two arms of a Wheatstone bridge, in a uniform temperature bath.

WILLIAM ALLINGHAM.

William Allingham, for many years principal assistant in the marine branch of the Meteorological Office, died suddenly January 24, 1919, at the age of 69. His early life was spent at sea, but, owing to a disabling accident, he obtained in the early seventies a post in the Admiralty, then in 1875 he was transferred to the staff of the Meteorological Office. In addition to a practical knowledge of navigation and meteorology, Allingham was gifted with considerable literary ability. His chief works were the compilation of a Manual of Marine Meteorology, and in conjunction with Capt. Wilson-Barker, a treatise on Navigation, Practical and Theoretical.—*From Symons's Met'l Mag., Feb. 1919, p. 4.*

CAPTAIN MELVILLE WILLIS CAMPBELL HEPWORTH.

Apr. 27, 1849–Feb. 25, 1919.

The death of Capt. M. W. C. Hepworth, following so soon after that of Mr. Allingham, is a serious loss to the Marine Division of the Meteorological Office, of which he had been Superintendent since 1899. The Monthly Meteorological Charts of the North Atlantic and Mediterranean, as well as of the East Indian seas, were initiated during his tenure of office, and the later editions of the Barometer Manual for the Use of Seamen and the Seaman's Handbook of Meteorology were compiled under his direction and attained a large circulation. Capt. Hepworth was much interested in marine biology and in the temperature and salinity of the sea. For the many years while at sea he made a study of meteorology which prepared him for his official position.—*From Nature (London) Mar. 6, 1919, p. 8 and Symons's Met'l Mag., 1919, pp. 13–14.*

RELATION BETWEEN VEGETATIVE AND FROSTLESS PERIODS.

By JOSEPH BURTON KINCER, Meteorologist.

[Dated: Division of Agricultural Meteorology, Weather Bureau, Washington, D. C., Jan. 13, 1919.]

The two most important climatic elements with reference to plant growth are temperature and precipitation. Of these, temperature is the more effective in establishing the geographic areas within which certain plants thrive best on the one hand, or even fail to mature on the other, and it also determines the period of the year during which growth is possible.

In any study of plant growth as affected by temperature, there are two important phenomena that may be considered as constituting critical or basic points from which reckonings must be made; these are the vegetative temperature and frost. The first defines the potential period of plant growth, which is determined by the date in spring when the temperature rises sufficiently high to render active the protoplasmic content of vegetable cells, and thus produces growth, and the date in fall when it falls below this point and growth ceases. The frostless period is determined by the dates of the last killing frost in spring and the first in autumn. It is the object of this paper to study briefly the relation of these two basic periods, and their variations in length in different sections of the United States.

The average growing season as determined by frost occurrence is understood to be the number of days between the average date of last killing frost in spring and the first in autumn, but some plants are more susceptible to frost damage than others and consequently the growing season as thus defined varies in length in the same locality for different plants. This is also true for the vegetative period as determined by the amount of heat necessary to produce plant growth, considered independently of the occurrence of killing frost. It has long been known, however, that for most plants in temperate climates, the vegetative or active period begins in spring, as a general rule, when the mean daily temperature rises to 6° C. (42.8° F.), and ends in autumn when it falls below that value. These limits have been adopted for the purpose of this study of the relation of the vegetative to the frostless period.

Chart I shows the average dates in spring when the mean daily temperature rises to 43° and Chart II the dates in autumn when it falls below that value. The vegetative period, represented by the average number of days when the mean daily temperature is 43° or higher, is shown for different sections of the country by Chart III. This period is not the same, of course, for each year, but varies from year to year, as does the frostless season or any other period determined by the average dates on which phenomena occur. From the Rocky Mountains westward the charts are highly generalized, owing to the great variation in the topographic features of that section of the country.

Chart I shows that the advent of the vegetative period in an average year ranges from the first of February in the northern portion of the Gulf States to May 1 in extreme upper Michigan and northern New England. Chart II indicates that this period comes to an end, on the average, in the extreme northern districts about the middle of October, but it continues till the end of the year in the South. Chart III shows that the length of the period ranges from less than 180 days in the extreme north and in the central and northern portions of the Rocky Mountain region, to 365 days in the south Atlantic and Gulf districts, and also in the central and southern Pacific coast sections. (The latest frost charts are those appearing in the frost section of the Atlas of American Agriculture, recently published.[1] See also "The Probable Growing Season," by William Gardner Reed, MONTHLY WEATHER REVIEW, Sept., 1916, 44, 509–512.)

The normal daily march of temperature is closely allied with the annual march in establishing the vegetative period. For example: If we assume that most vegetation is awakened from the dormant state when the daily mean temperature rises to 43°, it is evident that prior to the date on which this occurs, the temperature during the warmer portion of the day would be sufficiently high to produce growth and consequently, it would appear, that some growth actually begins before the mean temperature rises to the vegetative point (on the average, the temperature during approximately one-half of the day is higher than the daily mean). This, however, is true only in a limited degree, as will be evidenced by a careful consideration of the amplitude of the daily extremes of temperature. This amplitude varies with the moisture content of the air and its attending phenomena, with the latitude, and also with the sea-

[1] Advance sheets 2, pl. II, sec. 1; issued, 1918; 34 x 48 cm., 12 pp., 12 colored maps, 10 weather maps, 10 graphs. Selected bibliography. Review in M.W.R. 1918, 46:516–517.