coast. Also as they have traveled over an ocean surface, which is at a rather low temperature, their moisture contents are small, and they lose practically all their moisture when they strike the extreme southwest of Africa. The northeasterly winds which prevail during the summer months have traveled over much warmer water surfaces and, although they deposit the greater amount of their moisture along the Drakenberg Range, which runs parallel to the East Coast, have sufficient left to convey moisture well into the interior. The result of this is that the western half of the Union is, on the whole, much drier than the eastern half. The strip of land along the Natal coast has a rainfall of between 35 and 50 inches per annum, whereas the greater part of the Cape Province, excepting the southwest and south coastal regions, receives only between 5 and 15 inches a year.

Roughly speaking, the mean annual temperature over all parts of the Union is very nearly the same. The higher temperature which would naturally result from an interior situation is almost balanced by the effect due to the greater elevation of the interior. For example, whereas the mean annual temperature at Capteown is 62°, that at Bloemfontein, the altitude of which is 4,400 feet, is 61°.

The variations of temperature are, however, much greater over the interior than at coastal places. Frosts are practically unknown near the coast, but over the interior, owing to the intense radiation from the earth during the dry clear nights they are of frequent occurrence between May and September.

At Capetown, the average shade maximum temperature in January is 78.5°, and the average shade minimum in July is 47.2°, the difference being 31.3°. At an interior town, Kimberley, the average shade maximum in January is 90.5° and the average shade minimum in July is 36.5°, a difference of 54°. The diurnal range of temperature at an interior station as against a coastal station is even more marked than this.

Owing to the fact that the warm Mozambique current flows down the East Coast of South Africa whereas the cold Benguela current flows up the West Coast, the temperatures along the East Coast are higher than those along the West Coast. Durban and Port Nolloth are in very nearly the same latitude, but the mean annual temperature at Durban is 70.8°, that at Port Nolloth 57.5°. It is chiefly due to the influence of this current that the climate of the coastal strip of Natal is rather more tropical than semitropical.

AUSTRALIAN RAINFALL.[1]

HUNT, H. A., Editor. **Results of rainfall observations made in South Australia and the Northern Territory, including all available annual rainfall totals from 829 stations for all years of record up to 1917.** 421 pp.; maps, diagrs. Bur. of Meteorol., Commonwealth of Australia, Melbourne, 1918. 10s. 6d. 12 x 9½.

The activity of the Australian Commonwealth Bureau of Meteorology is remarkable. A steady stream of important publications continues to flow to the reviewer's desk. Even the war brought no interruption, only delay. The present volume is one of a series, of which three numbers (New South Wales, Victoria, and Queensland) have already been issued, leaving two more still to come (Western Australia and Tasmania). In the issue before us we have tabulations of all the available annual totals of rainfall and of wet days for 829 stations—surely a very large number considering the area concerned—up to the year 1917. For about 200 stations there are also monthly totals to 1915. Such complete information for these sections of Australia has not before been embodied under one cover. Owing to delays due to the war the annual totals for 1916 and 1917 appear in supplementary form. In order to have the work complete for reference and for comparison, authentic annual (for the individual years 1878–1917) and also average annual and monthly rainfall and monthly rainfall maps are included. There are notes on the annual variation and monthly distribution of the rainfall, and a record of notable meteorological events. The incidence of the summer and winter rainfalls and the resultant wheat yields in South Australia are given special attention, the data being presented in both tabular and map form. The monthly and annual meteorological elements and normals for Adelaide and Darwin are given in appendixes.

This mere enumeration of the contents of the volume will serve to show how very complete and extensive is the informatuon it contains. There is a remarkable abundance of excellent maps and of diagrams. While the details are of immediate concern only to those who are making special studies of Australian weather and climate, the volume is one which surely deserves mention in the Review. Those who, for one reason or another, have occasion to look up the rainfall conditions of the Australian Commonwealth will realize their lasting indebtedness to Mr. Henry A. Hunt and to his excellent staff of assistants and observers.—*R. DeC. Ward.*

[1] *Reprinted from* Geographical Review, New York, June, 1919, p. 432.

THE AUSTRALIAN ENVIRONMENT ESPECIALLY AS CONTROLLED BY RAINFALL.[1]

By Dr. GRIFFITH TAYLOR,

Commonwealth Bureau of Meteorology.

[Review—Summary[2] by Dr. S. S. Visher, Indiana University.]

This excellent treatise is the third of a series dealing with climatic control of settlement and production in Australia.[3] It is primarily a systematic study of the rainfall of Australia. The rainfall of each of the 15 regions into which the area is divided for the purpose of this study is discussed in some detail. The annual average precipitation for each section is shown in detail by isohyets, lining, and stippling on brown, relief maps (scale 1:5,000,000), compiled by Dr. Taylor.[4] Graphs of the distribution of rainfall throughout the year are given for several stations in each section. Conclusions as to the important sources of rainfall were derived from a study of the daily weather maps for the five-year period

[1] The Australian Environment (especially as controlled by rainfall). A regional study of the topography, drainage, vegetation and settlement; and of the character and origin of the rains. By Griffith Taylor, Physiographer in the Commonwealth Bureau of Meteorology, Commonwealth of Australia. Advisory Council of Science and Industry, Memoir 1, large 4to (10 by 12 in.) 25 by 31 cm., 188 pp., 15 colored contour maps, a Solar Control Model; 111 typical daily weather charts, 15 annual rainfall groups, and 42 other maps and diagrams. Selected bibliography. Government Printer, Melbourne, 1918.

[2] Cf. other reviews: *Scottish Geogr. Mag.*, July, 1919, pp. 259–261; *Nature* (London), Aug. 7, 1919, pp. 447–448; *Quart. Journ. Roy. Meterological Soc.*, July, 1919, pp. 260-261.

[3] The other two memoirs in the series are "The Control of Settlement by Temperature and Humidity," Bulletin 14 of the Meteorological Bureau, 1916, and "The Climatic Control of Australian Production," Bulletin 11 of the Meteorological Bureau (reviewed in *Geographical Review*, Nov. 1917, pp. 401–403, and Jan. 1918, p. 86). See also "The Settlement of Tropical Australia," *Monthly Weather Review*, 1917, 589–590; and "The Climatic Factors Influencing Settlement in Australia," 14 pp., in *Year Book of the Commonwealth of Australia*, No. 11, 1918.

[4] The maps here published were the basis of the first official orographical map of Australia, recently issued by the department of lands at Sydney.

NOTE.—The prompt publication of the present memoir by the bureau in which it was prepared being prevented by lack of funds, it was published by the Council of Science and Industry.

1910–1914. "The origin of the rainfall" is illustrated by approximately eight "typical charts" for rainy days for each of the 15 districts, one or two for each of the more important types of pressure conditions accompanying widespread rains.

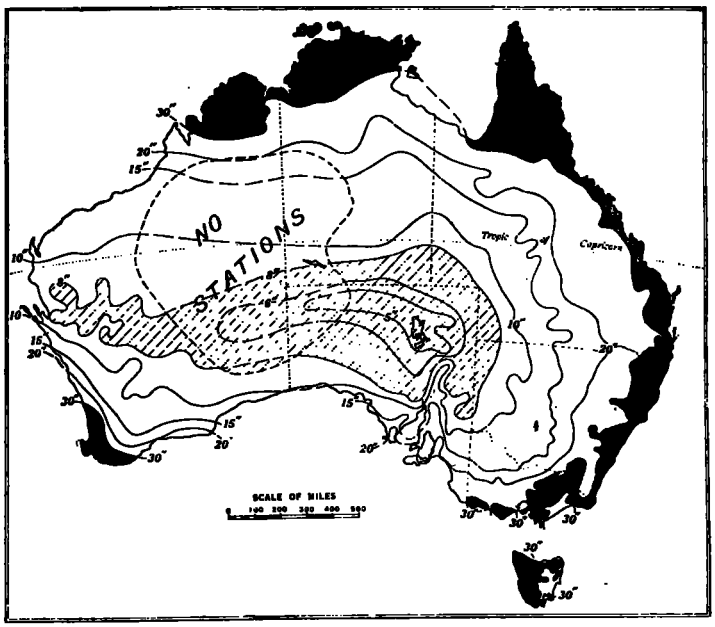


FIG. 1.—Average annual rainfall of Australia revised to 1916. Over 30 inches shown in black; the driest region (under 8 inches) is ruled. (The records in central West Australia are still too short for accuracy.)

An average-rainfall map revised to 1916 is reproduced as figure 1. More than two-thirds of Australia receives less than 15 inches and nearly one-fourth receives less than 8 inches. These drier portions are mainly in the interior. The sectional maps show that small coastal areas in northern and northeastern Australia receive more than 50 inches of rain and a few localities more than 60 inches. (See fig. 2.)

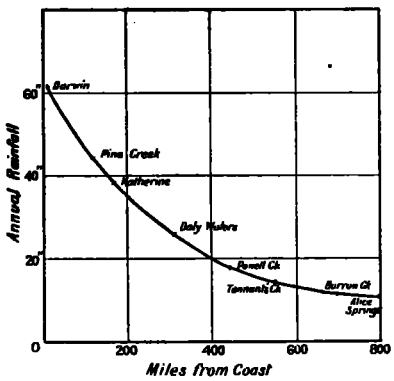


FIG. 2.—Relation of rainfall in Northern Territory to the distance from the coast.

The march of the rain belt is illustrated cleverly by "A solar control model." By sliding a cardboard up and down, the change in the amount of rainfall received each month is shown approximately by the shifting of belts of 1 to 2 inches and over. These belts are visible through an opening the shape of Australia. Other things shown on the movable cardboard are the 70°-isotherm (approximate); the trade-wind belt, belt of variables, belt of westerlies and "a line of centers of HIGHS." This last forms the indicator, it being placed opposite the required month as printed beside a slot. This line of the centers of HIGHS passes almost through Perth and Brisbane in midwinter and across the southern tip only in midsummer. For Australia there is a lag of five weeks. (Fig. 3.) There is very evident correspondence between the rainfall conditions of any month as

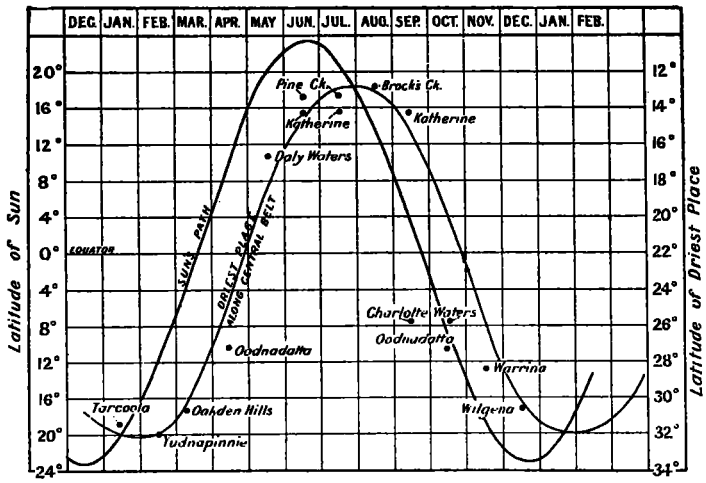


FIG. 3.—Relation of sun's march between tropics to the march of the rain belt. (Driest spot in each month being used as index.)

shown by this device and as mapped on inserts for January, April, July, and October, on the corners of the model. This model illustrates strikingly the solar control of rainfall in Australia and the interdependence of meteorological phenomena. Hence it is not surprising that Prof. Taylor

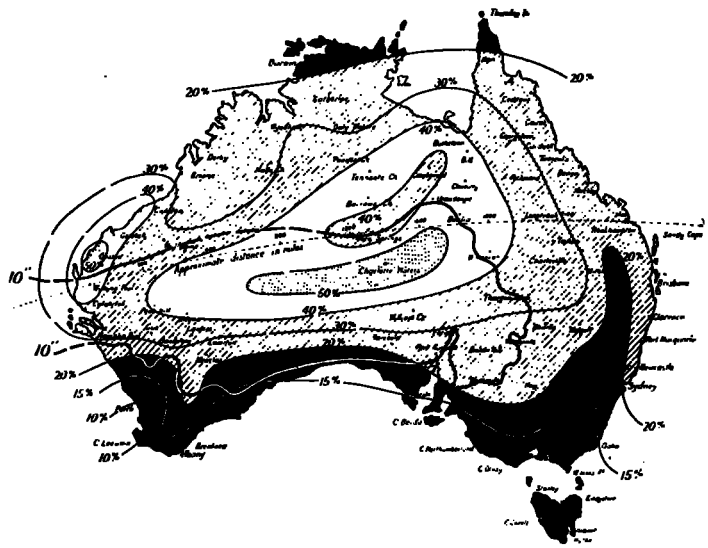


FIG. 4.—Rain reliability isopleths for Australia. The figures show the percentage variations from the normal annual rainfall (1891–1910.)

has found it helpful in his teaching at Melbourne University.

Rain reliability (fig. 4) and rain uniformity (fig. 5) are mapped for the first time for Australia. These maps differ greatly though both resemble most other maps of Australia in possessing a conspicuous contrast between coast and interior. At Onslow, near the western coast, just north of the Tropic, the annual rainfall has ranged from less than 1 inch in 1896 and 1912 to 19 inches in 1881 and

27 inches in 1900. The average rainfall there (1886 to 1916) is about 10 inches, but how little biologic significance is an average when derived from so erratic a series! The abnormal rainfalls at Onslow are related to occasional tropical hurricanes.

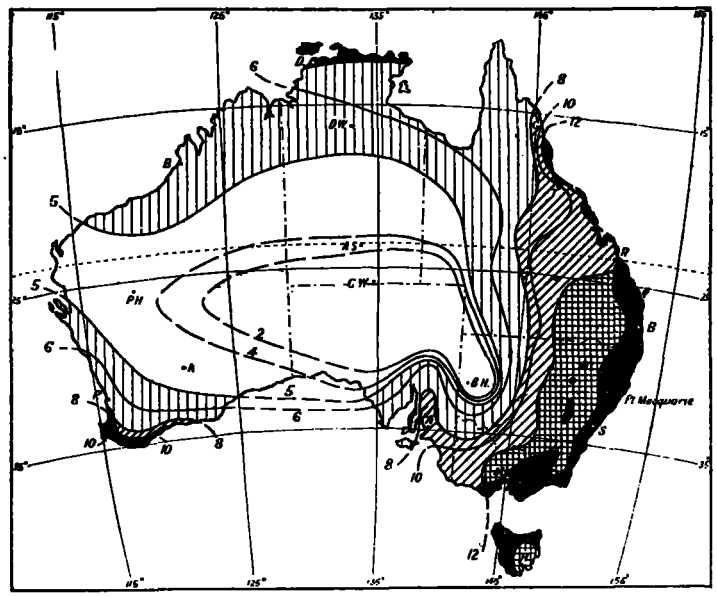


FIG. 5.—Rainfall uniformity. Isopleths show number of months receiving over 1 inch of rainfall. (Black areas receive 1 inch additional during each of seven months as well as 1 inch each month of year.)

The rainfall uniformity map (fig. 5) shows by isopleths the number of months receiving over 1 inch of rainfall.

Dr. Taylor presents a vegetation map of Australia based on that of Diels. (Fig. 6).

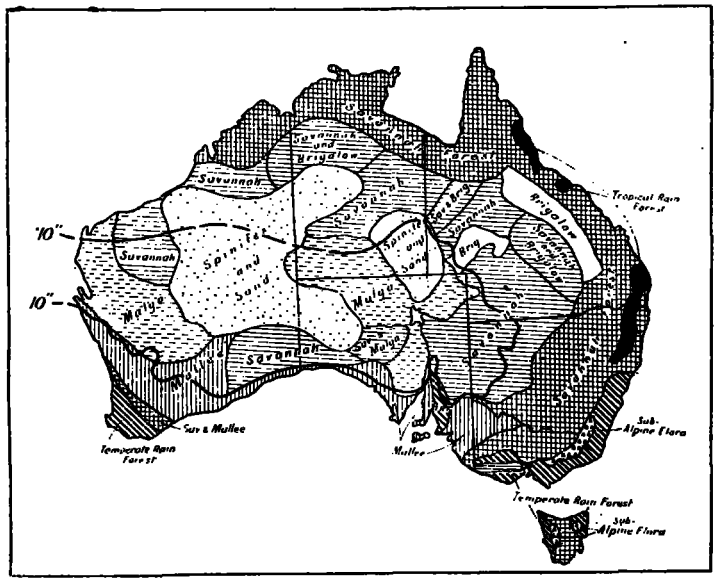


FIG. 6.—Vegetation map for Australia, based on that of Diels.

Savannah forest occurs even in regions having somewhat more than 50 inches of rainfall where during several months less than 1 inch of rain is received; for example, at the northern tip of Australia where for five months less than 1 inch per month falls and yet the annual rainfall is more than 60 inches. Comparison with the rainfall maps reveals that in tropical Australia a rainfall of approximately 25 inches is required for Savannah forest, but that in the cooler southeast such forest occurs where as little as 15 inches is received. Savannah, with acacia locally important, extends to the 10-inch isohyet at some points in the north, but quite generally reaches the 8-inch isohyet at the south and occurs near Lake Eyre with 5 inches of rain. Most of the drier portions of the continent possess scattered acacia (*Mulga*) and *Spinifex*. Temperate forest occurs in the southwest and southeast, occupying much of the eastern highland and coastal area north to latitude 32° S. Tropical-rain forest is shown only on or near the east coast in areas receiving 2 inches or more per month for each of seven months with a total rainfall of 40 inches or more. In the regional discussions, tables are given of the dominant trees or types of vegetation present in each district and the rainfall conditions which prevail in the areas occupied by each. In a suggestive "vegetative scheme after Koeppen's method" the major vegetative associations are correlated with the amount of rainfall received annually, with the temperature of the warmest and coldest month, and with latitude. Dr. Taylor maintains successfully that in Australia differences in rainfall are much more significant than differences in temperatures, so far as the vegetation is concerned.

Climographs based on wet-bulb temperatures and humidity are given for each of the 15 regions, for Berlin and London, and also a "Composite white race climograph based on 12 great cities." The particularly high temperatures and low humidities prevalent in Australian cities are made evident by the transposition of these 18 climographs on one page. (Fig. 7.) Dr. Taylor defends his use of wet-bulb instead of dry-bulb temperatures by the statement that "my 'tentative scale of discomfort'—which is the feature arousing most interest in Australian circles—is much more accurately indicated by wet-bulb than by dry-bulb. The conditions along our tropical coast seem to agree fairly with this scale. I shall be glad to hear how it applies in other hot regions."

An extension of the climograph method is made in the hythergraph, a graph made by plotting the average monthly temperature on one axis and the average monthly rainfall on the other. Hythergraphs have been prepared for seven Australian tropical stations and a graph representing the composite of these is transposed on hythergraphs of stations in other tropical regions where cotton, tea, coffee, wheat, and, rice respectively, are produced in quantities. (Fig. 8). The possibilities of the Australian tropics are thus suggested in a novel way.

Five-sixths of the volume is devoted to the study of the 15 regions into which Australia is divided. For each region the topics considered are boundaries, topography, drainage, vegetation, distribution of rainfall, topographic effect (on rainfall), season of rain, correlation with other regions, health, economics, character of rainfall, annual history of rainfall, and types of regional rain. Most of the boundaries are artificial. The major division is between the summer rain region and the winter rain region. The topography is discussed briefly but apparently skillfully. Quotations concerning regions Dr. Taylor does not know well are frequent. Correlation with other regions is done by tables of "homoclines," the data for foreign stations being taken chiefly from Hann. (See Table 1.) The distribution of rainfall throughout the year is shown clearly by annual rainfall graphs of several stations in each district. The "character of rainfall" concerns the type of pressure conditions bringing the rain, some 1,500 daily weather maps for 1910–1914 furnishing the data.

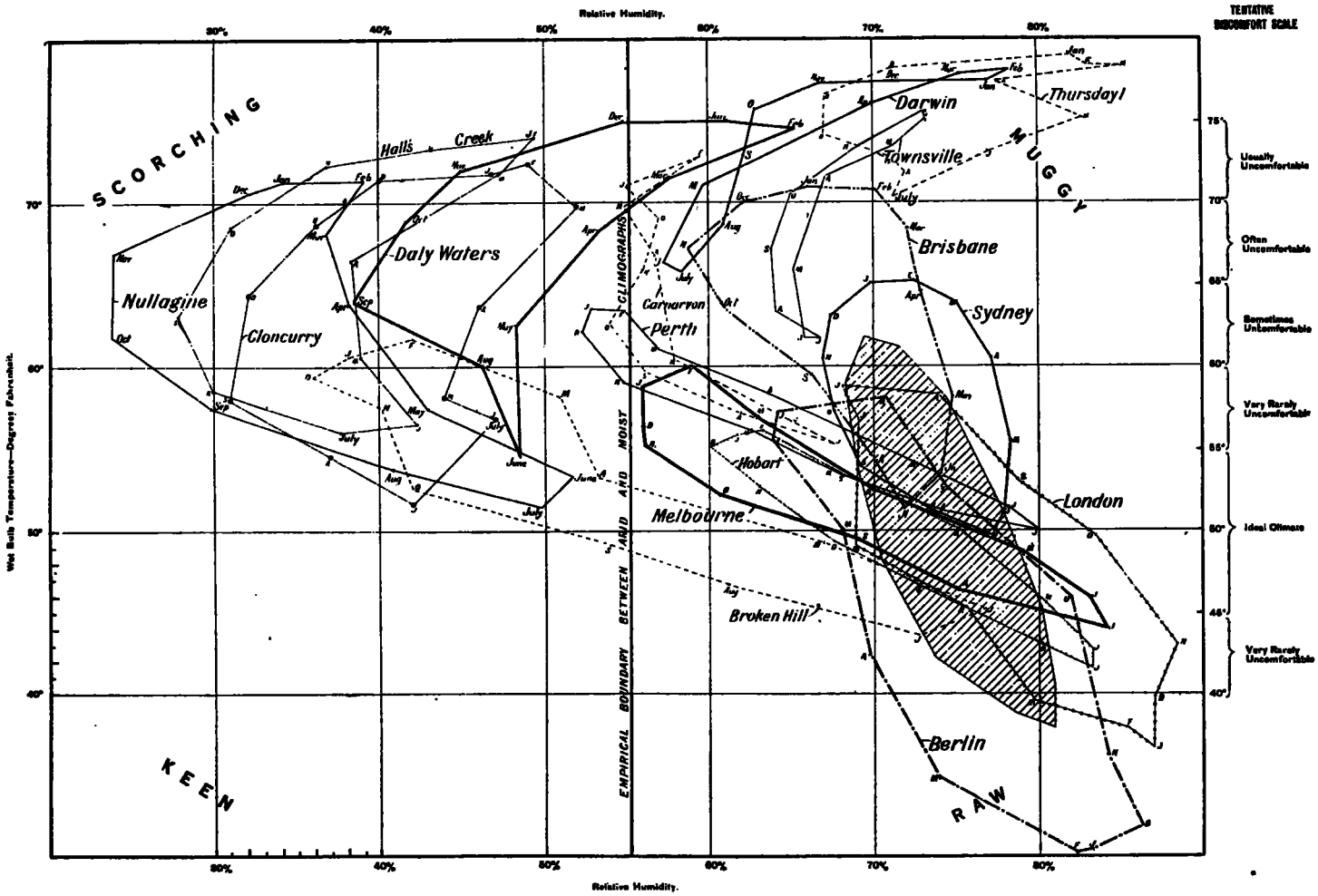


FIG. 7.—Typical climographs for Australia. (London and Berlin added for comparison.) The empirical boundary between arid and moist regions is given.
NOTE.—The shaded figure is the composite white race climograph based on 12 typical cities.

TABLE 1.—*Homoclines of East Victoria.*

	Monthly rainfall.			Monthly temperature.		
	Wettest.	Driest.	Annual.	Hottest.	Coldest.	Annual
	Inches.	*Inches.*	*Inches.*	°*F.*	°*F.*	°*F.*
Melbourne	2.64 (Oct.)	1.74 (Feb.)	25.5	67.5	48.4	58.3
Hamilton	3.34 (June)	0.95 (Feb.)	26.9	66.4	46.0	55.8
San Francisco	4.5 (Jan.)	.1 (July)	22.5	59.0	50.1	56.0
Portland, Oreg	7.4 (Dec.)	.6 (July)	45.0	67.0	39.0	53.0
Valparaiso	7.0 (July)	.0 (Feb.)	24.0	63.5	52.7	57.7
Oporto, Portugal	6.0 (Nov.)	1.0 (July)	48.0	67.3	47.5	57.4

Although an average of 70 per cent of the rainfall of each region is induced by two types of pressure conditions, four to eight types are discussed under each district. A total of nearly a score of rainfall types are considered. Weather maps illustrating the chief types are reproduced in profusion. (See figs. 9, 10.) The more important causes of widespread rain are western and eastern tropical LOWS, tropical trough, tropical tongue, tropical bulge, antarctic LOW, antarctic trough, central LOW, HIGH. Tropical LOWS bring most rainfall to northern Australia; antarctic LOWS bring most to Tasmania, to extreme southwestern, and to much of southeastern and east-central Australia. In central and east-central Australia tropical troughs are dominant as rain bringers, and they are second in importance in several districts elsewhere. Coastal cyclones, often developing into "willy-willies," are important in the northwest, as are Queensland hurricanes in the northeast.

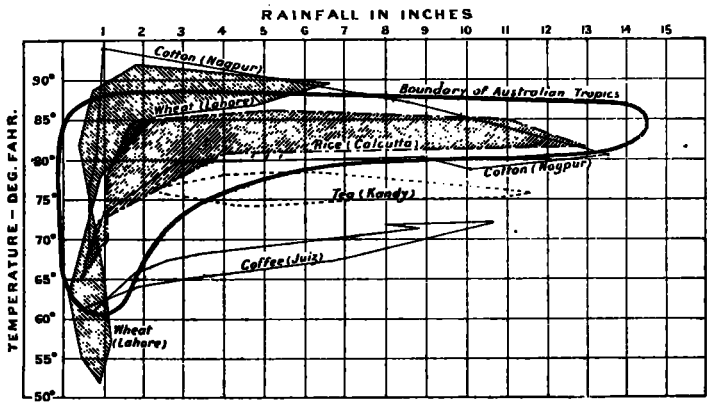
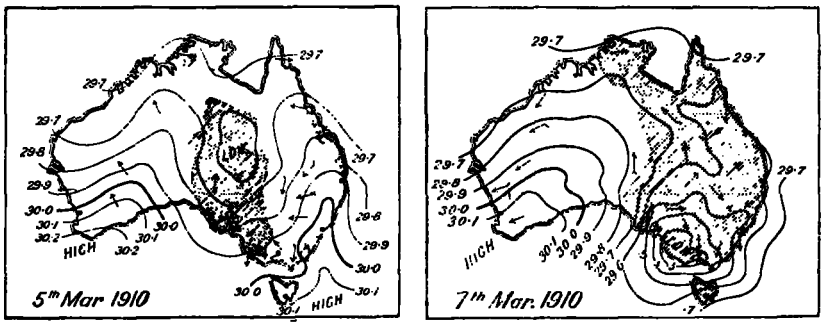


FIG. 8.—Hythergraphs for tropical areas growing wheat, rice, cotton, tea, and coffee. The heavy dark line shows the limit for most of our tropical localities.

The eastern coast also gets much rain from coastal LOWS which "surge down that coast" and from "southerly bursters which move up it." In the north "summer cyclones hover over the Territory for days" and yield

copious rain. At many points there a fall of more than 20 inches has been received within 24 hours, and several times falls in excess of 30 inches have occurred. An oval area 20 by 85 miles receives an annual average of more than 100 inches. One point (Harvey Creek) has a 19-year average of 163.7 inches.

This memoir with its 183 maps and diagrams and its 74 tables requires much more than the foregoing summary to be fully appreciated. It is an important piece of work well done. It would have been improved, however, by summaries, and index, and perhaps by the use of fuller base maps. No two of the larger maps of Australia are on the same scale, or on the same base; reference points and lines are quite inadequate on most



FIGS. 9, 10.—Australian weather maps: Tongue developing into cyclone, and cyclone forming at tip of tongue. (Rainfall indicated by shading.)

of these maps, and on the weather maps for intercomparison. Nevertheless, in each one the features shown are very clear.

CLIMOGRAPH CHARTS.[1]

By Sir NAPIER SHAW.

[Abstract.]

That the climographs, prepared by Dr. Griffith Taylor, which attempt to give graphically an idea of the climatic conditions of a locality by means of plotting relative humidity against the wet bulb temperature, are not the first attempt of this kind, is a fact that should be noted. Dr. John Ball, of the Egyptian survey department, in the Cairo Scientific Journal, vol. 1, No. 4, made use of similar diagrams, using the dry-bulb temperatures. The use of the dry-bulb temperature instead of the wet does no more than alter the position on the sheet and makes little difference in the general appearance of the diagram.

"As a matter of fact, neither form of diagram seems to be completely satisfying as distinguishing between the comfortable, the tolerable, and the unendurable in climate. Some years ago Mr. W. F. Tyler, of the Chinese customs service, pointed out that between the limits of temperature, say, 55° F. and 65° F., nobody minded much what the humidity was; but outside these limits of the 'generally comfortable' there was a range of temperatures of the 'just tolerable' order for damp air, which soon got the 'unendurable' on the side of the higher temperature. Beyond these, again, is a range of temperatures under which life is possible only in dry air. An effective climatic diagram would in some way or other exhibit the relation of the climate to the ranges compatible with comfort, life, and death."—*C. L. M.*

[1] *Nature*, London, Jan. 16, 1919, No. 2508, vol. 102, p. 383.

A NEW INTERPRETATION OF THE RELATIONSHIPS OF TEMPERATURE AND HUMIDITY TO INSECT DEVELOPMENT.[1]

By Dr. W. DWIGHT PIERCE, Bureau of Entomology.

[Abstract.]

"Upon the proper interpretation of the laws of climatic control of life rests the solution of many practical problems, and inasmuch as all plant and animal life reacts to climate in the same general manner it is apparent that

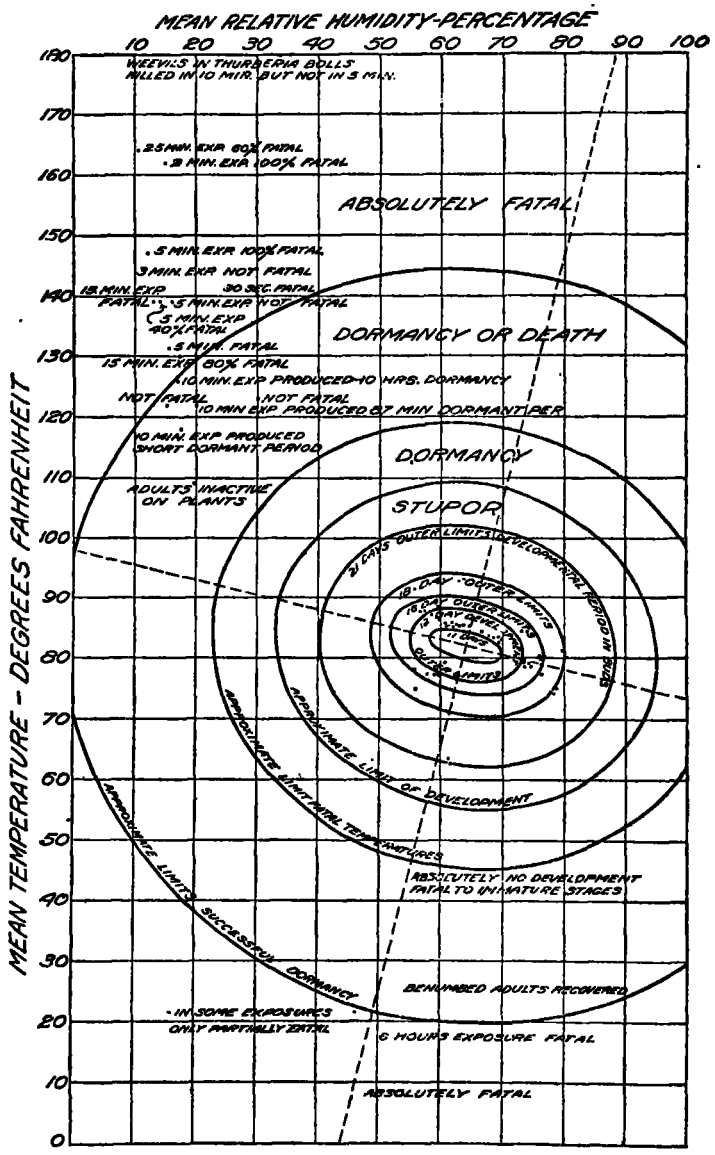


FIG. 1.—Graph showing the relations of temperature and humidity to cotton boll-weevil activity.

the study of the climatic control of insect development may throw light upon the problems of all other forms of life."

Mr. Pierce thus opens his discussion of the relationship problem, and further notes that all so-called theoretical laws of effective temperature for all life do not properly explain many of the phenomena that are observed. The former theory of a fixed zero of effective temperature, so long maintained by biologists, is only in recent years rejected upon the findings that each species might have a different zero. In addition, it is only recently that the factor of humidity has been definitely used in the solution

[1] Jour. Agr. Research, Dept. of Agr., Washington, Mar. 20, 1916, pp. 1183-1191.