The rainfall statistics for 23 States west of the Mississippi have been presented in slightly condensed form from that adopted by Dr. Clements and it is pointed out that for the 20 years considered a wet year is as likely as a dry one at times of spot maxima.

Rainfall statistics for Arizona and also for the United States as a single geographic unit are considered. These data may be interpreted as showing in some cases a relation such as is claimed; in other cases, however, there are large outstanding differences which have not been accounted for.

The diagrammatic method of presenting the data of Arizona and the United States for comparison with the sun-spot curve has been tried; the degree or success may be left to the reader. Generally the results reached by this method are more or less unsatisfactory. For the practical work of forecasting, this method can not be recommended.

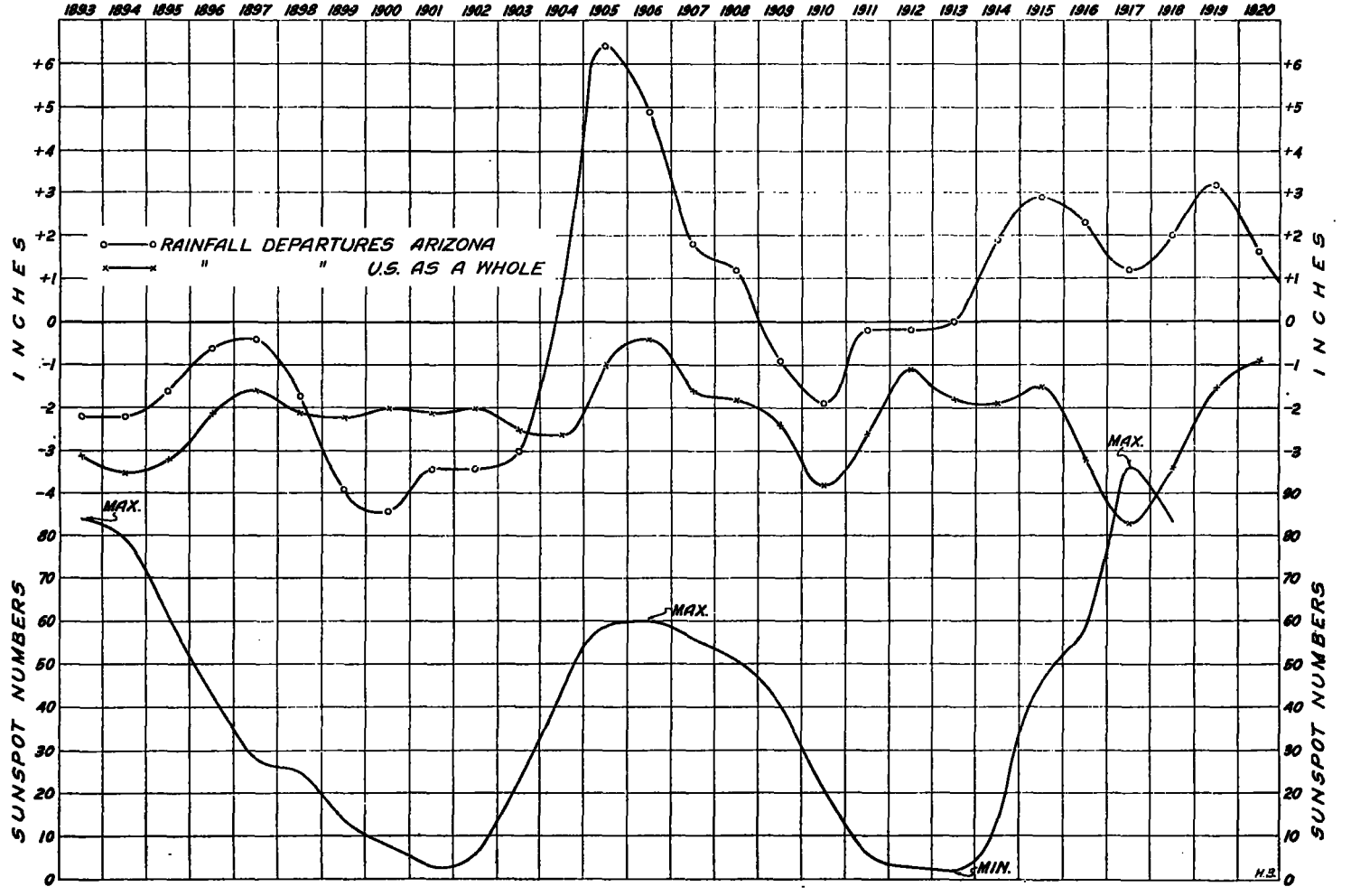

FIG. 1.—Rainfall abnormalities, Arizona and United States, and variation in sun-spot numbers, 1893-1920.

AN UNUSUAL HALO OBSERVED AT NEW HAVEN, CONN., FEBRUARY 25, 1922.

By CHARLES S. HASTINGS.

[Yale University, New Haven, Conn., Feb. 26, 1922.]

The halo was first seen by the writer at 10:10 a. m. At no time, either then or subsequently, was there a complete development. The feature which rendered it noteworthy was the effective presence of a single type of ice crystal. The common 22° circle was very faint, showing the approximate absence of fortuitously directed crystals, while the extreme faintness of the circumscribing oval, hardly more than suspected, demonstrated the almost total lack of elongated hexagonal crystals. On the other hand, the parhelion north of the sun was of a dazzling brightness, surpassing any which have previously been seen by me. The sky to the south of the sun was of a fine clearness, and therefore lacking in all indications of halo phenomena. Through the parhelion on the north was a well-defined portion of the parhelic circle, which extended through an azimuth angle of 20° to 30° beyond the parhelion to a portion of the sky free from haze. In the contrary direction it extended until lost in the light of the sun, being quite as bright where it crossed the 22° circle as at any other point.

Ten or fifteen minutes later the parhelion had become quite inconspicuous, with an added purity of the sky in its region, but of exceptionally pure spectral colors. At the same time upon a limited area of haze in the southwest appeared a well-marked portion of the parhelic circle and a paranthelion more distinct than any heretofore under my observation. The paranthelion was perfectly white, with no extension in any direction, and of a diame-

ter at least four or five times that of the sun. Both these features lasted only a few minutes, when the sky resumed an aspect of clearness.

All of these features could be produced by, and only by, thin hexagonal plates of ice with their crystalline axes steadily vertical, or, in other words, with the plates persistently horizontal. The paranthelion, the explanation of which has given so much trouble to theorists, is produced by successive total interior reflections from vertical faces inclined at 120°, according to a general theory of halos which I have developed in a paper published in the MONTHLY WEATHER REVIEW, June, 1920, 48: 322–330. As these crystals were the only effective ones in this particular display, the evidence in favor of the theory seems very conclusive.

Certain peculiarities of all the phenomena described I do not remember having seen noted before. These are, first, their very short duration, which in every case was determined by clearing of the sky, which must have been by evaporation of the crystals, not by transportation of the ice fog; second, the considerable size of the paranthelion. These argue a very small size for the individual crystals. Perhaps only such can possess great stability of direction in the atmosphere.

There is one feature of halos of which the theory is still in an unsatisfactory state, and that is the often-seen 46° circle. According to the long-accepted theory, this is produced by right-angled refracting edges with wholly random directions, just as the 22° circle is produced by 60° prisms. This theory has seemed to me questionable, a doubt founded chiefly upon my own very limited observations. Hence I have in the paper above cited offered an explanation which attributes the feature to horizontally directed crystals. If this circle is ever seen as quite uniform in brightness or of a brightness which, though not equal everywhere, shows no symmetrical distribution with respect to a vertical plane through the sun, or, finally, if the 46° circle is ever recorded as complete with its lowest point above the horizon, my criticism of the theory so long current would fall. I venture to suggest to meteorologists that these two points are quite worthy of attention.

COMPLEX SOLAR HALO OBSERVED AT ELLENDALE, N. DAK.

By C. S. LING.

[Weather Bureau, Ellendale, N. Dak., March 17, 1922.]

The circumzenithal halo is convex towards the sun and less than a semicircle in extent. The opposite Kern's arc has previously been reported as also less than a semicircle. However, this arc, if due to reflection of light parallel to that which gives the circumzenithal halo by vertical crystal faces, should be a complete circle as reported by Mr. Ling.—EDITOR.

An unusually brilliant display of solar halos was observed at Ellendale, N. Dak., on February 12, 1922. At 10:52 a. m., a bright halo of 22° formed, and simultaneously brilliant parhelia developed to the right and left of the sun. There was formed at 11:02 a. m. a complete, bright white, parhelic circle; at 11:30 a. m., a bright halo of 46°; at 11:54 a. m., simultaneously, dim Lowitz arcs to the right and left of the sun, a brilliant upper tangent arc, and a bright, complete circumzenithal arc. Rainbow colors (red, orange, green, blue) with red nearest the sun were observed with all the phenomena, except the parhelic circle, which was a bright white band about 2° width, and the Lowitz arcs, which were dim gray.

The Lowitz arcs were of short duration. At the time of measurement they were about 1° width and extended downward from the parhelia of 22° on the parhelic circle, a distance of about 8° vertical angular measurement. Their direction of extension was apparently about parallel with the curvature of the halo of 22°.

When the circumzenithal halo was measured at 11:58 a. m. it was separated from the halo of 46° by about 4° to 5°. It formed a circle of about 10° radius around the zenith, was 50° from the sun, was bright throughout (not noticeably brighter on the side next the sun), and the red, orange, yellow, and blue colors were sharply defined. At this time the angular altitude of the sun was 30°. The measurements of the radius of the circumzenithal halo and its distance from the sun were difficult to obtain and no doubt as a result are slightly inaccurate. On account of the base plate of the theodolite, the phenomena having high angular altitudes could not be sighted, and it was necessary to obtain readings by observing the theodolite's field as it was passed by the colored bands of the halo of 46° and the circumzenithal halo. With the exception of the ending of the Lowitz arcs at 12:08 p. m., no perceptible change of appearance of the miscellaneous halo phenomena was noted between 11:54 a. m. and 12:38 p. m. From 12:38 p. m. the circumzenithal halo or portions of it were visible until 3:05 p. m. At about 3 p. m. the low clouds which accompanied the phenomena began dissipating rapidly. Between 2:25 p. m. and 3:05 p. m. the circumzenithal halo formed a brilliant circle around the zenith. During this phase the circumzenithal halo was tangent to an arc of about 120° length of the halo of 46°. At the point of tangency, and near to it, these phenomena were exceptionally brilliant. Throughout the circumzenithal halo and the arc of the 46° halo the red, orange, yellow, green, and blue colors were well defined. A series of readings were made by theodolite at 3:02 p. m., by which the sun's altitude was 20° and the circumzenithal halo 46° from the sun. The arc of the halo of 46° ended at 12:38 p. m., began again at 2:25 p. m., and ended finally at 3:05 p. m. The parhelic circle became dim at 12:50 p. m. and ended at 2:10 p. m. The halo of 22° and the parhelia of 22° were brilliant throughout the period of observation and ended simultaneously at 5:04 p. m.

The halos were preceded by light snow, beginning 9:02 a. m. and ending 10:24 a. m. High barometric pressure existed over eastern Montana and low pressure over Wyoming. Thin, slightly bunched clouds of stratus appearance prevailed. As the bunched clouds passed near the sun the phenomena brightened. The base of these clouds was about 400 meters' altitude. Ice crystals are believed to have existed underneath the clouds to within about 275 meters of the ground.

These conclusions relative to altitude of the clouds are based on observations of a pilot balloon. When about 275 meters above the ground the pilot balloon was very dim, and immediately after the second minute of observation (414 meters' altitude) abruptly entered the base of the clouds. The clouds formed as result of a small temperature inversion about 300 meters above the ground. It is not thought they were the result of a diurnal temperature change. It is more likely they occurred along