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ANNUAL REPORT OF THE CHIEF SIGNAL OFFICER FOR 1887.

APPENDIX 46.

TREATISE

ON

METEOROLOGICAL APPARATUS AND METHODS,

BY

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BY AUTHORITY OF THE SECRETARY OF WAR.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1888.

CHAPTER XX.

THE MEASUREMENT OF RAIN AND SNOW.

149. THE PROBLEM.

The aqueous vapor in the atmosphere, after being condensed into cloud, falls to the earth in the forms of rain, hail, and snow. The measurement of such precipitation constitutes a class of observations in meteorology which has most extensive practical applications.

The precipitation of aqueous vapor is usually held to include all its visible forms, as the cloud, fog, dew, and haze, but rain, hail, and snow are the most important, and will alone be considered in this section.

The natural unit of measurement would be by volumes, but just as the barometric height has been adopted instead of pound's weight for expressing the pressure of the air, so the depth of the fallen water when spread uniformly over the horizontal projection of the surface on which it fell has been adopted as the conventional unit by which to measure precipitation; this horizontal projection of the surface corresponds to the legal method of measuring the area of land. The object of the rain-gauge is to collect the rain falling upon a given small horizontal area, and by its measurement to determine the height of rain-fall over that area.

150. ORDINARY APPARATUS.

The observation is of the simplest character when the instrument is a receiver with horizontal bottom and vertical sides.

Inasmuch, however, as for light rains the measurement of the height of the water is subject to a relatively large error, it has been customary to measure the "catch" in a gauge of smaller sectional area than the receiving surface. By this means the measured height is magnified and the real height is obtained with greater precision.

(*a*) *The gauge—Forms.*—Innumerable forms of receivers and measuring apparatus have been used. The receivers have been funnels, cylinders, or boxes, with or without beveled rims; their size has been a few square inches or square feet in area; their material has been sheet metal, porcelain, wood, or glass; their color has been light or dark, painted or unpainted.

Methods of measurement.—The height has been obtained by an immersed stick; the volume has been obtained by pouring the water into a graduated glass tube; the height has been computed from the volume; the water has been weighed by a balance and the height computed therefrom. The first method is the simplest and can be made sufficiently accurate.

The accompanying diagram (Fig. 97) shows the Signal Service standard rain-gauge. The diameter of the receiver is 8 inches, and the height of the instrument is 2 feet. The rim of the receiver is made of brass, beveled to a sharp edge and accurately circular. This brass rim is soldered to a galvanized iron funnel.

The collecting tube is made of seamless brass tubing No. 16 of 2.53 inches inside diameter and 20 inches deep. With these dimensions the area of the measuring tube is to the nearest hundredth of an inch, one-tenth of the area of the receiving surface.

The measuring stick is of well-seasoned cedar $\frac{1}{2}$ inch wide $\frac{3}{32}$ inch thick and carefully graduated.

Each instrument is tested to determine the outstanding errors in the accuracy of the measuring tube and its ratio to the receiving surface, and corrections are furnished for any errors greater than one-half of 1 per cent. of the measured rain-fall.

The size and quality of the measuring stick is such that the possible errors incident to its use need no special consideration.

Although the sectional area of the stick is small, yet the small displacement of the water in the tube is allowed for in the ratio of the receiving surface to the measuring tube. The graduations of the scale are made with all the accuracy needed for rain-fall measurement. The cedar wood out of which the sticks are made has a small capillarity, and gives a clear sharp line of wetting, whose position on the scale can be read off with all requisite accuracy.

The Signal Service rain-gauge needs therefore no purely instrumental corrections additional to those furnished by its correction card in order to measure the catch to an accuracy of 1 per cent., and this should be true of any other form of rain-gauge.

But more important than those of the instrument itself are the errors arising from its exposure, which are large and difficult of determination.

(*b*) *The exposure.*—Gauges have been exposed in all locations; on roofs, poles, towers, on the surface of the ground, and buried to the rim of the gauge. All these and numerous other modifications have given rise to a large literature on the whole subject, the details of which have mostly but little value to future observers, but are of vital importance to the proper interpretation of past records. Owing to peculiarities of exposure the amount of rain caught in the mouth of the gauge is not the same as would have fallen upon the same surface in the absence of the gauge itself, and, further, after correcting for this the rain falling at the place of exposure may not be with any accuracy the average amount of rain falling in the immediate vicinity. These sources of error, depending on exposure and location, respectively, have been shown to be ultimately due to the influence of the wind,

which in blowing against obstacles suffers variations in velocity and deviations in direction, and thereby brings about local inequalities in the distribution of the rain-fall.

That the catch of a gauge varies according to its location was noted by Dr. Heberden in 1766 by observing that gauges placed on the ground collect, in general, a larger amount of rain than gauges on roofs and high towers. In lack of any satisfactory explanation of this variation Dr. Heberden says "It is probable that some hitherto unknown property of electricity is concerned in this phenomenon." Some years later Benjamin Franklin suggested that the increase of rain collected in gauges on the ground might be due to the augmentation of the rain-drops by the condensation of moisture on their surfaces during their fall. Though this hypothesis was considered by Dr. Franklin himself to be inadequate and open to objection it became the generally accepted explanation of the phenomenon.

The insufficiency of this explanation was afterward shown by others, notably Sir John Herschel, who demonstrated that the increase of a rain-drop by condensation or otherwise within the last few hundred feet of descent must be absolutely inappreciable.

The first step towards a true explanation supported by the results of observation was made by Prof. A. D. Bache, of Philadelphia, in a paper presented in 1837 to the British Association, entitled "Note on the effect of deflected currents of air on the quantity of rain collected by a rain-gauge." Professor Bache made the important discovery that of four gauges placed at the corners of a roof, in general, the gauges to leeward received more rain than those to windward. From this difference he was led to the belief that the effect of eddy-winds is a subject of primary consideration in the whole question of rain-gauge exposure. In 1855 and 1859 Henry fully explained the errors of the Franklin hypothesis and gave the correct explanation of Bache's results.* A further elucidation of the variations in collection observed by Bache was furnished in 1861 by W. Stanley Jevons (Phil. Magazine, 1861: Signal Service Notes, No. XVI), who showed that when by reason of an obstacle of any kind the wind is forced into currents of varying velocity, greater and less than the normal, an irregular distribution of rain-fall will result. At places where the wind velocity is increased the rain will be carried over and past, and a deficiency will be collected, in like manner where the wind velocity is diminished an excess is collected. The rain-gauge is itself to be considered as such an obstacle to the wind, and the currents around it divert the rain-drops from the mouth of the gauge, causing a deficiency that is proportional to the wind velocity. Buildings, towers, fences, and trees are still greater obstructions, causing irregularities in distribution that vary with the direction and force of the wind, so that gauges located on or near them may give either deficient or excessive amounts, but more generally the

* See also, Maille; Ann. Soc. Met. de France, 1855, III., p. 165.

former. The smaller quantity of rain collected on a roof than on the adjacent ground is undoubtedly due to the deflections and eddies about the building and the gauge, which cause such locations to be classed as very "poor exposures" compared with the center of a cleared field.

Signal Service observations show that this deficiency in the rain caught by a roof gauge frequently amounts to 25 per cent. of the true total rain-fall, even in monthly and yearly averages. European observers have found that for gauges of different sizes exposed to the wind the very small gauges have the greater deficiencies, evidently because the eddies about them have a larger ratio to the receiving surface. Extended comparisons made by the Signal Service between 3-inch and 8-inch gauges when exposed to high winds have shown, in conformity with European experiments, the superiority of the larger gauge.

(*c*) *The standard exposure.*—The preceding considerations lead to the definition of the standard exposure as one in which no obstacles, including the gauge itself, have any influence on the catch. This criterion is attainable by placing a gauge in a large level space, and buried in the ground so as not to offer any obstruction to the wind. In practice the top of the gauge must, of course, be sufficiently above the surface of the surrounding ground to prevent any spattering drops from falling into the gauge.

Such an exposure was recommended about 1850 by Joseph Henry in his instructions (Tenth Annual Report of the Smithsonian Institution, 1855) to observers of the Smithsonian Institution. There are, however, several practical objections to such an exposure; gauges whose mouths are near the surface of the ground frequently become filled with leaves, dirt, and rubbish of all kinds, and are liable to accidental injury, and to disturbance from animals and unauthorized persons. It is also often impracticable to find such locations, especially in large cities. Therefore in 1858, in his memoirs on meteorology, Henry recommended what is now known as the shielded gauge (see his Scientific Writings, pp. 260–262).

151. THE SHIELDED GAUGE.

(*a*) *Henry's gauge.*—In view of the difficulties introduced by gauge-eddies Henry recommended a simple cylindrical gauge 2 inches in diameter, near whose mouth is soldered a collar, consisting of a horizontal sheet of metal "like the rim of an inverted hat." Comparative observations are said to have been made with this form.

(*b*) *Nipher's shielded gauge.*—As a solution of nearly all difficulties Professor Nipher recommends a post or pole exposure, and has sought to eliminate the effect of the gauge itself as an obstacle to the wind when in an elevated position by surrounding it with a shield that deflects the wind downward instead of allowing it to sweep up over the mouth of the gauge. The following description (Am. Assoc. Ad. Sci., 1878, p. 106) of this is given by Professor Nipher (see Fig. 98): Six inches from the lower end of the cylindrical rain-gauge a false bottom is placed, and the cylinder is set over a turned post for support. Around this gauge a trumpet-shaped shield is placed with the mouth or flaring part opening upward. The shield is furnished with a clamp screw at the bottom, and is braced near the top by metal strips set with their edges up and reaching from the shield to a sliding collar, which encircles the gauge. By this means the shield can be set at any desired altitude on the gauge. The upper part of the shield terminates in a horizontal annulus of copper wire cloth. All splashing is avoided as all drops fall through the cloth, and in order that this end may be secured the wire must be small (No. 20, B. W. G.), the meshes running about 8 to the inch. Comparisons between a shielded and unshielded gauge set 6 feet above the ground showed in the latter a rain-fall of 97 per cent. of that collected in the former. Further experiments made by Nipher on the roof of a tower confirmed the advantage of the shields, but nowhere on the roof could uniform results be attained, owing to the irregular distribution of rain over its surface. The gauge was then raised to an elevation of 18 feet above the roof and 118 above the ground. An unshielded gauge thus placed showed a catch of 90 to 50 per cent. of the catch of the shielded ground gauge. The shield was then placed around this upper gauge and clamped, so that its rim should be at various elevations above the top of the gauge; when this elevation amounts to an inch it is necessary to take precautions against splashing into the gauge. This was done by placing inside the shield a concentric cone of copper wire cloth separated from the shield by an interspace of half an inch. From the results of the experiments it appeared that when the shield is placed at an elevation of 3¼ inches the elevated gauge, 118 feet above the ground and 18 feet above the roof, gives about the same indications as the common unshielded gauge at the ground, although differing in level 112 feet.

Recent similar comparisons by Wild corroborate Nipher's conclusion that such a shield by annulling the eddies about the mouth of the gauge renders its records almost wholly independent of the wind that strikes it, so that wherever located it gives the true rain-fall for that spot. With Nipher's forms of gauge, therefore, we can examine the distribution of rain in the neighborhood of a building, tree, hill, or other obstacle, and for each direction of the wind, and decide upon the correction needed to reduce any exposure to the correct average of the neighborhood. In general, with regard to the roof exposure adopted in cities, there is little doubt that by raising the gauge above the roof and providing it with a shield the catch will approximate more nearly to the true rain-fall.

152. THE MEASUREMENT OF SNOW.

For collecting snow a simple cylinder 2 feet deep is used by the Signal Service in place of the funnel rain-gauge, which would be unsuited for the purpose. In cases of light dry snow-flakes and high wind, however, all gauges frequently fail to collect or to retain the proper amount of snow, and the catch should, when possible, be checked by measurement of the snow on an undrifted uniform flat surface. This is best done by plunging the cylinder vertically into the level snow until its lower edge reaches either the ground or the upper surface of the snow that fell since the last measurement. A sheet of tin is then slipped under the gauge; the snow thus collected is melted, and its amount represents the height of the snow-fall in equivalent inches of water.

As preparatory to such measures a small spot of ground should be kept covered with a sheet of tin or a few sheets of paper, so that one of these may be lifted up with the inverted gauge.

The measurement of the height of the snow and the reduction of this height to an equivalent height of water by assuming 10 inches of snow to 1 of water or some other factor, is subject to a large range of error because of the wide variability of this ratio for different kinds of snow. The rain and snow-fall should be melted and measured at every observation and not merely once a day.

The depth of the snow in inches as it lies on the ground is frequently wanted in weather predictions, and should be recorded at every observation in addition to the measure of snow-fall during the preceding few hours.

ILLUSTRATIONS.