HALOS AND PRECIPITATION AT WAUSEON, OHIO.

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[Dated Weather Bureau, Columbus, Ohio, Nov. 16, 1914.]

A summary of the record of halos observed and with it the percentage of halos that were followed by precipitation within 24 hours has been furnished by Mr. Thomas Mikesell, cooperative observer at Wauseon, Ohio. For this report he has used the 40-year period from 1873 to 1912, inclusive. During those 40 years a total of 2,918 halos were observed, or an average of 73 per year. Of these, 2,219 were solar and 699 were lunar halos. The greatest number observed in any one year was 109 in 1899 and the least, 40, in 1880.

The number of halos observed by months was as follows:

Month.	Solar.	Lunar.	Total.
January	171	97	268
February	215	74	289
March	294	78	372
April	293	74	367
May	276	55	331
June	204	41	245
July	130	17	147
August	110	17	127
September	96	35	131
October	139	55	194
November	145	77	222
December	146	79	225

Studying this record in connection with storms it was found that 58 per cent of the solar halos and 59 per cent of the lunar halos were followed by precipitation within 24 hours.

Studying the record in connection with barometer readings and storms the following interesting relations were found:

Condition of barometer.	Number of halos observed.	Percentage of halos followed by precipitation within 24 hours.	Percentage of halos not followed by precipitation within 24 hours.
Above normal and rising	230	37	63
At about highest point	495	42	58
High but falling	893	64	36
About normal	572	58	42
Below normal and falling	334	83	17
Near the lowest point	205	66	34
Low but rising	199	53	47

By months the records shows the following relations:

Months.	Percentage of halos followed by precipitation within 24 hours.	Percentage of halos not followed by precipitation within 24 hours.
January	61	39
February	60	40
March	58	42
April	62	38
May	57	43
June	49	51
July	56	44
August	59	41
September	55	45
October	50	50
November	63	37
December	65	35

This record shows a greater frequency of halos in winter and spring than in summer and fall, and when the barometer is falling rather than when it is rising. With a low and falling barometer the chances for precipitation following the observance of a halo are in the ratio of 5 to 1, but with a high or rising barometer the probabilities are against precipitation within the following 24 hours.

Mr. Mikesell states that by extending the time limit to 30 hours the number of halos observed that were followed by precipitation was increased about 8 or 10 per cent.

LIGHT PILLARS AT BERNE, IND.

The Weather Bureau cooperative observer at Berne, Ind., Mr. H. M. Reusser, writes under date of December 18, 1914, as follows:

DEAR SIR: I wish to report an extraordinary phenomenon of the sun and our atmosphere this morning from a little before 7 a. m. to 7:30 a. m. I also send two poor drawings [omitted] of the same as seen in stages 1 and 2.

Before the sun rose we could see a bright reddish (not prismatic) streak nearly as wide as the sun's disk, extend straight up to about 20° to 25°, fading away and resembling the effects of a powerful searchlight at night. Soon, or exactly at 7 a. m. the sun rose as a dark red ball, and as it rose above the horizon the streak was separated from the sun about 1°. As the sun rose higher it passed behind a small cloud and at that time the streak extended below the sun to about 3°. Finally, about 7:30 a. m., the sun passed behind the clouds and the wonder was past. Everybody that saw it said that this was the first of its kind ever seen by them and many asked me what the cause might be.

It is evident that Mr. Reusser describes an occurrence of solar light pillars belonging to what Bravais has called "pillars of the first class" and also to what he calls "pillars of the second class." Light pillars are not notably rarer than the other phenomena of the family of halos and parhelia or "mock suns." All these appearances owe their presence to the reflection or refraction of the light rays by very fine floating ice crystals of one form or another. The light pillar results from reflections from flat, horizontal ice surfaces slowly falling through the air and pendulating as they descend. In many cases, as in the one reported by Mr. Reusser, the light pillars appear alone, unaccompanied by other halo phenomena. This leads one to conclude that the crystal forms able to produce the curved halo phenomena are here absent.

At present one is scarcely justified in saying more than the above regarding the causes of these light pillars. The following explanation of the phenomenon, extracted from the most modern general work on meteorological optics, will serve to show the general line of reasoning of most writers on the subject; but one of the fundamental assumptions therein demands modifications pointed out by Prof. Charles Hastings on page 619 below. It remains for our students of the forms of cloud-building ice crystals to discover, photograph, and determine the frequency of occurrence of crystal forms competent to produce these light pillars. Perhaps they have already been photographed among the many forms recorded by Mr. Bentley (Monthly Weather Review, Annual Summary, 1902, **30:** 607, Pl. 1–22) and by others—[C. A. jr.]

LIGHT PILLARS.

[*Extract from* "Meteorologische Optik" by PERNTER & EXNER.]

The phenomenon of light pillars is briefly referred to in the MONTHLY WEATHER REVIEW for July, 1914, page 443 and figure 1 on page 437. They may be described and explained as follows: [1]

Light pillars may be grouped into two well-defined classes: (1) Those that rest upon the horizon; (2) those

[1] Pernter, J. M. & Exner, Felix M., Meteorologische Optik. Wien, etc. 1902-10. 4°. pp. 397-399.

that are visible accompaniments of luminaries standing above the horizon. In both classes the light pillar lies in the luminary's vertical; those of the first class are only above the luminary; those of the second class may be either above and below it, or only above it. Bravais has called the first group "light pillars of the first order" and those of the second group "light pillars of the second order." Both classes are to be explained as due to reflections from the basal planes terminating columnar ice prisms unmodified by pyramidal faces, as they float in the air.

Light pillars of the first order are essentially due to the simple reflection of the sun's rays from the lower bases of hexagonal prismatic ice needles, when the sun is below, just in, or very close to the horizon. Naturally such prisms are directed vertically when falling through the air [see, however, the criticisms by Charles S. Hastings on p. 619], but they must also be oscillating slightly in order to produce the appearance of a light pillar. If the falling prisms are not oscillating then such prisms can produce only a reflected image of the sun at rest and such an image would appear to be just as far *above* the horizon as the luminary might be below the same. As soon as the luminary reached the horizon the reflection would disappear. On the other hand, when the elongated vertically directed prisms oscillate, then the amplitude of the oscillations determines how high the sun may stand above the horizon before the resulting light pillar fails to appear. Suppose, to begin with, that the oscillation amounts to 10° and is always in the vertical of the luminary, then when the latter attained an altitude of 10° every reflection to an observer's eye would cease. If the luminary were in the horizon, however, then, since a reflection passes through twice the angle of the mirror, the oscillation would stretch out the image of the luminary to an altitude of 20°, i. e., the image would form a light pillar 20° in height.

Light pillars of greater heights have been observed, and the cause of those 30° and more in height is still a matter of discussion, even for cases where the sun is several degrees below the horizon (of course in the latter case the pillar has the red color of the low-lying sun). I consider it certain that an oscillation of as much as 20° frequently occurs, and that it is not impossible for even greater amplitudes to occur.[2] It is true one may still assume that even the triple reflection would also furnish a sufficient number of luminous rays to contribute to the formation of the upper structure of the pillar, although there must be a considerable difference in the intensity. Thus, suppose a ray reflected from a lower basal plane and on its path to the eye intercepted by an upper basal plane in a favorable position, and that it is reflected upward from this plane to a second lower basal plane also favorably located, then the reflection from this latter surface is the third reflection and can bring the ray to the observer's eye. The writer, however, would resort to the phenomenon of threefold reflections only in the extremest cases of light pillars exceeding 40° in vertical extent. The difference in intensity between simple and threefold reflections, and particularly between threefold and fivefold, etc., is too great to permit observers to overlook the strikingly different degrees of brilliancy that must result therefrom if the pendulation remains small. Specially favorable conditions may, indeed, produce a more gradual gradation in intensity; but I here maintain that one is not compelled to follow Bravais who, for the sake of consistency, must hold to the theory that the prism is practically fixedly vertical because his theory of the upper tangent arc of the halo of 46° demands this condition. We may at once assume that the pendulation amounts to 20° or 25°, and if need be may even assume that this value is exceeded, for we find it quite in the nature of things that small floating crystals may be forced quite far from the vertical as they fall through the air. The actual blinding brilliancy of these light pillars argues for a single reflection as their origin.

When the pillar is seen continued beneath the sun as the latter stands somewhat above the horizon, then the pillar is indeed to be referred to a threefold reflection. The width of these pillars is, however, greater than the solar diameter and for the reason that the pendulation of the prisms is not only in the plane of the sun's vertical but in all directions. For this reason the image of the luminary appears to suffer great longitudinal distortion, just as does the reflection of a light on a wavy water surface, and also appears somewhat wider although of course insignificantly so as compared with the lengthening. The light pillars undergo the same slight widening as a result of the prism pendulations not being restricted to the plane of the luminary's vertical.

Light pillars of the second order appear only during higher altitudes of the luminary. They are due to a twofold reflection from the basal planes of the vertical ice prisms, and appear above or below the luminary according to the relative positions of the two reflecting surfaces. Of course the pillars may appear above and below the luminary simultaneously. The light rays fall first upon an upper basal plane, whence they are reflected upward to a lower basal plane which throws them down to the observer.

[2] Bravais endeavors to show that an oscillation of only 4° is sufficient to produce these greater heights if one also calls upon the phenomenon of multiple reflection. He is forced to some such recourse, since he is unwilling to depart very far from his assumption that vertically floating prismatic needles are always free from oscillations. (*See* his Mémoire sur les halos, etc. Paris, 1847, pp. 168–169.)

ON HALOS.

[*Extract from* "Light" by CHARLES S. HASTINGS.]

An incisive and important work on halos, and their phenomena and theory is contained in the latter part of the work entitled "Light"[1] by Prof. Charles S. Hastings, of Yale University. As this work is almost unknown to our meteorological observers, we reprint, by permission of the author, the concluding pages, 221–224 of Prof. Hastings's text.—C. A.

As this completes the explanation of all known features of the complex phenomenon called the halo, it may be well to collect them in tabular form. We will first give those of which the origin has been known for a longer or shorter time, with the name of the physicist who first found the true explanation.

1. Halo of 22° radius. Mariotte.
2. Parhelia of 22°. Mariotte.
3. Oblique arcs of Löwitz. Galle.
4. Tangent arcs to the 22° halo, which become the circumscribing oval with high sun. Young and Venturi.
5. Halo of 46° radius. Cavendish. (Unless objections given on page 219 [of the above-mentioned volume] in regard to this feature are valid.)
6. Horizontal tangent arcs to the 46° halo. Galle; perfected by Bravais.

[1] Hastings, Charles S. Light. A consideration of the more familiar phenomena of optics. New York, Chas. Scribner's Sons, etc. 1901. xi, 224 p. illus. 8°. (Yale bicentennial publications.)