Professor Stearns excelled especially as a teacher of physics. He published but few papers, principally on the phenomena of thunderstorms.[1] His best known piece of experimental work was in the determination of the magnetic susceptibility of water, the results of which were published in the Physical Review of January, 1902.

Professor Stearns was married in 1894 to Miss Florence Curry of Streator, Ill., who survives him.

THE LAGGING OF TEMPERATURE CHANGES AT GREAT HEIGHTS BEHIND THOSE AT THE EARTH'S SURFACE AND TYPES OF PRESSURE CHANGES AT DIFFERENT LEVELS.

By HENRY HELM CLAYTON, meteorologist of the Blue Hill Observatory. Dated Hyde Park, Mass., November 30, 1907.

By permission of Prof. A. Lawrence Rotch, director of the Blue Hill Observatory, I am able to publish, in advance of a more detailed discussion by me in the Annals of the Astronomical Observatory of Harvard College, a few results of interest derived from a study of the records obtained with sounding balloons launched from St. Louis, Mo.

One of the earliest facts disclosed by the records obtained in the free air with kites at Blue Hill was that changes of temperature occur earlier at heights of 500 to 1000 meters than at the earth's surface.[1] It had also previously been disclosed by a study of the observations on Mount Washington that changes of temperature usually occur earlier at the summit than at the base.[2] In a recent number of the MONTHLY WEATHER REVIEW,[3] Prof. C. H. McLeod proposes to predict weather changes from observations on Mount Royal, Montreal, which show the coming of weather changes earlier there than at low stations.

Long before the fact of the earlier coming of temperature changes at heights of 500 to 1000 meters had been established, it was inferred that a change of temperature would occur first in the upper air because the upper currents move so much faster and overflow those below. This assumption has been used for many theoretical explanations of thunderstorms, tornadoes, waterspouts, and even of general storms. However, the recent records obtained at St. Louis with sounding balloons, by the staff of Blue Hill Observatory, show that at all heights except within about 1000 meters of the earth, the temperature changes occur successively later with increasing height above the ground. This fact is best shown by the records for April and May, 1906, because this series of observations is more complete and for a longer interval than any other yet obtained at St. Louis. The balloons were liberated by Mr. S. P. Fergusson near sunset each day, and the highest point, varying between 3 and 15 kilometers, was reached between 7 and 9 o'clock. Records were obtained on every day from April 28 to May 19, with the exception of three days. These records make it possible to follow the changes of temperature from day to day at different heights. The temperatures on different days at successive heights of 5 kilometers are shown in Table 1, and the results are plotted in Fig. 1.

It is apparent from the table and from fig. 1 that maxima and minima in temperature occur very considerably later in the upper air than at the earth's surface. What appear to be similar maxima and minima at different levels are marked by similar numerals, *1*, *2*, *3*, etc., in fig. 1.

By comparing the temperature maxima and minima at the ground, 167 meters above sea level, with the maxima and minima at 10,000 meters, it is seen that the maxima and minima at 10 kilometers occur almost constantly about twenty-four hours later than at the ground. The observations are not in sufficient detail to show whether this retardation is gradual from level to level or occurs in irregular steps; but apparently the change is not gradual. The maximum marked *5* occurs simultaneously at 5000 and at 10,000 meters, but occurs there about a day later than at the ground. On the other hand the maximum marked *8* occurs simultaneously at the ground and at 5000 meters, but occurs a day later at 10,000 meters. However, as observations were taken only once a day it is not possible to follow any gradual shifting occupying only one day. The observations at the height of 15,000 meters were not sufficiently numerous to follow the changes easily, but apparently the irregular ranges of temperature at this height are very much less than at sea level. From May 2 to 10, inclusive, records were obtained at each level from the ground to 10 kilometers, and during part of this time there were records at 15 kilometers also. The means of the changes of temperature from one day to another at different levels are found to be as follows: at the ground, 6.0° C.; at 5 kilometers, 5.2°; at 10 kilometers, 7.1°; and at 15 kilometers, 2.9°. These results indicate that the irregular changes of temperature reach a maximum at 10 kilometers, and suddenly decrease at 15 kilometers. Between these two levels there is found a marked inversion of temperature in both Europe and America; the air at 15 kilometers is warmer than that at 13 to 14 kilometers, and it may be that the changes in temperature in the two strata have little in common.

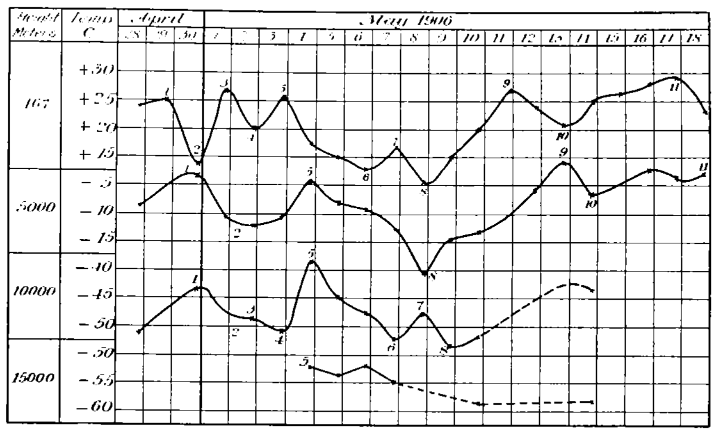

FIG. 1.—The temperatures at successive heights above sea level derived from records obtained with sounding balloons ascending from St. Louis, Mo., April and May, 1906.

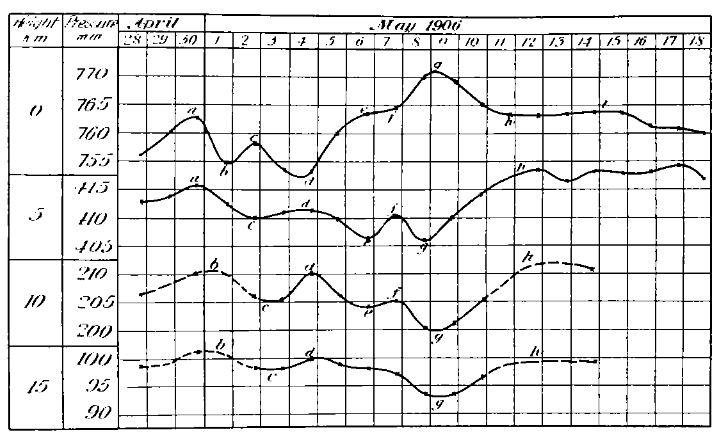

FIG. 2.–The pressures at successive heights above sea level derived from records obtained with sounding balloons ascending from St. Louis, Mo., April and May, 1906.

The mean pressures at different heights from sea level to 15 kilometers are given in Table 2. In obtaining these results

[1] See Monthly Weather Review, October, 1898, vol. 26, p. 452. "The effect of proximity to the sea on thunderstorm periods."

[1] See Blue Hill Meteorological Observatory Bulletin, No. 2, 1898, p. 2; also Annals of the Astronomical Observatory of Harvard College, vol. XLII, part I, 1897, p. 107.

[2] See American Meteorological Journal, vol. IV, p. 268, 1887.

[3] November, 1906, vol. XXXIV, p. 505–510.

the observed pressures at St. Louis were reduced to sea level, and the pressures at 10 kilometers were reduced to 15 kilometers on the days when there were no records at 15 kilometers, using for this purpose the mean observed difference in temperature between the two strata. The pressures at all other heights were derived from the records of the sounding balloons.

TABLE 1.—*Temperatures at different heights above sea level derived from records obtained with sounding balloons sent from St. Louis, Mo., 167 meters above sea level.*

Date.	Hour.	Height.	Temperature.	Date.	Hour.	Height.	Temperature.
1906.	*P. M.*	*Meters.*	°C.	1906.	*P. M.*	*Meters.*	°C.
April 28.	7:33	167	24.4	May 8.	7:05	167	10.1
	8:09	5,000	− 8.8		7:33	5,000	−20.6
	8:52	10,000	−50.7		8:07	10,000	−47.5
29.	7:00	167	24.6	9.	6:55	167	15.0
30.	6:14	167	14.1		7:24	5,000	−14.6
	6:49	5,000	− 3.8		8:04	10,000	−53.2
	7:33	10,000	−42.9		8:34	12,500	−53.7
	8:09	12,000	−55.6	10.	6:40	167	20.0
May 1.	6:40	167	26.7		7:09	5,000	−13.6
	7:22	5,000	−10.9		7:41	10,000	−51.4
2.	7:05	167	20.0		8:15	15,000	−58.1
	7:45	5,000	−11.9	11.	7:00	167	27.1
	8:41	10,000	−48.0	12.	6:33	167	23.9
3.	6:07	167	25.6		7:22	5,000	− 5.5
	6:47	5,000	−10.5	13.	9:00	167	21.1
	7:50	10,000	−50.8		9:36	4,000	3.4
4.	8:46	167	17.2	14.	6:33	167	25.3
	9:03	5,000	− 4.3		7:04	5,000	− 6.9
	....	10,000	−37.8		7:37	10,000	−44.2
	....	13,000	−51.4		8:04	15,000	−58.0
5.	6:54	167	15.0	15.	6:52	167	26.1
	7:26	5,000	− 8.0	16.	6:46	167	27.9
	8:02	10,000	−45.0		7:17	5,000	− 2.5
	8:58	15,000	−54.2	17.	6:26	167	29.0
6.	6:50	167	13.4		7:02	5,000	− 3.5
	7:23	5,000	− 8.4	18.	6:19	167	23.2
	7:56	10,000	−47.0		6:50	3,500	5.8
	8:24	15,000	−51.7				
7.	7:14	167	16.1		*A. M*		
	7:47	5,000	−13.2	19.	5:36	167	20.0
	8:22	10,000	−53.2		6:18	5,000	− 3.2
	9:08	15,000	−55.0				

TABLE 2.—*Pressures at different heights above sea level derived from records obtained with sounding balloons sent from St. Louis, Mo., 167 meters above sea level.*

Date.	Pressure at sea level.	Pressure at 2 kilometers.	Pressure at 5 kilometers.	Pressure at 10 kilometers.	Pressure at 15 kilometers.
1906, 7 p. m.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
April 28	757	599	413	207	99
29	761	....	....	....	....
30	763	602	416	211	101
May 1	754*	599	412	....	....
2	758	598	410	206	98
3	754	598	411	205	98
4	753*	595*	411	210	100
5	760	597	410	206	98
6	763	598	407	204	98
7	764	601	411	205	97
8	770†	601	406*	200*	93*
9	769	604	410	202	93
10	765	604	413	206	97
11	763	....	....	....	....
12	763	605	418	....	....
13	763	605†	417	....	....
14	763	605	418	211	99
15	763	....	....	....	....
16	762	605	418	....	....
17	761	605	419†	....	....
18	760	603	417	....	....

* Minima. † Maxima.

The pressures at different heights are plotted in Fig. 2. The maxima and minima in this figure are indicated by the letters *a*, *b*, *c*, etc. Comparing the maxima and minima at sea level and 5 kilometers the first maximum *a* occurs nearly simultaneously at the two levels, but after that the maxima in one level coincide with the minima in the other. This inversion is more marked at 10 kilometers where the pressure curve is almost the reverse of that at sea level. The pressure curve at 15 kilometers is somewhat similar to that at 10 kilometers, but the ranges are much reduced and the maxima and minima are evidently on the point of disappearing. In fact, in the interval from the 4th to the 8th, which was best covered by observations, the smaller fluctuations found at 5 to 10 kilometers do not occur at 15 kilometers. In the upper-air type of curve there is distinct evidence of lagging in the time of the most marked maxima and minima. The minima *c* and *g* and the maximum *d* evidently occur about twelve hours later at 10 to 15 kilometers than at 5 kilometers.

In order to ascertain at what level in the atmosphere the sea-level type of pressure changed to the upper-air type, the pressure for each day was obtained from the records for the height of 2 kilometers. These pressures are given in the third column of Table 2. The results show that the sea-level minimum of May 1 did not exist at 2 kilometers; but the minimum of May 4 was well defined at that level, altho with diminished range, and disappeared between 2 and 5 kilometers. The well-defined maximum at sea level on May 8 is not shown at 2 kilometers, and is replaced at 5 kilometers by a sharp minimum of pressure. These results indicate that the sea-level type of pressure does not extend to heights much exceeding 2 or 3 kilometers. This conclusion is sustained by the observations of clouds at Blue Hill, which show that the air ceases to rotate around centers of high and low pressure at heights of about 3 kilometers, and that above that height the motion is of an entirely different character, consisting only of deflections to the right and left in a general easterly drift.[4] When the pressures are charted synoptically, there are found at sea level elliptical isobars around which the wind circulates, going spirally inward or outward, according to whether the central pressure is lower or higher than that in surrounding regions. At about 3 kilometers this type changes suddenly to the upper-air type of pressure, in which the isobars are U-shaped or semi-circular, and not circles or ellipses as at the ground. The bottom of the U points southward when the pressure is below the normal, but is inverted (∩) and points northward when the pressure is above normal. In this type the line of minimum pressure is found near the place of minimum temperature, and many hundreds of miles distant from the minimum of pressure at the earth's surface. The line of maximum pressure is found near the place of maximum temperature, and far from the maximum pressure at the earth's surface. To some extent these facts were outlined by Doctor Köppen as long ago as 1888, when he first plotted isobars for the upper air; but it is not uncommon to find in the writings of meteorologists of to-day references to areas of high and low pressure as if they extended to great heights in the atmosphere. In future I think we must ascribe the unstable vertical gradients of temperature, which give rise to thunderstorms and tornadoes, not to the overflow of surface air by potentially cooler air above, but rather to the northward flow of relatively warm air at low levels, beneath currents moving from the west or northwest above, or to the heating of the ground and surface air by the sun.

My conclusion that cold waves are inclined strata of descending air felt first at the earth's surface and successively later at greater heights is given in the MONTHLY WEATHER REVIEW for March, 1907.[5] The reason of the later occurrence of warm waves aloft is no doubt because the areas of low pressure in the upper air are in the rear of areas of low pressure at sea level. The winds in front of these areas of low pressure in the upper air have a component of motion from the south and hence are relatively warm; while the winds immediately below, in the rear of the lows at sea level, have a component of motion from the north, forming the advancing lower front of the cold wave, and are relatively cold.

OUR PRESENT KNOWLEDGE REGARDING THE HEAT OF EVAPORATION OF WATER.

By Prof. ARTHUR WHITMORE SMITH, Ph. D. Dated University of Michigan, Ann Arbor, Mich., November 20, 1907.

Until quite recently our knowledge of the amount of heat required to evaporate water has been derived from the classic

[4] See Annals of the Astronomical Observatory of Harvard College, vol. XXX, 1896.

[5] Vol. XXXV, p. 118-120.