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SOME FURTHER USES OF THE CLIMOGRAPH.

By B. M. VARNEY.

[University of California, Aug. 2, 1920.]

SYNOPSIS.

The climograph as developed by Dr. Griffith Taylor, but in a modified form in which data for air temperature and relative humidity are used in place of those for wet-bulb temperature and relative humidity, is believed to be useful in many ways beyond the simple showing of monthly averages of climatic conditions as heretofore. In demonstration of this, four climographs (in addition to one using monthly averages) are given, three of them in a comparison of certain details regarding the climates of San Francisco and Fresno, Calif., the fourth to illustrate the climographic representation of a hot wave. Suggestions are made as to the usefulness of the climograph in depicting nonperiodic weather changes in general. The emphasis is on its value as a supplement to the conventional curve, as a help to the visualizing as far as possible of the *effects* of climate and weather on organic life.

The climograph, as a device for setting forth and interpreting climatic data, is not new. Dr. Griffith Taylor of the Australian Bureau of Meteorology showed some of its great possibilities in his paper on the Control of Settlement by Humidity and Temperature.[1] Since the publication of Taylor's paper other investigators have called attention to the climograph. It is the belief of the present writer that this device, used either in connection with the better established graphic methods, or by itself, is so powerful a means of putting vitality into the somewhat lifeless mass of climatic data (the interpretation of which is the climatologist's major business) that it merits further discussion.

One scarcely need point out the great usefulness, to the geographer, the business man, the physician, the teacher, of any device which helps to create living conceptions of the nature of climate and weather, so leading to a better estimate of the effect of a given atmospheric environment on human affairs. One suggestion will suffice. A physician, asked for his opinion on the desirability of a certain place from the point of view of its climate, may get sheaves of data from the Weather Bureau. From these, he can, if he has time and inclination, plot curves and arrive at a conclusion as to the probable physiological effects of the climate in question. But the probability is that, for all his pains, his conception of that climate will fall short of being an adequate basis of advice to his patient. Nobody is to blame for this (unless it be the climatologist). It is a case of a certain incompetency of the interpreting devices. This statement is not for a moment intended to belittle the fundamental value of curves plotted from data. But, however striking these may be, it is to be questioned if they enable us to interpret climate in terms of its effect on human affairs as well as some other device. No graphic device ever can fully do that. The climograph, however, is adaptable to expressing very many of the facts of climate and weather. Its use hitherto has been limited to the expression of monthly values. The object of this note is to point out its quite extraordinary usefulness in other ways.

Dr. Taylor in his climographs used the wet-bulb temperature and the relative humidity. This combination seems to the writer and others to suggest perhaps too much emphasis on the moisture element and too little on that of air temperature, for the reason that both are expressions of the actual to the possible moisture content of the air. The "sensible temperature" with wet bulb at 70° F. and the dry bulb at 71° F. is a vastly different thing from that with wet bulb at 70° F. and dry bulb at 85° F. In the climographs here presented, therefore, the values of *air temperature* and *relative humidity* are used,[2] those two factors being probably of greatest importance in determining the reactions of animal and plant life to atmospheric environment. This modification of Taylor's method of constructing the climograph, while it is believed to be an improvement, certainly does not minimize the essential value of the device as developed by him.

I have selected for illustration certain items in connection with two strikingly divergent types of California climate, those of San Francisco and of Fresno. San Francisco is almost entirely under a climatic régime typical of a cool windward coast in the subtropical belt. Fresno, in the middle of the broad and flat San Joaquin Valley, separated from the cooling influences of the ocean, has a climate which is in many respects of an extreme continental type, in the same belt. Without the aid of graphic devices, the resulting conditions can be somewhat vaguely pictured. For San Francisco, one thinks at once of moderate temperatures and moderate temperature ranges, high relative humidity, considerable sameness through the year. For Fresno, wide differences of temperature and relative humidity, ranging from very hot and dry to rather cold and damp—a climate of distinct variability. But what are the actual details, and how are they likely to affect health, or business? Such further questions as these must be answered: What is an average day like in July, or January, or some other month? Would a person in delicate health find the early forenoons too cold and damp to be out in? How do the conditions during the heat of the day vary through the year? Are the evenings cool and comfortable? Not long since the writer was asked for certain climatic data by a firm engaged in the producing and marketing of cider. The location of new distributing points was to be decided upon partly on the basis of the thirst-provoking qualities of the climate in various parts of California. Climographic evidence was brought in and proved immensely instructive to the inquirer.

Figure 1 is given by way of expressing the broad facts about the two climates suggested above. The climograph shares with the conventional curve the disadvan-

[1] Commonwealth Bureau of Meteorology, Bull. No. 14, Melbourne, 1914. See also a review by Huntington in Geog. Review, Vol. IV, No. 5, November, 1917, pp. 401-403. See also MONTHLY WEATHER REVIEW, December, 1917, 45: 589-590, and July, 1919, 47: 490-495.

[2] This combination was first used by Dr. John Ball: see MONTHLY WEATHER REVIEW, July, 1919, 47: 494, and May, 1920, 48: 279.

tages that arise if one attempts to create a conception of a climate in terms of monthly averages, for these give little hint of how wide ranging may be the values entering

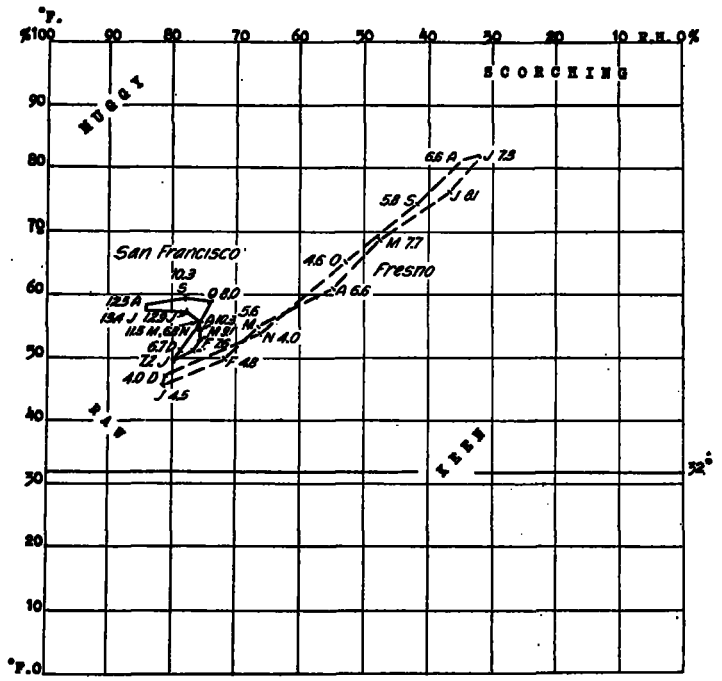

FIG. 1.—Climograph of monthly averages of air temperature and relative humidity at San Francisco and Fresno, Calif. Figures near the initial letters of the months show mean monthly wind velocity in miles and tenths.

them. The remaining figures, then, show the climograph as an interpreter of the more detailed facts.

In figure 2 is pictured the character of the average day at Fresno for two selected months. One's conception of

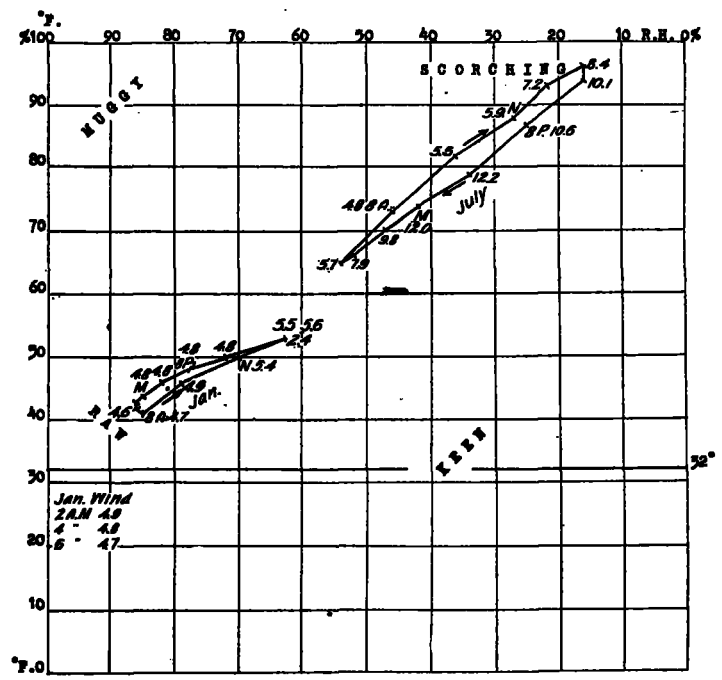

FIG. 2.—Bihourly averages of air temperature and relative humidity for January and July at Fresno, Calif. Figures near the hour marks show mean hourly wind velocity in miles and tenths.

the climate there, on inspection of the figures, could be summarized somewhat in this way:

(*a*) It is a climate of considerable extremes.

(*b*) An average midwinter day is chilly and damp in the early mornings (relative humidity around 85 to 90 per cent and temperatures 40° to 45°). The result in sensible temperatures is decided rawness. From 10 to 4, somewhat warmer and considerably drier (roughly 10° increase in temperature, with relative humidities around 60 per cent). The esult is pleasant sensible temperatures, sparkling, moderate weather during the middle of the day—decidedly agreeable. Chill and damp again become noticeable in the late afternoon, and nocturnal radiation further intensifies these conditions.

(*c*) An average midsummer day has excessively high temperatures, highest around 3 and 4, and very low relative humidity. For a short time at night only are conditions moderate. Temperature ranges are very great—twice as great as in winter. The long narrow form of the climograph shoots off into the "scorching" corner.

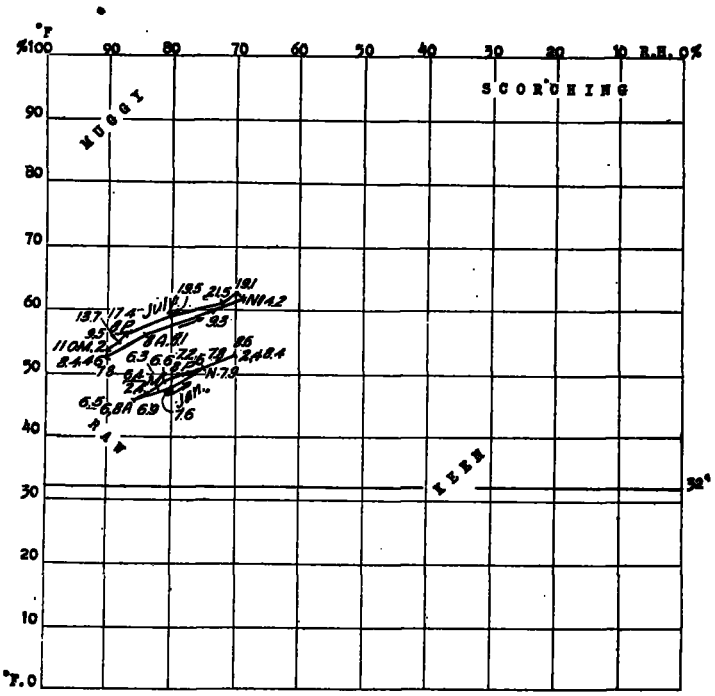

FIG. 3.—Bihourly averages of air temperature and relative humidity for January and July at San Francisco, Calif. Figures near the hour marks show mean hourly wind velocity in miles and tenths.

Its mere position and shape are as good as a page of description.

(*d*) From Fresno's coldest and dampest to its hottest and driest is a range of some 55° of temperature and 70 per cent of relative humidity.

Figure 3 compares the average day for January and July at San Francisco. The relative shapes and positions of these figures, together with those in figure 2, point the comparisons with great clearness. There is windward coast equability and continental variation in sharp contrast. There is the damp coolness of San Francisco's fog-bound summer against the Saharan heat of Fresno's, the bracing air of San Francisco's winter middays against the spring-like quality of Fresno's. Many other points are at once apparent.

Figure 4 shows the possibilities of tracing through the year the variations for any given part of the day. Again the long narrow figure indicates steady and fairly rapid progression from one extreme to the other, in one case from the raw, damp atmosphere of the winter mornings to the delightful early forenoons of midsummer; in the

other from the spring-like afternoons of winter to the desert heat of the summer afternoons.

A criticism of all climographs should be emphasized here, namely, that they can not show graphically the very important item of wind velocity as a determinant of human sensation in connection with temperature and relative humidity. The makeshift here adopted of placing alongisde of the month or hour points the average wind velocity is obviously unsatisfactory, but still a help to the fuller interpretation of the graphs.

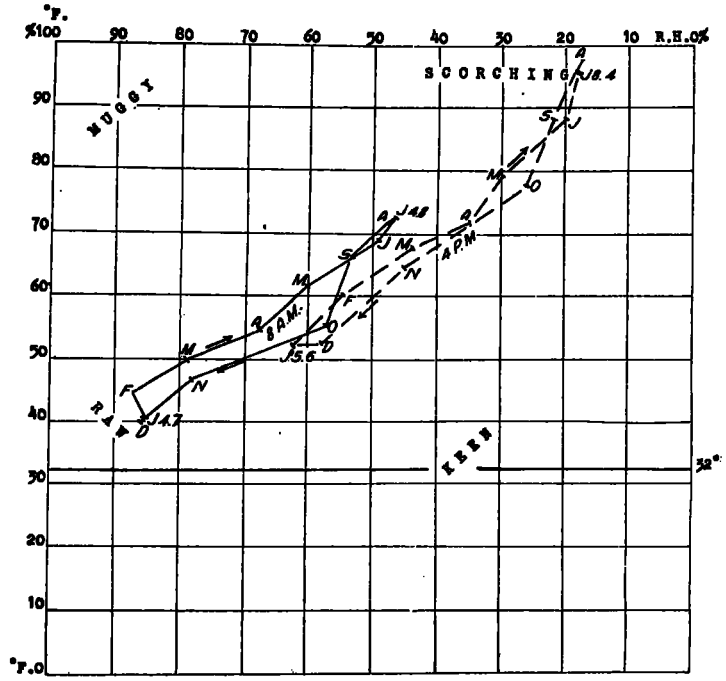

FIG. 4.—Monthly averages of air temperature and relative humidity at 8 a. m. and 4 p. m., Fresno, Calif. 8 a. m.—solid line, 4 p. m.—broken line. Mean wind velocities for January and July near initial letters of those months.

Finally, figure 5 is presented to show the versatility of the climograph in illustrating the effects of non-periodic weather changes. The example is that of an interruption of the smooth summer coolness at Berkeley, Calif., on the coast, by the passage of the center of a pronounced high pressure north of the station. Daily maxima of temperature and minima of relative humidity indicate the progress of the change from the 19th of the month through the 30th, and letters show the prevailing wind direction for the corresponding days.

From positions in the "moderate" area of the figure, the succession of points suddenly trends out into the "scorching" area, showing at a glance what would otherwise need two curves and considerable description to make clear.

The climograph can be used in visualizing the effect of other cyclonic weather changes, such, for instance, as occur at the passage of the wind-shift line. With it one's conception of the effects of thunderstorms, sea breezes, Texas northers, and many more of the important characteristics of local climate and weather can be made more vivid. With it the climatologist can illuminate somewhat more brightly the endless columns of data which too often are dark and uninteresting to the "average man." And, like the curve, the climograph can be used with moderation.

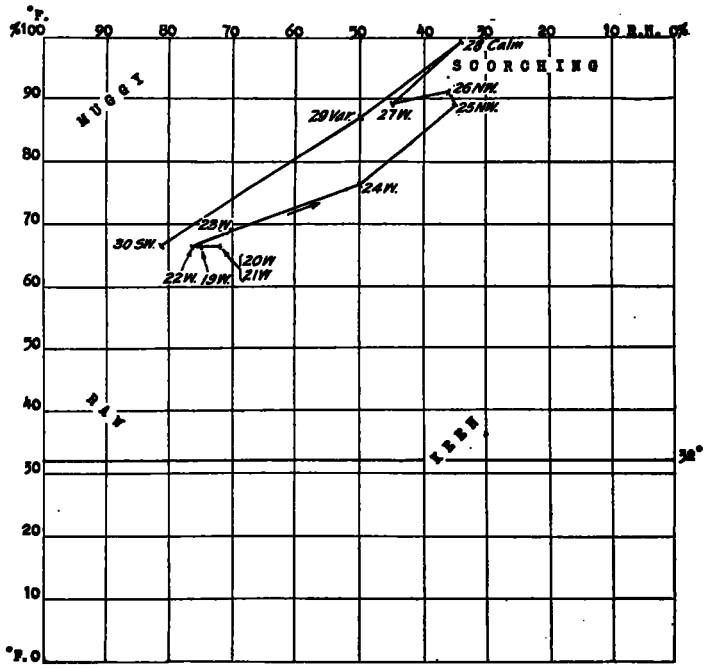

FIG. 5.—Effect of a hot wave on daily maxima of air temperature and minima of relative humidity at Berkeley, Calif., Sept. 19 to 30, inclusive, 1917. Figures=dates, letters=prevailing wind direction on the given date.

THE KATATHERMOMETER: AN INSTRUMENT TO MEASURE BODILY COMFORT.

By ROBERT A. JACOB.

[U. S. Naval Proving Ground, Dahlgren, Va., June 30, 1920.]

It has long been known that dry-bulb readings do not furnish a definite index of bodily comfort. The human body is a dynamic organism, maintaining, under normal health, a nearly constant temperature in the close neighborhood of 98.6° F. This standard condition is controlled physiologically by the heat gained in the internal combustion of food and by regulation of the amount of heat lost from the skin and respiratory membranes. Since the air temperature is generally far below 98.6° F., it is seen that the body may be thought of as a mass of hot matter constantly losing heat, which loss is perpetually being made good by physiological changes which very nearly maintain the uniform thermal standard referred to above. When the rate of loss remains greater than the rate of gain for any considerable period we say we are cold; when the rate of gain becomes and remains greater than the rate of loss we say we are hot.

In either case we are uncomfortable and a regulation of one or both is necessary to reinstate a condition of comfort. To all intents the rate of heat gain is beyond our control and so our efforts to remain comfortable have to do with a regulation of the rate of heat loss from the body. Obviously we are interested in this discussion in the measurement of the effect of the atmospheric condition on the body.

The methods we have at present for measuring the departure of our atmospheric environment from that standard which produces the greatest comfort are wholly inadequate. Measurements of dry temperature and relative humidity by means of the wet-bulb thermometer do not give a true idea of the condition. The dry thermometer is a static instrument and averages the influences of the environment, while the body, as has been said above, is a dynamic organism maintaining by its