The relative humidity was recorded by means of a special form of hair hygrometer, and this, combined with the temperature, gave the vapor pressure computed for each observation. The average relative humidity is given in Table 7. The ratio of the vapor pressure at any upper altitude to that at the earth's surface is given in Table 8. The results of work with balloons and kites are compared in Table 9, and give a remarkable confirmation of Hann's well-known formula.

TABLE 7.—*Mean relative humidity.*

[S=at ground, A=above.]

Stations.	1,500 ft.		2,000 ft.		3,000 ft.		4,000 ft.		5,000 ft.		6,000 ft.		7,000 ft.		8,000 ft.	
	S	A	S	A	S	A	S	A	S	A	S	A	S	A	S	A
Washington	76	68	75	67	77	64	75	61	80	60	78	66	73	59	79	58
Cairo	68	67	65	66	63	64	62	62	60	65	....	....	....	....	....	....
Cincinnati	70	67	65	68	64	63	66	68	65	64	63	70	....	....	....	....
Fort Smith	63	72	63	76	63	82	71	79	....	....	....	....	....	....	....	....
Knoxville	55	63	61	71	72	75	64	64	....	....	....	....	....	....	....	....
Memphis	59	70	67	77	72	77	69	69	60	62	....	....	....	....	....	....
Springfield, Ill	61	45	60	42	57	36	46	24	53	26	50	24	....	....	....	....
Cleveland	74	71	74	72	73	72	69	65	69	75	78	94	....	....	....	....
Duluth	70	72	66	69	60	65	62	64	61	57	58	57	54	70	....	....
Lansing	78	69	76	68	72	69	61	68	65	64	....	....	....	....	....	....
Sault Ste. Marie	80	71	73	69	73	69	63	68	59	73	....	....	....	....	....	....
Dodge	57	52	57	58	55	56	52	42	48	51	45	50	32	42	22	47
Dubuque	70	73	72	73	65	66	66	58	67	71	....	....	....	....	....	....
North Platte	53	56	51	56	47	53	46	52	42	49	30	60	....	....	....	....
Omaha	48	40	50	40	49	33	53	30	62	24	67	15	66	10	....	....
Pierre	57	63	56	61	55	66	52	60	43	58	48	64	....	....	....	....
Topeka	61	69	62	67	63	64	60	59	62	61	63	63	....	....	....	....
Means	65	64	64	65	64	63	61	58	60	57	58	56	56	45	50	52

TABLE 8.—*Vapor pressure.*

Diminution with altitude $\left(\frac{p}{p_0}\right)$.

Stations.	1,500 feet.	2,000 feet.	3,000 feet.	4,000 feet.	5,000 feet.	6,000 feet.	7,000 feet.	8,000 feet.
Washington, D. C	0.87	0.82	0.66	0.60	0.54	0.46	0.45	0.34
Cairo, Ill	0.71	0.69	0.63	0.54	0.54	......	......	......
Cincinnati, Ohio	0.73	0.69	0.57	0.51	0.49	0.45	......	......
Fort Smith, Ark	0.82	0.79	0.74	0.65	......	......	......	......
Knoxville, Tenn	0.83	0.73	0.66	0.76	......	......	......	......
Memphis, Tenn	0.88	0.86	0.76	0.61	0.54	......	......	......
Springfield, Ill	0.74	0.70	0.63	0.52	0.48	0.49	......	......
Cleveland, Ohio	0.83	0.77	0.68	0.55	0.55	0.48	......	......
Duluth, Minn	0.82	0.79	0.74	0.64	0.57	0.56	0.45	......
Lansing, Mich	0.87	0.83	0.73	0.56	0.51	......	......	......
Sault Ste. Marie, Mich	0.83	0.76	0.71	0.71	0.44	......	......	......
Dodge, Kans	0.85	0.84	0.80	0.71	0.61	0.56	0.51	0.55
Dubuque, Iowa	0.83	0.79	0.76	0.56	0.56	......	......	......
North Platte, Nebr	0.78	0.72	0.66	0.57	0.40	0.65	......	......
Omaha, Nebr	0.83	0.80	0.68	0.56	0.39	0.23	0.15	......
Pierre, S. Dak	0.90	0.86	0.75	0.72	0.69	0.69	......	......
Topeka, Kans	0.85	0.80	0.68	0.56	0.52	0.36	......	......
Mean	0.82	0.78	0.70	0.61	0.52	0.49	0.39	0.44

TABLE 9.—*Decrease of vapor pressure with altitude.*

Value of $\left(\frac{p}{p_0}\right)$ for the respective altitudes.

Character of observations.	1,500 feet.	2,000 feet.	3,000 feet.	4,000 feet.	5,000 feet.	6,000 feet.	7,000 feet.	8,000 feet.	No. of observations.
Kites	0.82	0.78	0.70	0.61	0.52	0.49	0.39	0.44	1,123
Balloons (Hammon)	0.96	0.96	0.87	0.68	0.44	0.59	......	......	4*
Balloons (Hazen)	0.89	0.83	0.80	0.78	0.67	0.46	0.44	......	2*
Balloons (Hann)	0.84	0.80	0.66	0.61	0.50	0.54	0.41	0.37	15†
Mountains (Hann)	0.83	0.81	0.80	0.66	0.61	0.58	0.55	0.47	6†
Computed by Hann's formula.	0.85	0.81	0.72	0.65	0.58	0.52	0.47	0.42	......

*American Meteorological Journal. †Meteorologische Zeitschrift, IX, 1874.

The velocity of the wind was not recorded, owing to the fact that the small and light anemometer designed to accompany the meteorograph could not be completed and tested in time for use.

The direction of the wind at any elevation is almost exactly given by the azimuth of the kite. A general study of these directions is given by Dr. Frankenfield in connection with each station, and may be summarized as follows:

The upper winds show an increase in velocity and a slight progressive deflection toward the right, increasing with the altitude, and rarely exceeding 90°. In the few cases of deflection toward the left, the velocity of the wind, as shown by the pull on the kite wire, diminished with increase of altitude. In a slight majority of these cases of deflection toward the left, rain followed within a few hours. The diurnal changes of the upper and lower winds were strongly marked at Duluth.

THE AVERAGE TEMPERATURE OF THE ATMOSPHERE.

When a long and complete series of observations with sounding balloons and kites becomes available, we may determine with great accuracy the normal temperature of the atmosphere over any station for each thousand meters of altitude up to great heights. Meanwhile, however, the diagram given by Teisserenc de Bort in an article that we have translated and published on page 412 tempts us to make a first approximation to this fundamental datum in dynamic meteorology. We can, however, only reason cautiously upon the data given by himself as the results of systematic work at Trappes, near Paris. As a first approximation, the Editor offers the mean monthly temperatures and annual averages given in Table 1, as representing an average year between April, 1898, and July, 1899. This is a rather bold and hazardous attempt at generalization, but when we consider that according to his own statement, the mean departure of the temperature from the mean at any given altitude in all types of weather, ranges from 5.2° nearest the ground to 6.6° C. at 6,000 meters, we see at once that the annual averages given in this table have some slight value as an approximation to the normal, provided no systematic instrumental errors intervene. Better figures will doubtless be given by the author himself at some future date.

TABLE 1.—*Approximate mean temperatures* (*Centigrade*) *observed in free air at Trappes during* 1898–99.

Altitude (kilometers).	January.	February.	March.	April.	May.	June.	July.	August.*	September.	October.	November.	December.	Annual mean.	Means of departures. Daily observations.	Means of departures. Monthly means.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
10	-50	-55	-55	-55	-68	-44	-45	(-45)	-45	-55	-55	-50	-51	......	4.8
9	-45	-45	-50	-45	-50	-38	-35	(-35)	-36	-45	-45	-40	-42	5.6	4.8
8	-35	-39	-44	-39	-40	-31	-28	(-28)	-28	-40	-40	-35	-38	6.0	4.8
7	-30	-31	-40	-32	-32	-23	-21	(-21)	-22	-30	-33	-30	-29	6.4	4.6
6	-25	-26	-32	-25	-24	-14	-15	(-14)	-13	-20	-25	-23	-21	6.6	5.2
5	-20	-21	-26	-17	-17	-10	- 9	(- 8)	- 7	-13	-18	-18	-16	6.8	4.8
4	-13	-11	-21	-12	-12	- 5	- 3	(- 2)	- 2	- 7	-12	-12	- 9	6.4	4.7
3	- 8	- 8	-14	- 7	- 7	0	+ 2	(+ 2)	+ 1	- 2	- 3	- 7	- 4	6.1	4.2
2	- 4	- 4	- 6	- 4	- 3	+ 6	+ 8	(+ 7)	+ 6	+ 2	0	- 4	0	5.6	4.5
1	+ 1	+ 2	- 2	+ 1	+ 1	+10	+12	(+12)	+11	+ 8	+ 3	0	+ 5	5.2	4.8
0	+ 4	+ 4	0	+ 5	+ 6	+15	+20	(+18)	+15	+14	+ 6	0	+ 9	5.5	6.2
Mean date	16	19	19	18	12	10	16	(19)	22	16	24	24	......	......	......
No. obs	3	4	6	9	6	6	2	0*	2	2	3	3	4.9	......	......

*The temperatures for August are interpolated.

It would not be proper to consider these figures as representing any other locality than the neighborhood of Paris. If the irregularities of temperature continue above the same as below, no matter how high we ascend in the atmosphere this shows that the general currents of air and the presence of clouds or haze control the temperatures. Such currents and moisture conditions change with the season, the relative position of land and water, and the latitude. The existence and motions of the cirrus cloud show that the general circulation of the atmosphere affects it to a height of 10 miles, and that average temperatures and gradients at that height must differ systematically according to the currents and moisture appropriate to the location of the station. The figures for Trappes may possibly represent, in general, France, Holland, and Denmark, but can hardly represent Great Britain or Norway or the interior of Europe, still less the eastern portion of the United States.

Although, relying implicitly upon the diagram published in the Comptes Rendus, we should be cautious about drawing conclusions finer than are warranted in view of the well-known sources of error incidental to all such observations.

In Table 1 we have included a column given by Teisserenc de Bort, showing the average departures of his individual temperatures from average values, from which we see that there is an average variability of 5° or 6° in the temperature of any one horizontal stratum, whence the mean temperature of the month should have a "probable uncertainty" of about 1.5° and the mean of the year 1°, as compared with normal values that would result from a very long series of observations. We have also added a column showing the mean departures of our present monthly values from their respective annual means.

The mean of all the departures of any observed temperatures from their average value is not quite the same as the so-called "probable departure" or "probable error." If we assume that the temperature of a stratum is constant throughout the whole series of observations, then any observed departure from this mean is like an error in making a measurement. Such errors are governed by certain laws, which, if they are unknown to us and can not be otherwise handled, must be treated as though they were due purely to chance. There will be fewer large but more small departures; the larger errors will have a smaller chance of occurring. The chance of occurrence of an error will diminish as the size of the error increases, but not exactly in the same proportion. The precise law, as given by the "theory of probabilities," is a logarithmic equation; that is to say, the logarithm of the probability of the occurrence of an error as large as x will decrease in proportion to the increase of the square of x. This probability is very neatly shown by a curve, called the "probability curve," whose ordinates represent the probabilities of the occurrence of the errors that are represented by the corresponding abscissas. Every value of x is possible and has its corresponding probability of occurrence; there is a special medium value, such that there will be as many others above it as there are below it, so that the chance of the occurrence of this particular error is just one-half. This is not "the most probable error," but has for a century past been adopted as a convenient index to the internal agreement or discrepancy of the observations among themselves and is called "the probable error." Instead of this, Teisserenc de Bort adopts the average of all the departures as an index to the agreement of the observations among themselves. The laws of probability show that "the probable error" is found approximately by multiplying the "mean of all the errors" by the factor 0.8453.

It is frequently necessary to calculate the average of the sum of the squares of the individual errors. The square root of this average is called "the *mean* error," not the mean of the errors, and from this "the *probable* error" may be found by multiplying by the factor 0.6745.

According to the figures given by Teisserenc de Bort for each horizontal stratum of air, the "mean of the departures" of the individual measurements of temperature vary between 5.5° and 6.6°. The corresponding mean of the departures for monthly mean temperatures will be found by dividing these latter figures by the square root of 30, and will, therefore, be about 0.9° and 1.1°, respectively. The mean of the departures of the respective annual means would be found by dividing by the square root of 365, and would, therefore, be about 0.3° C.

If we study, by themselves, the monthly means for each stratum, as given in Table 1, and form a system of twelve departures from their annual means, we find the means of these departures vary between 6.2° and 4.2°, as shown in the last column of the table, that is to say, the probable departures of the monthly means vary from 5.2° to 3.5°, respectively. These are so much larger than the 0.9° and 1.1° just quoted in the previous paragraph as to show that the changes in temperature due to annual periods are quite as important as those due to daily irregularities.

The "probable error" of each of the annual means for the respective altitudes would range from 1.1° to 1.7° as deduced from the monthly means, and assuming that there be no systematic annual periodicity and no important systematic instrumental error.

When we examine the column of annual means for the purpose of determining the average rate of decrease of temperature with altitude, we have to remember not only the annual periodicities and accidental irregularities in the actual temperatures of the air as just calculated, but that an important systematic instrumental error may also exist. These temperatures have all been determined by means of a self-register that ascended rapidly, and after a while descended rather more slowly to the ground. Now, every thermometer, and especially those of such registering apparatus, requires a little time to follow the changes of temperature to which it is subjected. The so-called sluggishness of the thermometer is a source of error as important as the variability of the actual temperature. Table 1 brings out the fact that throughout all these ascensions there has been a steady diminution of temperature with altitude, amounting to somewhere between 50° C. and 65° C. in 10 kilometers, and averaging exactly 60° C. Now, when a thermometer is plunged into a bath whose temperature is 60° lower than its own, and is stirred rapidly about in a large mass of water, so that the external surface of the glass bulb keeps a constant temperature of —60°, the interior glass and mercury requires some time to attain that temperature. It may be five or ten minutes, being longer in proportion to the poor conduction and convection of heat by the bulb. The temperature shown by the thermometer follows a logarithmic law of decrease, and after coming close to the temperature of the bath there is still an outstanding error of a few hundredths of a degree or, possibly, of a whole tenth. For any given difference of temperature between the bath and the thermometer, there is a certain rate at which the thermometer will change its temperature in its efforts to attain equilibrium with the liquid. If the liquid holds its own temperature constant, the thermometer will ultimately approximate equality with it.

But the thermometer in an ascending sounding balloon comes at every moment into new liquid whose temperature is lower than that of the preceding layer, it is, therefore, attempting to fall to the temperature of a liquid whose temperature is itself falling. If the balloon is ascending quite uniformly, so that the rate of fall in the temperature of the bath is uniform, then the cooling thermometer soon attains such a temperature, (a little above that of the air) that for this difference of temperature its own rate of fall is just the same as that of the uniform diminution of the temperature of the bath. When this condition has been attained the thermometer will, indeed, cool as fast as the temperature of the air falls with the rising balloon, but the thermometer will always be behind the temperature of the air by a constant number of degrees corresponding to a constant difference in altitude, and this may continue indefinitely.

To illustrate this by an example, suppose that the thermometer be one of those used by me at Poulkova in 1865, and whose correction for sluggishness is given on page 72 of my "Treatise on meteorological apparatus and methods," Report of Chief Signal Officer, 1887. In this case, when the temperature of the bath is one degree lower than the temperature of the thermometer, the latter cools at the rate of 0.255° per minute. If the temperature of the bath is some other quantity, such as N degrees cooler than the thermometer, the rate at which the latter will cool is $N \times 0.255°$ per minute.

If the difference of temperature is 4° the rate of cooling will be 1.02° per minute. If now, this thermometer is ascending in a balloon through layers of cooler air at such a rate that it rises 10 kilometers in an hour, and if the air temperatures diminish as they do in the column of mean annual temperatures in Table 1, namely, 60°, in this interval, then the thermometer is, as it were, in a bath whose temperature is falling 1° per minute. Therefore, our thermometer which can cool at the rate of 1.02° per minute when the bath temperature is 4° below its own, will soon come to a temperature of about 4° behind, that is to say, 4° warmer than that of the layer of air in which the balloon is located at any moment. This 4° in temperature corresponds to a vertical distance of $\frac{2}{3}$ of a kilometer for the assumed temperature gradient in the free air, therefore all recorded temperatures will be 4° too high for the altitude, and really belong to a layer of air $\frac{2}{3}$ of a kilometer lower down. The converse will hold good for descending balloons.

In applying the preceding argument to the self-registers used at Trappes, we recall that some similar instruments have shown a degree of sluggishness such as would be represented by a much larger figure than the 0.255° used in the above illustration. Thus in his report, on pages 34–92 of the Protocol of the Strasburg Meeting, April, 1898, of the International Aeronautic Commission, Teisserenc de Bort says:

In rapid ascents the temperature of the air can vary 2° or 3° per minute, since the balloons rise at the rate of from 4 to 9 meters per second, and descend with velocities of 2 or 3 meters per second. Thus the temperature recorded at a given altitude when the balloon is rising may be 14° in excess of that indicated for the same altitude when it is descending.

Again, in the same protocol, pages 93–103, Professor Hergesell gives the coefficient of "sluggishness," (whence by inversion we compute the coefficient of sensitiveness) for two Richard self-registering thermometers that have actually been used in some voyages with sounding balloons. When these thermometers are ventilated with sufficient rapidity, e. g., in a wind blowing at the rate of from 3 to 10 meters per second, in air of constant temperature, the coefficients of sensitiveness increase as the speed of ventilation and the attending increase of conduction and convection. They are, respectively, 1.3° or 1.6° for a velocity of 3 meters per second, and 5.0° or 6.2° for a velocity of 10 meters per second in air. This coefficient is, however, subject to a diminution with the diminution of convection in rarified air, and would therefore become perhaps one-fourth of the values here given, i. e., 0.4° and 1.5° for the air at the highest portion of an ascension. Professor Marvin's experiments at the Weather Bureau on the coefficient of sensitiveness of his own kite thermograph under an atmospheric pressure of 30 inches, indicate a value of 0.9° C. for a ventilation of 3 or 5 meters per second.

Under these conditions we see that even if the corrections for sluggishness have been approximately determined and applied to the observations on which Teisserenc de Bort has based his chart, yet there is room for considerable uncertainty of a systematic nature and we are quite safe in saying that the annual mean temperatures given in Table 1 are, on this account alone, still probably open to systematic corrections.

Beside the sluggishness of the self-registering apparatus, by virtue of which recorded temperatures are too high when ascending and too low when descending, the apparatus comes under the influence of solar radiation which warms it, and the surrounding air carried along with it, so that it tends to give records that are too high. This error is partly counteracted by artificial ventilation and by the convection due to the rapidly ascending motion of the balloon, but becomes very serious when the balloon has reached the upper limit of its ascent and is floating along with the local current of air. The converse holds good at nighttime, but to a much less degree when the apparatus is cooling by its own radiation without being warmed by the sunshine.

In the absence of any definite information as to the extent to which the balloon records have been affected by various sources of error, we may still cautiously draw from the annual means some interesting conclusions based on the following considerations:

The temperature of the air depends primarily upon the processes of cooling by radiation and warming by conduction and convection. The former tends to keep the earth's surface cold and the layer of coldest air lies close to the ground; this tends to bring the whole atmosphere into a condition of stable static equilibrium in which the temperature increases with altitude; the vertical gradient, therefore, is positive and may have any value up to infinity.

The process of convection carries warm and moist air upward in one place only to descend in another. In this boiling process the ascending currents cool by expansion and the descending currents warm up by compression. The tendency is to keep the whole atmosphere in thermo-dynamic equilibrium and the temperature diminishes with altitude. The vertical gradient is negative and may be anywhere between —2.0° C. and —9.9° C.

The general average between stable static and unstable dynamic conditions for the whole globe gives an "equilibrium gradient" of about 5° C. per 1,000 meters, as a close approximation to the annual average condition of the whole atmosphere up to the highest point that the sounding balloons have as yet attained. It would appear that at these greatest heights the convective processes are still as effective as at the surface, and it may be doubted whether there is any height to which they do not attain.

The adiabatic rate of change of temperature in dry air is that which would prevail in a mass of air ascending or descending without changing its quantity of internal heat, and is 9.9° C. per 1,000 meters: this is the same as that which would prevail if the loss of heat by internal processes were exactly counterbalanced by the absorption from outside sources; it is the same as that which prevails when the air rises or falls so rapidly that it has no time to lose or gain any heat. In moist air, not cloudy, it averages 9.8° C., but within cloudy air, with rain or snow in process of formation, it may be as low as 2.0° C. At the upper surface of a cloud there is a break or discontinuity in the gradient, owing to the absorption of solar heat by the cloud particles in the daytime and the radiation of heat by them at night time. The gradient will, therefore, vary with the speed of ascent or descent. The gradient 5° per kilometer may be taken as an approximation to that which the general condition of the air as to moisture, convection, and radiation appears to impose on the whole atmosphere.

TABLE 2—*Approximate observed diminution, with altitude, of temperature of free air at Trappes.*

Altitude (kilometers).	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual mean. Observed.	Annual mean. Equilibrium.	Annual mean. Difference.	Annual mean. Adiabatic diminution.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
10	—54	—59	—55	—60	—66	—59	—65	—63	—60	—69	—61	—50	—60	—50	—10	—98
9	—49	—49	—50	—50	—56	—53	—55	—53	—51	—59	—51	—40	—51	—45	— 6	—88
8	—39	—43	—44	—44	—46	—46	—48	—46	—43	—54	—46	—35	—47	—40	— 7	—79
7	—34	—35	—40	—37	—38	—38	—41	—39	—37	—44	—39	—30	—38	—35	— 3	—69
6	—29	—30	—32	—30	—30	—29	—35	—32	—28	—34	—31	—23	—30	—30	0	—59
5	—24	—25	—26	—22	—23	—25	—29	—26	—22	—27	—24	—18	—25	—25	0	—49
4	—17	—15	—21	—17	—18	—20	—23	—20	—17	—21	—18	—12	—18	—20	+ 2	—39
3	—12	—12	—14	—12	—13	—15	—18	—16	—14	—16	— 9	— 7	—13	—15	+ 2	—29
2	— 8	— 8	— 6	— 9	— 9	— 9	—12	—11	— 9	—12	— 6	— 4	— 9	—10	+ 1	—20
1	— 3	— 2	— 2	— 4	— 5	— 5	— 8	— 6	— 4	— 6	— 3	0	— 4	— 5	+ 1	—10
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

The temperatures corresponding to the adiabatic rate, 9.8° for dry air, and the equilibrium rate, 5.0°, are shown in columns seventeen and fifteen, respectively, of Table 2, and the departures of the observed temperatures from the equilibrium rate are shown in column sixteen.

It will be noticed that up to 4 kilometers the observed annual mean diminution of temperature for Trappes is slightly less than that which we call the equilibrium rate, but the differences are within the limits of the general uncertainty or probable error of the annual means. On the other hand, between 7 and 10 kilometers, the observed diminutions are greater and the temperatures are appreciably cooler than equilibrium would require, that is to say, the atmosphere above Trappes is so cold at these heights that it has a tendency to descend to the earth's surface. Of course, in doing so it warms up by compression, and, therefore, sinks down only so fast as the cooling by radiation may counteract the dynamic heating, so that the air may still appear cool when it eventually arrives at sea level. An examination of the means for separate months shows that this tendency prevails throughout the year at the 8, 9, and 10-kilometer level, but is most pronounced in the warmer half of the year; it also prevails in the warmer half at the 7-kilometer level. In other words, the annual change of temperature at the ground is, in general, inverse to that which takes place in the upper strata. This inversion we must attribute almost entirely to the annual changes in the circulation of the atmosphere, by virtue of which the warm air that in the summer months left the surface of the ground in far distant warm regions has, after a long journey, been brought to the region above Trappes, and has been cooled by radiation until it is now pressing its way down to the ground.

The little that we know about the movements of the upper air favors the presumption that the upper southwest wind, or antitrade, flowing from the equatorial to the arctic region is slowly descending, except in special regions, where underlying continents and mountains or underflowing northeast and northwest winds, or some form of wave or vortex disturbance temporarily forces it to rise a little. The formation and dissipation of the highest cirrus clouds seems to suggest the localities over which this current has a special ascending or descending motion, but far above these clouds similar motions must take place in regions ordinarily inaccessible to observation. The locations of these regions must be subject to annual changes somewhat corresponding to the seasonal shifts in the locations of our large subpermanent areas of high and low pressure. The gradients of ascending and descending motions in the atmosphere, at and above the level of the cirrus clouds, are probably steep enough to produce great velocities, on account of the wonderful mobility of the air, whose internal friction or viscosity, diminishes rapidly with temperature. A mass that ascends at the equator to the height of 20 kilometers, and descends at the pole to the surface of the earth, must flow along an average grade of $\frac{20}{10000}$ or $\frac{1}{500}$. This grade produces a swift rapid in a river of water and can produce a velocity of 100 miles per hour in the free air.

The radiation of heat by a pure and dustless gas is a very small quantity, but it may be greatly increased by the presence of dust or such vapors as aqueous vapor, ammonia, or carbonic acid gas. Several attempts have been made to determine the actual coefficient of radiation (see my article on "Atmospheric Radiation," American Journal of Science, May, 1892, Vol. XLIII, p. 364, reprinted in The American Meteorological Journal, 1892, Vol. VIII, p. 549).

The rate of radiation of a unit mass of air doubtless varies with its altitude, its temperature, pressure, moisture, dust, &c., but our first crude approximation must assume it to be constant and that its effect, namely, the lowering of the temperature of the mass, goes on in proportion to the lapse of time and the gradient of temperature outward from it toward the surrounding region or the inclosure. The lowest value that has been suggested as plausible for the coefficient of radiation is one that would cause a mass of air to cool at the rate of 2.88° C. per day by radiation toward an inclosure that is 1° cooler than itself. On the other hand, the dynamic cooling of an ascending mass of gas, or the dynamic heating of a descending mass, depends essentially upon the changes of pressure and the resulting expansion or compression that it experiences; for moist, air without cloud, it amounts very closely to 0.98° C. for a change in elevation of 100 meters, although it is quite common to use the approximate ratio of 1° C. per 100 meters. Adopting 0.98°, we see that a change of 294 meters in altitude would correspond to a change of 2.88° C. in temperature. Hence, the dynamic warming, due to a descent of 294 meters in one day, would just counteract the cooling due to the loss of heat by radiation during one day. In general, the total cooling during the time (t), expressed in days, due to the effect of radiation (k) *plus* the effect of a change of altitude at the rate of r meters per twenty-four hours, is expressed by the formula

$$T - T_0 = k\,t + c\,r\,t = (k + c\,r)\,t,$$

where c is the rate $-0.98°$, as above given. If we assume $k = -2.88°$ and give r a number of assumed values, as in the first column of the accompanying Table, 3, positive for ascending and negative for descending air, then the total change of temperature in twenty-four hours will be as given in the second and third columns. If these total changes of temperature be divided by the vertical distances in the first column, there results the rate of change in temperature per 100 meters of altitude as given in the fourth and fifth columns. These latter are gradients, properly so called; the altitudes are supposed to increase positively when measured upward; the observer ascends, although the air is descending; therefore the numbers given in the fifth column have the opposite sign to those in the third column.

TABLE 3.

Assumed daily rate of change of altitude.	Corresponding temperature gradient per 100 meters.		Resulting temperature change per day.	
	Ascending	Descending.	Ascending.	Descending.
	°	°	°	°
0 meters	−2.88	−2.88	*	*
147	−4.32	−1.44	−2.94	+0.98
294..................	−5.76	0.00	−1.96	0.00
441..	−7.20	+1.44	−1.63	−0.33
588.........	−8.64	+2.88	−1.47	−0.49
Infinity	−Infinity.	+Infinity.	−0.98	−0.98

*If the rate of ascent or descent is 0 in the free air, then every particle is in stable equilibrium; no vertical motions can originate spontaneously, and the gradient of temperature may be anywhere between −0.98° and + infinity.

Now, on the average of a whole year, and throughout the atmosphere of the whole globe, each horizontal layer contains equal masses of ascending and descending air, otherwise there would be an increasing accumulation at some place. But it does not follow that at any high point above the earth equal masses of ascending and descending air pass by during the year, since a steady ascent at one place might be counterbalanced by an equal steady descent elsewhere. The average temperature gradient at any place depends, not on the mass that passes by it, but on the rate of rise or fall and on the duration of time occupied by each; it is, in fact, the average of the products of the temporary gradients by the respective durations. Ascents are usually rapid and local, descents are slow and extensive. If the temperature gradients are uniformly distributed throughout the year, then only do the respective times drop out of consideration, and the resulting local gradient depends upon the actual rates of ascent and descent and the moisture of the air. If the air is not cloudy and the ascending gradients have been the same as the descending gradients, then, the resulting annual average will be the mean of the two figures given on any line in Table 3, that is to say, it will always be 0.98, and will, therefore, be independent of radiation. In other words, in this ideal case of a cloudless atmosphere and rapid convection, the radiation effect is uniformly distributed throughout the mass, and does not affect the vertical gradient, but, of course, this is far from being the actual condition of the earth's atmosphere.

THE INTERNATIONAL ELECTRICAL CONGRESS AT COMO, ITALY.

An International Electrical Congress was held, September 18–25, 1899, at Como, Italy, in connection with the so-called Volta Electrical Exposition. Modern electrical science began with the work done by Volta, who was a native of Como. The exposition opened with brilliant promise early in the present year, and, notwithstanding the disastrous fire that soon followed, the exposition and the congress form an interesting epoch in the history of electricity. The congress was opened with an address by Colombo, president of the Italian Electro-Technic Association, who also represented the minister of public instruction. Many of the most distinguished electricians were present. Among the items that may especially interest meteorologists, we quote the following from the report by Martinez in The Electrical World and Engineer of October 21, page 615:

Professor Blaserna desired the congress to commit itself in favor of the adoption of the double trolley, or of accumulator traction, for lines passing in the vicinity of scientific laboratories. The proposition was not received with much favor by the audience, which was largely composed of a modern element, to whom the disturbances of a galvanometer in a laboratory had much less importance than the economy of electric traction.

Mr. Gisbert Kapp expressed the opinion of the majority of those present in saying that savants, instead of asking that electric traction systems, which gave such great advantages to the majority of citizens, should be changed, should endeavor to perfect their instruments, so that they would not be disturbed from that cause, and, if this can not be done, they should move their laboratories to the country, far away from electric railways.

M. Campelio expressed his agreement with Mr. Kapp.

Mr. Pinna, director of the Turin electric plant, said that accumulator cars differed little from the trolley in their effects on delicate instruments.

Mr. Mengarini, director of the electrical plant at Rome and engineer of the project of transportation of power from Tivoli to Rome (2,000 horse power at 6,000 volts, a rash proposition in 1891), sought to give some satisfaction to Professor Blaserna, in speaking of the serious trouble produced by electric railway return currents on water and gas pipes. He asked, not that the earth return should be prohibited, but that, in the insulation of street railways, all possible precautions should be taken to avoid damage from the return currents.

The discussion having begun to extend over a wide ground, the president adjourned it to the next meeting, and gave the floor to Professor Blaserna, who read a paper on the variation of the earth's terrestrial magnetism in antiquity. The idea of the investigation was due to a learned and very modest coadjutor of Professor Blaserna, Dr. Folgheraiter, of the University of Rome. Dr. Folgheraiter had observed that earthenware will preserve indefinitely the magnetism that it possessed when it was baked. Etruscan vases, roman bricks, etc., he found presented magnetic phenomena so striking as to enable the terrestrial magnetic conditions existing when they were baked to be deduced. The etruscan vases of the year 600 B. C. showed with certainty that at that epoch the direction of the terrestrial magnetic field was almost vertical at Rome and in central Italy. Professor Blaserna expressed the hope that similar observations would be made in other countries.

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At the joint session with the Italian Physical Society, on September 21, Professor Somigliano of the University of Como, discussed the changes of levels in the Italian lakes, a matter that was also observed by Volta, in connection with Lake Como. This lake, as well as others in Italy, is subject to abrupt changes of level which cannot be explained on the supposition of increased flow of water from the streams flowing therein. Recently instruments have been installed to make observations on Lake Garda, with a view to making a careful study of the phenomena. Professor Chistoni gave some interesting details on electrical discharges on Mount Cimone, 7,100 feet high high, the highest peak of the Apennines in the Tuscany and Lombardy region. An observatory has been placed on the summit of this mountain, where aerial conductors have been installed to study the phenomena of atmospheric electricity, which so much interested Volta.

Professor Voltena read a paper of capital importance on "Energy" in the treatment of which a new method of mathematical analysis was followed.

Professor Lemstrom spoke of the artificial reproduction of the aurora borealis. He advanced the conclusion that there is in the atmosphere a permanent electrical current vertical inflow. Professor Wiedemann did not agree with this opinion, observing that we can not have luminous phenomena with differences of potential as small as those mentioned, which, however, may be caused by alternating currents of high frequency.

In the afternoon of September 22, at the meeting of the Italian Physical Society, Professor Maragoni, of Florence, gave a summary of the different theories of the formation of hail, and concluded that the theory of Volta still remains the most plausible, if slight modifications are applied to it.[1] The discussion was participated in by several of the members.

Señor Zublena proposed that the meeting should express an opinion in favor of the encouragement of theoretical and practical researches relating to hail, the occurrence of which in certain parts of Italy constituted a real affliction.

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Professor Bongiovanni showed an apparatus illustrating the phenomena of terrestrial magnetism, and M. Arno made some interesting experiments on the rotations of insulating disks by electro-static action.

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At the last meeting of the Physical Society, Mr. Rizzi, of Naples, read a paper on the magnificent colorations in the Gulf of Naples. He showed that the explanations which have thus far been given concerning the marvelous coloring of the sea and of the sky in that locality do not suffice.

The meeting expressed the wish that the Italian Government should undertake the publication of the complete edition of all the works of Volta, as it has already done for the works of Galileo.

INSTRUCTIVE LABORATORY EXPERIMENTS.

On another page we publish a short contribution by Mr. Ralph B. Marean on whirling columns of mist. This suggests one of many forms of experimentation practicable in physical laboratories, and essential to the development of exact meteorological science.

It is well known that determinations of the coefficient of viscosity of the air have been made by exact observations upon whirls driven by rapidly-revolving cylinders or circular plates. But in these experiments the inertia of the moving masses is so great that the viscosity becomes a minor matter and is not determined with all the precision that is desirable.

The mist whirls seen by Mr. Marean can, undoubtedly, be formed and observed at pleasure by proper laboratory arrangements. If, as he describes, a whirl of small height but considerable diameter is observed beginning in a lower stratum of mist, but finally is converted into a small, slender, rapidly-rotating column which ascends and is finally converted into a horizontal cloud in which there is no rotation, then it is evident that the ascent is due to the slight buoyancy of the original mass, and probably depends almost wholly upon its having a temperature slightly higher than its surroundings, but the disappearance of the rotation depends on the inter-

[1] It is proper for the readers of the MONTHLY WEATHER REVIEW to remember that according to the theory of Volta, hailstones grow by accretion, as they are alternately repelled upward and downward electrically, between two oppositely charged layers of clouds. This working hypothesis of a century ago is now obsolete in meteorology, and wholly replaced by the convective processes fully explained by Ferrel and the thermo-dynamic processe explained by von Bezold, and abundantly confirmed by observations in balloons and on mountain tops.—ED.