that period stock on the ranges suffered considerably. After the 15th much warmer weather prevailed, and the close of the month found all live stock, as a rule, in excellent condition.—*B. H. Bronson.*

Ohio.—The temperature during the first two-thirds of the month averaged about 15° below normal, but during the remainder it was about normal. The precipitation also was deficient. The ground was well covered with snow, especially during the coldest portion of the month. Wheat, rye, meadows, and pastures were well protected, although some damage occurred by top freezing. Peach buds were injured somewhat in the southwest. Tobacco shipping was delayed by lack of moisture and warmth.—*J. Warren Smith.*

Oklahoma and Indian Territories.—February was marked by the lowest temperatures on record at many points, the monthly mean temperatures ranging from 6° to 13° below the normal. A thick covering of snow protected and benefited wheat and placed it in fair to good condition. Ground was in fine condition for spring work and was thoroughly saturated. Stock was in poor to fair condition and suffered considerable loss during severe cold. Apricots, peaches, pears, and berries were badly winter killed, other fruit in fair condition.—*C. M. Strong.*

Oregon.—The coldest weather of the winter occurred during the first half of the month. The latter part was warmer than usual, and there were several periods of warm, sunshiny weather. The precipitation, while deficient in all sections, came at opportune times, and was of great benefit. Wheat, rye, and oats came through the cold weather practically uninjured, and at the close of the month all fall sown grain was unusually promising.—*A. B. Wollaber.*

Pennsylvania.—The mean temperature for the month was the lowest in the last eighteen years. The average precipitation was the least since 1901 and was only 56 per cent of the seventeen-year normal. The average snowfall was 9.5 inches as against 6.7 last year. Winter grain was amply protected and was thought to be uninjured.—*T. F. Townsend.*

Porto Rico.—The rainfall was light, but generally sufficient to keep crops in good condition, except in the southern division where young canes and pastures were drying up. Sugar making continued throughout the month without interruption, and the grade of juice obtained was good, except in a few places where the wet weather of January prevented the canes from maturing well. Much cane was planted. Considerable cotton was picked; yield good. Coffee trees blossomed well. Tobacco cutting was active and a good crop was being obtained. Pineapples promised a good crop. Pasturage was scarce in places, and cattle were suffering.—*E. C. Thompson.*

South Carolina.—The month was cold and wet. The precipitation was largely in the form of mixed snow, sleet, and rain, which froze as it fell, melted slowly, and thoroughly saturated the soil. Freezing damaged oats somewhat, but not wheat nor fruit buds, which remained dormant. Truck planting was seriously delayed and growth of such as was up was checked. Some tobacco seed beds were burnt and seeded. The closing week was mild and pleasant, and plowing and preparations for early planting made good progress.—*J. W. Bauer.*

South Dakota.—The forepart of the month was very cold, two stations recording a minimum temperature of −48° on the 2d. Generally favorable conditions for live stock prevailed after the 16th; before that date, however, snow on the ground and severe cold necessitated heavy feeding of sheltered stock and reduced flesh on range stock, but only normal actual losses on the ranges were indicated. Winter rye and the limited acreage of winter wheat were protected by snow during the severe weather and no injury therefrom was reported.—*S. W. Glenn.*

Tennessee.—Abnormally low temperature and hard freezing wrought serious damage to winter grains, but in many sections snow protected the young plants. Wheat sown early, especially that which was drilled and fertilized, stood the winter fairly well, but late sown was badly uprooted by the freezes. Winter oats and fall grasses were badly killed. Little or no farm work was done during the month.—*H. C. Bate.*

Texas.—Unusually cold and wet weather prevailed during the first two decades, and a cold wave of great severity swept across the State early in the second decade. During the third decade the weather was fair and moderately warm. Farm work was greatly retarded by unfavorable weather, but conditions were more favorable by the end of the month. Winter grains were injured by severe weather, but favorable weather later caused improvement. Soil was well supplied with moisture, but spring seeding was delayed. Severe weather caused some damage to garden truck and some loss of cattle.—*M. E. Blystone.*

Utah.—Abnormally high temperatures prevailed, except during the middle of the month when a very severe cold wave occurred. Rain and snow fell during the first decade, the amounts being moderate over the northern portion and heavy to excessive over the middle and southern sections. Winter grain was generally in good condition, though in some few localities somewhat damaged. The range was fine and stock thriving. Some fruit reported winter killed. Considerable plowing and sowing was done.—*R. J. Hyatt.*

Virginia.—The periods of cold weather occurring throughout the month were more than ordinarily prolonged, and, while lower absolute temperatures have been recorded in February of other years, notably 1895 to 1899, there was but one with the temperature as low. Fortunately, precipitation came mostly as snow, which remained on the ground and furnished excellent and continuous protection to all fall sown crops.—*Edward A. Evans.*

Washington.—Month not generally favorable to crops. Severe freezing 10th to 17th badly injured winter wheat in localities where ground was bare, and injured peach and apricot buds in localities of southeast counties. Warm weather after 20th took snow and frost from ground, except in northern counties, causing winter wheat to grow vigorously. Where wheat came up in the fall and was not injured by frost the stand was good, although the wheat was short. Some fall sown did not germinate, and resowing was necessary.—*G. N. Salisbury.*

West Virginia.—Cold weather prevailed during the greater part of the month, and the ground was frozen very deep. The snowfall was generally sufficient to afford protection to wheat and rye, but the prospects for these crops were very poor. Stock looked well and the feed on hand was thought to be sufficient. No plowing or other farm work was done.—*E. C. Vose.*

Wisconsin.—Decidedly cold weather prevailed throughout the State during the first half of the month, but as there was an ample covering of snow winter grains and grasses were thoroughly protected and suffered no injury. The temperature conditions were much more moderate during the latter part of the month. The snowfall for the State averaged 11.9 inches, which is about normal.—*W. M. Wilson.*

Wyoming.—The first half of the month was unusually cold, culminating on the 12th in one of the most severe cold waves ever experienced in the State. The latter half of the month was very mild and pleasant. Notwithstanding the severe cold weather, stock losses were very light, and were confined to the southeastern counties of the State, where the snowfall was the heaviest and where for a few days stock found it difficult to secure sufficient feed.—*W. S. Palmer.*

SPECIAL ARTICLES.

A RELATION BETWEEN AUTUMNAL RAINFALL AND THE YIELD OF WHEAT OF THE FOLLOWING YEAR—PRELIMINARY NOTE.

By W. N. SHAW, Sc.D., F.R.S., Secretary of the Meteorological Council.

[Read before the Royal Society, February 2, 1905.]

By autumn, in this note, is to be understood the period from the thirty-sixth to the forty-eighth week, both inclusive, of the year, as represented in the Weekly Weather Report of the Meteorological Office; it covers the months of September, October, and November, approximately. The rainfall to be referred to is the average amount in inches, for the "principal wheat producing districts," for the period mentioned, in successive years. The amounts are taken from the summaries of the Weekly Weather Report.

The yield of wheat is that given for successive years in the annual summaries of the Board of Agriculture and Fisheries as the average yield in bushels per acre for England since 1884, or more strictly since 1885, as that is the first year for which the figures for England are given separately. In 1884 the figure for Great Britain, which generally differs but little from that for England, is used.

These are the only figures in the official publications which are immediately available for the purposes of comparison. The totals of rainfall for the thirteen weeks have been compiled from the weekly amounts; otherwise the figures are taken as they stand in published returns. The areas referred to are not exactly coterminous, but they are more nearly so than if the rainfall values had been taken for the whole of England, or the wheat yield for Great Britain.

When the autumn rainfall and the yields of wheat for successive years from 1884 to 1904, as thus defined, are plotted, the rainfall curve being inverted, i. e., rainfall being measured downward on the paper while yield is measured upward, there is a very striking similarity between the curves, so much so as to suggest that if the scales were suitably chosen the two curves would superpose and show general consonance, with exceptions, more or less striking, in a few of the years. In other words, the yield of wheat in any year seems to depend mainly on the absence of rainfall in the previous autumn, and but little on any other factor.

The obvious algebraical expression for such a condition as the curves represent is a linear equation, and the equation

which represents the relation between yield of wheat for England and the previous autumn rainfall is:

Yield = 39.5 bushels per acre — 5/4 (previous autumn rainfall in inches).

If we call the yield obtained from the rainfall by this equation the "computed yield," a comparison with the actual yield for the twenty-one years shows that the computed yield agrees with the actual yield within half a bushel in seven years out of the twenty-one. In fourteen years the agreement is within two bushels; in the remaining seven years the difference between computed and actual yield exceeds two bushels. The extreme variation of yield in the twenty-one years is nine bushels, from 26 bushels per acre in 1892 and two other years, to 35 bushels per acre in 1898.

Of the seven years for which the formula gives yields differing from the actual by upward of two bushels, 1896 is the most conspicuous; its actual yield exceeds the computed yield by 4.5 bushels.

These seven years all show anomalous seasons. Taken *seriatim*, they are 1887, 1888, 1893, 1895, 1896, 1899, and 1903.

In 1888 and 1903 the crops were washed away by ten inches of rain in the summer; 1893 is the year of phenomenal drought and the crop was below the computed figure by 2.5 bushels. The years 1892 and 1899 are interesting, because, though the amounts of rain were up to the average, the former had eight dry weeks and the latter ten dry weeks out of the thirteen included in the conventional autumn. They were thus dry autumns, the average amount of rainfall being made up by a few exceptionally wet weeks. The yields correspond with dry autumn values. They are above the average and above the computed figures by some two or three bushels per acre.

There remain 1895 and 1896; 1895 was the year of remarkably cold weather, and in that year the yield fell short, but in the following year the deficiency was made up by a yield as much above the computed value as the previous one fell short. It would appear that in this instance the productive power not utilized in the year of the great cold was not lost but stored. On the other hand, it must be remarked that 1896 had the advantage of a specially dry winter.

It appears from these considerations that the dryness of autumn is the dominant element in the determination of the yield of wheat of the following year. The averages of yield and of rainfall are taken over very large areas, and it may be taken for granted that the investigation of the question for more restricted areas would introduce some modification in the numerical coefficients, if not in the form of the relation.

The data for making such an investigation are not yet in an available form. A comparison has been made between autumnal rainfall for "England, East" and the average yield for the counties of Cambridge, Essex, Norfolk, and Suffolk, which shows a similar relation but a magnified effect of autumnal rainfall upon the crop, and also two exceptional years which have not yet been investigated.

CONTRIBUTIONS TO MARINE METEOROLOGY.

Two important contributions to the meteorology of the sea have recently appeared:

1. *Observations océanographiques et météorologiques dans la région du courant de Guinée. (1855-1900.) I. Text et tableaux. II. Planches.* Utrecht. 1904.

This work, which is published by the Royal Meteorological Institute of the Netherlands, is a thorough discussion of the winds, currents, air pressure, air temperature, number of rainy days, surface temperature, and density of sea water for the region indicated in the title. All the above-named features are fully charted. The region covered by this work lies between the parallel of 25° north and the equator, and the meridians of 0° and 40° west.

2. *Wind charts for the South Atlantic Ocean.* Published by the Hydrographic Department of the British Admiralty, January, 1904.

These charts embrace the region lying between the equator and 65° south latitude, and between the meridians of 20° east and 90° west. Except for small areas in the extreme south of this region, for which observations are lacking or insufficient, wind-roses are given for each 5-degree square; and many useful notes are added regarding local peculiarities of wind and weather. The charts include isobars and isothems. The introduction contains a very interesting and practical discussion of the meteorology of the whole region, together with charts showing the distribution and frequency of fog. This work embodies the results of nearly a million observations. Some portions of these results, dealing with the regions adjacent to the South American coast, were published in 1902.—*C. F. T.*

HIGH WATER IN THE GREAT LAKES.

By Prof. ALFRED JUDSON HENRY.

Very great interest has recently centered in the fluctuation in level of the Great Lakes during the last ten years, the revival in interest being directly due to the unusually high water of 1904. A decided rise in level above what may be called normal stages means greatly increased earning capacity, especially for the larger vessels afloat on these inland seas. In a recent issue of the Chicago Chronicle comparisons were made between low water of 1895 and high water of 1904. The extreme range, about three feet, was shown to have occurred on Lake Ontario, and the least range, about one-tenth of a foot, on Lake Superior. The rise on Lakes Michigan and Huron from 1895 to 1904 was shown to have been a little over a foot and a half and on Lake Erie nearly two feet. It should be remembered in this connection that the low water of 1895 was the culmination of one of the greatest droughts this country has ever experienced. In that year severe and prolonged drought centered in the Lake region and the Middle Atlantic States, and the lowest water of a quarter of a century was reached in many of the rivers and small streams. This period of drought was followed by years of plentiful precipitation, and the Great Lakes, as well as the rivers, returned to normal conditions.

Two distinct series of oscillations are recognized on the Great Lakes. The first consists of the annual rise of the waters to a maximum stage in summer, followed by a decline to a minimum stage in winter or spring. The second series is superposed upon the first, and generally extends through a period of several years. It is illustrated on the diagram, fig. 1, by the upward tendency shown on the curve for Lakes Michigan and Huron from 1896 to 1899; also on the curve for Lake Erie, wherein, it will be noticed, the crest or flood stage for each year from 1895 to 1898 is somewhat higher than for the year immediately preceding.

The annual rise in the Great Lakes begins with the breaking up of ice in the tributary rivers and small streams, and the maximum or flood stage is generally reached in midsummer. Owing to marked climatic differences between the northern and southern portions of the Lake region, the spring rise begins about a month and a half earlier on Lake Erie, the most southern lake, than it does on Lake Superior, the most northern. The time of high water on the last-named lake is also from one to three months later than on Lake Erie. The period of replenishment on all of the lakes, except Superior, is from March to June; on Superior from April to September. As soon as high water is reached the lakes begin to fall, slowly at first, but quite rapidly as the winter season approaches.

The annual rise and the nonperiodic variations are doubtless due to atmospheric influences, the most important of which are precipitation, temperature, and evaporation. Changes in lake level may be also due to other causes, such as an increase