Cyperaceæ 7 genera and 95 species, Cruciferæ 28 genera and 69 species, Rosaceæ 28 genera and 61 species, Leguminosæ 13 genera and 72 species, Compositæ 66 genera and 89 species. The genera containing more than 15 species are: *Agrostis* 18, *Poa* 22, *Carex* 73, *Juncus* 23, *Salix* 19, *Polygonum* 20, *Ranunculus* 19, *Lupinus* 19, *Trifolium* 20, *Epilobium* 18, *Erigeron* 17 and *Senecio* 17. All of these genera with the exception of *Trifolium* and *Lupinus* are common not only throughout the cooler parts of North America, but of Europe and Asia as well. In fact, while there are many endemic species, the general floral element is that of the Boreal Realm, just as we would expect, since the region lies within the Arctic to Transition zones. Very few of the typical American genera of the arid regions of the west are represented.

The text is supplied with keys to families, genera and species, but the descriptions of the species are often meager, too much so we fear in some cases for certain identification. But in the reviewer's mind the most disappointing feature of this admirable work is the extremely meager and indefinite distributional notes. It is to be regretted in this respect that the authors did not follow the excellent example set by the senior author in his "Flora of Washington," and give the zonal distribution. Two additional words would have been sufficient, and these with a little fuller definition of each zone in the preface would have been of great service to the student of plant distribution.

LEROY ABRAMS

NOTES ON METEOROLOGY AND CLIMATOLOGY

FROST

PROFESSOR ALEXANDER MCADIE and Mr. William G. Reed have each recently presented several papers on the meteorology of local frosts, the causes of frost damage to plants and methods of protection, the dates of occurrence of frost, and bibliography of frost in the United States.

The meteorology of frost formation is discussed by Professor McAdie in an article entitled "Temperature Inversions in Relation to Frosts."[1] Two laws of frost formation are enunciated as follows:

(1) Where the air is in motion, there is less likelihood of frost than where the air is stagnant; (2) frost is more likely to occur when the air is dry (and dustless) than when it is moist.

The first is true because local frosts are connected essentially with local "air drainage." Soon after sunset, cold and dense air, cooled chiefly by radiation to the ground, drains slowly down the slopes into the valleys and low places. Strong winds mix the air and so prevent the occurrence of local frosts. The second law is based on the retardation of temperature change due to moisture in the air. The water vapor strongly absorbs the heat rays from the earth, acting in this way as a blanket. If condensation occurs, there is further retardation of the cooling by the liberation of latent heat. Since dry air is denser than moist air at the same temperature, a loss or gain of moisture as well as a change in temperature affects the rate of "air drainage." To obtain a continuous record of the weight of water vapor in grams per cubic meter of air, Professor McAdie has devised a "saturation deficit recorder." This instrument is essentially a hygrograph mounted on the pen of a thermograph. The thermograph indicates the maximum weight of water vapor possible in the air at the temperature prevailing, and the hygrograph indicates the percentage of saturation.

Protection of plants from injury by frost involves the conservation of the earth's heat with covers, the addition of heat to the air, or the use of some agency with high specific heat, such as water, to prevent cooling. Preventable damage often results from too rapid defrosting in the morning; fortunately, the same agents which keep the temperature from falling retard its rise.

Mr. Reed treats the subject of protection as a whole in an illustrated article, "Protection from Damage by Frost."[2] The methods most successful commercially depend upon the com-

[1] *Annals*, Harvard College Observatory, Vol. 73, pp. 168 to 177, 4 pl., Cambridge, 1915; or see *Scientific Monthly*, December, 1915, pp. 293 to 301.

[2] *Geographical Review*, February, 1916, pp. 110 to 122.

bination of heat and smoke; in the best orchard practise there is a fairly clean-burning small fire to each one or two trees. Economical and effective use of heaters involves the information and warnings issued by the U. S. Weather Bureau, and knowledge of the local seasons of frost and places of lowest temperature. The methods of protection should be studied, and the type which has proved successful in the particular region or in one where the conditions are similar should be selected. The campaign should be carefully planned in advance. Protection is so expensive that crops of high value only can carry the charge.

Protection is but one aspect of the frost problem. The problem for the farmer is to determine the frost conditions he will have to meet and to arrange his crops and his agricultural practise to suit these conditions. Apparently, the first frost maps of the United States were made by Mr. P. C. Day.[3] Maps are presented showing average and extreme dates of the last killing frost in spring, and of the first in autumn, and the average length of the growing season. Isochronal lines are shown east of the Rocky Mountains, and figures are given at stations west of the mountains. Later, more extensive frost data, included in the original records of the cooperative observers of the Weather Bureau, were edited, and tabulated; and new frost maps of the United States have been constructed on a scale of 1/2,500,000, the records used being within the period 1895 to 1914. In this work the Office of Farm Management and the Weather Bureau cooperated. A preliminary study of these maps was presented by Mr. Reed at the Second Pan-American Scientific Congress. Parts of the author's abstract are quoted here:

> Killing frost . . . is a temperature low enough to destroy plant tissue. Frost is measured by the effect on plants, but it would be better to use some definite temperature.
>
> Most of the United States is subject to annual killing frosts. Low temperatures are most dangerous to plants at the beginning and end of the growing season. Frost is an anticyclonic phenomenon. East of the Rocky Mountains it is frequently possible to follow a frost across the country; west of the Rocky Mountains frost occurs when an anticyclone overlies the region.
>
> Records of frost occurrence are now available for over 5,000 places. These may be supplemented by knowledge of topography and vegetation, and although the term is of doubtful meaning, "average dates" of killing frost may be determined. Frost risks may be determined by the use of the "standard deviation." Maps of the average date of last killing frost in spring, and the frost killing in autumn, and of the length of the season without killing frost have been drawn. Between one quarter and one third of the country is subject to frost after June 1 and before September 1. Computed dates of last spring frost and first autumn frosts in nine years in ten, as well as the length of the season without killing frosts in four years in five, have been mapped.
>
> Mountain masses are more subject to frost than lower regions, but the relations are complicated by "air drainage," which makes frost more common in valleys than on slopes. . . .

Mr. Reed and Miss Cora L. Feldkamp have published a "Selected Bibliography of Frost in the United States."[4] It is arranged with the later papers first, as most of the work is very recent; earlier papers cover substantially the same ground. Thus 26 of the 94 articles are dated 1914 or 1915. An index by states is added. Although the titles are few in number, they were selected from all the material on "frost and frost prevention under American conditions," found in the libraries of Washington, the published bibliographies of the John Crear Library (Chicago), and references in many agricultural and meteorological magazines and other publications.

WEATHER AND THE WAR

There are two aspects of the relationships between weather and the war: weather has a decided control on military operations; but it is a question whether the war has any effect on the weather. Professor R. DeC. Ward has undertaken a thorough study of the former, and has published some of the results in the

[3] Weather Bureau Bulletin V., 1911, 5 pp., 5 maps.

[4] *Monthly Weather Review*, October, 1915, pp. 512 to 517.

Popular Science Monthly[5] and in the *Journal of Geography*.[6] The decrease in military activity at the opening of winter indicates the deterrent effect of winter weather on military operations. As the speed of movements in the field is dependent primarily on the condition of the ground, cold weather in winter is almost invariably accompanied by greater military activity. Since the Russian theater has colder and drier weather in winter than that in the west, operations there are less hindered by mud. On the other hand, in autumn the flooding rains present great difficulties in the east. The prospect of the usual autumnal rains and the intrenchment difficulties of the winter probably spurred the Germans and Austrians to their remarkable activity in the summer of 1915 even in spite of heavy mud.

At great altitudes, meteorological hindrances are much more acutely felt. High mountains mean cold and snow even in summer. Also mountains have more clouds, more rain and more thunderstorms than the lowlands. In winter, fighting is extremely difficult. Operations in the Alps, Carpathians, Balkans and Caucasus have almost always been mentioned in the same breath with the unfavorable weather conditions.

Furthermore, too great dryness makes operations difficult anywhere. Thus on Gallipoli peninsula and in Mesopotamia there was a scarcity of water, and the dust was almost unbearable in the summer dry season. The difficulties of operations in deserts are such as to make Egypt fairly safe from attack. The story of the operations in Mexico is not without mention of the winds, dust, sand and heat of the desert.

For air and naval engagements, foggy conditions are generally chosen. This has been shown abundantly in the Zeppelin raids on England, the aeroplane raids of the French in Germany, and in the infrequent naval attacks on coasts. For the use of asphyxiating gases, wind conditions must be just right: steady, moderate, and from the proper quarter.

On the effects of battles on rainfall, the excessive raininess of the winter of 1914 to 1915 in the British Isles and weather anomalies elsewhere have occasioned some comment. Charles Harding presented before the Royal Meteorological Society[7] a summary of the weather conditions for eight stations in Great Britain and eight continental ones for the period August, 1914, to April, 1915. In connection with the discussion as to the cause of the extraordinarily heavy rainfall which was experienced in England, Dr. H. R. Mill, director of the British Rainfall Organization, made the following statement:

> The vastness of the work done by the quiet processes of nature requires only to be realized in order to show the incalculable improbability of gunfire in France producing a wet winter in England. Take the case of the three and a half inches of rain which fell in excess of the average in December over 58,000 square miles of England and Wales. This quantity is 203,000 square mile inches or 13,126,920,000 tons. At winter temperatures, saturated water vapor would form about 1 per cent. of the mass of the atmosphere containing it, hence the minimum quantity of air which must have been carried over England and Wales in December, 1914, must have exceeded 1,300,000,000,000 tons. The amount of force required even to deviate the direction of moving masses of this magnitude is surely far beyond that which can be exerted even by nations at war.

Professor Cleveland Abbe in the *Popular Science Monthly*, January, 1911, shows by laboratory experiments that the firing of cannon or dynamite to produce rain can not possibly succeed. *The Scientific American*, October 24, 1914, contains an instructive article on the subject; and Professor McAdie in the *Scientific Monthly*, February, 1916, gives a brief summary of the question.

HEAVY SNOWFALL IN NEW ENGLAND

DURING the past winter the snowfall in parts of New England exceeded all previous records (since 1873) for any winter. The

[5] December, 1914, pp. 604 to 613.

[6] February, 1915, pp. 169 to 171; March, 1915, pp. 209 to 216; November, 1915, pp. 71 to 76; June, 1916, pp. 374 to 384.

[7] *Quarterly Journal*, October, 1915, pp. 337 to 348.

snowfall of the early winter was greater in the western than in the eastern part of New England, but not later, owing to the cooling of the ocean water.[8]

SNOWFALL, 1915 TO 1916 (INCHES)

	November	December	January	February	March	April	Total	Av. 1895 to 1913
Eastport, Me.......	T	4.4	14.2	21.8	15.7	6.5	62.6	87.2
Portland, Me.......	T	12.0	12.2	20.2	36.3	7.9	88.6	73.1
Boston, Mass	0.2	6.7	4.8	30.3	33.0	4.2	79.2	41.1
Blue Hill, Mass.[9]	1.0	12.3	6.4	33.4	42.2	16.2	111.5	58.2
Worcester, Mass.[9]	T	15.8	6.2	24.9	36.0	5.6	88.5	50.9
Albany, N. Y......	0.1	40.3	0.6	13.7	37.9	2.1	94.7	46.0
Providence, R. I...	0.3	3.5	0.8	15.1	19.1	4.7	43.5	42.1
New Haven, Ct. ..	T	18.0	1.6	24.7	29.0	2.7	76.0	37.8

In New Haven the ground was snow-covered from February 3 to March 28, 1916. Two features prevented the occurrence of floods when the snow melted. First, on account of the lateness of the melting, the ground was thawed out below and so received readily the water from the melting snow. Second, the melting took place in clear, cool weather and lasted over a period of four days.[10]

The season ended with a fall of snow in eastern New England on April 28, amounting to eight inches at Blue Hill.

PROFESSOR CLEVELAND ABBE

At the annual meeting of the National Academy of Sciences held in Washington in April, 1916, Professor Cleveland Abbe was awarded its gold medal for "eminence in the application of science to the public welfare, in consideration of his distinguished service in inaugurating systematic meteorological observations in the United States." Unfortunately, on account of illness Professor Abbe could not be present to receive the medal in person. Since last June he has been incapacitated by partial paralysis for his work as editor of the *Monthly Weather Review*.

Professor Abbe, who is in his seventy-eighth year, has had forty-four years of distinguished service in government meteorology, a period significantly equal to the length of record of most regular Weather Bureau stations. Early in his career, Professor Abbe was an astronomer. On September 1, 1869, while he was director of the Cincinnati Observatory, he inaugurated daily weather reports for the Cincinnati Chamber of Commerce, which at once led the United States government to take up similar work. From 1871 to 1891 he was professor of meteorology and civilian assistant in the office of the chief signal officer, U. S. Army; and with the change of the weather service to a civil bureau in 1891 he continued as professor of meteorology in the Weather Bureau. As editor of the *Monthly Weather Review* from the time of its foundation to the present[11] Professor Abbe has been in touch with, and stimulated great numbers of meteorological observers and investigators. Although he was in a position to carry on but few original investigations, he did an immense amount of translation and compilation of the results of others' meteorological investigations. Among the more important of his works are: "Meteorological Apparatus and Methods" (1887); "The Mechanics of the Earth's Atmosphere" (1891 and 1909); and "First Report on the Relations between Climates and Crops" (1905, as of 1891).

To him belongs the credit of publishing a "Report on Standard Time" (1879) which started the agitation that resulted in the modern standard hour meridians from Greenwich.

Professor Abbe is a member of a great many domestic and foreign scientific societies, among them being five meteorological societies of Europe. Two signal honors from his con-

[8] See SCIENCE, February 11, 1916, p. 212.

[9] Sleet included; since January 1, 1909, regular Weather Bureau Stations have measured sleet separately. Thus, if sleet were included, the total for New Haven would be 82.3 instead of 76 inches.

[10] See article on snow-melting, by A. J. Henry, *Monthly Weather Review*, March, 1916, pp. 150 to 153.

[11] In the period 1909 to 1913, inclusive, the *Monthly Weather Review* was divided into two sections, the one which kept the title including the observational material, and the *Bulletin of the Mount Weather Observatory*, the discussional. Professor Abbe edited the latter only.

temporaries abroad are the degree of LL.D. from the University of Glasgow in 1896, and the Symons Gold Medal of the Royal Meteorological Society in 1912.

CHARLES F. BROOKS

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SPECIAL ARTICLES

A NEW FORM OF PHOSPHOROSCOPE[1]

EXISTING phosphoroscopes are of two types, those with a periodically interrupted source of light and those employing a steady source.

To the first type belongs the classical instrument of E. Becquerel,[2] subsequently modified by E. Wiedemann,[3] in which the object is placed between two parallel revolving disks and is alternately illuminated and observed through properly placed and adjustable openings.

In 1908 Merritt,[4] devised a phosphoroscope in which the phosphorescent surface *P*, Fig. 1, was illuminated periodically by the passage

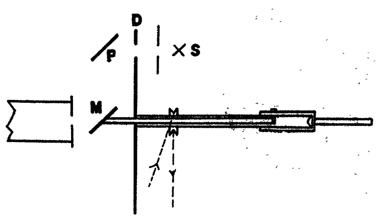

FIG. 1.

of an opening in a revolving disk *D* mounted between it and a source of light *S*. The phosphorescence was observed at the desired time after exposure by means of a small revolving mirror, *M*, mounted obliquely on the end of the shaft. The disk was carried upon a hollow sleeve revolving with the shaft and the angle between the opening in the disk and the plane of reflection of the mirror could be varied during rotation.

With this apparatus curves of decay of numerous cases of phosphorescence of short duration were determined by Messrs. Waggoner[5] and Zeller.[6]

In these phosphoroscopes, the source of light is not in itself necessarily intermittent, the periodic interruption of excitation being produced by the use of a revolving sectored disk. Another group of instruments of this general type employs the intermittent discharge from an induction coil or transformer, as in the spark-phosphoroscope briefly described by Laborde in 1869,[7] Crookes's device with sectored disk and commutator for observing the afterglow of substances subjected to kathode discharge,[8] Lenard's[9] phosphoroscope of 1892 and de Watteville's[10] apparatus for the spectroscopic study of phosphorescence (1906). Lenard's instrument differs from the others of this group in that the eclipse of the exciting spark is produced by the linear movement of a screen mounted upon the plunger of a Ruhmkorff mercury interrupter in the primary circuit of the induction coil.

The other type of phosphoroscope, in which an uninterrupted source of light is used, likewise had its origin with Becquerel.[11] It was later used for lecture demonstrations at the Royal Institution by Tyndall[12] and for measurements by Kester,[13] Waggoner[14] and others. It consists simply of a cylinder revolving on a

[1] A paper presented at the April meeting of the American Physical Society, 1916.

[2] E. Becquerel, *Annales de Chimie et de Physique* (3), 55, p. 5, 1859.

[3] E. Wiedemann, *Wiedemann's Annalen*, 34, p. 446 (1888).

[4] Nichols and Merritt, "Studies in Luminescence," Carnegie Institute of Washington, Publication No. 152.

[5] C. W. Waggoner, *Physical Review* (1), XXVII., p. 209.

[6] Carl Zeller, *Physical Review* (1), XXX., p. 367.

[7] Laborde, *Comptes Rendus*, 68, p. 1,576.

[8] Crookes, *Proc. of the Royal Society*, 42, p. 111 (1887).

[9] Lenard, *Wiedemann's Annalen*, 46, p. 637.

[10] C. de Watteville, *Comptes Rendus*, 142, p. 1,078.

[11] E. Becquerel, *Ann. de Chimie et de Physique* (3), 62, p. 5 (1861).

[12] See Lewis Wright, "Light," London, 1882, p. 152.

[13] Kester, *Physical Review* (1), IX., p. 164.

[14] Waggoner, Publications of the Carnegie Institution of Washington, No. 152, p. 120.