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NOCTILUCENT CLOUDS*

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(With Plate VI)

ABSTRACT

The observations and photographs of noctilucent clouds taken at Meanook, Alberta (Lat. 54°37′N., Long. 113°20′W.), on the night of July 20-21, 1933, are given, the observation being possibly the first recorded in America. A method of determining their least possible heights from single station photographs is developed and these heights deduced for the clouds observed at Meanook. A summary of 290 previous observations taken on 187 evenings of the years 1885-1933 is given in brief tabular form. A statistical study of the distribution of evenings of occurrence indicates a close conformity to a normal error law, the maximum frequency appearing about 10 days after the summer solstice, at which time the clouds appear to be most brilliant. The times of yearly preponderance of striking cosmic phenomena, explosive volcanic eruptions and relative sunspots have been compared with the yearly frequencies of noctilucent clouds. The general characteristics of the clouds during the past half century and their probable origin are discussed.

I. INTRODUCTION

NOCTILUCENT, or night-luminous, clouds are of unknown nature and origin and are truly remarkable because of their surprising heights[1, 2] in the stratosphere, and the great velocities[3, 4] they commonly attain. It is generally considered that clouds due to water vapour occur only in the troposphere, of which iridescent clouds ascribed to supercooled water droplets are the highest. The latter type of cloud is common, and is often seen near the sun, giving iridescent effects; but its present wide literature indicates that it is not to be confused with some of the so-called iridescent clouds reported in the journal "Nature" in 1884. Thus very occasionally

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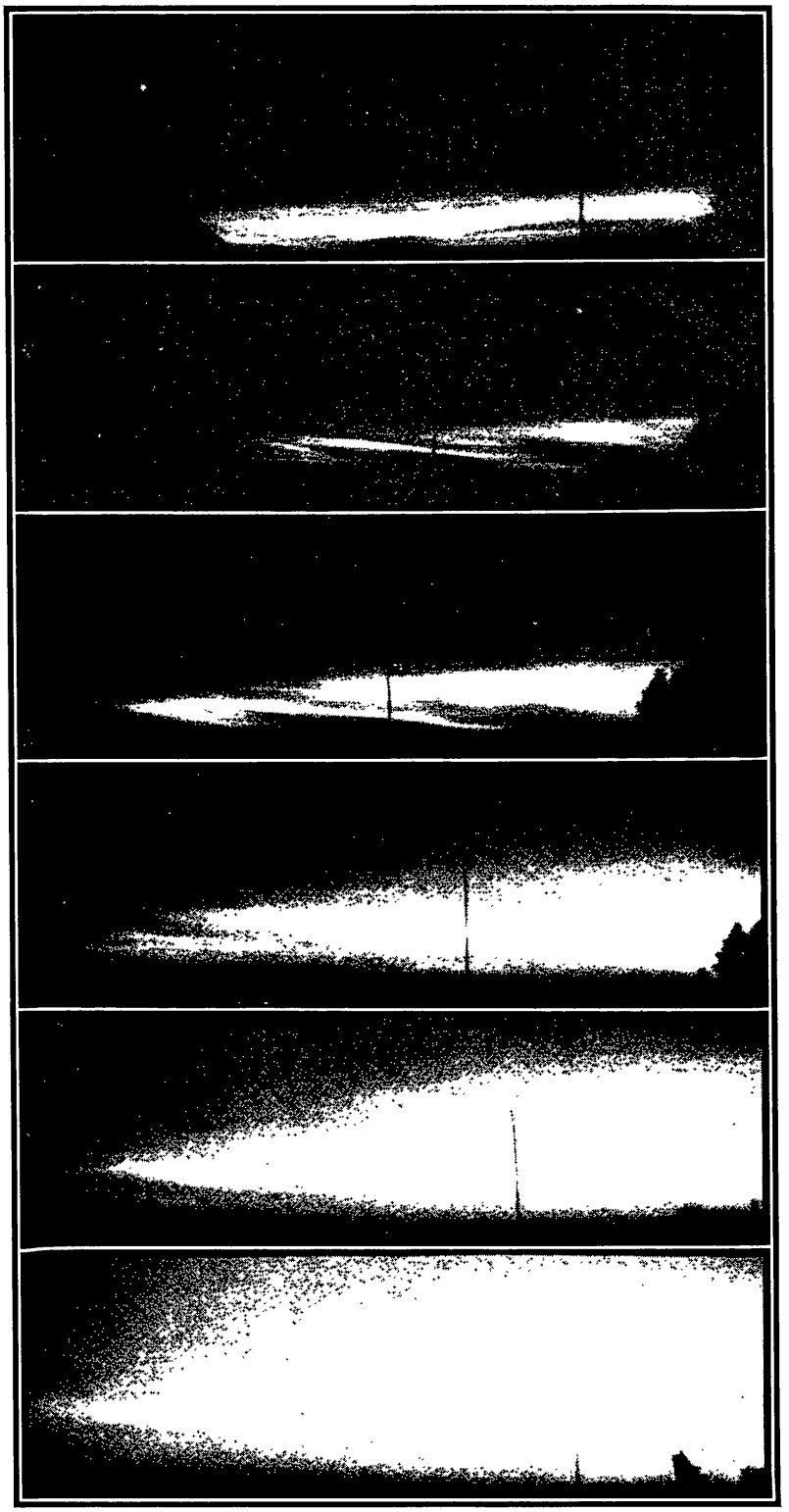
PLATE VI.



PHOTOGRAPHS OF NOCTILUCENT CLOUDS TAKEN AT MEANOOK ON THE NIGHT OF JULY 20-21, 1933.

a. 00.30 (prox.) 105th M.T.; b. 01.39-01.46; c. 01.47-01.58; d. 01.59-02.10; e. 02.11-02.22; f. 02.23-02.34.

cloud-like formations have been observed in the stratosphere and are of special interest in view of the distribution and importance of water vapour in controlling the temperature of the air.

The lowest clouds in the stratosphere are known as mother of pearl,[5] nacreous or "irisierende Wolken", because of the purity of their beautiful spectral band-like colouration. These occur at heights of 22-30 km. Stenzel[6] and others have observed a peculiar cloud-like phenomenon described as "self-luminous" clouds, the heights of which have not been measured, but which probably also occur at very high altitudes. Although all clouds in the stratosphere are rare in occurrence the most commonly observed are the noctilucent, also called luminous night-clouds or "leuchtende Nachtwolken", which have measured heights of 80-90 km.

Noctilucent clouds are difficult to explain in terms of present conceptions, and observation of them is adding to our knowledge of the upper atmosphere. In our interpretations of air movements in the upper atmosphere we are at present restricted to data derived from the observation of glowing meteoric trains, possibly sunlit aurora[7] and quiet cloud-like remains of aurora, and noctilucent cloud movements within a thin layer, or stratum, at a mean height of 82 km. above the earth. Further developments may result from the fact that the clouds occur near the position of the earth's shadow where peculiar changes also seem indicated from observations on sunlit aurora. Since little is known of this stratum in the stratosphere, noctilucent clouds can furnish valuable information and are of great interest both to the astronomer and the physicist.

Noctilucent clouds have been seen in north temperate latitudes from the latter part of May to the middle of August and in south temperate latitudes during the period of the year about six months later. They are visible only by reflected light from the sun during the time the sun lies from about 10° to 18° below the horizon and usually only under conditions of optimum visibility. Hence they are seen within the twilight circle on summer evenings from points in the zone extending from 45° to 62° north latitudes, according to Jesse, and are brighter in the more northerly latitudes.

In strong displays the clouds may fill most of the twilight circle and have been seen at times as early as 15 minutes after sunset covering the greater part of the sky almost as far as the south-

eastern horizon. As the sun goes lower below the horizon the illumination then recedes symmetrically towards the position of the sun. The clouds continue visible during the night in the portion of the sky restricted to the twilight circle so that the area of illuminated cloud tends to follow the position of the sun, with a minimum extent of display around midnight. A peculiarity some observers have described in the case of brilliant displays is the appearance of what they describe as a zone of darkened appearance in the northwestern sky in the early evening about the time the display is receding through the zenith. Ordinarily the clouds may appear in the northwest about an hour after sunset, the area of illumination progressing with the twilight circle so that illuminated clouds appear in the north and at minimum altitude at midnight. Later they appear mostly in the N. to N.N.E. and appear brighter and the display may fade out in the northwest about an hour before daybreak. Since 1889 the clouds have been seen more frequently after midnight, and observers have rarely seen them higher than 10° above the horizon.

Noctilucent clouds have many remarkable and highly striking characteristics. Ordinarily their form resembles that of cirrus or cirro-stratus, the latter form having been observed more frequently during the early morning hours. They are subject to rapid and continuous change of shape and form, individual details in structure escaping recognition after an interval as short as five minutes. They may appear to twist about, and sometimes take on appearances like that of wound-up lengths of loose yarn. Occasionally they are made up of long parallel silvery streaks aligned along their direction of motion, with smaller parallel streaks at right angles filling the space between and arranged in uniform wave-like sequences. These smaller cloud waves Jesse found at right angles to their direction of motion. They are highly tenuous and the intensity of the light from stars suffers little diminution in passing through them.

The intensity of illumination varies on different occasions. During the summers of 1885 and 1886 they possessed enough brilliance at times to cast definite shadows from terrestrial objects and to permit the reading of ordinary print at night. Ordinarily the

intensity of illumination may be compared to that of the moon near the eastern horizon at the time the sun is just setting in the west.

Their colouring varies with their position relative to the horizon. Near the horizon they have a golden or reddish-orange appearance, and with increasing altitude they take on a white or bluish-white sheen. Still higher they evince a blue-grey hue not unlike that of unpolished silver.

The spectrum shows no emission lines, the Fraunhofer lines being clearly present, and the spectrum on the whole resembling that of daylight.[2] Observers have found the light to be polarized, the only evidence to the contrary being an observation due to Robert von Helmholtz.[8] They are seen clearly through blue filters but the intensity of the light is greatly diminished by red filters.

There is a high degree of consistency in accurate determinations of their heights made in different years and from different locations. Simultaneous photographs of the same clouds against the same background of stars from stations a known distance apart have permitted the identification of the same parts of cloud on each, anp have given accurate determinations of heights. During the summer months of the years 1889-91 Jesse[1] obtained 24 pairs of plates giving 287 heights, ranging from 79 to 90 km., the weighted mean being 82.08 km. In 1932, Störmer,[2] using simultaneous photographs from his auroral stations and applying the same admirable technique he and his colleagues have developed for the determination of the heights of aurora, obtained a mean height of 81.8 km. on July 10, 1932, and 81.1 km. on July 24, 1932, the average mean of 37 heights from 7 pairs of plates being 81.1 km. Measurements have also been made in Moscow, giving a height of 66 km., but the observers question the accuracy of their photographic observations. The use of the earth's shadow method, which can give only an estimate of their least possible heights, has resulted in values of 30-70 km. in Europe. Störmer[2] has shown that this method may give values 30-50 km. too small, owing to the clouds apparently receiving no illumination from the sun's rays passing through the troposphere.

Velocities attained by the clouds are often truly remarkable. Jesse[3],[4] obtained a velocity as high as 177 m. per sec. (400 miles per hour) in 1888. Archenhold[4] has published a summary of the results of Jesse's velocity measurements during the years 1889-94. Before

midnight most movements were from an azimuth 48°E., after midnight from azimuth 63°E., with a possible secondary maximum from 73°W. The mean velocity from west azimuths was 31 m. per sec., and 67 m. per sec. from east azimuths. Movements from west azimuths were uncommon and few measurements showed any southern component. Störmer found velocities of 44-55 m. per sec. from the N.N.E. for the clouds of July 10-11, 1932. Thus the clouds appear to move from the N.E. before midnight, from the N.N.E. after midnight and apparently with a component away from the position of the sun or twilight circle.

Jesse obtained measurements varying little from a mean value of 9.4 km. for the distance between successive wave-like crests in the clouds, Störmer[2] finding a value of 9 km. in 1932.

Data on noctilucent clouds were first collected by Jesse in 1885 in a paper "Die Auffallenden Abenderscheinungen am Himmel im Juni und Juli 1885," which gave the observations of some fifteen observers. The first observation in 1885 is due to Backhouse, who observed them at Kissingen on June 8. Rowan, however, states in a paper written in 1886, that he had seen them during the previous two or three years. Earlier observations are probable and Arago[9] has collected a number of observations on various manifestations of luminosity in clouds in a chapter in his works dealing with "l'emission continue de lumière à la surface de certains nuages." He mentions observations on luminosity in clouds made by Rozier on August 15, 1781, by Deluc and Verdeil during 1783, "the year of the great dry dust" and eruption of Asama, and by Beccaris. During 1783 Verdeil mentions a luminosity at night covering the entire sky and permitting the observation of terrestrial objects at a certain distance. Unfortunately, these descriptions are somewhat vague and lacking in detail, particularly with reference to other factors which may have been responsible for the appearance of luminosity.

II. Meanook Observations, July 20-21, 1933.

In the following observations the times indicated are corrected chronometer local zone time (105th M.T.). Angular measurements were made with a pilot-balloon-type theodolite. The azimuth of

the radio pole seen in the pictures in Plate VI was found to be 1.45°W. of N. Photographs *b* to *f* were taken from a fixed position on the flat top of the lookout; *a* was taken from another position. The following is the record of the observations:

23.45—The noctilucent clouds resembled a number of yellowish-orange well-defined cirrus-like streaks about 1° above the horizon in the N.N.W. The streaks were inclined to the horizon at an angle of about 30°, the highest part of each streak being to the west. The streaks were separated by a definite space several times their width. Intensity of illumination 3 (comparing intensity with that of brilliant aurora taken as 4). Gave impression of being at a great distance, and as if illuminated by sun, although sun had set more than an hour previously. No auroral green line (pocket auroral spectroscope used and only a faint general illumination seen through it when directed at the clouds).

24.00—Illumination of the display now extended farther to the east and lower, the streaks in the west having faded out. Fainter and less definite golden and orange fringes and streaks barely visible in north. Gradually the impression that the display was about over was experienced. These streaks and fringes changed in shape, outline and intensity of illumination against their fainter yellowish-orange background so that great difficulty was experienced in attempting to complete a sketch of them. The central position of the area of illumination continued moving east. Plate Ia was taken near the time the display was at a minimum of about 00.30, a long exposure of about 15 minutes being given with a cheap box camera loaded with roll film. After this time the display appeared to brighten somewhat in the N. to N.N.E.

1.10—Estimated range of the cloud display, 5°W. to 25°E.

1.26—Maximum height 1.70° at 6.2°E. Display brightening considerably, especially in western portion.

1.39-1.46—Plate VI*b* exposed.

1.47-1.58—Plate VI*c*.

1.55—Display extending to 20°W.

1.59-2.10—Plate VI*d*.

2.05—Illumination extending westward to 35°W. Highest angular height 3.57°. Colouration white, sharp and beautifully clear.

2.11-2.22—Plate VI*e*.

2.18—Quite bright, more than four on auroral classification. Brightest along lower edge of largest cloud giving a straight white line effect there. No auroral line present.

2.23-2.34—Plate VI*f*.

2.25—West to 36.7° from north.

2.32—A new blue-grey cloud observed at 12.3°E.-32°E. at altitude 9.7°. Resembled a very long lenticular cumulus cloud with lower edge silhouetted like

the lower part of a series of fairly regularly spaced dark smoke puffs partially joined together in line.

2.35—New portion becoming illuminated at 21.5°W. and 7.7° altitude.

2.38—Clouds to the N. and N.N.E. quite faint but to the N.W. still clearly defined against the darker background of the sky. Close to the northern horizon a noticeable orange to reddish glow.

2.52—Purplish hue on clouds 45°W. and 1° altitude and on clouds at 50°W. and 1-2° altitude. Brightness most marked in westward part of twilight circle. Reddish-purple portion in extreme N.W. fading rapidly at 3 a.m. In twilight zone low in N.E. a number of very long (very thin) faintly dark striations running from west to east which were not a part of the display. Steady crackling static very marked on radio. Purple of twilight to about 30° south of zenith.

3.34—Only visible portion a short pair of striations together at 80°W. and 7° altitude. These appeared to shine with a white light although no stars could be seen in that region.

The movement of the clouds was from the E.N.E. The moon was a narrow crescent 24 hours before new. At 24.00 a dull auroral arc consisting of several dull scattered rays was seen several degrees above the display of noctilucent clouds and showed the green auroral line. The aurora lasted about five minutes.

Since there had been no evidence of any thunderstorms in this region the Bureau of Standards in Washington was communicated with to ascertain if anything unusual in the height of the Kennelly-Heaviside layer had been noted which might be associated with the radio static disturbances. Dr. E. C. Crittenden states that unfortunately records for the particular night of July 20-21 were not obtained and kindly comments as follows:

During most of the year, reflected waves from the upper atmosphere at 2500-4400 kc./sec. at night come most often from the F region, with virtual heights of the order of 300 km. However, it frequently happens that strong reflections will suddenly appear from the E region with virtual heights of the order of 100 to 120 km. These E-region reflections were especially prevalent during June and July. Thus, they were in evidence on 17 of the 20 nights in July for which records were available. They were particularly strong during the night of July 19-20. During six consecutive nights in October, on the other hand, these reflections appeared only once. It is possible that the changes in the E region may be connected with appearances of the noctilucent clouds you mentioned, and it is hoped that further observations will throw more light on this question.

On the night of July 20-21 at sunset, the western sky was cloudless. The visibility increased to 9 during the night. On the fol-

lowing day the sky appeared unusually blue. The barometer had remained very steady but low for several days.

A. Thomson, Chief Physicist of the Meteorological Service of Canada, gives the following summary with respect to weather conditions:

> On the morning of July 20th, a poorly defined front or frontal zone had developed along the Rocky Mountains from Alaska to the International boundary, which divided the Polar Pacific air covering British Columbia from the Polar Canadian air over the western provinces. A large area of moderately high pressure was centered some distance off the British Columbia coast while a low-pressure area covering the provinces of Alberta, Saskatchewan and Manitoba had a centre at 8.00 a.m. about 200 miles west of Port Nelson on Hudson Bay. The pressure gradients were small at the surface so that the winds recorded at all synoptic weather stations in Alberta, Saskatchewan and Manitoba did not exceed 10 miles per hour. The morning temperatures in Alberta were low but rose rapidly.
>
> During the following 24 hours, covering the period noctilucent clouds were observed, the frontal zone became very broad but appeared to have moved eastward. The pressure decreased slightly over Western Canada, and the gradient over the Rocky Mountains became of the order of 1/10 inch for 400 miles. The pilot balloon observations at levels from 1 km. to 4 km. showed moderate westerly or northerly winds so that probably a slight current of Pacific air during the night of July 20-21, was blowing across the Rockies.

The following table summarizes the meteorological data at Meanook for July 20-21:

	July 20, 9h.	July 20, 21h.	July 21, 9h.
Pressure observed (in.)	27.55	27.57	27.59
Sea level (in.)	29.94	29.98	29.98
Temperature (°F.)	52.0	46.4	56.2
Relative humidity	73	89	72
Vapour tension (mm.)	7.2	7.2	8.3

III. Method of Calculation of the Least Possible Heights of Sunlit Clouds at High Altitudes Above the Earth

The problem is essentially that of calculating the height of a sunlit cloud particle lying on the edge of the earth's shadow, being given the time, azimuth and apparent altitude of the particle as observed from a known point on the earth lying within this shadow.

Should the sunlit particle be outside the earth's shadow, a value giving its least possible height can then be deduced.

The plane of the paper (Fig. 1) includes O the centre of the earth, the position F of a sunlit particle of cloud just touched by a ray S from the sun passing at grazing incidence to the earth, E the point of grazing incidence to the earth, and the centre of the sun. Let

A be the position of the observer on the surface of the earth but not necessarily in the plane EFO

AB the tangent plane to the earth at A

D the point on the earth directly beneath the particle

R the radius of the earth adjusted for latitude and sea-level

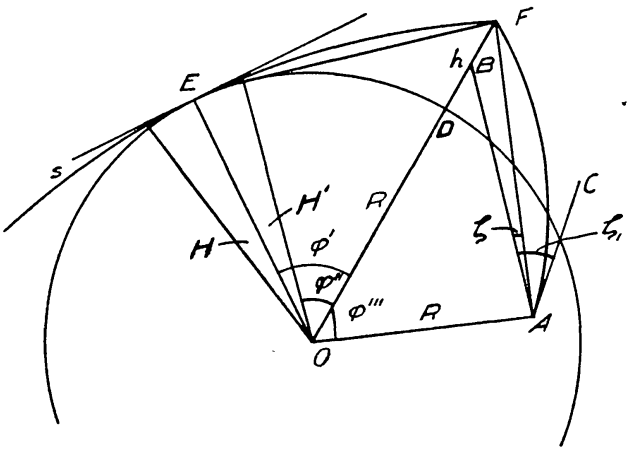


Fig. 1. Position of sunlit particle with reference to a refracted ray s from the sun which passes at grazing incidence to the earth.

h the height of the cloud particle above the earth

H the horizontal astronomical refraction for the ray from the sun grazing at E

H' the horizontal refraction for the ray passing along a length of path EF in the atmosphere

ϕ' the apparent dip of the horizon as seen from F

ϕ'' the dip of the horizon as seen from F corrected for the refraction H'

ϕ''' the angle between radii of the earth at A and D

ζ_1 the apparent angular altitude of the sunlit particle above the tangent plane at A, as observed at A

ζ the apparent angular altitude after being corrected for the atmospheric refraction of the ray passing along the path FA, calculated for the atmospheric conditions approximately known at A

α the azimuth of the particle from the meridian taken positive from north around by east

(L, ϕ) west longitude and latitude of the observer

(L_1, ϕ_1) west longitude and latitude of the point D

h_1 the negative altitude of the sun as seen from D

t_1 hour angle of the sun at D

δ the declination of the sun

s semi-diameter of the sun.

The factor upon which the amount of the atmospheric refraction of a ray depends at a particular height is given by [10]

$$k = 670.4 \frac{p}{T^2} (\tau + 0.0342)$$

where p is the atmospheric pressure

τ the lapse rate in °A/meter

T the absolute temperature.

For altitudes as great as 40 km., k becomes very small, even for large lapse rates, and if calculated is of the order 0.001, so that no significant error in the calculated amount of refraction for rays above this region will result if k be neglected. For altitudes greater than 40 km. the ray of light passing along the path EF may then be treated as subject to horizontal astronomical refraction, and the ray along FA as subject to astronomical refraction.

Then from the figure the dip of the horizon as seen from F is given by $\phi' = \phi'' + H'$ ..... (1)

$$\text{also } \sec \phi'' = \frac{R+h}{R} = 1 + \frac{h}{R} \quad \text{..... (2)}$$

An expression for h can be obtained in terms of R, ζ and ϕ''' from

$$\frac{R+h}{\sin (90° + \zeta)} = \frac{R}{\sin (90° - \phi''' - \zeta)}$$

$$\text{or } h = R \left[\frac{\cos \zeta}{\cos(\phi''' + \zeta)} - 1 \right] \text{..... (3)}$$

L_1, ϕ_1 the latitude and longitude of D are given by the formulae

$$\sin (L_1-L)\cos\phi_1 = -\sin\phi'''\sin\alpha$$
$$\sin\phi_1 = \cos\phi'''\sin\phi - \sin\phi'''\cos\phi\cos\alpha.$$

Since ϕ''' is usually small the differential formulae

$$L_1 = L + \frac{\phi'''\sin\alpha}{\cos\phi}, \quad \ldots\ldots (4)$$

$$\phi_1 = \phi - \phi'''\cos\alpha \quad \ldots\ldots (5)$$

may be used.

Then the negative altitude of the sun h_1 as seen from (L_1, ϕ_1) at the time of observation may be computed from

$$\sin h_1 = \sin\phi_1\sin\delta - \cos\phi_1\cos\delta\cos t_1 \quad \ldots\ldots (6)$$

where $t_1 = t+12-L_1/15+E$, t being the Greenwich Civil Time of observation and E the equation of time. The values of δ and E may be taken from tables of the sun's ephemeris.

The negative altitude of the sun in order that F may be just touched by some part of the sun's rays is given by

$$h_1 = \phi' + H + s \quad \ldots\ldots (7)$$

The value of h is then completely determined by means of these 7 equations, and may be solved for in terms of known values. It is found more economical, however, to carry out part of the deduction graphically and approximate the value of h, as follows:

A graph may be constructed from (2) so that h becomes known for a given value of ϕ'' (Fig. 2).

From (3) a series of curves may be drawn for the values of $\zeta = 1°, 2°, \ldots$ or if preferred the values of ζ obtained from the observations, for various values of h and ϕ''', so that for any value of ζ and assumed h, then ϕ''' may be read off (Fig. 3).

The value of ϕ''' thus obtained may be substituted in (4) and (5) so that (L_1, ϕ_1) is obtained for the height assumed and the observed azimuth of the point, and h_1 obtained from (6). If $h_1-(H+H'+s)$ comes out greater than ϕ'' as given in Fig. 2, the height assumed has been too small, and three or four trials will readily approximate the minimum height of the cloud particle in order that it may be just illuminated by some portion of the rays of the sun.

If the height h is less than 40 km. the solution may be carried out in the same manner from the approximate formulae

$$\phi' = \left[\frac{2}{R(1-k)}\right]^{\frac{1}{2}} \sqrt{h}$$

$$\frac{h}{R} = \phi''' \tan \zeta_1 + (\tan^2 \zeta_1 + \overline{1-k} \sec^2 \zeta_1) \frac{\phi'''^2}{2}$$

where the value of k used may be obtained graphically from the relation for k given above, since it depends on the height.

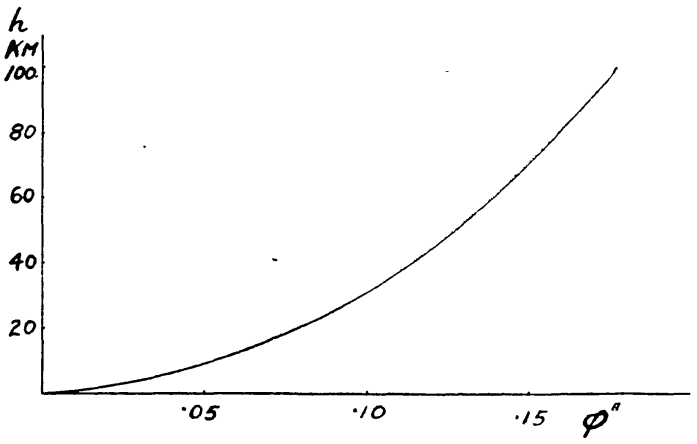


Fig. 2. Value of depression of the horizon ϕ'' in radians as seen from a point at various altitudes in km. above the earth by unrefracted light.

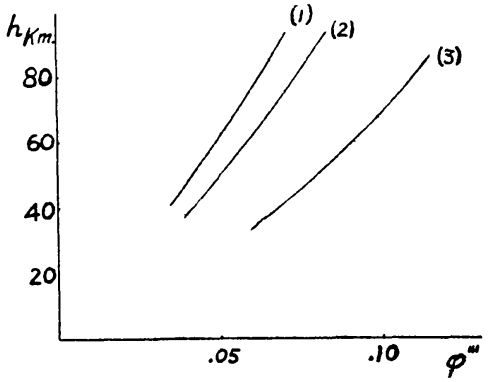


Fig. 3. The altitude in km. of a particle in the atmosphere for a given value in radians of the angle between the radius of the earth at the point of observation, and the line joining center of the earth to the particle, for a given value of the true angular altitude in degrees above the tangent plane at the observer. Curves (1), (2) and (3) refer to values of ζ obtained from ζ_1 given in table of heights.

The following values for the least possible heights were obtained for the clouds observed at Meanook:

G.M.T.	ζ_1	a	L_1	ϕ_1	$h_1 - 2H - s$	h km.
9.05	3.57°	8°W	114°32′	59°33′	0.1261	51
9.27	9.7°	22.0°E	112°19.5′	57°07′	0.1322	57
9.35	7.7°	21.5°W	115°28.5′	57°46′	0.1272	55.5

IV. Summary of the Observations, 1885-1933

In spite of the rarity of the phenomenon a fair amount of observational material has accumulated during the past fifty years. At least 300 observations of varying excellence have been made. The published information, however, is so widely scattered in

various scientific journals covering this period that a brief summary of the main features has been attempted.

Noctilucent clouds were observed frequently during the summer months of 1885-1894. While most marked in their brilliancy and frequency in 1885-1886, from 1888-1894 they fell rapidly in intensity so that only four weak displays are given by Jesse for 1894. In the earlier years it was observed that the clouds were very bright before midnight but in later years they were more intense after midnight. During 1885, however, observations were usually continued only up to the midnight minimum when the clouds disappeared. In 1889-1894, the clouds were observed only six times before but 33 times after midnight. In 1885 the clouds appeared as early as 15 minutes after sunset, some displays covering most of the sky; in later years of this period they rarely appeared before an hour after sunset with elevations usually well under 6° in 1894. Towards the end of the period, according to Jesse, the brightness was most marked in August displays. The displays were observed from between latitudes 45° and 62° N. (with a possible observation at 40°N.) and were seen brighter in the northern sections of this zone.

The period 1894-1898 seems one in which noctilucent clouds were either very weak or infrequent in appearance and there is scanty reference to them in well-known journals. The weakness and infrequency since 1894 and the fresh appearance of several displays during June to August in Russia during 1899 appears in "Gaea".

In "Nature", Backhouse indicates the observation of a bright display at Sunderland on July 8, 1903.

From 1904 to 1905 there appears to be little reference to appearances of the clouds. It is possible, however, that if displays were observed during this period they may have been very weak, or interest in them had flagged so much that observers failed to communicate their observations.

Noctilucent clouds were again seen in 1906, 1908, 1909, 1910, 1911 and 1914.

An observation on luminous clouds was made by Meyer in 1916 which, however, indicates some characteristics not usual in noctilucent clouds. According to Wegener they were also seen in 1917,

and he reports observing them during the summers of 1919 or 1920. Archenhold reports that they were seen in 1918.

No reference was found indicating their observation during the years 1921 to 1931, but they reappeared in 1932 and 1933.

In the following list of observations an attempt has been made to collect the observations recorded in well-known German, English and French scientific journals. This list no doubt lacks completeness, but at any rate should give a fair representation of the frequency and nature of the displays seen from a limited portion of northern Europe, during the years 1885-1933. However, in the sparsely settled regions of northern Europe, Asia and America, covering the major portion of the zone favourable to their observation, it is likely that many occurrences would be unreported.

In the summary local time commencing at midnight is indicated for the hours of observation. In most cases this has been reduced from the hours of observation given for the astronomical day. In a few observations where zone time has been used the standard of time is stated. Where the observer has failed to state the standard of time used it is assumed local time is indicated. When it is definitely indicated in the observation that the phenomenon was observed during the early morning hours the date for the morning is placed after that of the date given. The order observed in the list is the sequence: year, date, place of observation, observer, time, azimuth of the display, angular altitude, direction of movement and comments of the observer.

1885

June 8 Kissingen, BACKHOUSE (Met. Mag., vol. 20, p. 133, 1885), very brilliant cirrus clouds late at night, invisible when sun ceased to shine on them.

June 10 Colouring of upper part a steel blue, then dull green to yellow and orange below and reflecting sunlight.

June 23 Steglitz, JESSE (Met. Zs., Bd. 21, pp. 9-15, 1886), 21.50, 55W.-20E., alt. 20°, dir. N.E. 45, circular forms with striations of silver-white cirrus; lower zone somewhat yellowish, silvery above with bluish upper zone.
Danzig, KAYSER, EGGERT, 21.15, W.-E., alt. 55°, no sunset colours except at base; like bright cirrus.
Swinemünde (WILLERT), 22-24, N.-N.N.E., alt. 40°, bright clouds resembling cirrus.
Kiel, E. LAMP, N.W., strongly lit clouds resembling cirrus.
Wilhelmshavn, BÖRGEN, N, lighted and like cirrus.
Berlin, KÜSTNER, 21, NE, resembling cirrus; wound up forms; white illumination, 21.30, alt. 50°. appeared to withdraw towards the west.

June 24 Kiel, LAMP, KRÜGER, 21-24, NW, silvery cirrus-like clouds.
Hamburg, NEUMEYER, 22-23.30, N,NW- bright cirrus-like clouds.
Berlin, KÜSTNER, 23, N., near northern horizon and like cirrus bands.
Steglitz, JESSE, 22.07, E.N.E., alt. 9°, dir. N.E. 67, not as bright as on June 23.
Wilhelmshavn, ANDRIES, 23, N., silvery white clouds; no aurora; weak magnetic disturbance.
Wilhelmshavn, BÖRGEN, 1 a.m. (night of the 24th), N.W.-N., only within the twilight circle.

June 25 Bülow, KAMMERHERRN, 21.45, N.-E., alt. 10°, like aurora.

June 27 Holstein, J. LAMP, 22.15-24, N., alt. 7°, milk-white with a tinge of green; no magnetic disturbance.

June 30 Holstein, J. LAMP, 23, N-W, alt. 12°.

June 30 Steglitz, JESSE, 21.38, alt. 90°, top fringe through zenith; ordinary cirrus dark and moving south; lit clouds stationary; 22.24, alt. 8.4°, least height 41.8 km.

July 1 Steglitz, JESSE, 22-, bright patch seen near horizon.

July 2 Steglitz, JESSE, 21.30-22, very bright; seen through stratocumulus.

July 6 Steglitz, JESSE, 22.19, ordinary cirrus present was dark; seen by SPRUNG also.
Southampton, LESLIE (Nat., vol. 32, p. 245, 1885), 22-, W.-N., alt. 12° for lower edge; a sea of luminous silvery clouds.
Hamburg, KIESSLING (Met. Zs., Bd. 21, pp. 9-15, 1886), greenish yellow clouds; like cirrus.

July 7-8 Wilhelmshavn, BÖRGEN, 22-23, N., only inside twilight circle; unlit portions projecting outside.
Hamburg, MEYER, 21.30, W.-E., alt. 90°, white colouration of cirrus. Seen also by SPRUNG in Germany, and KIESSLING.
Steglitz, JESSE, 20.40, N., dir. N.N.E. 22, clear sky at time of setting of sun at 20.20; 20.53, almost over entire sky; 21.02, very bright; 21.33, alt. 90°, no clouds left in the S.E. sky; 21.53, alt. 24.5°; 22.20, alt. 9.5°; least heights 45 to 56 km.
Berlin, BATTERMAN (Met. Zs., Bd. 21, p. 179, 1886), 1 a.m., N.N.E., cast definite shadows from terrestrial objects; very good visibility; no moon; 1.30 a.m. alt. 8°, 1.45 a.m., N.E., higher and brighter in the sky; 2.05 a.m., N.E., parallel bands present; 2.12 a.m., to Alpha Auriga, stars visible through the clouds; 2.29 a.m., alt. 90°, nearly to zenith, weaker; 2.45 a.m., S.W., dir. N.E.(?), weak in N.E.; 3.10 a.m., almost indiscernible in the N.E.
Rügen, FÜRSTENAU (Met. Zs., Bd. 21, p. 14, 1886), 22.15-24, N., alt. to 30°, shadows cast from terrestrial objects; stars visible through the clouds; followed progress of sun; black threatening zone within twilight circle; seen for 14 days.
Kissingen, BACKHOUSE (Met. Mag., vol. 20, p. 133, 1885).

July 8 Steglitz, JESSE (Met. Zs., Bd. 21, p. 15, 1886), 22-, weak.
July 9 Steglitz, JESSE; seen through ordinary clouds; weak.
July 17 Steglitz, JESSE, 22.02, alt. to 9.8°, somewhat noticeable; 22.08, alt. 9.0°.
Hamburg, KIESSLING, 22.25, N., greenish-yellow cirrus-like clouds.
July 19 Steglitz, JESSE (Met. Zs., Bd. 21, p. 16, 67, 1886, Weltall, 27 Jahrgang, Juli 1928), 20.24, extraordinarily brilliant display commencement; 20.40, alt. 14.3° in S.E.; 21.17, alt. 90°, 22.10, alt. 7.2° in N.W.; appeared 15 minutes after sunset with grey cirrus-like streaks almost over the entire sky excepting a small portion in the south-east. The arrangement of the clouds was extremely regular and consisted of long parallel silvery streaks running from the N.N.E. to S.S.W. separated at the zenith by 10° (12° given in Weltall) and converging towards the horizon like the ribs of a fan. Between these streaks were uniformly spaced cross-ribs at right angles separated at the zenith by about 5°. The display lacked sharp definition at first, became brighter and then dissipated itself progressively from the S.E. to the N.W. About the time that the display extended to the zenith the north-western portion had a dark threatening appearance, while the clouds increased in brilliancy to the time when the clouds were at an altitude of 15° in the N.W. The colouration was reddish-yellow near the horizon in the west, bluish above and finally a duller bluish-white. Direction of movement from the N.N.E. 30 at 20.51, least heights 10-60 km.
Hamburg, SPRUNG, 20.45, over entire sky; 21.45, like polar bands; dir. N.E. 45.
July 21 Breslau, GALLE, 21.30, N.W., alt. 10°, sunset at 20.01; golden yellow near horizon; no magnetic disturbance.
Steglitz, JESSE, 22, N.N.E., alt. 15°, dir. N.W.-22, only a few bright streaks and direction of movement uncertain.
July 22 Steglitz, JESSE, 21.11, alt. 69° S.E., 21.51 alt. 9.2° N.W.; sunset at 20.05, illumination began at 20.40; 20.47, dir. E. 90; least heights 44-55 km.
July 23 Breslau, GALLE, 20.45, alt. 60°, sunset at 19.58; only a small part left at 21.55, colouration a bright white, phosphorescent? Least heights 41-58 km.
July 27 Görlitz, KÜSTNER.
Görlitz, BUSCH (Weltall, 1928), 20.45, dir. E. 90.
July 29 Jönköping (Nat., vol. 32, p. 375, 1885), midnight, bluish clouds like icebergs.

1886

May 28 Isle of Wight (BACKHOUSE), (Nat., vol. 34, p. 239, 1886).
June 2 Sunderland, DIXON.
June 3 Sunderland, DIXON.
June 5 Wilhelmshavn, ANDRIES (Weltall, 1928), 23.
June 8 Hamburg, HANN (Met. Zs., Bd. 21, p. 323, 1886), alt. 20°, in direction towards position of sun.
Steglitz, JESSE (Weltall, 1928), 21, dir. W.N.W. 67.
Rügen, GALLE, 22.

June 10 Steglitz, JESSE,
June 13 Steglitz, JESSE, dir. W.N.W. 67.
Sunderland, DIXON (Nat., vol. 34, p. 239, 1886).
June 16 Sunderland, DIXON.
June 18 Belfast, SHAW (Nat., vol. 42, p. 246, 1890), midnight, N.W., alt. 20°.
June 22 Sunderland, DIXON (Nat., vol. 34, p. 239, 1886).
Dublin, ROWAN (Nat., vol. 34, p. 192, 1886), N., alt. 5°-10°, showed an opaque pearly lustre; says he has seen them during the previous two or three years; azimuthal width 7°.
June 23 Bideford (Nat., vol. 34, p. 239, 1886), upper edge five-eighths of the distance up to γ Andromeda at 22.18.
Sunderland, DIXON, very striking.
Königsberg, HAHN (Met. Zs., Bd. 24, p. 187, 1889).
Hamburg, KÖPPEN (Weltall, 1928), 23.15, stationary.
Hamburg, HANN (Met. Zs., Bd. 21, p. 323, 1886), 23.20, alt. 6°.
June 24 Steglitz, JESSE, 22, dir. E.N.E. 67.
June 26 Königsberg, HAHN (Met. Zs., Bd. 24, p. 187, 1889).
June 28-29 Hamburg, HANN (Met. Zs., Bd. 21, p. 323, 1886), 23.30-01.00 a.m., alt. 4°, height over 50 km.
June 30 Königsberg, HAHN (Met. Zs., Bd. 24, p. 187, 1889).
July 1 Sunderland, BACKHOUSE (Nat., vol. 34, p. 312, 1886).
3 Steglitz, JESSE (Weltall, 1928), 21, dir. N.N.E. 22.
7 Steglitz, JESSE, 22, dir. W. 90.
July 8-9 Dublin, ROWAN (Nat., vol. 34, p. 264, 1886), 23.30-2.00 a.m., 10 W.-30 E., made sketches by cloudlight.
July 9-10 Dublin, ROWAN, 1.30 a.m., N.-N.E., a golden lustre shown at midnight.
July 9 Königsberg, HAHN (Met. Zs., Bd. 24, p. 187, 1889).
July 11 Naugard, KLOPSCH, 21.30, dir. S.W. 135, 22, dir. W.S.W. 112.
July 11-12 Eckerberg, STEINBRINK, 2.30 a.m.
July 12 Southampton, LESLIE (Nat., vol. 34, p. 264, 1886), 19.30-22, N.W., dir. N., cloud waves present; seen previously during the summer; brilliant.
Sunderland, BACKHOUSE (Nat., vol. 34, p. 312, 1886), 22.14 G.M.T., dir. N. -3.
Trier, ANDRIES (Weltall, 1928), 21.15.
July 18 Sunderland, BACKHOUSE (Nat., vol. 34, p. 312, 1886).
July 18-19 Eckerberg, STEINBRINK (Weltall, 1928), 3 a.m.
20 Sunderland, BACKHOUSE (Nat., vol. 34, p. 312, 1886), 21.22, dir. N. or E. covering most of sky (note other article dealing with remarkable halos).
Hamburg, KÖPPEN (Weltall, 1928), 21.30.
July 24 Sunderland, BACKHOUSE, 21.56 G.M.T., dir. E. 90.
July 25 Swinem, KLOPSCH, 21.00, dir. N.W. 45.
Lichtenw, RICHTER, 21.00, dir. N.W. 45.
July 27 Gilsland, BACKHOUSE.
July 27-28 Edinburgh, SMYTH (Nat., vol. 34, p. 312, 1886), 1 a.m., trace of auroral line? Black zone effect above.

July 29 Eckerberg, STEINBRINK (Weltall, 1928), 21.
July 30 Eckerberg, STEINBRINK, 21.30.
Aug. 1 Sunderland, BACKHOUSE, 22.00 G.M.T., dir. E.N.E. 68.
Aug. 10-11 Sunderland, BACKHOUSE (Nat., vol. 34, p. 386, 1886, Weltall, 1928), 2.30-4.11 a.m.; at 3.34 a.m., G.M.T., dir. E. 81; no auroral line; disappearance due to overpowering light of sun in morning.

1887

June 4-5 Steglitz, JESSE (Weltall, 1928), 21.15; 2.30 a.m. dir. E.S.E. 112.
June 6 Berlin, JESSE (Met. Zs., Bd. 24, p. 186, 1889), 21.55, photograph reproduced.
June 9 Königsberg, HAHN (Metz. Zs., Bd. 24, p. 187, 1889), trace.
June 13 Ben Nevis, OMOND (Nat., vol. 38, p. 220, 1888), midnight, seen almost every clear night.
June 14 Clifton, BURDER (Nat., vol. 41, p. 198, 1890), N.N.W., 22.45.
Sark, BACKHOUSE (Nat., vol. 36, p. 269, 1887), weak.
June 15 Königsberg, HAHN (Met., Zs., Bd. 24, p. 186, 1889), quite noticeable; sun ring in afternoon.
June 16 Hamburg, HANN (Met. Zs., Bd. 22, p. 335, 1887).
Steglitz, JESSE (Weltall, 1928), dir. E. 90.
June 17-18 Hamburg, HANN, 2 a.m.
June 18 Hamburg, HANN.
Sark, BACKHOUSE (Nat., vol. 36, p. 269, 1887), weak.
June 19 Königsberg, HAHN (Met. Zs., Bd. 24, p. 186, 1889), 23, over whole northern sky; tolerably bright.
Dublin, ROWAN (Nat., vol. 36, p. 245, 1887), 25W.-50 E., increasing development of phenomena to June 29.
Sark, BACKHOUSE (Nat., vol. 36, p. 269, 1887), weak.
Hamburg, HANN (Met. Zs., Bd. 22, p. 335, 1887).
Steglitz, JESSE (Weltall, 1928), dir. N.E. 45.
June 20 Hamburg, HANN (Met. Zs., Bd. 22, p. 335, 1887).
June 21 Dublin, ROWAN (Nat., vol. 36, p. 245, 1887).
June 23 Königsberg, HAHN (Met. Zs., Bd. 24, p. 186, 1889), trace.
June 24 Königsberg, HAHN, trace.
Dublin, ROWAN (Nat., vol. 36, p. 245, 1887), more developed than on June 21.
June 25 Königsberg, HAHN (Met. Zs., Bd. 24, p. 186, 1889), -24-. Peculiar in that the brownish gold edge appeared before the clouds themselves; fairly strong.
Steglitz, JESSE (Weltall, 1928), 21.00, dir. N. 0.
June 26 Steglitz, JESSE, 21.30, dir. N.E. 45.
Köngisberg, HAHN, -24-, glistening towards midnight; sky beneath a dark yellow and "black space" in sky above present as illusion.
Dublin, ROWAN (Nat., vol. 36, p. 245, 1887), more developed than on June 24.
June 27 Königsberg, HAHN (Met. Zs., Bd., 24, p. 186, 1889), weaker; strong sun ring towards evening.

June 27-28 Berlin, HELMHOLTZ (Mets. Z,. Bd. 22, p. 335, 1887), N., alt. 5°, seen all night and a minimum at midnight; spectroscope showed a deficiency of red light in the cloud illumination; light not polarized; blue filters had little effect but red filters greatly diminished the intensity of the light, least height 75 km.
June 28 Königsberg, HAHN, 23.15, present but far away.
Dublin, ROWAN, a magnificent display.
June 29 Dublin, ROWAN, brightest of Dublin displays.
Königsberg, HAHN, sun rings from 8-15 hrs.; a weak display.
Steglitz, JESSE (Weltall, 1928), 21.15, dir. N.E. 45.
Templehof, ETZOLD, 21.30, dir. E. 90.
July 1 Königsberg, HAHN (Met. Zs., Bd. 24, p. 186, 1889), weak trace.
2 Steglitz, JESSE (Weltall, 1928), 21.30, velocity too low to be measurable.
July 3 Steglitz, JESSE, 21.30, dir. W. 90.
Stettin, KLOPSCH, 21.30, dir. N.N.W. 22.
Königsberg, HAHN, shifting from N.W. to N.E. noticeable; distinct.
July 4 Königsberg, HAHN, very weak.
July 6 Königsberg, HAHN, tolerably strong.
Chamonix, BACKHOUSE (Nat., vol. 36, p. 269, 1887), brilliant display.
Steglitz, JESSE (Met., Zs., Bd. 22, p. 424, 1887), height from simultaneous photographs gave 75 km., uncertain.
July 7 Karlsruhe, V. REBEUR PASCHWITZ (Weltall, 1928), 21.15.
July 9 Königsberg, HAHN, 22, not present at 21 hrs.; partly like white fog, higher up like granulated snow.
July 14 Königsberg, HAHN, weak.
July 15 Königsberg, HAHN, weaker than on 14th.
July 17 Königsberg, HAHN, weak, but traces near horizon.
July 18 " " " " " " "
July 19 " " " " " " "
July 20 Ben Nevis, OMOND (Nat., vol. 38, p. 220, 1888).
July 22 Königsberg, HAHN (Met. Zs., Bd. 24, p. 184, 1889), doubtful trace.
July 24 Königsberg, HAHN, as on July 17-19.
July 25 " " " " "
July 29-30 Sunderland, BACKHOUSE (Nat., vol. 36, p. 365, 1887, Weltall, 1928), 22.52 N.N.W.-N.N.E., dir. N.E. 45, seen mostly in the morning; very brilliant; a border of faint yellow above the blue colouration; present also at 2.26 a.m., G.M.T., dir. N.N.W. 34.
July 30 Königsberg, HAHN (Met. Zs., Bd. 24, p. 184, 1889), at 22.30 only one small patch; distinct.
July 31 Königsberg, HAHN, very weak, none in August. Seen on 25 out of 45 clear nights of the summer of 1887.

1888

June 3 Königsberg, HAHN, aurora?
June 4 Ben Nevis, OMOND (Nat., vol. 38, p. 220, 1888), midnight, visible almost every clear night up to July 2.
June 12 Cornwall, BACKHOUSE (Nat., vol. 38, p. 197, 1888), faint.

June 14 Cornwall, BACKHOUSE, weak; growing fainter each summer since 1885.
June 22 Steglitz, JESSE (Met. Zs., Bd. 25, p. 369, 1888), now appearing $1\frac{1}{4}$ hours after sunset.
June 23 Steglitz, JESSE.
Stolp, V. REBEUR-PASCHWITZ (Met. Zs., Bd. 23, p. 369, 1888).
Königsberg, HAHN (Met. Zs., Bd. 24, p. 187, 1889), seen widespread over Europe, at least 7 different localities; brownish-gold at horizon.
Moscow, CERASKI (Met. Zs., Bd. 23, p. 369, 1888).
June 24 Königsberg, HAHN, stronger than on June 23. Also seen at Steglitz and Hamburg.
June 25 Königsberg, HAHN, clearly present. Also seen at Steglitz and Hamburg.
Sunderland, BACKHOUSE (Nat., vol. 38, p. 197, 1888), first very distinct display of the year.
June 26 Königsberg, HAHN, "black space" above.
July 1 Sunderland, BACKHOUSE (Weltall, 1928), 22.45, G.M.T., N.N.W. 67.
July 4 Königsberg, HAHN, through clouds.
July 4-5 Steglitz, JESSE.
July 5 Königsberg, HAHN, through clouds.
July 7 Königsberg, HAHN, weak; sun ring in afternoon.
July 15 Königsberg, HAHN, trace.
July 23 Königsberg, HAHN, trace deep on horizon; none in August.
Dec. — Puntas Arenas, STUBENRAUCH (Met. Zs., Bd. 24, p. 186, 1889), seen twice during the southern summer.
Beagle Channel (Astr. Nachr. No. 2885), seen several years ago. HAHN observed the clouds on 10 out of 31 clear nights in 1888.

1889

June 7 Dublin, ROWAN (Nat., vol. 40, p. 151, 1889), 22-24.
June 12 Steglitz, JESSE (Nat., vol. 43, p. 60, 1890), height 90 km.
June 22-23 Steglitz, JESSE (Astr. Nachr. Bd. 140, p. 161, 1896, long table of heights given for the years 1889-1891 determined by several station simultaneous photographs; range of mean heights 81-89 km., mean 82.08 ± 0.009 km.), 13.53 (B.M.T).
July 2-3 Steglitz, JESSE (Sitzber. Ak. Wiss., Berlin, p. 1031, 1890-91; Met. Zs., Bd. 25, p. 37, 1890; Weltall, 1928), 1.21-2.06 a.m.; dir. E.N.E. 68, velocities 94-177 meters/sec.
July 9-10 Steglitz, JESSE, 1.51 a.m., alt. 6.6°, dir. W.S.W. 106, velocity 57 m/sec.
July 24-25 Steglitz, JESSE, 2.47 a.m.
July 30 Copenhagen, PECHÜLE (Astr. Nachr., Bd. 126, Nr. 3002, p. 29, 1891). Midnight, band up to only $\frac{3}{4}°$ above horizon in north; a higher cloud in N.E.; one hour later, 5 E.-45 E., alt. 3°.
July 31-1 Steglitz, JESSE, 2.48 a.m.
Aug. 11 Lat. 48.5°N., Long. 34.4° W., VOGELSANG (Met. Zs., p. 440, 1889).
Aug. 18-19 JESSE (Met. Zs., Bd. 25, p. 38, 1890), seen in morning.
Lillelevdalen, STÖRMER (University Observ., Oslo, Pub. 6, p. 44, 1933).

1890

May 26 Steglitz, JESSE.

June 17-18 Sussex, M. E. (Nat., vol. 42, p. 198, 1890), 22.30-1 a.m., quite bright; purplish haze above, then white and finally yellow below.

June 17 Kingstown, ROWAN (Nat., vol. 42, p. 222, 1890), first conspicuous display of the summer.
Sunderland (BACKHOUSE), (Nat., vol. 42, p. 246, 1890).

June 25 Kingstown, ROWAN (Nat., vol. 42, p. 222, 1890), luminous forms now less definite and more nebulous than in former years.

June 29 Ben Nevis (ROWAN).

July 4 Aberdeen, ROWAN, alt. 30°, ending above in cirrus-like wisps.
Belfast, SHAW (Nat. vol. 42, p. 246, 1890), 22-, N.-N.E., alt. 15°, very storm-tossed, like scattered cirrus after a storm.

July 6-7 Urania, ARCHENHOLD (Weltall, 1928), 1.41 a.m., alt. 14°, dir. E.S.E. 114, mean velocity 46 m./sec.; 2.23 a.m., alt. 15°, dir. E.N.E. 64, velocity 79 m./sec.; 2.28 a.m., alt. 15°, dir. N.E. 54, velocity 84 m./sec.

July 9-10 1.29 a.m., alt. 15°, dir. N.N.E. 19, velocity 55 m./sec.

July 10-11 1.17 a.m., alt. 14°, dir. N.E. 46, velocity 71 m./sec., also seen at 22.34.
2.11 a.m., alt. 16°, dir. N.E. 60, velocity 40 m./sec.
2.29 a.m., alt. 24°, dir. E.N.E. 85, velocity 83 m./sec.

July 12-13 Copenhagen, PECHÜLE (Astr. Nachr. B. 136, p. 319, 1894), -24-, 60 W.-60 E., alt. 5°.

July 15-16 Sunderland, BACKHOUSE (Weltall, 1928), 2.36 a.m., G.M.T., alt. 24°, dir. N.W. 1, velocity 151 m./sec.

July 24-25 Steglitz, JESSE (Astr. Nachr., Bd. 140, p. 161, 1896), 2.22 a.m.

Oct. 27 Grahamstown (Astr. Nachr., Bd. 126, Nr. 3008, p. 123, Met. Zs., Bd. 27, p. 231, 1892), 19.45-20.32, in latitude 30°S. (Authenticity a matter of opinion).

1891

June 3 Kingstown, ROWAN, (Nat., vol. 44, p. 231, 1891).
June 7 " "
June 9 " "

June 25-26 Steglitz, JESSE, 1.24-2.10 a.m. (Astr. Nachr., Bd. 140, p. 161, 1896).

June 30 Sunderland, BACKHOUSE, dir. N.E.
Kingstown, 23.30-00.30 a.m., alt. 5°.

July 10-11 Copenhagen, PECHÜLE, trace early in evening.

July 11-12 Copenhagen, PECHÜLE (Astr. Nachr. Bd. 136, p. 319, 1894), -24-, 25 W.-25 E., alt. 1°, bright.

1892

May 17 Haverford (Met. Zs., Bd. 27, p. 414, 1892), in lat. 40°N. (according to a letter to Jesse).

July 24 Butterworth, LEY (Nat., vol. 46, p. 294, 1892), 21.35-22.35.

July 24-25 Ben Nevis (LEY).

July 24-25 Copenhagen, PECHÜLE (Astr. Nachr. Bd. 136, p. 319, 1894), 2 a.m., 30 W.-60 E., alt. 10°, brightest at 25°W.
Seen 10 times in 1892 and brightest Aug. 2-6 (Jesse).

1893

June 15 Kiel, LAMP (Astr. Nachr. Bd. 133, p. 131, 1893), 23 hrs.
16 Kiel, LAMP, 23 hrs.

July 8 Kiel, KREUGER.
Steglitz, JESSE, 22.30 N.W.

July 8-9 Copenhagen, PECHÜLE (Astr. Nachr. B. 136, p. 319, 1894), 23 hrs., at 24 hrs., 40 W.-15 E., alt. 7°, brightest at 10°W.; 1 a.m., 50 W.-0, alt. 15°, brightest at 25 W., white clouds at alt. 5°, and blue at alt. 15°.

1894

June 9-10 Copenhagen, PECHÜLE, -24, 40 W.-15 W., alt. 2°, a minimum at midnight and clouds at 00.30 at 35 W. and 1.5° alt.

July 12-13 Grunewald, ARCHENHOLD (Weltall, 1928), 1.59 a.m., alt. 14°, dir. E.S.E. 106, velocity 47 m./sec.
Four weak appearances in 1894 (JESSE).

1899

June 28 Linz, BAUERNBERGER (Met. Zs., Bd. 35, p. 419, 1900), 23 hrs., N.W., doubtful display.

June to
August Russia, HANN, (Met. Zs., Bd. 35, p. 182, 1900; Gaea, vol. 35, p. 634, 1889), fresh recurrence of several displays; brightest in the N.E. after midnight; seen weaker and infrequently during recent years.

1903

July 8 Sunderland, BACKHOUSE (Nat., vol. 59, p. 31, 1903), bright display; volcanic dust corona about sun all day.

1906

July 19 Sunderland?, BACKHOUSE (Nat., vol. 78, p. 127, 1908).

1908

May 27 Sunderland, BACKHOUSE (Nat., vol. 78, p. 127, 1908), a very feeble display.

June 29 Bristol, DENNING (Nat., vol. 78, p. 247, 1908), nights preceding June 29 unusually dark.
Russia, SHOENROCK, (Met. Zs., Bd. 43, p. 369, 1908), two observers state display seen on this date.

June 30-1 Russia, SHOENROCK, very brilliant and many observers; display seen in latitudes 45°-60°N., east longitudes 23°-48° for the displays of June 29-July 2. Most observers saw the display of June 30 in the north in some cases nearly to the zenith; colouration orange or reddish-orange or greenish; velocity 83 m./sec. from the east.[24]
Heidelberg, WOLF (Met. Zs., Bd. 43, p. 556, 1908), -24-, N., alt. 49°, dir. E., brightness of day at 1.15 a.m., due to lit cirrus-like clouds; thought the display due to a sinking cloud of dust; colouration brownish.

June 30-1 Berlin, GELLHORN (Met. Zs., Bd. 43, p. 365, 1908), positive identification not assumed, 22 hrs., greenish to bright blue above, then yellowish-red and finally brownish-red near the horizon.
Arnsberg, BUSCH (Met. Zs., Bd. 43, p. 314, 1908), 22.55, alt. 5°, entire twilight zone filled with noctilucent clouds; least possible height 52 km.; Bishop's rings the following day; exactly similar to the noctilucent clouds of 1885.
Krakau, KRASSOWSKI (Met. Zs., Bd. 43, p. 313, 1908), 22 hrs., (M.E.Z.) N.W.-N., bright with dirty yellow colouration; 23.15, alt. 90°, very bright and illuminating distant terrestrial objects.
Prague, BRAUNER (Nat., vol. 78, p. 221, 1908), 23-1.30 a.m. N.N.E.-N.E. alt. 20°-30°, orange to yellow colouration.
Bristol, DENNING, very strong glow over the north at midnight.

July 1 Russia, SHOENROCK, much weaker.
Berlin, GELLHORN, 22-24, much weaker.
Heidelberg, WOLF, dir. E., much weaker.
Arnsberg, BUSCH, light strongly polarized negatively.
Bristol, DENNING, many clouds of various tints at night; brilliant.

July 2 Bristol, DENNING, N., attractive coloured cloud scenery; weaker.
Berlin, GELLHORN, much weaker than on July 30.
Russia (SHOENROCK), weak.

1909

July 27-28 Dröbak, STÖRMER,[2] 23.

1910

June 24-25 Seebad Bansin, ARCHENHOLD (Astr. Nachr., Bd. 185, p. 87, 1910; Weltall, 1928), 22.30-1.30 a.m.

July 17 Wongrowitz, KORN (Weltall, 1928).
Berlin?, ARCHENHOLD, 22.05-22.35 (Weltall, 1928), alt. above Capella.
Seen after a wonderful red sunset.

1911

June 24 Bothkamp, SCHILLER (Astr. Nachr., Bd. 189, p. 71, 1911), seen on the nights of June 24 to July 9.

July 4-5 Heidelberg, WOLF (Astr. Nachr., Bd. 189, p. 15, 1911), 1.25 a.m., M.E.Z., 0N-8 E., alt. 6°, colouration from above to horizon was first bluish, then greenish, yellow ochre, brownish red and finally blood red at horizon the entire night.

July 11 Königsberg, BATTERMAN (Astr. Nachr., Bd. 189, p. 71; Met. Zs., Bd. 46, p. 416, 1911), 1.04 a.m., alt. 5°; like the clouds of 1885. Seen especially after midnight on the nights of July 11, 13, 14 and 15.

1914

June 27 Königsberg, BATTERMAN (Met. Zs., 1914), 22.45 L.M.T., N.N.W.-N.E., alt. 10°; -24-, alt. 5°.

July 1 Königsberg, BATTERMAN, -24-.
July 5 Königsberg, BATTERMAN, -24-.

1916

Aug. 25 Steckborn, MEYER (Met. Zs. Bd. 51, p. 517, 1916), 23.28, concavity of bands towards east.

1917-1918 (GUTENBERG,[16] ARCHENHOLD[4]).

1919 or 1920 (WEGENER, Met. Zs., Bd. 63, p. 404, 1925.)

1919, 1920 (GUTENBERG[16]).

1920

June 29-30 Germany, BOTTLINGER (Met. Zs., Bd. 55, p. 230, 1920), 1.30 a.m., N., alt. 6°-7°; 2 a.m., N., alt. 20°, dir. N.E. or N.N.E.; end of display at 2.50.

1932

July 1-2 Riga, MEYER, 00.20 E.E.T., alt. 25°44′ in N.N.W., least possible heights 51.7-55.3 km., colouration bright greenish-blue with yellow twilight horizon.[2]

July 7-8 Hanover, HARTMANN (Met. Zs., Bd. 49, p. 272, 1933), 1.45 a.m., alt. 30°, dir. N.N.E., glistening white cloud; 2.15 a.m., alt. 50°, dir. N.N.E., velocity 22 m./sec.; least possible height 25 km.

July 10-11 Oslo, STÖRMER, mean height 81.8 km. with range in values 74-92 km.; velocities 44-55 m./sec.[2]

July 13-14 Bergen, BJERKNES, 22-1.14, G.M.T., N.W.-N.E., alt. 10°, dir. E., velocity 90 m./sec. if height taken as 80 km.; colouration bluish-white and more greenish-white at the western and eastern ends; like ci. filosus and cicu. undulatus in mixed composition.[2]
Mehammersåta on Stord, Jelstrup, midnight, dir. N.E.; at 1.06 M.E.T. the clouds had moved far to the S.W.[2]

July 23-24 Darbu, HASSEL, 00.45 M.E.T., small faintly luminous cirrus-like clouds in N[2].

July 24-25 Oslo, STÖRMER, appeared some time after sunset and faded out in the dawn; mean height 81.1 km., range in values 75-85 km., dimensions of cloud waves 9 km.[2]
Darbu, HASSEL, brighter than on July 23-24.[2]

Aug. 8-9 Sollia (about 62°N. lat.), WISCHMANN, 1 hr. E.M.T., N.N.W., alt. 5°-10°, dir. E.; when first seen were feebly bluish-white, yellow later, and almost white when they disappeared at 3.30.

1933

July 12-13 Köln, MALSCH (Zs. f. ang. Met., H.8, 50 Jahrg., p. 255, 1933), 2.30 a.m. M.E.T., no stars could be seen; 2.45 a.m., N.W.-N.E., alt. 15°; least possible height 64 km., dir. N.E.-E., velocity greater than 80 m./sec.

Aug. 6 Ostseebad, SPANGENBERG, idem, p. 324, 22.10, N., alt. 34°, dir. W.. greenish-blue colouration, more whitish later; moved 76° in 20 minutes,

Sept. Ostseebad, SPANGENBERG, 22.15, alt. 12.5°, colouration greenish.(?)

(To be contined)