SNOWFALL IN THE MOUNTAINS.

The month was one of light snowfall in the mountains of California. In certain portions of the Sierra Nevada the precipitation was slightly above the normal; but in the range as a whole, and likewise in the Sierra Madre and the Coast Range, both rain and snow were deficient. The season as a whole has been one of light snowfall. The depth and area of the snow cover were less than at the corresponding date last year and also 1911.

The snow that now remains at the high elevations will melt rapidly, and there is every likelihood that the season will be an early one and most of the passes open and available for travel by the beginning of June. The waterfalls and mountain streams will show a marked decrease in volume before the middle of June.

SPECIAL COMPARATIVE REPORTS.

Summit.—The following table shows depth of snow on ground at Summit, Placer County, on several dates in April for a number of years:

	Apr. 1.	Apr. 15.	Apr. 30.
	Inches.	*Inches.*	*Inches.*
1907	240	165	117
1908	50	31	23
1909	188	158	129
1910	65	32	12
1911	135	145	96
1912	50	30	32
1913	50	41	24

SUNSHINE.

The following table gives the total hours of sunshine and percentages of possible:

Stations.	Hours.	Per cent of possible.	Stations.	Hours.	Per cent of possible.
Eureka	231	58	Sacramento	317	80
Fresno	333	84	San Diego	322	83
Los Angeles	309	79	San Francisco	292	74
Mount Tamalpais	292	74	San Jose	300	76
Red Bluff	263	66	San Luis Obispo	267	68

There was more sunshine during the current April than during April last year.

NOTES ON THE RIVERS OF THE SACRAMENTO AND LOWER SAN JOAQUIN WATERSHEDS DURING APRIL, 1913.

By N. R. TAYLOR, Local Forecaster.

Sacramento watershed.—Precipitation throughout this watershed was below the normal for the month. It occurred, for the most part, as scattered showers during the first and second decades, with some snow in the higher levels.

Notwithstanding the shortage of precipitation all streams in the drainage basin of the Sacramento Valley rose as a result of melting snow, and their average stages were higher than during any month since the spring of 1911. They were, however, below the stages that are usually maintained during the month in question and, in many cases, were the lowest on record for April, except that of 1912.

The average stage at Red Bluff on the Sacramento River was 0.6 foot below the 15-year average and 1.8 feet above the lowest previous average for the month. At Colusa the Sacramento averaged 11.2 feet, which is 2.4 feet below the average of the past 7 years, and 4.2 feet above the lowest on record for the month. The Sacramento at Knights Landing averaged 4 feet below the normal of the past 15 years, and 4.3 feet above the lowest for the mouth. At Sacramento City the river was 4.4 feet below the average of the past 20 years and 4.3 feet above the previous low-water average for the month.

In the Feather-Yuba watersheds all watercourses rose slowly during the greater part of the month, and while they were from 1 foot to nearly 3 feet above the stages during the corresponding month in 1912 they were much below the usual April stages.

The American River carried more water than for any month since that of June, 1911. It was, however, about 1 foot below the usual April stage.

Lower San Joaquin watershed.—There was much less than the usual amount of precipitation in this watershed, but all streams rose slowly and steadily as a result of melting snow, except the Calaveras. They were, however, below the usual April stages, especially in the lower San Joaquin itself, which was nearly 8 feet below the 15-year normal.

NOTES ON STREAMS OF THE UPPER SAN JOAQUIN WATERSHED.

By W. E. BONNETT, Local Forecaster.

Except in the lower reaches of the upper San Joaquin itself, the stages of streams of the upper San Joaquin drainage area were slightly higher than in April, 1912, but they were everywhere much lower than the average April stages. Fairly heavy rains on the 13th and 14th had no appreciable effect on the flow at any point, and only during the closing week of the month were substantial rises recorded. The maximum stages at the several stations occurred on the 27th and 28th following the abnormally warm weather of the 24th, 25th, and 26th.

At Merced Falls the average monthly stage was 1.2 feet, and the range from 0.9 foot on the 10th to 1.7 feet on the 27th. The 7-year average stage at this point is 1.6 feet. At Friant on the San Joaquin the mean stage was 0.5 foot as compared with a 7-year average of 2.1 feet for April at that point. Daily stages ranged from 0.1 foot on the 9th to 1.3 feet on the 27th. Firebaugh had an average stage of −0.2 foot as compared with a 7-year average of 4.6 feet. At this station the daily stages ranged from −0.9 on the 3d to 3 feet on the 28th. The average stage in the Kings River at Piedra was 6.7 feet as compared with 5.8 in April, 1912, and an approximate average of 7.8 feet for a 10-year period. Here the daily stages ranged from 5.6 feet on the 8th to 8.7 feet on the 27th.

Shortage of rainfall during the spring months created an early demand for irrigation water and the available supply was seriously inadequate. At the close of the month some ditch systems had received no water at all.

FROST STUDIES—DETERMINING PROBABLE MINIMUM TEMPERATURES.

By Prof. A. G. McADIE.

Loss of heat occurs in three ways—first, by radiation; second, by convection; and third, by conduction. In frost investigations the loss by conduction is unimportant and may be neglected. In fact the soil during night hours, while losing heat in other ways, gains heat by slow conduction through the earth. Air, however, is such a poor conductor of heat that practically nothing is gained at a height of a few feet above the ground, and it is doubtful if any heat supplied to the air through the process of conduction is appreciable at the level of the tops of lemon and orange trees.

Radiation is the chief agency in lowering the temperature during frosty nights. In more than 90 per cent of the injurious frosts which have occurred in California the lowest temperatures have occurred in the early morning hours and have been due essentially to intense radiation. The great frost of January 4–7, 1913, is, however, an exception, for the chilling was due more to loss of heat by convection and excessive evaporation than to radiation. The conditions prevailing at this time were described in the Monthly Weather Review for January, 1913.

In radiation two factors of importance are, the nature of the radiating surface, whether a slow or a rapid absorber and therefore a slow or rapid radiator, and the character of the absorbing medium, in this case, the atmosphere. The quantity of acquired or stored up heat energy is also important, inasmuch as there is an increase of radiation with increase of temperature. Incidentally, it may be noted that there is an increase of absorption, as shown by Prof. Humphreys, with increase of pressure. Unless the air is dust free, vapor free, and quiet, the reemitted heat from the earth (wave lengths approximately 0.012 mm.) is absorbed and trapped. Free radiation is interfered with and the temperature does not fall as low as would otherwise be the case.

The question is often asked, Why is it that on still nights frost occurs, while on windy nights frost does not occur? As we shall later see, frost can occur on windy nights provided the humidity is low and the moving air has a temperature below freezing. In general, however, a still condition favors loss of heat for these reasons: First, there is no transfer of heat from the higher levels which on still nights as a rule are warmer than the surface air, or in other words, there is no gain of heat due to mixing; second, there is no gain of heat by compression due to motion; and third, since the intensity of radiation varies as the square of the refractive index of the layer of air, a higher value occurs when air is arranged according to its density than when several layers of air of different density overlie each other. Furthermore, still nights usually occur under conditions of high barometric pressure, generally following the passage of an area of low pressure, and this increases somewhat the refractive indices for all radiations. Finally, the absence of dust and vapor particles due to settling is of great importance by increasing the diathermancy.

Windy nights, on the contrary, are not likely to be frosty because the conditions are unfavorable for free radiation. The mixing of the air strata results in gain of heat by convection and also prevents a settling of the air according to density. As air cools its weight per unit volume increases, and if not kept in motion the coldest or heaviest air will sink to the bottom. Water vapor, however, grows lighter per unit volume as the temperature falls. Thus in a given mixture the vapor tends to rise and the air to sink as the temperature falls. Likewise, the pressures of the air and water vapor vary, the air pressure increasing per unit volume as the temperature falls and the vapor pressure decreasing. The vapor pressure, however, is only a small fraction of the air pressure.

Windy nights can be favorable for frost, or rather injury to vegetation by what is commonly called frost can occur when there is such forced evaporation that the temperature is materially lowered. Moreover, the temperature of the air may be so low that no mixing is of avail, and still further the mixing may have been accompanied by expansion and cooling. Such conditions happened apparently on January 4 to 7, 1913, throughout California, and especially in the San Gabriel Valley. The air stream had by previous expansion been robbed of most of its water vapor in passing from Nevada southward up and over the Sierra Madre. The descending air falling a distance of 2,000 meters or more was somewhat warmed by compression, it is true, but was much drier than at a corresponding level on the other side of the range.

The blanket of vapor which usually forms a few feet above the soil after sunset did not form as early as usual, if indeed it formed at all, and the air motion was so vigorous that the water vapor could not have remained at any uniform height nor preserved a stratification. From the viewpoint of the orchardist this was doubly unfortunate, first, because the blanket of vapor would have served to retain heat and interfere with radiation; and second, because the presence of the vapor undoubtedly acts as a control on transpiration. During the period under discussion the extreme dryness of the air must have robbed the leaf surface of its moisture at such a rate that no proper balance could be maintained between supply and demand, or in other words, between the internal work due to sap pressure and the external work of transpiration. Therefore serious injury to the plant structure resulted. The frost as a whole presented many unusual features, and the damage done varied considerably within short distances. This of course is not unusual with frost, as the problem is essentially one of air drainage, but it seems likely that the extreme dryness of the air was the cause of greater injury than the change in temperature.

It may not be out of place to note here that frost in the common acceptation of the word—that is, the presence of congealed water, does not necessarily indicate the place of lowest temperature. Paradoxical as it may seem, the frost crystals are in reality an agency for conserving heat owing to the high specific heat of water. The latent heat of fusion of ice, using ordinary water, is 73,000 calories per kilogram. Theoretically, it requires 80 calories to melt 1 gram of ice; but because a cubic centimeter of ice at 0° C. weighs only 92 per cent of a gram, the true heat required reduces to 73 calories. Water is at its maximum density at 4° C. and the change of form under laboratory conditions occurs at 0° C.; but just what the freezing temperature is for water on the plant surface, or in the intercellular spaces, or in combination with other fluids, is unknown.

Fruit surfaces, leaf surfaces, mold, and old boards will show a covering of frost when other bodies similarly exposed show no such deposit. As stated above, this does not mean always that the temperature was lower here than elsewhere, for the congelation may be connected with the hygroscopic character of the surface and a supply of water furnished by capillarity and under such physical conditions that the change of form readily occurs. Other things being equal plant surface is a good radiator, but just how the water exuded from the stomata and under pressure of surface tension freezes remains to be determined.

Two interesting records of the percentage of saturation during this frost period are available and bear directly upon the question of minimum temperature. The first record was made at Ryan, or, more definitely, Greenland Ranch, in Death Valley, about 10 miles southwest of the station known as Death Valley Junction on the Tonopah

& Tidewater Railroad. This is in Inyo County, Cal., and the air moving 600 miles southwest would pass over the Mojave Desert, then up and over the Sierra Madre, descending into the Great Valley of southern California. We thus have a record of the percentage of saturation of a great air stream at two points 600 miles distant, with an intervening range, the average elevation of which is 6,000 feet. Beginning Saturday, January 4, and lasting until January 8, there was a distinct decrease in the relative humidity and the percentage was much lower at the southern station. Low temperatures prevailed throughout this period, culminating January 6.

It would therefore seem that in future studies concerning the best methods of frost protection, special attention must be given to the moisture content of the air. This factor seems to play a controlling part in determining minimum temperatures. Not only this, but it is of great importance in connection with the maintenance of proper plant functions, especially in connection with transpiration.

THE RAINFALL OF BERKELEY, CAL.[1]

By WILLIAM GARDNER REED.

A rainfall record has been kept by the University of California as a cooperative station of the United States Weather Bureau since 1886, so that this record now covers a period of over 25 years. The university is located at Berkeley, which is 12 miles (19 kilometers) east-northeast from the Golden Gate and the Pacific Ocean, on the shoreward edge of a narrow coastal plain, which slopes gently from an altitude of 300 feet (90 meters) at the university campus to San Francisco Bay about 2 miles (3 kilometers) distant. East of the university the Berkeley Hills rise to an altitude of nearly 2,000 feet (600 meters) in 2 miles. The record, as shown in the table, is consistent with itself, and is of value as showing tendencies, if nothing more, although the exposure has been changed twice during the period and has at no time been ideal. Except for the years between 1892 and 1899 the exposure has been on a roof more or less protected by trees, but too far away to directly shelter the gage.

The table shows the monthly precipitation for the 25 years. This rainfall was recorded by the University and the results sent each month to the Weather Bureau Office in San Francisco, where they have been checked and corrected when necessary. It has been deemed advisable to use a rainfall year from July 1 to June 30 rather than the calendar year, as the rains at Berkeley are of the type known as subtropical, dry summers and winter rains under cyclonic control, so that the autumn rains should be grouped with those of the winter and spring of the following and not of the same calendar year. The mean monthly rainfall is shown graphically in figure 1.

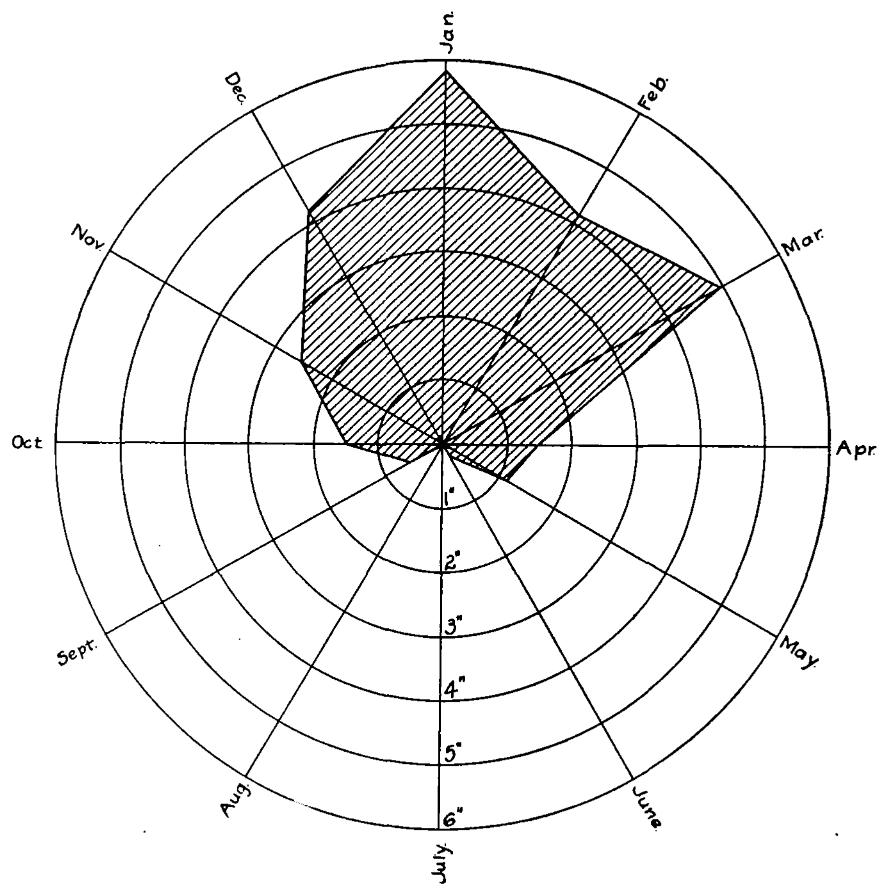

FIG. 1.—Mean monthly rainfall in inches at Berkeley, Cal.

July and August are months of little rain. Much of the precipitation in these months is from fog and occurs in amounts barely sufficient to be measured. The rainy season is generally preceded by light rains in September and October. But three Septembers and three Octobers have been rainless. September has an average rainfall of about half an inch (13 millimeters) and October about three times that amount. November may be said to mark the beginning of the season of heavy rainfall; the

[1] Published in full in the University of California Publications in Geography, vol. 1, No. 2, Berkeley, 1913.