THE BLUE HILL

TEOROLOGICAL OBSERVATORY.

AN ACCOUNT OF ITS FOUNDATION AND WORK.

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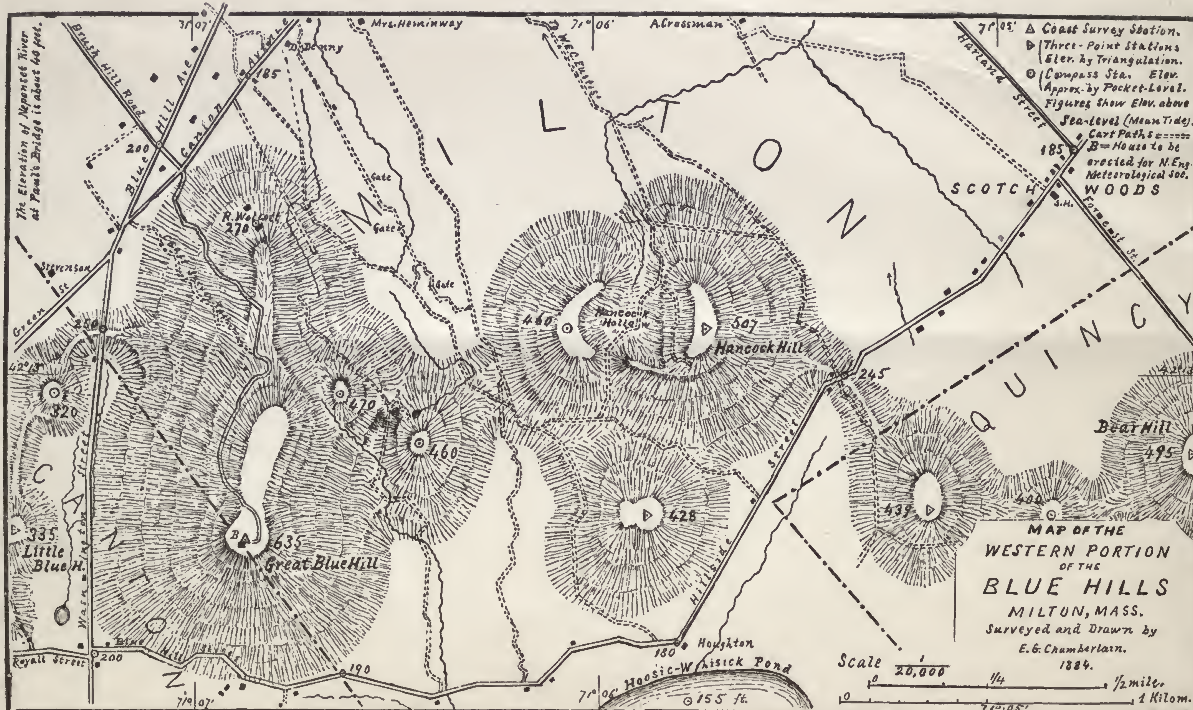
MAP OF THE
WESTERN PORTION
OF THE
BLUE HILLS
MILTON, MASS.
Surveyed and Drawn by
E. G. Chamberlain.
1884.
Δ Coast Survey Station.
Three-Point Stations
Elev. by Triangulation.
Compass Sta. Elev.
Approx. by Pocket-Level.
Figures Show Elev. above
Sea-Level (Mean Tide).
Cart Paths
B = House to be
erected for N. Eng.
Meteorological Soc.
The Elevation of Neponset River
at Paul's Bridge is about 40 feet.
Scale 1/20,000
0
1/4
1/2 mile.
0
1 Kilom.
M I L T O N
Q U I N C Y
C A N T O N
SCOTCH
WOODS
Great Blue Hill
635
Hancock Hill
507
Hancock Hollow
460
470
460
428
439
400
Bear Hill
495
R. Wolcott
270
Little
Blue H.
335
320
250
200
185
185
245
180
190
200
Mrs. Heminway
A. Crossman
W. E. C. Eustis
D. Denny
Houghton
Stevenson
S.H.
Gate
Gate
Gate
Brush Hill Road
Blue Hill Ave
Canton Avenue
Harland Street
Forbes St.
Green St.
Washington Street
Hillside Street
Blue Hill Street
Royall Street
Hoosic-Whisick Pond
155 ft.
71° 07'
71° 06'
71° 05'
42° 13'

AN ACCOUNT

OF THE

FOUNDATION AND WORK

OF THE

BLUE HILL

METEOROLOGICAL OBSERVATORY.

A. LAWRENCE ROTCH, S. B.,

Member of the German Meteorological Society and Fellow of the Royal (London) Meteorological Society.

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1887.

THE BLUE HILL

METEOROLOGICAL OBSERVATORY.

OBJECT OF THE OBSERVATORY.

The study of high-level meteorology is an important one, but to which little attention has been given in this country. It is true that the United States Signal Service station on Mount Washington was the first complete mountain station in the world, and that the station on Pike's Peak is still the highest, but the observations have not been published *in extenso*. Excepting these two stations, the writer does not know of a single meteorological station in the United States elevated distinctly above the surrounding country. It is not so in Europe. The writer visited, in 1885, nine mountain stations situated at heights ranging from 3,740 to 9,440 feet, whose observations are published in a comprehensive manner; and a number of other mountain stations exist. The French observatories, in particular, have been especially constructed for their purpose, and equipped with registering instruments, at a large cost, which the additions to our knowledge of the physics of the upper atmosphere obtained from them amply repay. (See "The Mountain Meteorological Stations of Europe," by A. Lawrence Rotch, in *American Meteorological Journal*, Vol. II., Nos. 10, 11, and 12, and Vol. III., No. 1.)

Prof. W. M. Davis, in an article in *Science*, Vol. V., No. 121, p. 440, says: "At the level of Pike's Peak the cyclonic rotation of the winds is hardly observable, the observatory there being above the strata of the atmosphere whose circulation is seriously disturbed by passing storms. On Mount Washington the winds whirl round almost in a circle about the progressing storm centre. At Blue Hill we may hope to dis-

cover the true circulation of the lower air, unaffected by the natural or artificial irregularities of surface that modify the records of so many of our Signal stations. The value of observations taken at moderate elevations is attested by the increasing number of mountain observatories in Europe. . . . As Blue Hill has the first private observatory of the kind in this country, we shall look with especial interest for the results of studies based upon its records."

The original plan was to use the Observatory on Blue Hill only for special investigations in meteorology, leaving the regular observations to be carried on by the Signal Service, the writer reserving the right to occupy the station or to close it to the Government by giving due notice. The Chief Signal Officer, however, refused to enter into an agreement to furnish observers, unless the entire control was given to the Signal Office for a period of not less than two years. The writer therefore determined to conduct the observations himself. The proposed work of the Blue Hill Observatory was stated by the writer, in a paper read at the first meeting of the New England Meteorological Society, Oct. 21, 1884, to be as follows: "The investigation of the rainfall at this elevation, the velocity and direction of the wind, the maximum and minimum temperatures, the paths of thunder and other local storms, and such other phenomena as may present themselves. It has been suggested that atmospheric electricity could well be studied here, and for seismometric apparatus the situation of the station would secure absolute freedom from the jar and vibration incident to the passage of neighboring trains and vehicles." It will be seen from the account of the work of the Observatory, that these investigations, with the exception of the last, have been undertaken, together with several others.

THE SITE OF THE OBSERVATORY.

The Blue Hills, situated in Norfolk County, Massachusetts, about ten miles south of Boston State House, are the nearest mountain range to Boston; and though their elevations are not high, the fact that the surrounding country is low makes them count for nearly their full height. Great Blue Hill, the highest

of the range, has an elevation of six hundred and thirty-five feet, and is not only the highest land in eastern Massachusetts, but is also the highest point within ten miles of the Atlantic coast from Maine to Florida. As Great Blue Hill exceeds the other summits of the range by more than one hundred feet, it has the nature of an isolated hill, commanding an unbroken view of the sea-level horizon, thirty-three miles distant, the New Hampshire mountains, seventy miles away, and a hundred and twenty towns and villages. The situation is thus admirable for a meteorological station; and the idea of establishing one, which occurred to the writer in August, 1884, being encouraged by Rev. A. K. Teele of Milton and Prof. W. H. Niles of Cambridge, an acre of land on the south side of the Hill, and a small amount, including the highest point on which were the ruins of the old lookout, was purchased with difficulty. Other land has since been bought, so that there are now some sixty acres about the Observatory. The top of the Hill comprises several acres of nearly barren ground, which culminates in a rocky ledge, fifteen or twenty feet above its general level. The dividing line between Milton and Canton was decided by the selectmen of these towns to pass over the ledge, just south of the site of the Observatory tower, placing the latter in Milton and the main building in Canton. Although careful search was made under the ruins of the lookout for the copper bolt, set by Simeon Borden, about 1832, for the Massachusetts Trigonometrical Survey, it was not found. Its position was, however, known to be 26.25 feet N. 15° 37′ E. of the bolt fixed by the Coast Survey in 1844, which is in plain view, and a brass plate on the lower floor of the tower now marks the site of the Borden bolt, 2.2 feet below it, in latitude 42° 12′ 44″ N., longitude 71° 6′ 53″ W., and 635.05 feet above mean tide. Surveys made by Mr. E. G. Chamberlain and by students of the Institute of Technology confirm the height as sufficiently accurate.

There were two foot-paths leading from the Canton road to the summit, which united about a quarter of a mile below it. It was decided to improve the path starting at the 'Great Oak' opposite Brush Hill road, and accordingly, on Sept. 1,

twenty men began work on it, and in ten days had completed a fair carriage road to the top, having a length of $\frac{7}{8}$ mile and an average grade of about 1 in 10. The Hill is easily accessible, as, from the foot of this road, it is only a mile and a half to the Readville station, reached in half an hour from Boston by two railroads. Readville is the railroad station and post-office for the Observatory.

The accompanying map of the western portion of the Blue Hills, prepared under the supervision of Rev. A. K. Teele, for his forthcoming History of Milton, is kindly allowed to be published here. It should be stated that the 'House to be erected for the New England Meteorological Society,' which appears on this map, represents the Observatory.

THE BUILDING.

Many were the speculations concerning the building to be erected on Blue Hill, some saying it was a fort, others that it was a monastery, but the majority believed it to be a station for the Signal Service. There were no stations in this country which could be taken as models, and the design was left mainly to the architects, Messrs. Rotch and Tilden, who fixed the cost at $3,500. The contractors, J. H. Burt & Co., commenced work Oct. 18, 1884, and made rapid progress during the fine autumn weather. By Dec. 6 the building was roofed in, rendering the workmen independent of the weather, which had now become cold and stormy. The outside pointing and some of the masonry were left until spring. Plastering was begun Dec. 22, and on Jan. 31, 1885, the writer and his observer moved in.

The Observatory is built of the broken stone found on the Hill, with granite trimmings. It consists of a two-story circular tower of twelve feet inside diameter, twenty-five feet high with a flat roof, which contains the instruments. Extending southward from this tower is a one-story hip-roof house, with two bedrooms, a dining-room and kitchen. A wooden shed adjoins. In the construction every precaution was taken to insure solidity, the walls being twenty inches thick, and the roof well anchored to them. It has, however, been found im-

possible to make the walls impervious to rain, which is driven by heavy gales through the minute cracks which the stone must contain. Several coats of marine varnish have served to disfigure the stone-work, but not to render it water-proof. The walls of the living-rooms are plastered and the floors are of hard pine. In the cellar is a wooden tank, holding nine hundred gallons of water, obtained from the rain falling on the roof, which has always proved sufficient for domestic purposes. A spring furnishes water for drinking. A large stove in the lower room of the tower heats the upper room through a register, and by its flue and that of the kitchen range warms the other rooms also. About ten tons of coal are burnt annually. Double windows are put on throughout the building in winter. A safe built into the chimney protects the records and charts from fire. A telephone line extends down the south side of the Hill to the central office in Milton. There are no houses within a mile of the Observatory, so that, even with this connection with civilization, it is largely dependent on its own resources.

The accompanying photographs of the Observatory and Hill were taken by Sergt. O. B. Cole, of the Boston Signal station.

THE INSTRUMENTS.

When first opened, the Observatory had the instruments of a first-class Signal station. Since then, many self-recording and other instruments have been added, several being brought from Europe last year by the writer. All the elements observed, with the exception of the force of the wind, the kind of clouds and their direction of motion, are now recorded continuously, and with the exception of the New York Meteorological Observatory in Central Park, the writer believes this Observatory to be the best equipped in the United States. The instrumental outfit is now as follows:

Barometers. These are kept in the lower room of the tower, where the temperature is most uniform. The Observatory standard is a Hicks Fortin barometer, reading to .002 inch. Although verified at Kew Observatory, its corrected readings,

as determined indirectly, differ by —.013 inch from the Signal Office standards at Washington. A smaller Green barometer, which reads also to .002 inch, has been compared with those of the Signal Service at Washington and Boston. In reducing the pressure to sea-level, instead of applying a monthly constant, as was the practice of the Signal Service, the correction at Blue Hill is obtained from a table based on Laplace's formula, calculated for a height of six hundred and forty feet, in which the temperature of the external air at the time of observation is one factor. The correction to reduce to the standard gravity of latitude 45°, is the same as that used by the Boston office, as are the temperature correction tables. A Draper barograph, multiplying three times and giving a continuous record, has been in operation since May, 1885. Commencing in July, 1885, the record has been checked by daily comparisons with the standard barometer, and the barograph is now so well regulated that the correction is usually less than .01 inch. A Richard aneroid barograph is kept ready as a reserve instrument.

Thermometers, *Hygrometers*, *etc.* The thermometers have all been verified, and the Observatory has Hicks thermometers with Kew certificates, and others made by Baudin of Paris, as standards. From the north side of the tower, fifteen feet above the ground, is built a window shelter, in the construction of which special pains were taken to secure ventilation by making the roof double and by setting the shelter six inches out from the wall, and to prevent radiation by having double windows. An isolated shelter, built according to Prof. H. A. Hazen's specifications, shows seldom a difference of 1°, except during rapid changes of temperature, when the wall shelter is somewhat sluggish. For convenience, therefore, the Green wet and dry bulb and maximum and minimum thermometers, together with the Richard thermograph and registering hygrometer, are kept in the window shelter. The error of the Richard thermograph, ascertained daily by readings with the thermometers, is ordinarily less than 1°. A Draper metallic thermograph, kept at the base station, has a somewhat larger error. A "turnover thermometer" of Negretti and Zambra can be set to register the temperature at any pre-determined hour, and

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GREAT BLUE HILL FROM THE SOUTH.

there are Hicks solar and terrestrial radiation thermometers, which have, however, not yet been used. A Koppe hair hygrometer has proved to be the best method of determining the relative humidity in cold weather, and there is an Alluard condensation dew-point apparatus to be used as a test. The tables for calculating the dew-point and relative humidity are those calculated for a pressure of thirty inches in the *Instructions for Voluntary Observers of the Signal Service*. A Richard registering hygrometer has given satisfactory results for this class of instrument. Its readings are corrected daily by comparisons with the psychrometer or hygrometer. Browning and Hilger rain-band spectroscopes have been employed to determine the humidity of the upper atmosphere.

Anemoscope and Anemometers. These are exposed eleven feet above the roof of the tower and thirty-five feet above the ground. A Draper anemoscope and anemometer, recording mechanically the direction and velocity of the wind, have given continuous records since March, 1885, with the exception of short periods during which repairs were necessary. Together with the other Draper instruments, they were made for the Observatory by Black & Pfister of New York. A Hahl anemometer of the Signal Service pattern, recording electrically each mile of wind by means of the Gibbon self-register, has been in operation during 1886, and serves to show brief gusts and to supply breaks in the Draper record. These instruments agree tolerably well together, and with a Hicks hand anemometer, graduated at Kew, and of a pattern adopted by the English Meteorological Office. A pressure gauge, constructed for the writer, presents a disk with a square foot of surface normal to the wind by means of a vane. Pressure upon the plate stretches a spring and leaves an index at the maximum pressure in pounds to which it has been subjected in the course of the day. The agreement of this gauge with the anemometer, after the equivalent velocity is deduced from the pressure, is remarkable, as the figures given in the next chapter show. Another pressure gauge, with a rack and pawl to hold the plate in the position corresponding to the maximum pressure, designed to obviate the error which might be caused by the momentum of the plate in the preceding gauge, has not proved satisfactory.

Rain and Snow Gauges. The standard rain gauge is that devised by the New England Meteorological Society. It is eight inches in diameter, and the water is poured into a tube multiplying ten times and measured with a stick. A snow gauge with the same receiving surface as the above but enlarged below to prevent the snow from blowing out, was used last winter with success. To prevent loss in melting the snow for measurement, this gauge is weighed on a spring balance graduated to inches and hundredths and compensated for the weight of the empty gauge. Weighing is now the method used for rain, as the amount which has fallen can thus be quickly ascertained at any time during a storm without emptying the gauge. A rain gauge, recording the time of occurrence, the rate and amount of the rainfall, made by Richard Brothers of Paris, on the weighing principle, after the writer's design, has been in use since March, 1886, and gives fairly good results. A satisfactory gauge for recording snow is yet to be devised, and the writer is working on the problem.

Sunshine and Cloud Instruments and Tests of Visibility. A Campbell-Stokes sunshine recorder registers by burning a card the hours of bright sunshine, while a Jordan instrument registers both bright and faint sunshine photographically. The former, which is the standard instrument the world over, has been in use since December, 1885. From the percentage of possible sunshine, the mean cloudiness is obtained, it having been found that the mean cloudiness thus determined differs but slightly from that calculated from three daily "eye" observations. A cloud mirror, in which the altitude and azimuth of clouds can be measured, was made by Mr. Lowe of Boston, for Mr. Clayton, the present observer, and some measurements of the velocity and height of clouds have been made by him. The velocity with which the clouds move is found by noting the time which their shadows require to traverse known distances on the plain below. Only clouds of the stratus and cumulus type give shadows which can be thus used. The velocity of a cloud being known, two angular measurements from the same point, at a definite interval of time apart, enable its height to be calculated. Particular attention has, of late, been given to

the direction of motion of clouds, particularly those of the cirrus type. A record of visibility of the mountains situated at different distances is kept, and the clearness which is said to precede storms is found to have significance under certain conditions of pressure. A 4-inch telescope, made by Clacey of Cambridgeport, though not strictly a meteorological instrument, may be mentioned.

In order to insure continuity of records in case of a break-down, the instruments are mostly in duplicate, and when the whole instrument cannot be duplicated, spare pieces, such as clocks, are kept on hand. The wind instruments are especially liable to accident, and when it is considered how they are strained by violent gales, and that some 13,000 miles of wind pass over them each month, the necessity for good workmanship in their construction, and careful attention to their action is apparent. The Observatory was, necessarily at first, and is still to some extent, an experimental station where new instruments are tested and modified as experience may suggest.

THE WORK OF THE OBSERVATORY.

Tri-daily "eye" observations at 7 A. M., 3 and 11 P. M., synchronous with and similar to those of the Signal Service, were begun Feb. 1, 1885, and continued until April 1, 1886, without an omission. In one case, only, was an observation taken an hour late. A summary of these observations for the year ending Jan. 31, 1886, together with the summary of the corresponding observations made at the Boston Signal Service station, ten and a half miles north of and five hundred and fifteen feet below the Observatory, has been printed and sent to the weather services of this country and Europe and to persons interested.

This summary shows the mean pressure for the year, reduced to sea-level, to have differed but .002 inch at the two stations. The mean annual temperature was 44.4°, or 2.7° degrees lower than at Boston, giving a decrease of one degree for each one hundred and ninety-one feet of elevation, which is a much more rapid decrease than the normal; but it may be explained by the fact that the temperature of a city is abnormally higher than at

the same elevation in the country. The difference was least (1.1°) in May, due to the cooling influence of the east winds which prevailed in Boston, and greatest (4.0°) in February, when the city was most heated artificially. The extremes of temperature on Blue Hill were 91.2° and —15.0°, or 1.6° and 4.9° lower, respectively, than the corresponding temperatures at Boston. The mean relative humidity (73.7 per cent) was 4 per cent higher on the Hill than in the city, though the very low humidities of 13 and 14 per cent were recorded. The total precipitation (39.00 inches), instead of being greater, as is usual at high stations, was 7.85 inches less than in Boston; but, since the deficiency was greatest in the winter, this may be partly due to the blowing of the snow out of the gauge, at that time used, by the high winds on Blue Hill. But the greatest discordance is in the wind records, which show how much the wind is influenced by friction with the earth's surface. The total wind movement for the year was 63 per cent greater than at Boston, though the anemometer there is on a high building. Blue Hill, in fact, is one of the most windy stations at which observations are made in the United States, the total movement of the wind for the year ending with January, 1886, for Blue Hill and the four most windy Signal Service stations being as follows: Mt. Washington, N. H., 275,244 miles; Pike's Peak, Col., 173,859 miles; Cape Mendocino, Cal. (11 months), 160,226 miles; Blue Hill, Mass. (insufficient), 166,110 miles; Sandy Hook, N. J., 142,696 miles. The average hourly velocity on Blue Hill was, therefore, 18.9 miles per hour, as against 11.7 miles at Boston. The greatest number of miles in one hour was 74; the highest wind in Boston having blown at the rate of 64 miles per hour for fifteen minutes. Calms on the Hill are very rare. The direction of the wind frequently varies considerably from that at Boston, though the prevailing wind for the year at both stations was west.

Normal values of the chief elements for Blue Hill have been computed by comparing the first year's observations with the corresponding observations of the Signal Service at Boston, whose deviations from a mean of fifteen years were known and assumed to be the same as for Blue Hill. On account of the

uncertainity of the precipitation record on Blue Hill for the first year, the normal precipitation there has been provisionally assumed to be the same as for Boston. The monthly and annual normals are given in this table:

NORMALS OF THE BLUE HILL OBSERVATORY.

MONTH AND YEAR.	PRESSURE REDUCED TO 32° AND SEA LEVEL.	TEMPERATURE IN DEGREES FAHR.	PRECIPITATION IN INCHES.
January	30.09	22.7	4.44
February	30.10	24.8	3 85
March	29.94	30.4	4 61
April	29.91	41.9	3.87
May	29.98	55.2	3 50
June	29.95	63.2	3.51
July	29.91	69.7	3 64
August	30.03	66.7	4.53
September	30.06	59 9	2.96
October	30.12	49.7	4 28
November	30.10	36 3	5.10
December	30.05	26.9	3.51
Year	30.02	45.6	47.80

Most of the data is now obtained from the charts of the self-recording instruments, whose indications are checked daily by an "eye" observation of the standard instruments at 11 P. M., and occasionally at other times. The corrected figures are entered in a daily "form." A monthly summary, compiled from this, and manifolded by the cyclostyle process, is now sent to some twenty persons interested, besides the New England Meteorological Society and the United States Signal Service, whose special "forms" are also filled out. Some of this data appears in the monthly *Bulletin* of the Society and the *Weather Review* of the Signal Service. The records of the Observatory are at the service of any one who wishes to make use of them, and copies of the original traces have been occasionally supplied. The Observatory receives the daily record of the observations of the Boston Signal station, and monthly reports of temperature and precipitation from Milton and Randolph. Since July, 1886, it has had its own station, provided with thermometers and rain gauge, at the base of the Hill, which is visited daily. This station is situated at the junction of Canton and Blue Hill

Avenues, in Milton, and is three quarters of a mile northwest of and four hundred and forty feet below the Observatory. It would be premature to compare the records of the base and summit stations, but the fact that some marked inversions of temperature have occurred, amounting in one case to twenty degrees, should be mentioned. The conditions which accompanied one of these inversions were described by Mr. Clayton in *Science*, Vol. VIII., Nos. 188 and 190. The variation of rainfall between the two stations is also sometimes remarkable, having been nearly an inch in a single storm.

Thunder-storm observations made on the Hill for the New England Meteorological Society, which has undertaken to investigate the subject during the past two summers, were valuable, because this station was one of the few provided with self-recording instruments. The thunder-storms are generally attended by curious oscillations of pressure, which have elsewhere been found to be characteristic of thunder-storms, and their occurrence on the barograph sheet has served to detect storms of this class, even when their thunder and lightning were not noted. Other sharply serrated curves on the barograph sheet during heavy gales have been well maintained by Mr. Clayton in a lively discussion in Vols. VII. and VIII. of *Science* to be due to gusts of wind. Professor Abbe of the Army Signal Office has suggested experiments be made here on this subject, which the writer has agreed to carry out.

Perhaps the most important work was commenced last February in the tabulation of the hourly values of the atmospheric pressure, and of the velocity of the wind, in order to establish their diurnal periods for each of the months. Up to the present time, no breaks in the record have occurred, and the tabulation and reduction have been kept up to date, the laborious additions being facilitated by the use of the Colmar Arithmometer. It is intended to publish these hourly means, with the original figures, at the end of the year, and, as this will be almost the only data of the kind published for this country, it will be valuable to meteorologists.

The following experimental work has been done: —

During June, 1885, Mr. Alexander McAdie of the Signal

Corps made some experiments at the Observatory upon atmospheric electricity, using a kite and a Trowbridge electrometer. An account of these experiments was communicated to the *American Academy of Arts and Sciences* in June, 1885.

A series of comparisons of a rain gauge placed in the centre of the tower roof, 24 feet above the ground, with a gauge on the ground, made during the spring of 1885, showed an increase of 56 per cent in the precipitation caught in the ground gauge, which was almost entirely due to the wind eddies on the tower. This shows that a rain gauge should not be placed on a roof as is done at many of the Signal Service stations.

A series of comparisons of thermometers exposed in the Hazen shelter, adopted by the Signal Service, and in a window shelter, have been conducted this year. Referring the readings of the thermometers to those in the Hazen shelter as a standard, the mean error for the window shelter was, for the dry bulb $+0.4°$, and for the wet bulb $+0.5°$, during February, but only $+0.1°$ and $+0.2°$, respectively, during March. Extreme differences of nearly 2° have occurred. Maximum and minimum thermometers exposed in these shelters showed errors of $+0.5°$ for the maximum and $+0.4°$ for the minimum during July, and of $-0.2°$ for both thermometers during August. These differences seem to be influenced by the direction of the wind; and, as they are small, it has been concluded that with such a strong circulation of air as exists on Blue Hill, the exposure of thermometers in a window shelter is sufficiently good.

It is generally supposed that the dew-point and relative humidity of the air, obtained from readings of the wet and dry bulb thermometer in cold weather, are not to be depended on. Some experiments on this subject were made during February and March, 1886, when simultaneous tri-daily observations were taken of the Koppe hair hygrometer and of the wet and dry bulb thermometers, from whose readings the relative humidity was calculated. The mean relative humidity for February was 79 per cent by the psychrometer and 73 per cent by the hygrometer, and for March 75 per cent by the psychrometer and 72 per cent by the hygrometer; which shows that when properly manipulated the psychrometer gives fairly good results

in cold weather, assuming from the following experiments that the hygrometer is reliable. The relative humidities obtained by the two methods during July, 1886, gave a mean of 59 per cent and 58 per cent, respectively, for the 3 P. M. observation, and both gave a mean of 82 per cent for the 11 P. M. observation. As the psychrometer is trustworthy in warm weather, these experiments prove that the hair hygrometer, or, at least, the Koppe form of it, is a very good instrument for determining the relative humidity at all seasons.

On account of the unusual advantages which the Observatory offers for the study of the relation of wind pressure and velocity, its investigation has been undertaken this year, using the Hahl anemometer and the pressure gauge situated on the tower. Some of the results of these experiments are given in the following table. The velocity corresponding to the recorded pressure is obtained from the table computed by Colonel James, who assumed that the square of the velocity in miles per hour, multiplied by .005, gave the pressure in pounds per square foot.

RELATION OF THE PRESSURE TO THE VELOCITY OF THE WIND.

Pressure per Square Foot, in lbs.	Equivalent Velocity, in Miles per Hour.	Highest Mean Velocity for Five Minutes, in Miles per Hour.	Number of Experiments Quoted.
2.0	20	22	3
4.0	28	28	3
6.0	35	35	3
8.0	40	38	3
10.0	45	40	2
12.0	49	45	3
15.0	55	55	2
17.0	58	56	3
21.5	66	65	1
24 0	69	64	1
25.5	71	66	1
26.0	72	70	1
26.5	73	66	1
31.0	79	75	1
32.5	81	72	1
36.5	85	84	1
43.7	93	84	1

The Blue Hill experiments seem to show that this formula gives a close approximation to the relation between pressure and velocity. The extreme velocity of the gusts would naturally

BLUE HILL METEOROLCGICAL OBSERVATORY FROM THE NORTHEAST.

be expected to exceed the mean velocity for five minutes as shown by the anemometer, and this is generally found to be the case. It will be noticed that the agreement is closest at moderate velocities, but whether this is due to the inertia of the pressure plate, causing it to lag with light winds, or whether the velocity of the gusts exceeds in a greater ratio the mean velocity during high winds than during low ones cannot now be stated.

Experiments were conducted for nine months during 1885–86, with the rain-band spectroscope, to test its efficiency to foretell rain. Its use has been recommended in England by Smyth, Mill, Cory, and others, but the results obtained at Blue Hill do not confirm their conclusions. The observations were first made with a Browning and afterwards with a Hilger instrument, at 7 A. M. and 3 P. M., and the rainfall in the following eight hours noted. A possible ten being taken as the sum of the maximum intensity of two readings at the horizon and at an angle of 45°, five was considered as a sign of rain. The average success of predictions made for eight hours in advance from the spectroscope alone, for the warm months of July, August, and September, was eighty-five per cent for the morning and eighty per cent for the afternoon observation; for the cool months of October and November, eighty-one per cent for the morning and eighty-seven per cent for the afternoon observation; and for the cold months of December, January, February, and March, seventy-five per cent for the morning and eighty-one per cent for the afternoon observation. A higher degree of success in rain predictions for eight hours in advance could probably be attained by simple observations of the wind and clouds.

The display of weather signals has become such an important part of the work of the Observatory, that an account of the development of this branch is given in a special chapter.

This comprises an outline of the work of the Observatory up to the present time. As to the future, little can be said. Since the Observatory is a private enterprise, its maintenance is less assured than if managed by a corporation or by the Government. It is thus a creature of circumstance, but, should it

now cease to exist, many of the objects for which it was established will have been accomplished, and the data already obtained will furnish abundant material for future study.

WEATHER SIGNALS.

One of the first efforts, after the establishment of the Observatory, was to utilize its conspicuous situation to disseminate the weather predictions over the surrounding country. Accordingly, an order having been obtained from the Chief Signal Officer authorizing the observer at Boston to transmit the orders relating to the cold wave signal, the following circular was sent to twenty post-offices and twenty-six railroad stations within a five-mile radius of the Hill, from whose neighborhood the flag on the Observatory could be seen:

To the Postmaster at.....

PLEASE POST IN A CONSPICUOUS PLACE.

COLD WAVE FLAG.

In co-operation with the United States Signal Service and the New England Meteorological Society, a Cold Wave Flag (white with a black centre) will be displayed henceforth from the summit of Great Blue Hill, Milton, as a warning of the approach of decidedly colder weather.

A. LAWRENCE ROTCH,
Proprietor of the
BLUE HILL METEOROLOGICAL OBSERVATORY.

FEB. 1, 1885.

The displays have been continued up to the present time, the flag being ordered up by telephone from Boston, on receipt of the telegraphic order from Washington. Out of twenty-eight displays to April 1, 1886, twenty-two, or seventy-nine per cent, were considered verified. The verification, as estimated at the Boston Signal station, is larger.

Besides the cold wave warnings, it was decided to attempt the local prediction of rain, as the most important weather element, in order to give an added interest to the study of storm movements. Accordingly the following circular was issued:

PLEASE POST IN A CONSPICUOUS PLACE.

RAIN WARNINGS.

Beginning May 1, 1885, the Blue Hill Meteorological Observatory will attempt to give warning of rain.

A square Red Flag displayed during the day and a Red Lantern shown by night, at the Observatory on Blue Hill, will indicate that Rain is expected in the vicinity within Twelve Hours from the first display of these signals.

The display of the Black and White Cold Wave Flag, as ordered by the United States Signal Service, will be continued.

As the Rain Warnings are an experiment of the undersigned, they will be discontinued if unsuccessful.

A. LAWRENCE ROTCH,
BLUE HILL METEOROLOGICAL OBSERVATORY,
READVILLE P. O., MASS.

In making these predictions all available data was used, including the Signal Service reports furnished through the courtesy of the Boston observer, Sergeant O. B. Cole. During May, the rain signal was displayed eleven times, and of these displays, eight, or seventy-three per cent, were followed by rain within an average time of six hours. The Signal Service rain indications for New England for twenty-four hours, tested for Blue Hill, gave a verification of fifty-one per cent. During June, owing to the numerous local showers, the success of the Observatory and Signal Service rain predictions was only about forty-two per cent. Partly on this account, and partly on account of the watchfulness necessary to continue these predictions made at any hour, the Council of the New England Meteorological Society, on taking charge of the Observatory, July 1, 1885, sent out this circular:

PLEASE POST IN A CONSPICUOUS PLACE.

RAIN WARNINGS.

Until further notice, the Rain Signal on Blue Hill will consist of a Red Flag by day, which will be displayed in accordance with the weather indications issued by the United States Signal Service for New England.

NEW ENGLAND METEOROLOGICAL SOCIETY,
In charge of
BLUE HILL METEOROLOGICAL OBSERVATORY.

JULY 1, 1885.

From the important requisite of visibility at a distance, none of the weather flags, with red and blue suns, moons and stars, which had been introduced by the Society, were possible on Blue Hill, and the red flag was, therefore, retained to indicate rain. The practice followed was to display the flag when the midnight indications of the Signal Service for New England, received by telephone at 7.30 A. M., warranted it; but to have the flag also governed by the 10 A. M. indications, received at the Observatory about noon, and in all cases to lower the flag at sunset. These warnings were continued during the summer and autumn, and the per cent of verification of each set of predictions, considering the weather at Blue Hill as either fair or rainy, was as follows:

MONTH.	TWENTY-FOUR HOURS, FROM	
	7 A. M.	3 P. M.
July	65	71
August	45	61
September	80	80
October	64	77

A modification of the method was commenced in November, by which the flag was hoisted after the receipt, at 7.30 A. M., of the special predictions made by the Signal Service for the Meteorological Society, whenever the flags numbered 4 or 6 of its code were specified. The percentage of verification of each day's predictions for the weather of the twenty-four hours commencing at 7 A. M., was as under:

November, 1885, 77; December, 84; January, 1886, 74; February, 83; March, 81; April, 66.

Better local predictions were made possible after May 1, 1886, by the charting of a daily weather map in Boston, showing the weather conditions existing over the United States at 7 A. M., 75th meridian time. Hitherto such a map had been lithographed only in Washington, and as it is received here thirty-six

hours after the observations on which it is based are made, it is useless for predicting purposes. The issue of this map in Boston was brought about by Sergeant Cole, who got permission from the Chief Signal Officer to chart the telegraphic reports, which have always been received in Boston, and to manifold this chart by a cyclostyle apparatus furnished by the writer. It is thus printed within four hours after the observations are made, and at once distributed through the mail. This map proved so satisfactory in Boston that the morning tabular bulletin has been discontinued at certain central stations, and the map substituted. It is now received at the Observatory about 2 P. M., Sundays included, being taken to and from the trains by messengers.

Local predictions were accordingly resumed at the Observatory May 1, 1886, just a year after the first attempt, subject to these rules: When the flag was hoisted, rain was expected to occur within twenty-four hours. If at the end of that time more rain was expected, the flag was kept up. If rain fell on any afternoon and the flag was not displayed before noon, it was accounted a failure to predict the rain. A flag displayed in the afternoon indicated rain the next day. The verification at Blue Hill of the weather predictions for May, those of the Signal Service being made for Massachusetts at 1 A. M., and appplying from 7 A. M. of that day to 7 A. M. of the following day, was as follows:

Blue Hill, 81 per cent.

Signal Service, 68 per cent.

During June a modification of this plan of display was adopted, which required the flag to be hoisted between 7 and 8 A. M., and to apply for the succeeding twenty-four hours. The comparison of the two sets of predictions was as under, the conditions being now practically identical as regarded the public:

Blue Hill, 90 per cent.

Signal Service, 77 per cent.

Finally a definite plan was announced to go into effect July 1, through this circular:

PLEASE POST IN A CONSPICUOUS PLACE.

BLUE HILL
WEATHER SIGNALS.

The following Rules will govern the display of signals at the Blue Hill Meteorological Observatory on and after July 1, 1886.

I. A Red Flag will indicate, as heretofore, Probable Rain in the vicinity.

II. Two Red Flags, one above the other, will indicate Possible Rain. This is not intended as a rain prediction, but simply to show that some of the conditions are favorable for rain.

III. The absence of Red Flags will indicate that no rain is expected.

IV. The prediction will be made before sunset to indicate the weather expected for the following day, and will extend from midnight to midnight. These predictions will be revised each morning at eight o'clock, and the Signals changed if necessary.

V. A White Flag with a Black Centre (seldom displayed in summer) will indicate an apppoaching Cold Wave.

These predictions, with the exception of the last, will be independent of those of the U. S. Signal Service.

A. LAWRENCE ROTCH,
BLUE HILL METEOROLOGICAL OBSERVATORY.

It was decided that if rain occurred with the two flags, the prediction was a failure, while fair weather would make this display a success. This rule was intended to make the rain prediction as definite as possible. The midnight indications of the Signal Service for Massachusetts continue to be received by telephone, at 7.30 A. M., at the Observatory, and, together with the local weather observations, help to make up the morning prediction. The afternoon prediction is dependent on the morning weather map, and upon the local weather observations. The comparison of the Blue Hill weather predictions, with those of the Signal Service, up to the present time, is as follows:

	PER CENT VERIFIED.				
	JULY.	AUG.	SEPT.	OCT.	NOV.
Blue Hill Sunset Predictions for 24 hours from midnight	84	81	80	78	77
Blue Hill 8 A. M. Predictions for 16 hours following	90	84	83	90	90
Signal Service Midnight Indications for 24 hours from 7 A. M.	68	71	63	81	70

It should be stated that in all cases each set of predictions has been tested at Blue Hill in a precisely similar manner, .01 inch or more of rain or melted snow within the specified time constituting rain. It is difficult to estimate the value of the Blue Hill weather signals, which can be plainly seen by travellers on the Boston & Providence and New York & New England Railroads, and in nine towns by some forty thousand people, who are, undoubtedly, more dependent upon the weather in their daily avocations than are the dwellers in cities. Inquiry shows that, although implicit confidence is not always placed in the signals, yet that farmers and others at least keep their weather eye open when a flag is flying on Blue Hill. Mr. Clayton has the charge of these signals, and to him their success is due. Lest these predictions, ostensibly *pro bono publico*, be regarded suspiciously, it should be stated that by attempting such predictions, a constant interest is given to the study of the development and progress of storms, which is one of the legitimate objects of the Observatory.

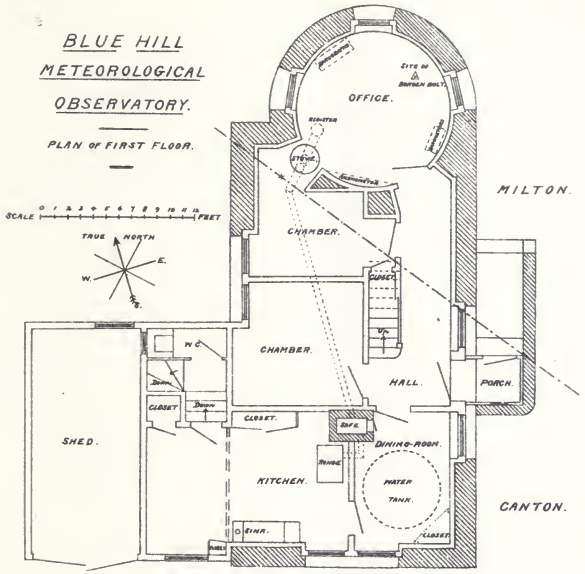
The superiority of these local predictions over the Washington predictions of the Signal Service lies in the fact that it is impossible for predictions made at one central station to take into account local causes which may influence the weather at any distant place. These influences each meteorologist learns for his own locality; and, when his observations are combined with a knowledge of the weather conditions existing that day over a large extent of country, as shown by a synoptic chart, he is better able to predict the weather for his locality than is the Signal Service, which must generalize its predictions for large areas, though the weather probabilities for his own town are what each inhabitant thereof wishes to know. Another advantage in favor of local predictions is the celerity with which they may be disseminated. Thus, if the 7 A. M. observation of the Signal Service shows indications of rain that day, notice cannot be given to the public before afternoon; while if the fact is locally signalled from the predicting station, by flags or otherwise, the public can be at once informed. The Signal Service has recently attempted to overcome this difficulty, by having its predictions commence seven hours after they are issued, but this aiming at longer range naturally impairs their accuracy.

The data at the service of the Washington office for making predictions is, of course, far greater than that available at this Observatory. Instead of one daily synoptic chart of the weather over the United States and Canada, one is prepared in Washington each eight hours; and this map, besides containing reports from many more stations than does the map charted in Boston, has the elements separated, with the changes which have occurred in each during the preceding eight hours. With these facilities at hand, it seems that the predictions of the Signal Service should be better. The obvious reasons for the shortcoming appear to be the haste with which forecasts for so many districts must be drawn up, and the frequent changes made in the predicting officer, which prevent a systematic study of weather types. As the preceding verifications in this locality of the Signal Service indications may seem exceptionally small, it can be stated that they agree substantially with the percentages of revised verifications for New England, published in the official *Monthly Weather Review;* though the verifications of the Signal Service indications, made at certain flag-display stations, and communicated through the Boston Signal office to the New England Meteorological Society, for publication in its monthly *Bulletin*, are evidently carelessly made, and show a considerably higher success than do the official estimates before mentioned. The proper method of verifying weather predictions has been much discussed, but no definite plan had been universally adopted, so that predictions tested at different places cannot be compared, unless the methods used are rigidly the same.

ANNALS OF THE OBSERVATORY.

The Observatory was taken possession of Jan. 31, 1885, by the writer and the observer, Mr. Gerrish, and at midnight a discharge of rockets announced the opening of the highest meteorological station on the Atlantic coast. The lower room of the tower and the adjoining bedroom only could be occupied, and for the first two days, until the steward arrived, the observers did their own cooking.

The month of February was one of the coldest months ever known in this region. The mean temperature on the Hill was


BLUE HILL
METEOROLOGICAL
OBSERVATORY.
PLAN OF FIRST FLOOR.
SCALE 0 1 2 3 4 5 6 7 8 9 10 11 FEET
TRUE NORTH
E.
W.
S.
OFFICE.
STONE.
MILTON.
CHAMBER.
CLOSET.
CHAMBER.
W.C.
HALL.
PORCH.
SHED.
CLOSET.
CLOSET.
SAFE.
DINING-ROOM.
RANGE.
KITCHEN.
WATER TANK.
CANTON.
SINK.
CLOSET.

16.5°, or 4° lower than the Signal office figures for Boston, but the high winds made the difference seem greater. The lowest temperature was, however, only —3.2°, or 4° lower than the Boston minimum. This cold was unpleasant to the occupants of the unfinished building, which double windows afterwards rendered more comfortable. On Feb. 16 occurred a gale which has hardly been equalled since, and which served to test the stability of the building. Both anemometers were blown away, so that the highest velocity of the wind is unknown; but before the accident occurred, 74 miles per hour were registered, and the observer thinks that for five minutes the velocity was 90 miles per hour. The cups of the Hahl anemometer were again blown off in December by much less wind. There was little snow during the winter, though the cold weather continued through March. The spring was pleasant, and from this time forth crowds of people visited the Hill at all hours of the day and night. A newspaper complaint, entitled "Is it a Monopoly of the Blue Hill view?" elicited a card from the writer, in which he stated that while the top of the Hill, as heretofore, would continue to be open to the public, subject only to the restriction that visitors should disturb neither the Observatory nor the instruments outside, yet that, as the grounds were private property, no injustice was done when disorderly or objectionable people were ordered from the premises. The road, which had been badly washed, was repaired so that it was again practicable for carriages. The parapet around the tower was now completed, and the stone-work pointed.

On account of the absence of the writer in Europe, the Council of the New England Meteorological Society kindly assumed charge of the Observatory during the summer, Mr. Gerrish remaining as observer, and conducting thunder-storm observations for the Society. Some of these storms were severe, the squall of July 21 being described as terrific. Owing to its short duration, the velocity of the wind could not be ascertained from the anemograph then in use, but an idea of its force may be had from the fact that a heavy dog-kennel was carried several hundred feet down the Hill and smashed to fragments, and stones hurled against the building with sufficient force to indent the

wood. The thunder-storms, however, generally moved around the Hill, but occasionally lightning played about the building, which, on account of insufficient ground connection, is not provided with conductors. The highest temperature during the summer was 1.6° lower than at Boston, but the continual breeze made the heat seem much less. The spring on the roadside having dried up, water for drinking was brought from the base, the cistern proving sufficient for cooking and washing. The Hill was occupied in June, and at various times since, by surveyors of the United States Geological and State Topographical Surveys, and a signal was erected by the latter over the Coast Survey bolt.

The autumn, which was cool and pleasant, passed uneventfully, and the writer resumed charge of the Observatory in October. The permanent snow of the winter came very late, and, in consequence, the supply of coal which was to be replenished by sled, ran low. The upper part of the road became covered with ice, so that the coal could be brought but half-way up the Hill. On Jan. 9 occurred a heavy snow-storm. The following extract from the Journal of this period reads like an arctic experience:

Jan. 9. "At sunrise a snow-drift, two feet deep, was found in the hallway, having been forced in through the cracks of the doors and windows by the high wind. There is little snow on the Hill, but below the roads are reported to be blocked."

Jan. 11. "The observer and the steward went to the base and brought up a large basket of provisions hung on a pole between them. The ascent (usually made in twenty minutes) occupied an hour. At noon, as the last coal was burning low, a rude sled was constructed, with a view of attempting to drag up a load from the pile on the roadside. At this juncture the teamster, who had been sent for the day before, succeeded in breaking through the drifts and reaching the summit with some of the coal which was distributed along the road."

The fall of the barometer in this storm was very great, amounting to over one inch in fifteen hours. The barograph sheet has been reproduced in the December number of the *American Meteorological Journal* by Prof. Upton in a discussion of this cyclone, whose centre seems to have passed over Blue Hill. It was followed within a week by an anti-cyclone which sent the

barometer (reduced to sea level) from 28.67 inches up to 30.85 inches, and the thermometer down to —15°, the highest and lowest pressures and the lowest temperature on record. The ice-storm which occurred the last of January was a transformation to fairyland. The trees, building, and in fact every object was incrusted with ice crystals, the anemometers and vane being so incased as to be rendered useless. The weight of a small branch was increased forty-five times by the rain and fog which froze on it and many trees were thus broken, while the telephone wire had a girth of eight inches. During this period, genuine frostwork, which had once before been observed on the Hill, attained a length of one or two inches.

Mr. Gerrish was succeeded by Mr. H. Helm Clayton as observer, on Feb. 1, and some new investigations were then undertaken. The flood in the Neponset Valley in February was an interesting sight from the Hill. The Canton meadows were a lake filled with floating cakes of ice, through which, for several days, the trains on the Providence Railroad could be seen creeping like snails, with the water up to the car steps. Communication with Readville by road was during this time interrupted. The rainfall which caused the flood was here six inches in fifty hours, but this was increased at least two inches by the sudden melting of the ice and snow on the ground. The building leaked badly then, as during other heavy rains, the water being driven by the wind through the pores of the stone. During the last days of February occurred the violent northwest gales, which are probably remembered by many. The highest velocity of the wind on the Hill during a whole hour was seventy-three miles, on the 28th, and, for five minutes, eighty-five miles per hour. The highest velocity at Boston during fifteen minutes was only fifty-one miles an hour. At the Observatory, a maximum pressure of over forty-three pounds per square foot was recorded, which shows the velocity of the gusts to have been ninety-three miles an hour. The total movement of the wind during the 28th was 1,467 miles, or 420 miles more than any previously recorded daily movement. During the last three days of February, 3,735 miles of wind blew over the Hill, and the gale continued during the first

days of March with diminishing force. No damage resulted from the blow, but it was found impossible to keep the building warm, the observer noting that water froze in a basin, within a few feet of the stove, the temperature of the air outside being in the neighborhood of 0°. The spring records of 1886 show no remarkable features, and the cool, dry summer and pleasant autumn have passed in the same manner.

The preceding events are the most important which have occurred in the history of the Observatory. Many interesting meteorological phenomena, however, have not been described. Among these may be mentioned the wonderful effects of cloud and fog the latter sometimes covering the country like a milky sea from whose upper surface the highest hills protrude like islands, the glorious sunrises and sunsets, the brilliant moonlight scenes, the approach of thunder-storms and the succeeding rainbows; all these sights and many more, which not one in a thousand of the visitors to Blue Hill sees, rarely escape the notice of the weather-watcher, and render a sojourn on the Hill interesting, regarded simply for the scenic effects.

THE STAFF OF THE OBSERVATORY.

This consists of the writer, who directs the work, an observer and the steward. The first observer was Mr. Willard P. Gerrish, whose mechanical skill greatly facilitated the setting up of the instruments. He remained a year, and was succeeded by the present incumbent, Mr. H. Helm Clayton, who had already become known by his writings on meteorological subjects, while at the Ann Arbor (Michigan) Observatory. He is an enthusiastic meteorologist, and has continued his investigations since coming to Blue Hill. Last, but by no means least, so far as physical welfare is concerned, is the steward, Frank Brown, who has been at the Observatory almost since its opening, and has satisfactorily performed his duties, at times under difficulties. The fact that there has not been a day's sickness on the part of any of the inhabitants of the Observatory, testifies better than statistics of the amount of ozone, etc., to the healthful climate of Blue Hill.

Besides the above persons, the Hill colony embraces the St. Bernard "Alp," — a true weather dog, — and a varying number of cats and mice, the latter taking refuge in the Observatory in cold weather. The current expenses of the Observatory are about twenty-five hundred dollars a year.

FRIENDS OF THE OBSERVATORY.

Rev. A. K. Teele of Milton has taken an active interest in the enterprise from its inception, and has been of much assistance in looking up the deeds of the land purchased. Pleasant relations have existed with the United States Signal Service. General Hazen, Chief Signal Officer, who visited the Observatory last August, spoke of it in a complimentary manner, and hoped that some of the registering apparatus might be introduced at the Signal Service stations. Professor Abbe, the chief scientist of the Washington office, has visited the Observatory recently. The Signal Service observer in Boston, Sergeant O. B. Cole, and his associates, have been uniform in their courtesy. The Council of the New England Meteorological Society, including Professors Niles, Davis, and Upton, and Messrs. Fitz Gerald and Weston, have done much to aid the Observatory, and Dr. Draper, the director of the New York Meteorological Observatory, has given the benefit of his long experience with recording apparatus. The eminent meteorologists whom the writer met last year in Europe manifested much interest in this Observatory, and the publications of some of the foreign stations are received in exchange for the hitherto meagre reports of its work. It is for these friends, as well as for many others, both at home and abroad, that this account of a somewhat unique enterprise has been prepared.

BLUE HILL METEOROLOGICAL OBSERVATORY, DECEMBER, 1886.