hourly variations are equally regular and accordant. The figures in fig. 4 and in the following table, No. 10, give the values above and below the mean for each month and for three months, respectively. The signs are those needed to reduce actual observations to the monthly means:

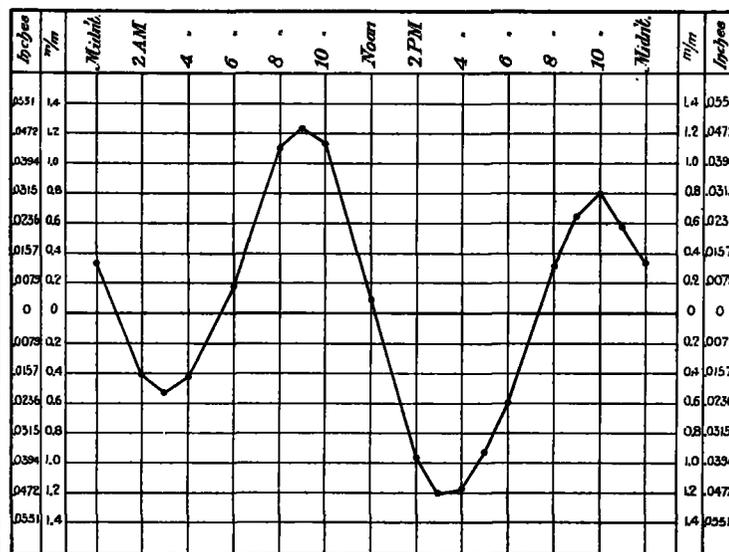


FIG. 4.—Hourly departures of mean barometric pressures.

These data are interesting, verifying as they do the well-known fact that the canal has ports, both on the Atlantic and Pacific coasts, that are quite free from the storms which accompany important variations in barometric pressure. Here

ships will not be delayed on account of the winds<sup>1</sup>. Similarly, in passing through the canal, particularly during the rainy season, the winds in the interior will often be calm or weak and will not be a source of trouble.

TABLE 10.—Hourly departures from the mean barometric pressure.

Table with 6 columns: Hours, November 1897, December 1897, January 1898, Mean, Remarks. Rows include Midnight, 2 a.m., 3 a.m., 4 a.m., 5 a.m., 6 a.m., 7 a.m., 8 a.m., 9 a.m., 10 a.m., Noon, 2 p.m., 3 p.m., 4 p.m., 5 p.m., 6 p.m., 7 p.m., 8 p.m., 9 p.m., 10 p.m., 11 p.m.

PRECIPITATION.

The archives of the present canal company contain much data which throw light upon the question, which rainfall is summarized in the following tables. These numbers sometimes differ from those published elsewhere, but having been copied from the original manuscript record of the Panama Canal Company are believed to be authoritative and correct.<sup>2</sup>

TABLE 11.—Precipitation at Colon.

Table with 13 columns: Year, January, February, March, April, May, June, July, August, September, October, November, December, Annual. Rows include years 1881 through 1898.

TABLE 12.—Precipitation at Bohio.

Table with 13 columns: Year, January, February, March, April, May, June, July, August, September, October, November, December, Annual. Rows include years 1896 through 1898.

<sup>1</sup>In this report it may be observed that the first canal company made daily observations of the tides at Colon and at Naos during sixty months, from 1882 to 1887. The most marked movements in each of these months gave for Colon a mean amplitude of 1.434 feet, with a maximum amplitude of 2.07 feet in August, 1883, and a minimum amplitude of 0.62 feet in March, 1886. At Naos these amplitudes were: mean 18.750; maximum 20.93 in October, 1883; and minimum 16.40 feet in December, 1882, respectively. At Colon only thirteen tides exceeded 1.64 feet, and at Naos only fourteen exceeded 19.68 feet during these sixty months.

<sup>2</sup>The conversions here given follow General Abbot's data and occasionally differ from conversions based on the figures published in the Annals of the Central Meteorological Bureau of France, owing to the omission of fractions of a millimeter and to errors in printed documents, from which the figures given in the Annals appear to have been taken. The latest manuscript corrections and additions by General Abbot have been incorporated in these tables.—Ed.

TABLE 13.—Precipitation at Gorgona.

Table with 12 columns: 1896, 1897, 1898, 9.02, 6.81, 5.16, 8.98, 13.35, 10.94, 14.37, 7.16, 7.91, 3.94.

TABLE 14.—Precipitation at Gamboa.

Table with 13 columns: Year, January, February, March, April, May, June, July, August, September, October, November, December, Annual. Rows include years 1881 through 1898.

\* The figures 1.38 for December, 1882 have been added to this table for Gamboa by copying from the Annals of the Central Meteorological Bureau for 1882, Part IV, p. 118.—Ed.

TABLE 15.—Precipitation at Bas Obispo.

Table with 13 columns: Year, January, February, March, April, May, June, July, August, September, October, November, December, Annual. Rows include years 1884 through 1898.

TABLE 16.—Precipitation at Emporador.

Table with 13 columns: 1888, 1.26, 11.50, 10.33, 10.71, 5.47, 5.04.

TABLE 17.—Precipitation at Culebra.

Table with 13 columns: 1884, 0.20, 0.04, 0.67, 3.78, 10.24, 13.62, 8.70, 10.12, 11.18, 1.46, 1885, 0.28, 0.00, 0.00, 1.61, 15.89, 4.29, 5.35, 11.88, 10.63, 7.20, 34.57, 1886, 0.43, 0.55, 0.16, 1.18, 13.78, 12.64, 14.33, 8.19, 7.36, 20.63, 14.29, 5.43, 96.97, 1887, 3.15, 0.00, 0.04, 3.50, 7.91, 9.96, 6.10, 8.74, 7.64, 9.65, 12.13, 7.95, 73.77, 1888, 0.24, 0.00, 0.51, 0.35, 11.42, 7.99, 2.91, 6.54, 11.26, 5.75, 9.58, 7.73, 64.25, 1894, 12.13, 13.50, 13.23, 10.00, 1895, 0.75.

TABLE 18.—Precipitation at Panama.

Table with 13 columns: Year, January, February, March, April, May, June, July, August, September, October, November, December, Annual. Rows include years 1879 through 1882.

TABLE 19.—Precipitation at La Boca.

Table with 13 columns: 1881, 10.94, 11.65, 7.16, 1884, 7.48, 12.73, 6.42, 7.32, 10.51, 6.73, 8.27, 1895, 1.38, 0.08.

TABLE 20.—Precipitation at Naos.

Table with 13 columns: 1881, 0.00, 0.04, 0.04, 0.94, 4.53, 5.06, 1.61, 1.14, 1.14, 2.72, 7.48, 2.87, 25.12, 1882, 0.59, 0.00, 0.00, 1.93, 4.45, 2.56, 5.47, 5.51, 4.64, 4.25, 7.04, 3.11, 39.78, 1883, 2.01, 0.04, 0.00, 0.94, 4.84, 4.17, 3.65, 2.99, 5.71, 8.31, 8.69, 1.34, 45.62, 1884, 0.55, 0.90, 0.00, 0.91, 2.56, 5.63, 2.64, 3.51, 4.17, 9.96, 4.89, 1.92, 41.42, 1885, 0.00, 0.28, 1.31, 1.92, 5.20, 6.26, 3.61, 5.91, 20.75, 6.10, 4.49, 3.74, 66.06, 1887, 0.79, 0.04, 0.04, 2.38, 5.24, 9.88, 4.06, 6.69, 6.97, 7.05, 6.82, 5.59, 57.52, 1888, 0.08, 0.00, 0.04, 0.28, 5.55, 4.88, 2.01, 5.71, 8.58, 7.11, 4.02, 1.30, 40.55, 1889, 0.00, 0.00, 0.91, 4.41, 5.79, 5.48.

Finally, the results which flow from these figures can be seen at a glance in fig. 5, herewith. Remembering that the monthly means relate to the middle of the month, we see that throughout the whole Isthmus the rainy season begins immediately after May 1, but that soon the rains decrease on account of the northward advance of the layer of rising air. This diminution takes place in July in the interior of the Isthmus, but is subject to a delay of one month on the Pacific side and of two months on the Atlantic side. A second maximum in the rainfall occurs at the end of September in the interior, but at the end of October on the Pacific coast and in the middle of November on the Atlantic coast. Then comes the dry season, which, everywhere on the Isthmus, begins about the 1st of January and continues for four months, on account of the southward return movement of the ascending layer.

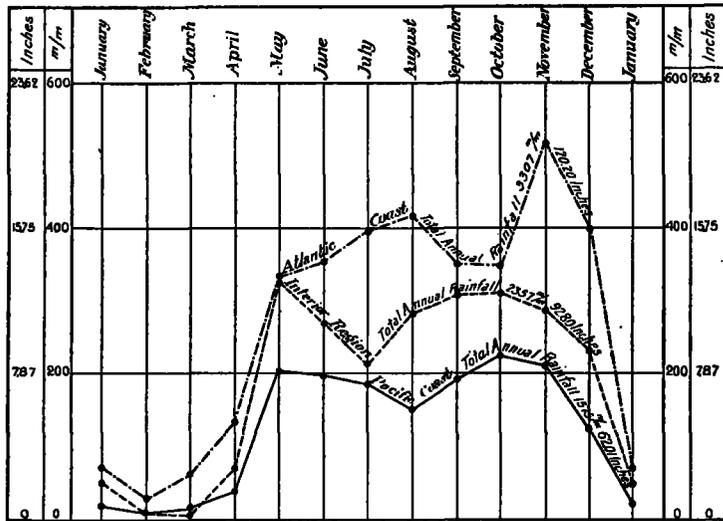


FIG. 5.—Total monthly precipitation on the Isthmus of Panama. These curves are based on the following data: For the Atlantic coast one station, Colon, for 15 years. For the Pacific coast three stations, La Boca, 1 year; Naos, 8 years; Panama, 4 years; total, 13 years. The interior of the Isthmus four stations, Gorgona, 2 years; Gamboa, 15 years; Bas Obispo, 10 years; Culebra, 5 years; total, 32 years.

These two periods of heaviest rains do not differ much from each other as to the maximum volume of water, except on the Atlantic coast, where the second period has a greater quantity of rainfall; but it must be particularly noted that the total quantity of precipitation is far from being the same everywhere. The figures are given in the following table.

TABLE 21.—Annual precipitation, in inches.

Section and station.	Length of record, years.	Maximum.	Minimum.	Mean.	General mean.
Atlantic coast:					
Colon .....	15	154.89	116.36	130.20	130.20
Interior region:					
Gorgona .....	2	.....	.....	99.77	92.80
Gamboa .....	15	196.58	71.65	96.54	
Bas Obispo .....	10	123.08	76.69	89.29	
Culebra .....	5	96.98	64.25	85.07	
Pacific coast:					
Panama .....	4	84.73	45.59	66.77	62.01
La Boca .....	1	.....	.....	73.70	
Naos .....	8	66.06	64.49	45.98	

These facts show that all the most difficult works of the Panama Canal, except, perhaps, the locks and the dam of Bohio, are situated in the interior or near the Pacific, where the rains are not very violent. Although the quantity of rainfall is large it is quite comparable with what is to be found in the United States near the Gulf of Mexico. Thus, the observations for many years give the following comparisons:

Station.	Number of years.	Mean precipitation.	Annual maximum.
New Orleans, La.....	23	Inches. 51.18	Inches. 67.32
Mount Vernon Arsenal, Ala.....	15	66.14	106.69
Baton Rouge, La.....	15	59.45	116.54
Isthmus of Panama:			
Interior .....	33	92.91	136.61
Pacific coast .....	13	61.81	84.66

APPENDIX.

By A. J. HENRY, Chief of Division, Weather Bureau.

The following contains additional tables of rainfall for the Isthmus of Panama, compiled from manuscript and other records now in the archives of the Weather Bureau.

The observations at Colon, 1862 to 1874, were made by Drs. W. T. White and J. P. Kluge, surgeons of the Panama Railway Company. Those for 1893-95 were kept by O. B. Schaffer, C. E., Panama Railway.

The record for Taboga Island, 1861-66, is drawn from a report on interoceanic ship canals, page 29, published as Senate Ex. Doc. No. 75, Forty-fifth Congress, 3d Session.

It is proper to state that the officials of the Panama Railway Company have been asked to furnish a complete record of rainfall made by the officers of the Company at Panama, from the beginning of observations in 1862 to the present time.

TABLE 22.—Precipitation at Colon.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1862 ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1863 ..	1.75	2.94	0.85	.....	13.09	15.32	35.76	10.34	15.54	11.23	17.59	15.21	.....
1864 ..	1.90	0.77	0.73	0.44	15.87	5.78	.....	13.37	17.55	12.53	17.90	16.40	.....
1865 ..	[1.10]	1.06	0.62	3.89	9.32	16.85	9.61	15.33	8.55	9.69	22.16	6.58	107.4
1866 ..	3.99	1.07	0.21	4.07	14.76	12.17	16.72	12.72	18.52	15.04	21.72	8.42	129.7
1867 ..	1.58	0.80	0.48	1.30	11.83	8.55	16.08	19.82	5.35	20.50	.....	.....	.....
1868 ..	11.17	2.77	2.18	0.87	7.24	18.11	20.80	14.50	16.16	13.13	21.58	3.72	120.0
1869 ..	0.83	0.77	0.49	5.04	6.72	10.66	18.23	14.02	6.98	14.23	24.13	10.10	114.8
1870 ..	4.30	3.33	4.95	6.46	20.35	12.48	15.60	16.35	8.74	11.21	32.42	14.85	149.6
1871 ..	15.42	0.53	0.05	1.52	1.63	7.70	23.27	11.53	8.00	12.53	12.38	4.94	99.6
1872 ..	3.57	0.75	0.63	1.30	21.42	22.00	19.90	19.97	16.20	30.23	19.11	13.12	163.5
1873 ..	6.33	0.25	0.13	2.18	3.22	13.20	12.50	10.69	10.91	14.30	11.77	0.94	87.1
1874 ..	5.33	1.34	3.94	18.02	8.92	15.87	13.62	17.23	8.22	16.65	20.62	7.89	137.7
1893 * ..	1.78	3.36	1.81	8.05	6.65	12.34	11.44	15.10	9.92	12.23	17.78	30.94	131.90
1894 ..	5.35	1.69	0.26	2.18	9.84	12.24	19.05	23.02	13.79	12.43	23.66	25.12	153.75
1895 ..	3.35	1.32	2.03	22.36	16.17	9.26	17.10	14.15	12.11	16.47	.....	.....	.....

\* O. B. Schaffer, C. E., Panama Railway. See M. W. R., 1898, page 363. † One day missing.

[Mr. C. F. Talman, Weather Bureau Observer at Colon, reports that the rainfall for Colon in 1895, as published in the MONTHLY WEATHER REVIEW, 1898, p. 352, and 1899, p. 203, differs in some cases from the records in the office of the Panama Railroad Company at Colon, which, he states, reads as follows: 1895, April, 21.96 (not 22.36); May, 18.14 (not 16.17); September, 12.10 (not 12.11). No explanation of these differences is known.—Ed.]

TABLE 23.—Precipitation at Taboga Island.

N. 8° 48', W. 79° 32'; altitude 10 feet.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1861 ..	0.00	0.00	0.00	2.16	14.30	10.91	8.27	4.30	8.87	11.19	5.23	6.76	71.99
1862 ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1863 ..	0.00	0.00	0.00	0.26	1.60	8.80	8.11	9.54	11.94	1.62	2.87	3.77	48.51
1864 ..	0.50	0.00	0.00	0.00	3.13	4.78	2.08	5.91	3.60	11.33	2.97	11.42	45.72
1865 ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1866 ..	.....	.....	.....	.....	.....	.....	.....	8.74	4.90	5.16	5.12	4.30	.....

SPURIOUS TORNADO PHOTOGRAPHS.

By Mr. ALFRED J. HENRY, Chief of Division.

We have watched with interest and curiosity the efforts of some manipulators of the camera to reproduce the phenomena of nature in all her varying moods. There can be no particular fault found with the enterprise of the photographer, be he amateur or professional, who sallies forth at high noon, or soon thereafter, and under the friendly shadow of an accommodating cloud makes moonlight views by the score. We confess, too, that we can pass into the waste