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WORLD METEOROLOGICAL ORGANIZATION

INTERNATIONAL NOCTILUCENT CLOUD OBSERVATION MANUAL

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of the World Meteorological Organization

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NOTE

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FOREWORD

At its fourth session (Brussels, 1965) the Commission for Aerology (now Commission for Atmospheric Sciences) noted the desire expressed previously at the third IQSY Assembly that regular observations of noctilucent clouds should be continued after the IQSY and adopted a recommendation on this subject. This recommendation, which was subsequently approved by the seventeenth session of the WMO Executive Committee, required that observations of noctilucent clouds be carried out and recorded in conformity with a uniform set of instructions to be published by WMO. The outcome of this recommendation is the International Noctilucent Cloud Observation Manual, which is contained in the present publication.

This manual is the result of an international collective effort. At the International Noctilucent Cloud Symposium held in Tallinn, Estonia in March 1966, a working group was formed to plan a single standard international manual to be used by all NLC observers. The decision was made to prepare a provisional version of this manual based on the second version of the Fogle (1965) manual, which contained many of the features of earlier manuals by Grishin (1957), Fogle and Gotaas (1963), Paton (1965), and Khvostikov, Willmann, and Grishin (1964). This provisional manual, published in late 1966 by the Special World Geophysical Centre for Noctilucent Clouds at Tartu, Estonia under the editorship of Dr. Ch. Willmann, was revised by Drs. Christie, Willmann and Fogle at the Noctilucent Cloud Working Group Meeting in Prague (May 1969). Dr. Fogle was assigned responsibility for making the agreed revisions to the manual and preparing the final version for publication by WMO in 1969. The nomograms and photographs in this manual were provided by Dr. Fogle of the National Centre for Atmospheric Research in Boulder, Colorado.

On behalf of the Organization I should like to thank all those scientists who have contributed to this publication and particularly Dr. Fogle. I am sure that this manual will succeed in improving both the quality and quantity of observations of these very interesting clouds.

D. A. Davies

D. A. Davies
Secretary-General

I. SUMMARY OF NLC CHARACTERISTICS

I.1 Introduction

Noctilucent clouds (abbreviated NLC), situated high in the atmosphere, are seen against the background of a dark sky while they are still illuminated by sunlight when the sun is well below the horizon. They frequently resemble cirrus or cirrostratus, often having a delicate filigree pattern, with marked wave structure. They have a considerable range of brightness and extent.

These clouds began to attract the attention of scientists in 1885; the first recorded observation, recognizing that they were an unusual and remarkable phenomenon, was made by T. W. Backhouse (1885) at Bad Kissingen, Germany, on June 8 of that year. Many other observations were made at about that time (E. Hartwig at Tartu; V. K. Tserasky in Moscow; O. Jesse in Berlin); in later years the number reported rose and fell, partly depending on the attention given to them by interested observers. The visual observation of noctilucent clouds is now being done on a routine basis at many of the meteorological stations in the northern and southern hemispheres between 45° and 90° latitude, and the observational data are collected at three centres—Edinburgh, Scotland; Tartu, Estonia, and Toronto, Ontario. These data are used to obtain a better understanding of the climatology of NLC. Over a thousand occurrences of NLC are on record so far, and while many of their characteristics have been studied, much remains to be learned. In the following sections of Part I the current descriptive and analytical information on NLC are reviewed, and in Part II instructions for their uniform observation and recording are given.

I.2 Colour

The colour of NLC is usually bluish-white. The spectrum of these clouds is similar to that of daylight with the Fraunhofer lines clearly present and no emission lines (Störmer, 1933; Grishin, 1956). This indicates that the light from NLC is scattered sunlight and that the cloud particles scatter better in the blue than in the red. Polarization measurements (Witt, 1960; Willmann, 1962) show that the light from NLC is polarized.

The clouds are usually tenuous and of low brightness. However, they are occasionally bright enough to cast shadows and permit the reading of printed matter outdoors.

I.3 Structure, morphological forms

The structure present in NLC may be divided into the following five different forms: veils, bands, billows, whirls and amorphous. A detailed description of these forms is given in section II.8.

I.4 Height

Over the past 80 years, hundreds of height measurements have been made (Jesse, 1896; Störmer, 1935; Witt, 1962; Paton, 1949; Khvostikov, 1952; Burov, 1959, 1966; Dirikis, Evdokimenko, Franzman, 1966). The values range from 74 to 92 km, the average being 82 (Burov, 1959; Fogle and Haurwitz, 1966). The 82 km level agrees closely with that of the mesopause where the air temperature has its second minimum value.

The method generally used in determining the height of NLC is that of parallactic photography. In this method, simultaneous photographs of NLC are taken from the end points of a base line of about 40 km. The parallax between identical points in corresponding photographs is measured and from this the height is obtained. This method of height determination is described in detail by Störmer (1935), Burov (1959) and Witt (1962). A considerable improvement and simplification of this method has recently been made by Koening and Brandy (1965).

The recently developed optical radar which utilizes a laser beam may greatly simplify the measurement of the thickness and height of NLC (Fiocco and Smullin, 1963).

I.5 Observing conditions

While NLC are generally observed during the twilight periods when the sun is between 6° and 16° below the observer's horizon, the optimum solar depression angle (SDA) for their visibility is around 10° (Fogle, 1968). When the SDA is less than 6°, the sky background is too bright for a moderate display to be observed, and when the SDA is greater than 16°, the 82 km level where the clouds are formed is no longer illuminated by the sun's rays. Bright NLC are detectable when the SDA is between 2° and 6°, but it is difficult to distinguish them from high cirrus at such times. Below 60° latitude there is an interval of time every day of the year when the SDA is greater than 6°, but as one proceeds polewards of this latitude, there are periods when the sun does not sink below this value, and NLC cannot be seen.

I.6 Latitudes of observation

In the northern hemisphere, the lowest and highest latitude sightings of NLC were made from 45°N and 80°N respectively, but most of the observations have been made over the latitude range of 50°N to 65°N. Based on the observational data from the U.S.S.R. and North America, the frequency of occurrence of NLC as a function of latitude shows that the optimum latitude for seeing the clouds is around 58° (Pavlova, 1960; Fogle, 1968).

In the southern hemisphere, the latitude for observing NLC appears to be similar to that in the northern hemisphere. Reliable reports of southern hemisphere NLC have been made over the latitude range of 51°S to 70°S (Fogle and Haurwitz, 1966). However, southern hemisphere reports are far fewer in number than for the northern hemisphere, owing to the relative scarcity of land and people and the poor observing conditions in the 50°S-70°S zone.

No reliable reports of naturally occurring NLC from places below 45° have been received* and it seems likely that these clouds do not extend to such low latitudes. Astapovic (1958) reported that a watch for NLC during 700 cloudless summer nights from Askhabad, Russia (37.5°N, 58.3°E) gave no sightings. A careful watch kept at Hanover,

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* Artificial noctilucent clouds

Over the past few years there have been over a dozen sightings of artificial NLC (Meinel et al., 1963) at latitudes below 45°. These clouds have been associated with rocket launchings from the Point Magu Missile Range at 34°N, 118°W. Most of the sightings have been correlated with launchings of the SCOUT missile, which has a solid propellant and burns high into the atmosphere. The exhaust products of the SCOUT missile are rich in water vapour and solid particles, and it appears that these substances are introduced into the mesopause region in sufficient amount to create artificial NLC. When the winds are toward the east, the clouds drift over Arizona where Meinel has observed them.

New Hampshire (43.7°N, 72.3°N) during the summers of 1963 and 1964 also resulted in no sightings, although a number of displays were observed from higher latitudes during the same period (Fogle and Haurwitz, 1966). These results, along with an analysis of the area over which NLC have been seen, indicate that the zone of occurrence of NLC is symmetric about the geographic rather than the geomagnetic pole. If the clouds were symmetrical about the geomagnetic pole, then they would have been observed at lower geographic latitudes in North America than in the U.S.S.R. More information on this feature is, however, desirable.

The data obtained at Edinburgh, Scotland (56°N) over the past 15 years show that NLC have been observed there later than August 2 on only one occasion (Paton, 1967), while they have often been observed from Torsta, Sweden (63.3°N) and College, Alaska (65°N) in late August. These results, along with the apparent latitude dependence of the peak of NLC activity (Fogle, 1968), suggest that the clouds recede polewards in late summer, but more data from the networks of observing stations will be needed before this can be established with certainty. Complicating the determination of the true variation of NLC activity with latitude is the marked variation of observing time with latitude (see section II.5).

I.7 Season for observation

In the northern hemisphere, NLC have been reported as early as March and as late as October, but they have been observed most frequently during the summer months of June, July and August. The frequency distribution of recorded NLC sightings (from 1885 to 1964) as a function of season shows that the majority of sightings were made after the summer solstice with the peak of activity occurring during the first half of July (Bessonova, 1963; Fogle and Echols, 1965; Fogle, 1968).

Based on the limited available data (around twelve reliable reports), southern hemisphere NLC also appear to occur predominantly during the (austral) summer months of December, January and February with the peak of activity occurring in early January, shortly after the austral summer solstice (Fogle and Haurwitz, 1966).

I.8 Spatial extent

At an altitude of 82 km a circular area of about 1,000 km in radius is theoretically visible from the ground, but only a part of this can be illuminated by sunlight against a dark sky. In the case of small NLC displays covering an area of a few tens of thousands of km^2 the whole boundary may be visible from a station. Occasionally extensive NLC displays occur and are observed from many stations over a wide range of latitudes and longitudes. The spatial extent of these widespread displays are sometimes in excess of two million km^2. This does not mean, however, that there is a continuous sheet of NLC over such areas. In general during NLC displays there are areas of clear sky separating discrete patches of NLC, and even in a given patch, particularly one containing bands, there is often a considerable range of brightness. It is possible that NLC might at times cover all longitudes around the pole and have an area of the order of $10^8 km^2$; but this if true would be difficult to establish by observations of the kind so far available, because they are restricted to twilight, and only stations in a sector of about 120° in longitude can see them at the same time. Spatial extent studies could be extended by satellite observations from an appropriate orbit.

I.9 Duration

The observed duration of NLC varies from a few tens of minutes to more than 5 hours. Sometimes extensive NLC are seen on two or more successive nights, but whether they are parts of a distribution that is continuous throughout the intervening day-times is uncertain. Since observations of these clouds are confined to the twilight hours, it is not possible at present to determine whether they form or disappear during day-time.

I.10 Drift motion

The evidence now suggests that the drift motion of NLC may only be estimated from measuring successive positions of the cloud envelope rather than by tracking local high-intensity areas which more likely represent wave motions. However, information obtained from studies of internal structure may have direct application to the understanding of internal gravity waves.

Drift motion studies show that, in the northern hemisphere, NLC displays as a whole generally drift toward the south-west at average speeds of 40 m/sec, and that the band and billow structure often move at speeds and in directions different from the whole display (Witt, 1962; Fogle and Haurwitz, 1966). Studies of the limited southern hemisphere data show that NLC displays there generally move toward the north-west at speeds similar to that in the northern hemisphere (Fogle, 1964, 1965; Fogle and Haurwitz, 1966). Time-lapse photography of NLC is very useful in studying the motion and morphology of NLC.

I.11 Particle size and number density

Polarization measurements (Witt, 1960; Willmann, 1962) have shown that the average diameter of NLC particles is about 0.3 microns and that the particles probably consist of stony dust of meteoric origin or of ice-coated dust particles. Efforts to obtain more detailed information on the size, distribution, number density and composition of NLC particles using rocket-borne sampling techniques have been underway since 1962, but as yet these experiments have not produced definitive and unambiguous results (Witt, Henemway and Soberman, 1964; Soberman, Chrest and Carnevale, 1969).

I.12 Theory

A satisfactory theory of NLC must explain why they occur at or near the mesopause, apparently only in summer and in latitudes above 45°, how they are formed, why they are present only on some nights and not on others, why they are thin and why they generally last for some hours.

The earliest sightings (1885) came when dust from the great volcanic eruption at Krakatoa had become dispersed over the globe, producing sunsets of unusual brightness and splendour. This led to the sky being more widely observed at that time, but statistics show that there is no apparent correlation of NLC occurrence with volcanic activity, comets, meteor shows (Vestine, 1934) or the sunspot cycle (Fogle and Haurwitz, 1966). A series of temperature measurements of the high latitude mesopause during winter and summer months and during the presence and absence of NLC have shown that the high latitude mesopause temperature is much lower in summer than in winter, but there is no appreciable difference during the presence and absence of NLC in summer months (Theon et al, 1967). These results suggest that while a low mesopause temperature may be a necessary condition for NLC formation, it is not a sufficient condition, and some other factors probably influence cloud formation.

The low mesopause temperature when NLC are present along with the results of some of the particle sampling experiments support the view that the clouds consists of ice-coated extraterrestrial dust particles and that the conditions for their formation are a low temperature and the presence of adequate water vapour and dust nuclei at the mesopause.

Several hypotheses of NLC formation based on the above considerations have been made. One of these, widely held by many authors (Webb, 1965; Charlson, 1966; Hesstvedt, 1969), is that vertical motions of around 20 cm/sec, which is considerably higher than the average value of 1 cm/sec determined by Murgatroyd and Singleton (1961), occur near the high-latitude mesopause on occasion during summer, and that these updrafts (1) impede the descent of dust particles and possibly carry such particles upwards from below, thereby causing increased particle concentration at the mesopause, and (2) they transport to the mesopause sufficient water vapour to supersaturate the layer and produce ice-coated dust particles. A somewhat different view advanced by Chapman and Kendall (1965) assumes that: (1) the increased particle concentration at the mesopause is caused by the turbopause descending from about 110 km down to the mesopause; and (2) if ice coating of particles occurs, the supersaturation at the mesopause is due to sufficient water vapour being transported from below by updrafts of about 1 cm/sec, as determined by Murgatroyd and Singleton. A more recent suggestion by Christie (1969) is that NLC are caused by local increases in the vertical turbulent transfer near the high-latitude mesopause in summer. These increases in vertical turbulent transfer, assumed to be generated by internal gravity waves originating in the tropospheric jet stream, could produce a supersaturated mesopause and cause NLC. Further data on NLC and the region where they form is required to test the validity of these views.

Most of the band and billow structure frequently observed in NLC is indicative of wave motion. Theoretical considerations suggest that NLC bands are produced by internal gravity waves and that NLC billows may also be produced in this way (Hines, 1959; Haurwitz, 1964; Fogle and Haurwitz, 1969). However, more data are needed on the temperature and wind distribution near the mesopause when NLC are present before the causative mechanism for NLC wave structure can be established with certainty.

I.13 Research on related problems

In order to achieve a better understanding of the nature of noctilucent clouds and how they form, more information is required on related problems such as: (1) wind and temperature distribution at the NLC level; (2) the source and concentration of water vapour at the heights; (3) the mechanism causing the dust concentration at the mesopause to increase on some occasions and not on others, and (4) the height of the turbopause when NLC are present. Also useful would be additional information on: (1) photochemical processes at the mesopause; (2) condensation processes at low temperatures; (3) OH rotational temperature studies, and (4) the sodium layer.

II. INSTRUCTIONS FOR NOCTILUCENT CLOUD OBSERVATIONS

II.1 Purpose of world-wide observations of NLC

The main objectives of the world-wide observations of NLC are to: (1) determine the diurnal, seasonal, geographical, spatial and temporal distribution of NLC; (2) search for periodicities in their occurrence; (3) examine the geographic distribution of billow and band morphological forms in relation to features of the underlying terrain and wind shear, and (4) compare NLC occurrence with other upper-atmospheric phenomena.

II.2 Months of observations

In the northern hemisphere, NLC observations should be made each night from the beginning of March to the end of October. In the southern hemisphere, the observation period is from the beginning of September to the end of May. Although no well-documented NLC sightings have been made during the winter, observers are urged to continue their watch during this period to ensure that no display, however improbable, is ignored.

II.3 Selection of observing post

The observing post selected should: (1) have an unobstructed view of the horizon toward the twilight sector of the sky (that is, SE through N through SW in the northern hemisphere and NE through S through NW in the southern hemisphere); (2) be away from bright lights, and (3) be the same for the entire period of observation.

II.4 Detection and identification of NLC

When bright, well-developed NLC displays are observed under clear-sky conditions, identification is easy, even by an inexperienced observer.

Difficulties arise in identifying NLC when they are faint and lack structural detail. The identification problem is made more difficult when much of the sky is obscured by tropospheric clouds.

To avoid mistaken identification, the observer should in doubtful cases check to make sure that the object is not an aurora or a sunlit or moonlit tropospheric cloud or contrail.

The following comments will serve as useful aids in identifying NLC: (1) NLC are always brighter than the twilight sky, therefore clouds which stand out as dark silhouette against the sky background cannot be NLC. (2) Tropospheric clouds when illuminated by the moon, city lights, or light scattered from the bright part of the sky may appear brighter than the sky background when the latter is fairly dark. These clouds can usually be distinguished from NLC by their colour and form. They are milky-white whereas NLC are bluish-white, and unlike NLC these clouds will continue to be visible during civil twilight and after sunrise. (3) Cirrus clouds illuminated by the sun when it is below the horizon are usually coloured yellow, orange and pink. Clouds having these colours usually are not NLC.

To gain familiarity with the colour and form of NLC, the observer should study carefully the photographs at the end of this manual. If the station personnel includes a person who has seen NLC, and he happens to sight them, it is important that he gathers all the other observers to show them NLC under natural conditions.

II.5 Visual observations

NLC observations should be made at 15-minute intervals throughout the part of the twilight when the sun is between 6° and 16° below the observer's horizon. The times when the SDA is within this range varies markedly with time of year and station latitude (see Figure 1). Observers in the northern hemisphere may determine for their stations the approximate times for SDA — 6° to 16° — from the accompanying nomograms. (see Figures 2-17). Observers in the southern hemisphere will need to change these nomograms so that January reads July, February reads August, etc. (that is, a six-month shift of the time axis) in order to determine the observation times for their stations. The nomograms of NLC observation times are given in local mean time (LMT)*.

Observations are made in standard meridian time (SMT)*, or universal time (UT)— which is the standard meridian time at 0° longitude.

To convert LMT to standard meridian time (SMT) use the following equation.

$$SMT = LMT \pm CD$$

where C = 4 minutes per degree of longitude.

D = Difference in degrees of longitude of station and standard meridian. D is always positive. The plus sign is used before CD when the station is west of the standard meridian and the minus sign when it is east.

Alternatively to convert LMT to UT use the expression:

$$UT = LMT + CD$$

where C = 4 minutes per degree of longitude.

D = Difference in degrees of station longitude and 0° longitude. The plus sign is used before CD when the station is west of 0° longitude and the minus sign when it is east.

Example: Find SMT and UT for station FORT SMITH, NORTH WEST TERRITORIES (60°01'N, 111°58'W) when the LMT of the initial observation as obtained from the nomogram for the appropriate latitude (Figure 9) and date is 2100 LMT.

$$\text{Longitude} = 111°58'W = 105° + 6°58'$$

$$SMT\ (105) + LMT + (6 + \tfrac{58}{60})\ .4 = 21 \text{ hours} + 27.9 \text{ min} = 2128.$$

6° increasing SDA: $UT = LMT + (111 + \frac{58}{60})\ .4 = 21 \text{ hrs} + 7 \text{ hrs } 27.9 \text{ min} = 0428$

6° decreasing SDA: $UT = LMT + (111 + \frac{58}{60})\ .4 = 03 \text{ hrs} + 7 \text{ hrs } 27.9 \text{ min} = 1028$

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* Local mean time is the time defined so that the mean sun is due north relative to that particular observing location at local midnight.

Beginning at the quarter-hour directly preceeding the 6° solar depression angle time for the particular station and date when converted to SMT or UT as shown above and at 15-minute intervals thereafter, the observer should carefully scan the twilight sector to determine the presence or absence of NLC, and to estimate the amount of tropospheric clouds obscuring the twilight sector (see section II.5.8). In the example shown above this would imply that observations would be taken at the following times:

0415 universal time
0430 " "
0445 " "
:
1015 " "
1030 " "

Observations should be recorded in a special log similar to form 1 of this manual as itemised below by columns.

II.5.1 - 5.11 Instructions how to complete form 1

II.5.1 Column 1. Date (local time). Enter the dates of the evening and morning twilights that represent a local overnight observation period: e.g. July 25/26.

If more than one night's observations are recorded on the same form, the observer must leave two lines blank, and enter the next date couplet in the next column 1 position.

II.5.2 Column 2. Time (universal time). Enter the time of observation in universal time beginning with the quarter-hour directly preceeding the time that the solar depression angle (SDA) increases to 6 degrees. (In the case of stations where the standard meridian time differs from universal time by more than half the interval between the 6° SDA increasing and the 6° SDA decreasing times, all observations recorded will occur in a sequence from only one day of the date couplet. See example above.)

If another time system (e.g. local standard time or local mean time) is preferred, this should be clearly noted in the log.

II.5.3 Column 3. Presence of noctilucent clouds. Enter "No" if the observer can see no NLC after carefully scanning the twilight sector of the sky. Enter "Yes" if NLC is detected and clearly identifiable, and "Yes?" if a luminous area resembling NLC, but which cannot be positively identified as such, is noted. In the latter case the observer should comment on his doubts about identification in the remarks column 12 (see below).

II.5.4 Columns 4 to 9. These columns will be left blank when NLC has not been detected and "No" has been entered in column 3.

* Standard meridian time is equivalent to local mean time only at the meridian, and since the same standard meridian time is used for convenience for 15-degree longitude belts, and there exist SMT values for 0, 15, 30 degrees longitudes and upwards at 15-degree intervals, a correction is necessary to express the LMT at any point between these meridians in terms of the station longitude.

II.5.5 Columns 4 to 7. Delineation of cloud area. Columns 4 and 5 represent the azimuth of the left and right borders of the observed NLC. If a theodolite or transit is not available for measuring angles, the observer should use easily recognisable landmarks to estimate the direction, and these are recorded in degrees measured clockwise from geographic north.

Columns 6 and 7 represent the elevation, measured upwards from the horizon, of the lower and upper borders respectively of the observed illuminated NLC. These may be estimated by using a clinometer or a stick notched such that when held at arm's length, the distance between successive notches corresponds to 5°.

II.5.6 Column 8. Brightness. Enter the value indicating the brightness of the NLC (see photographs for examples) according to the following 5-point scale.

(1) Very weak NLC, barely visible against the background of the twilight sky, detected only through very careful examination of the sky;

(2) NLC easily detected, but having low brightness;

(3) NLC clearly visible, standing out sharply against the twilight sky;

(4) NLC very bright and attract attention;

(5) NLC extremely bright and noticeably illuminate objects facing them.

II.5.7 Column 9. Morphological forms. Enter the type(s) and group(s) of cloud structure observed in the NLC using the classification system shown below (see photographs for examples).

Type I. Veils: These are very tenuous, lack well-defined structure and are often present as a background to other forms. They resemble cirrus clouds, occasionally contain faintly fibrous structure, and often exhibit a flickering luminosity. Veils are the simplest form of NLC and often precede (by about half an hour) the appearance of NLC with well-defined structure.

Type II. Bands: These are long streaks, often occurring in groups arranged roughly parallel to each other or interwoven at small angles, but occasionally an isolated band is observed. Two groups of this type occur:

II.a, are comprised of streaks with diffuse, blurred edges,

II.b, have sharply defined edges.

Bands show little change in location at low elevation angles, but changes in brightness can occur in periods of 20 to 60 minutes within the general stucture. Blurred bands with little mobility are often the predominant structure in the NLC field, particularly when the brightness is low. Smaller streaks with twists or bends may lie across the bands or branch out from them. Distances of 10 to 60 km separating successive bands are common (Haurwitz and Fogle, 1969) and values of over 100 km have been reported.

Type III. Billows: These are arrangements of closely spaced, roughly parallel short streaks. The distance separating adjacent billows ranges from about 1 to 10 km. Billows sometimes lie across the long bands, giving the appearance of a comb or feather. At other times they appear alone against the veil background. The billows may change their form and arrangement, or appear and disappear within several minutes or tens of minutes, much more rapidly and frequently than the long bands. This NLC type also may be divided into two groups:

III.a, are comprised of short, straight and narrow streaks;

III.b, exhibit a wave-like structure with undulations.

Type IV. Whirls: These are partial or, on rare occasions, complete rings of cloud with dark centres, and may indicate the presence of turbulence near the mesopause. They are sometimes seen in veil, band and billow forms. Three subgroups may be observed:

IV.a, are comprised of whirls of small radius of curvature (0.1 to 0.5°), and may appear as small bright crests looking somewhat like light ripples on a water surface;

IV.b, have the form of a simple bend of one or several bands with a radius of curvature of 3-5°;

IV.c, have a large-scale ring structure.

Type V. Amorphous: These are similar to veils in that they have no well-defined structure, but they are brighter and more readily visible than the veil type.

In complex displays, two or more forms may be seen simultaneously, and it is not unusual for two intersecting groups of long bands to occur, and these give rise to bright knots where the waves cross.

II.5.8 Column 10. Tropospheric cloud cover of the twilight sector. Enter the amount of cloud cover in the direction of the twilight sector of the sky according to the following classification:

(a) The twilight sector is completely clear of tropospheric clouds;

(b) The twilight sector contains scattered cloud or thin, high transparent cloud such as cirrostratus:

(c) Only part of the twilight sector is visible through breaks in tropospheric clouds;

(d) Twilight sector completely overcast or obscured by fog.

II.5.9 Column 11. Total amount of cloud and types present. Enter, in tenths of the whole sky, the amounts and types of each layer of clouds occurring in ascending order. In determining the amount of cloud in layers above the lowest, enter only the amount actually seen, not what is estimated to be hidden by the lower layers. In this way the total cloud amount will never exceed 10/10.

Cloud types will be entered using the appropriate abbreviation as listed below. When two or more types of cloud are observed at the same level, enter only the one which has the greatest amount.

Clouds	Abbr.	Clouds	Abbr.
Altocumulus	AC	Cumulus	CU
Altocumulus castellanus	ACC	Cumulus congestus	CU+
Altostratus	AS	Cumulus fractus	CF
Cirrocumulus	CC	Stratus fractus	SF
Cirrostratus	CS	Nimbostratus	NS
Cirrus	CI	Stratocumulus	SC
Cumulonimbus	CB	Stratus	ST

(The cloud classification is that described in The International Cloud Atlas.)

II.5.10 Column 12. Remarks. Enter comments required when "Yes?" has been entered in column 3. See following examples:

(1) Possible fog (or low cloud) over bright lighting;

(2) Possible aurora;

(3) Possible moonlight (or sunlight) on cirrus;

(4) Only small patches of twilight sector visible, identification not clear;

(5) Observation outside expected times of suitable illumination.

II.5.11 An example of a completed day's report is shown below (page 12).

II.6 NLC photography

Photographs of NLC are a valuable supplement to visual observations and should be taken whenever possible. If a camera is not available to the observer, sketches of the NLC should be made. Details on the photography of NLC are given in Appendix 2.

II.7 Aircraft observations

Ground-based observations of NLC are often hampered by considerable tropospheric cloud cover, but observers in high-flying aircraft do not have this problem. Thus, airborne observations of NLC are of great value, and pilots flying during the twilight hours are strongly urged to keep watch for these clouds and report their results using the standard log form or a form similar to that shown below. At the end of the flight, the reports should be sent to one of the NLC data centres or given to the meteorological officer for forwarding to one of the centres.

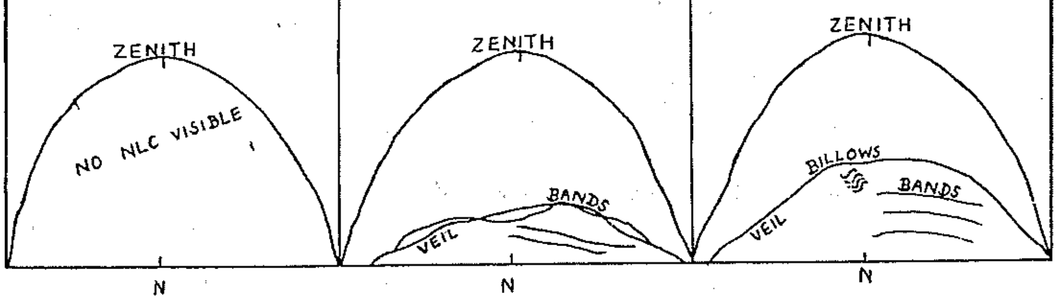
NOCTILUCENT CLOUD OBSERVATIONS

STATION PRINCE ALBERT
PROVINCE SASKATCHEWAN
INDEX NUMBER 72869
(5 figs)
YEAR

DATE	TIME OF OBSERVATION hr min	PRESENCE OF NOCTILUCENT CLOUDS yes no	NOCTILUCENT CLOUD INFORMATION: AZIMUTH LEFT BORDER °	AZIMUTH RIGHT BORDER °	ELEVATION LOWER BORDER °	ELEVATION UPPER BORDER °	BRIGHTNESS 5 POINT SCALE	MORPHOLOGICAL FORMS	TROPOSPHERIC CLOUD: COVERAGE OF THE TWILIGHT SEGMENT LETTER CODE	GENERAL TOTAL AMOUNT OF CLOUD AND TYPES PRESENT	REMARKS
1	2	3	4	5	6	7	8	9	10	11	12
Aug. 12/13	0300 Z	No	—	—	—	—	—	—	C	4 Ac	
	0315	No	—	—	—	—	—	—	C	4 Ac	
	0330	No	—	—	—	—	—	—	C	3 Ac	
	0345	No	—	—	—	—	—	—	A	2 Ac	
	0400	YES	340	250	55	0	1-2	I	B	2 Ci	
	0415	YES	350	250	60	0	2	II a	A		
	0430	YES	360	260	60	0	2	II a	B	3 Ci	
	0445	YES	010	270	50	0	2	II a	A	2 Ci	
	0500	YES	020	270	45	0	2	IIa, IIIa	B	1 Sc 2Ci	
	0515	YES	020	290	40	0	2	IIa, IIIa	B	2Sc2Ci	
	0530	NO	—	—	—	—	—	—	B	2Sc2Ci	
	0900 Z	YES	050	310	40	0	2	II a	A	3 Sc	
	0915	YES	070	300	50	0	2-3	IIb, IIIa	A	2 Sc	
	0930	YES	080	290	65	0	2-3	IIb, IIIa	A	2 Sc	
	0945	YES	090	290	80	0	3	II b	C	2Sc 2Ac	
	1000	YES	090	300	80	5	3	II b	C	2Sc 2Ac	
	1015	YES	090	300	75	5	3	III b	C	3 Ac	
	1030	YES	090	310	80	10	3	III b	C	2Sc 3Ac	
	1045	YES	100	310	75	10	2-3	II b	C	3Sc 4Ac	
	1100	YES	100	300	75	25	2	II a	C	3Sc 5Ac	NLC INVISIBLE AGAINST BACKGROUND
	1115	NO	—	—	—	—	—	—	C	3Sc 4Ac	

Alternate form for reporting aircraft observations of NLC

Time	2345 UT	Time	0030 UT	Time	0100
Latitude	58°N	Latitude	59°N	Latitude	60°N
Longitude	24°W	Longitude	26°W	Longitude	29°W
Height	35,000 ft	Height	33,500 ft	Height	35,000 ft
NLC brightness		NLC brightness	1	NLC brightness	3



III. INSTRUCTIONS FOR INTERNATIONAL DATA EXCHANGE

III.1 Procedure for submission of data to collection centres

All participating stations and institutions should send the monthly logs (form 1) or the punch-cards of their observations to one of the data collection centres not later than two months after the observations were conducted. Forms may be reproduced locally. Results of observations conducted on expeditions to remote regions should be reported as soon as possible after the expedition returns.

III.2 Collection centres for NLC data

The collection centres for NLC observational data are:

(1) The Special World Geophysical Centre (SWGC),
Attn. Dr. Ch. Willmann,
W. Struve Astrophysical Observatory of Tartu,
Academy of Sciences, Estonian S.S.R.,
U.S.S.R.

(2) ATMOSPHERIC ENVIRONMENT SERVICE
4905 DUFFERIN STREET,
DOWNSVIEW, ONTARIO
M3H 5T4
CANADA
Attn: Dr. A. D. Christie

(3) Department of Meteorology,
Attn. Professor J. Paton,
University of Edinburgh,
Edinburgh 8, Scotland.

III.3 Exchange of data

The centres will exchange raw data on request, preferably using punch-cards or magnetic tape. They will also publish annual summaries of the data received from their respective areas of responsibility not later than June 1 of the year following that in which the observations were made. These summaries will be distributed to all interested scientists.

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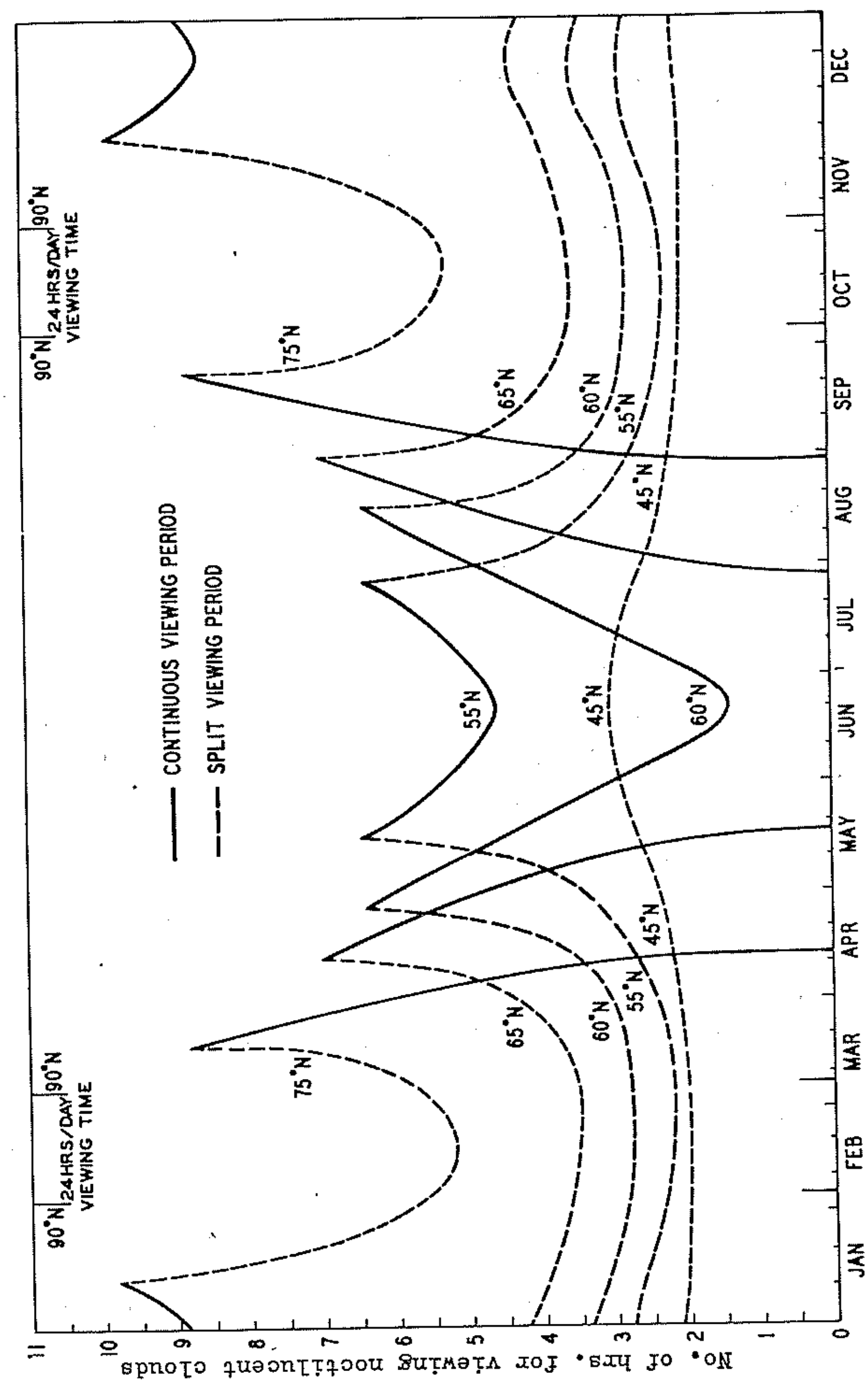


Figure 1 - Variation of NLC observing period with latitude and season

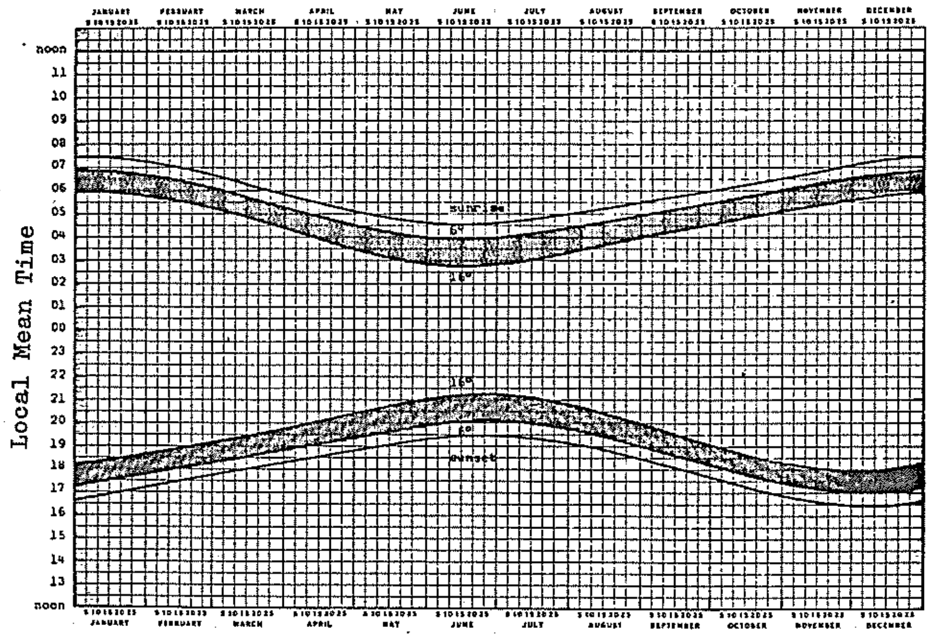


Figure 2 - NLC observation periods for 40°N

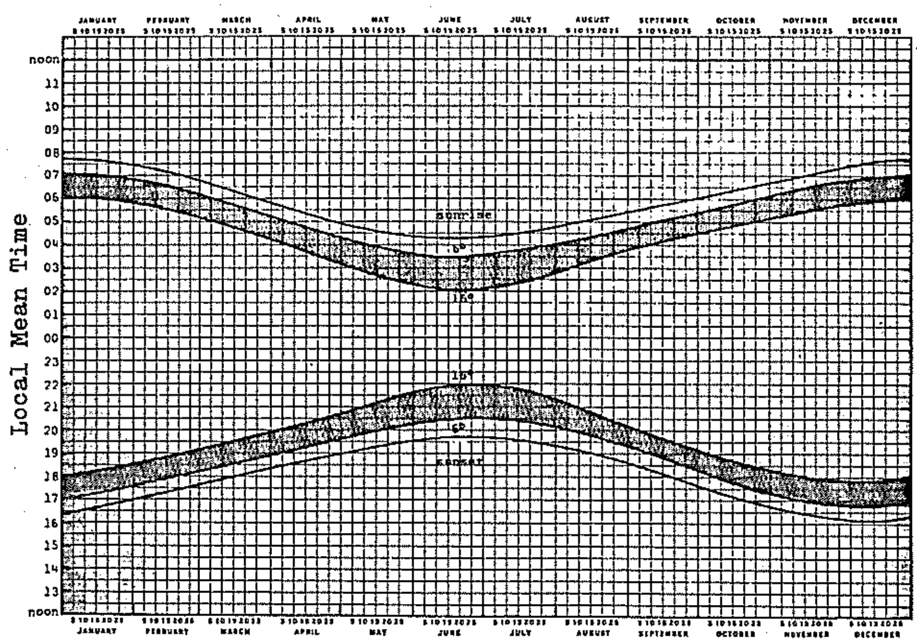


Figure 3 - NLC observation periods for 45°N

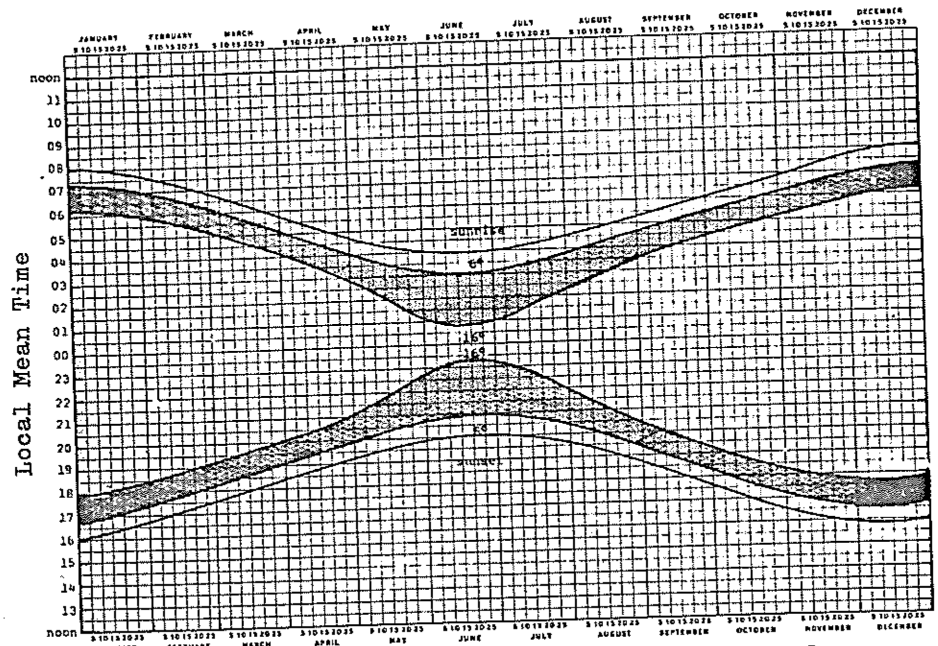


Figure 4 - NLC observation periods for 50°N

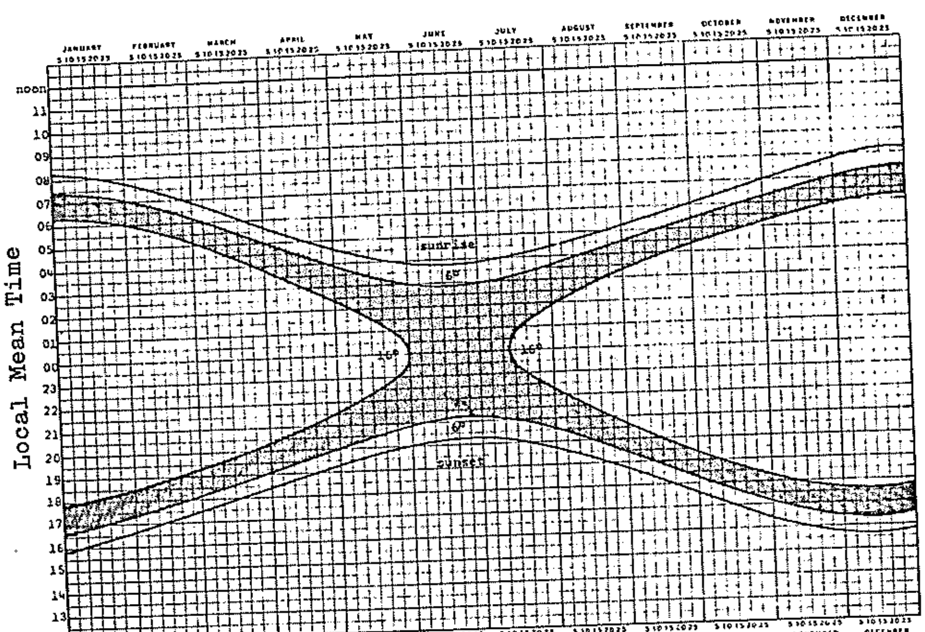


Figure 5 - NLC observation periods for 52°N

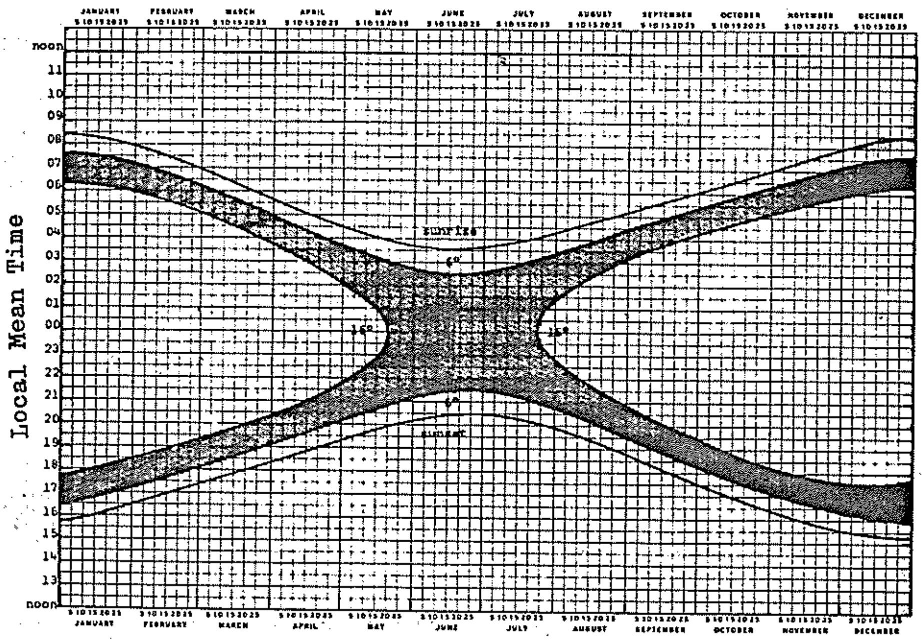


Figure 6 - NLC observation periods for 54°N

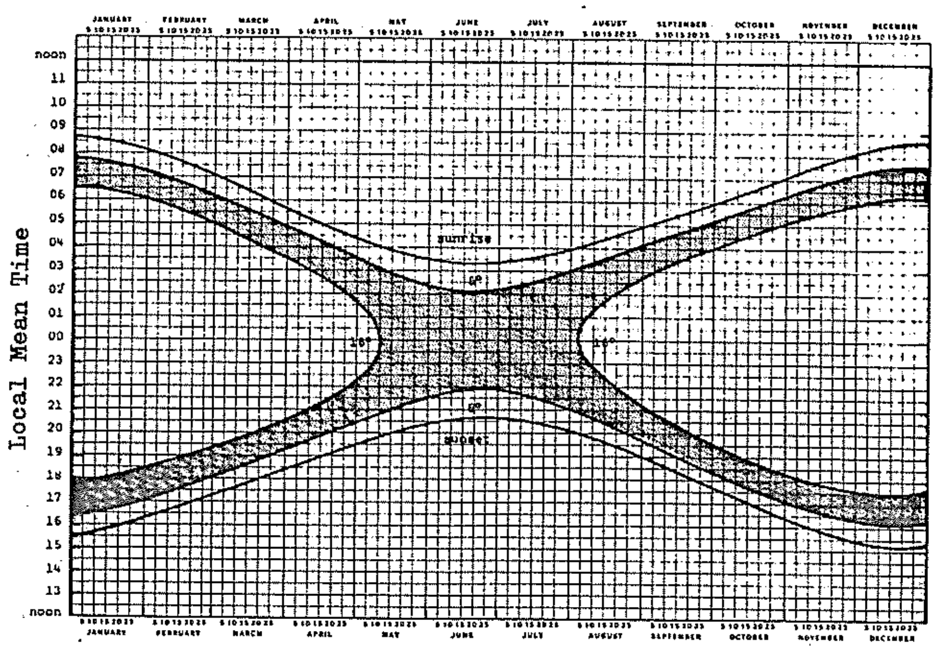


Figure 7 - NLC observation periods for 56°N

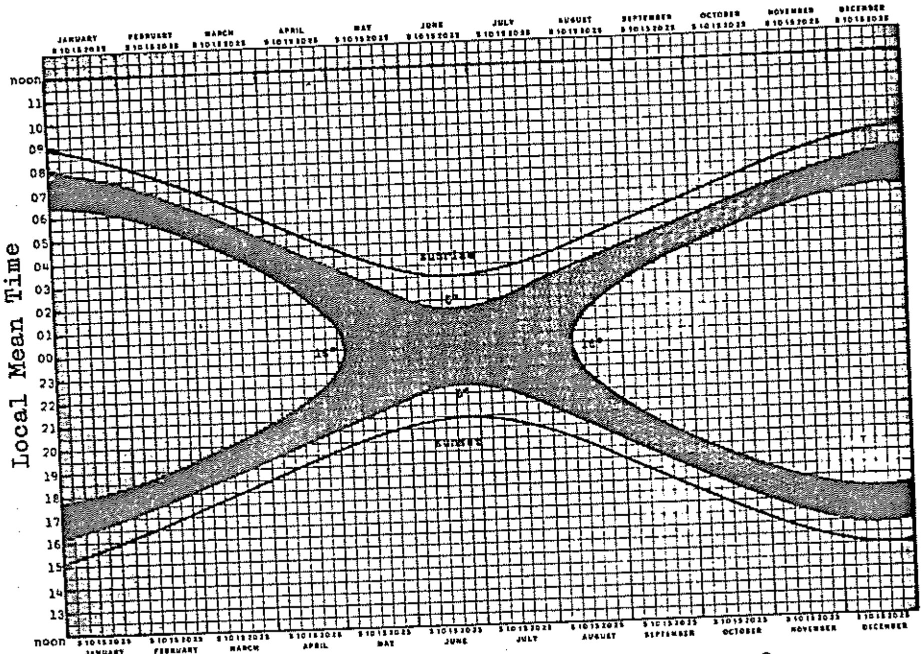


Figure 8 - NLC observation period for 58°N

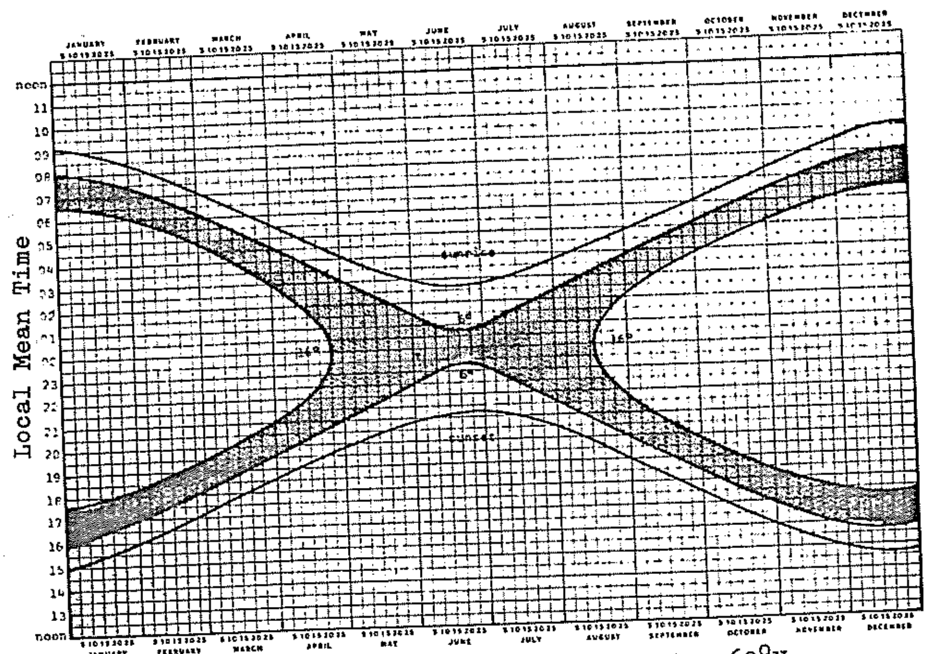


Figure 9 - NLC observation period for 60°N

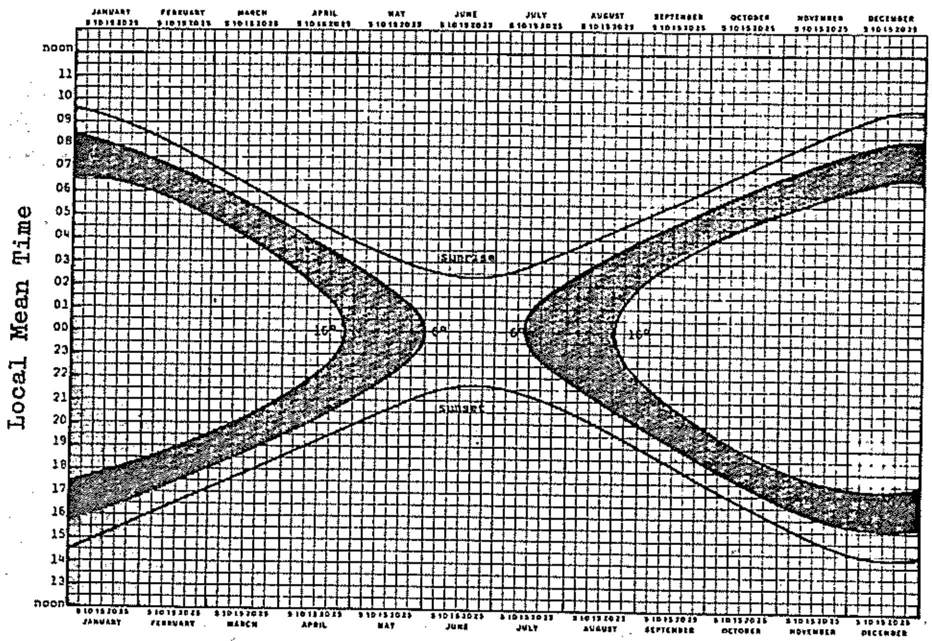


Figure 10 - NLC observation periods for 62°N

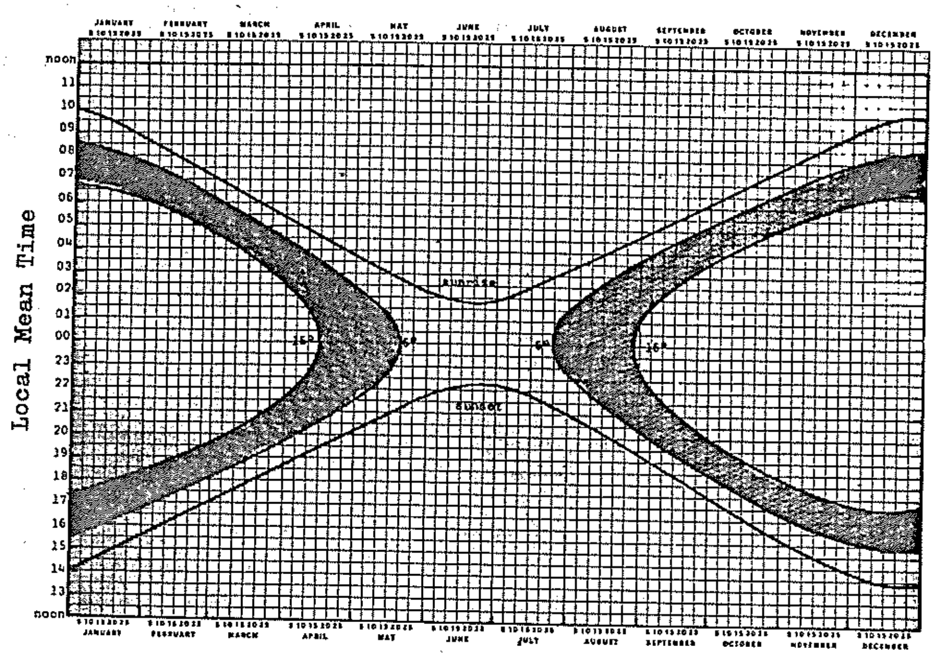


Figure 11 - NLC observation periods for 64°N

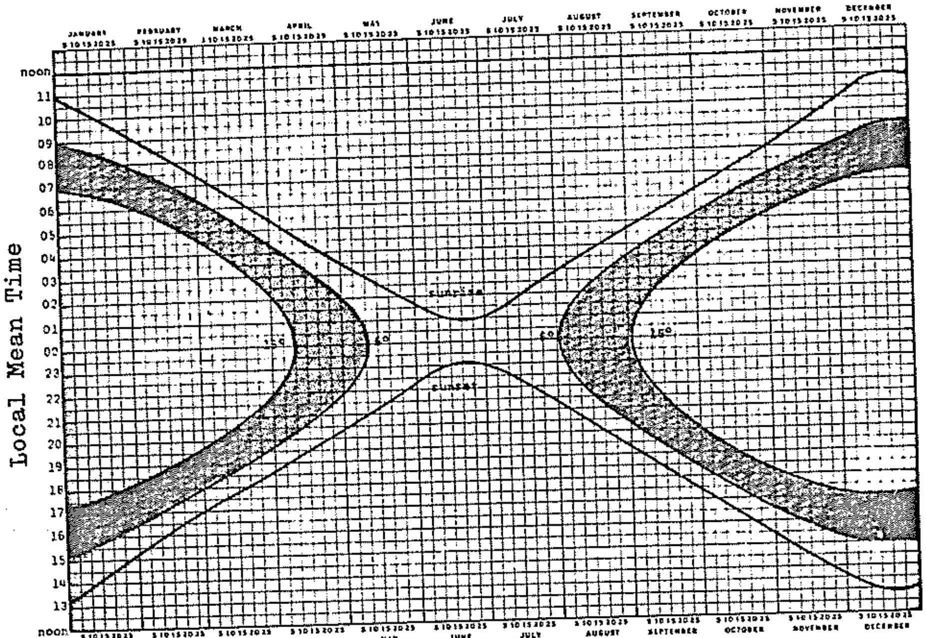


Figure 12 - NLC observation periods for 66°N

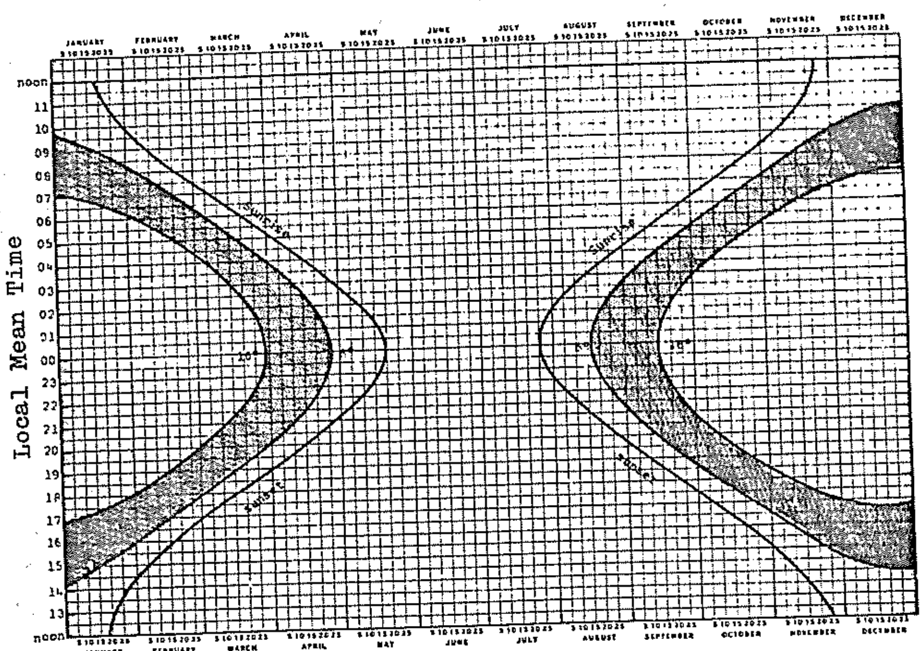


Figure 13 - NLC observation periods for 70°N

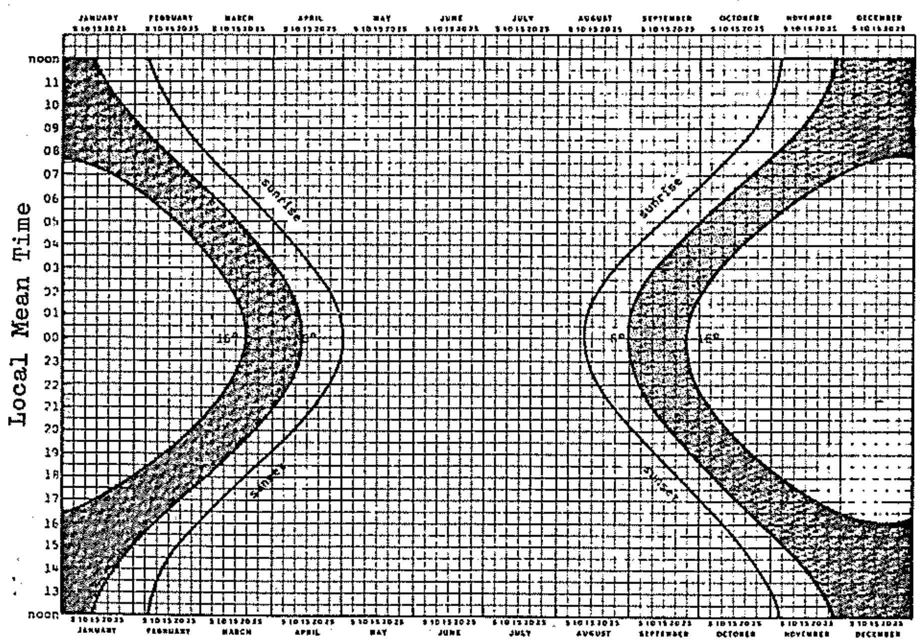


Figure 14 - NLC observation periods for 75°N

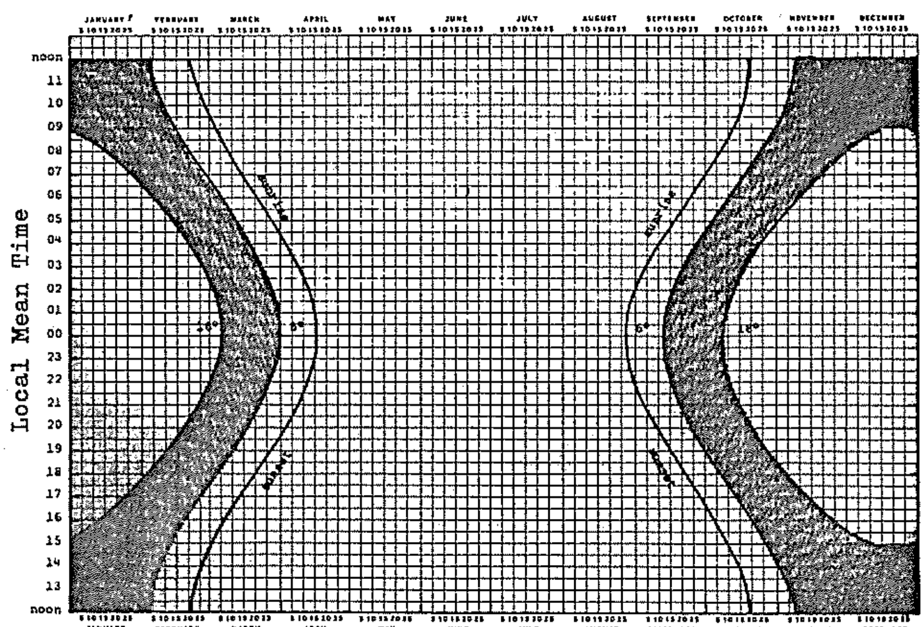


Figure 15 - NLC observation periods for 80°N

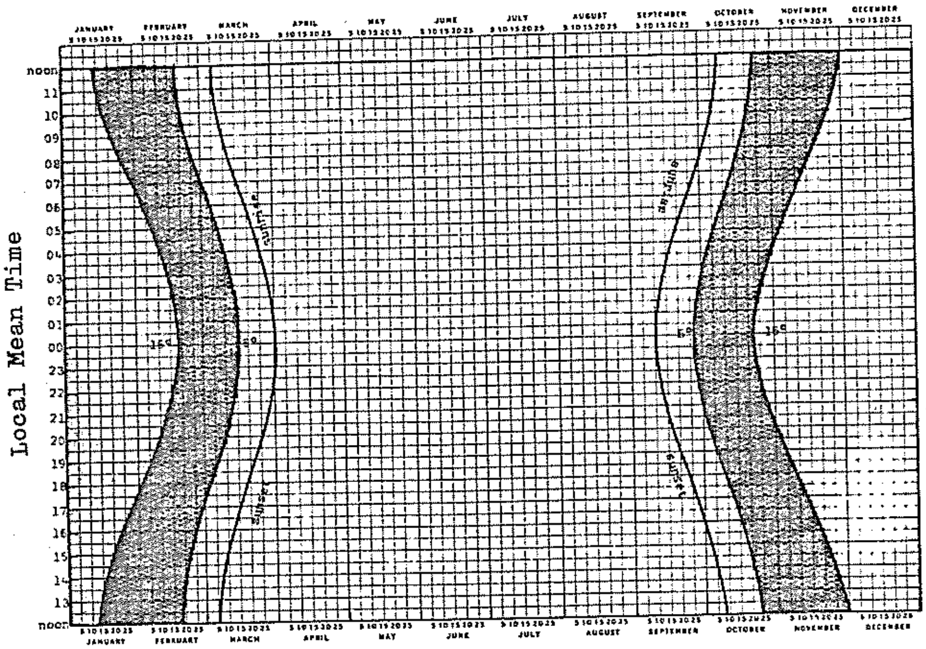
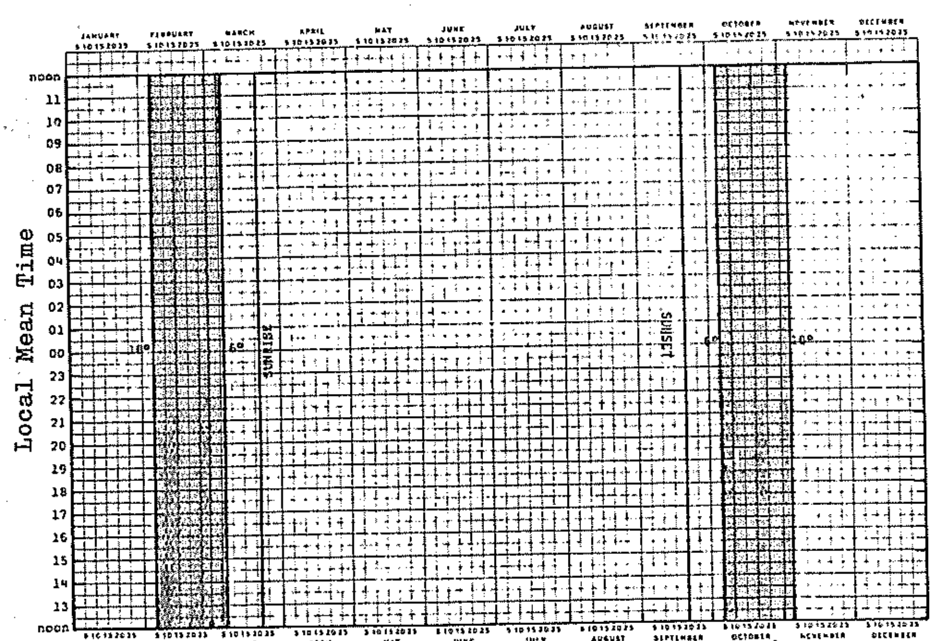


Figure 16 - NLC observation periods for 85°N



July Aug Sept Oct Nov Dec Jan Feb Mar Apr

Figure 17 - NLC observation periods for 90°N

(A) 15/16 JULY 1965 DISPLAY
Grande Prairie, Alberta

Veil (Type I)
Bands (Type II.b)
Intensity 4.

(B) 26/27 JULY 1965 DISPLAY
Watson Lake, Yukon Territory

Veil (Type I)
Bands (Types II.a,II.b)
Billows (Type III.a)
Intensity 4.

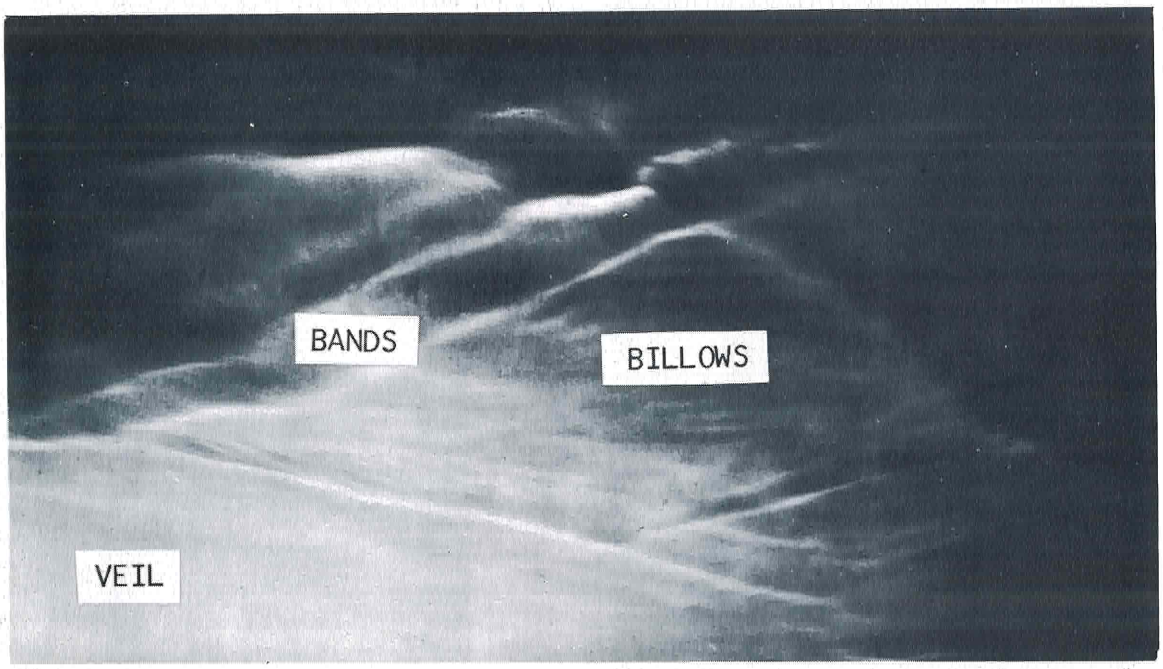
(C) 27/28 JULY 1965 DISPLAY (WITH AURORA)
Watson Lake, Yukon Territory

Veil (Type I)
Amorphous (Type V)
Intensity 2.

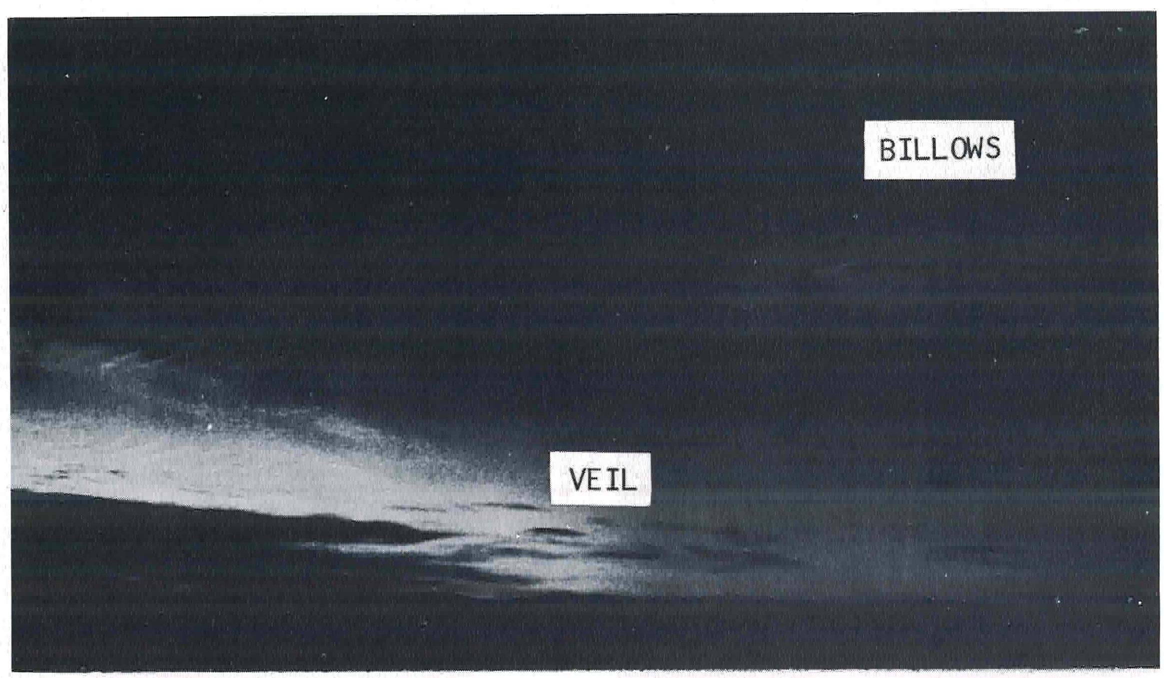
(D) 3/4 JANUARY 1966 DISPLAY
Punta Arenas, Chile

Veil (Type I)
Bands (Type II.a)
Intensity 2.

Figure 18 Unusual noctilucent cloud displays

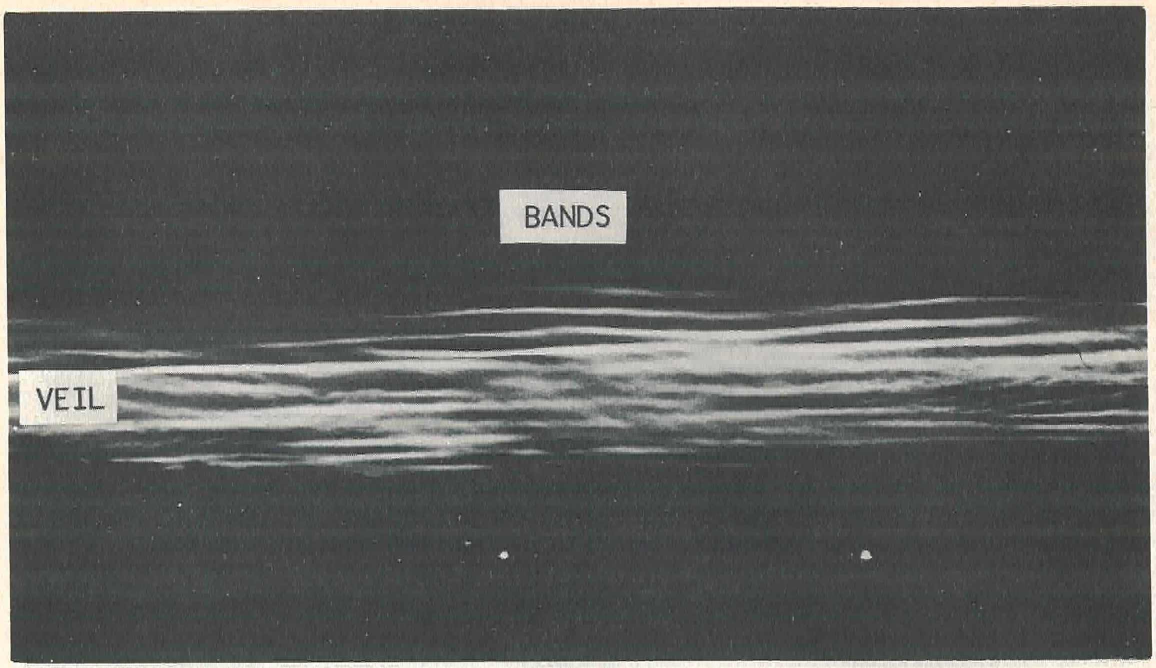


(A) NLC with Veil (Type I), Band (Type II.b), and Billow (Type II.a) forms. Intensity 4.

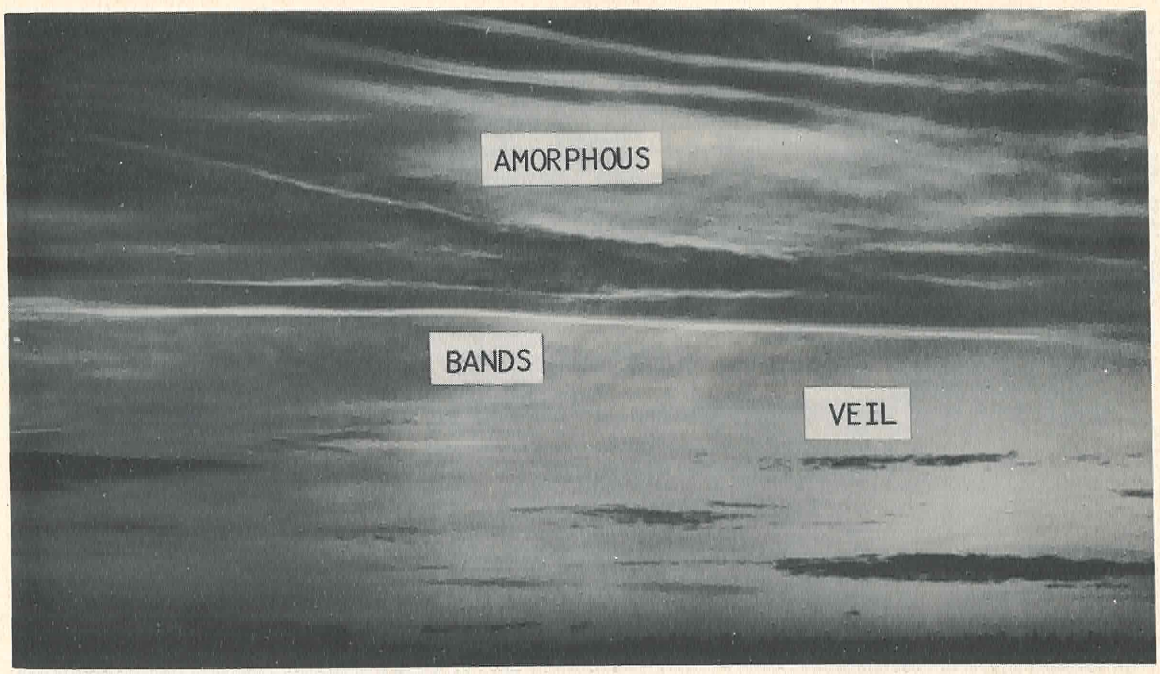


(C) NLC with Veil (Type I) and Billow (Type II.b) forms. Intensity 1.

Figure 19 - (A and C) Selected noctilucent cloud displays

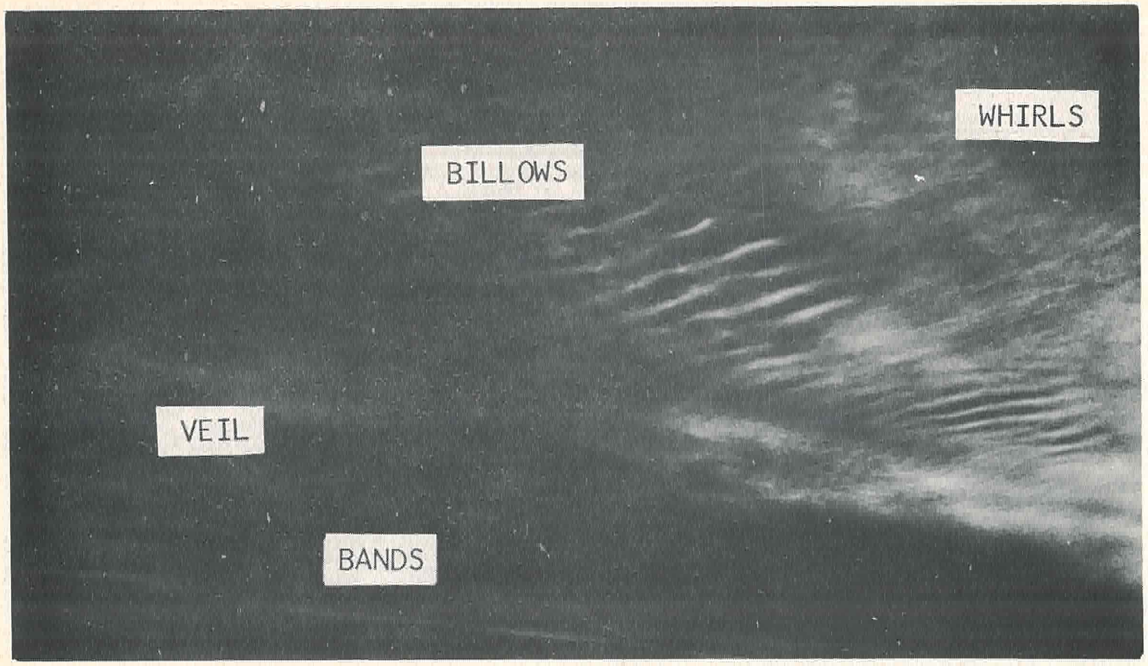


(B) NLC with Veil (Type I) and Band (Type II.b) forms. Intensity 4.

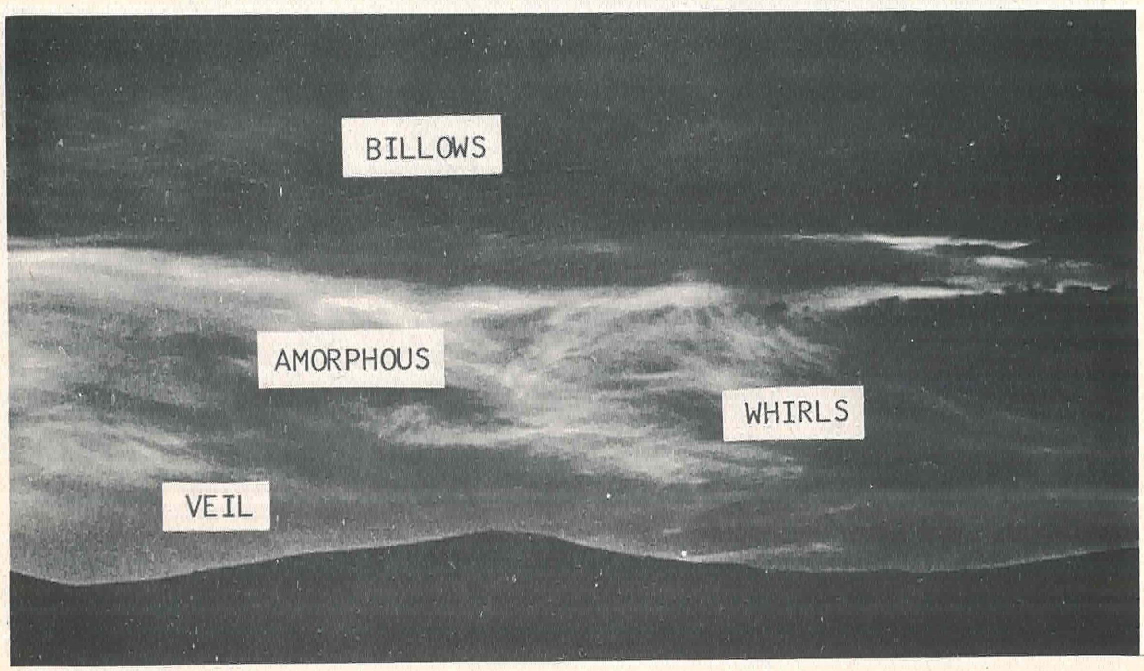


(D) NLC with Veil (Type I), Band(Types II.a and II.b), and Amorphous forms. Intensity 3.

Figure 19 - (B and D) Selected noctilucent cloud displays

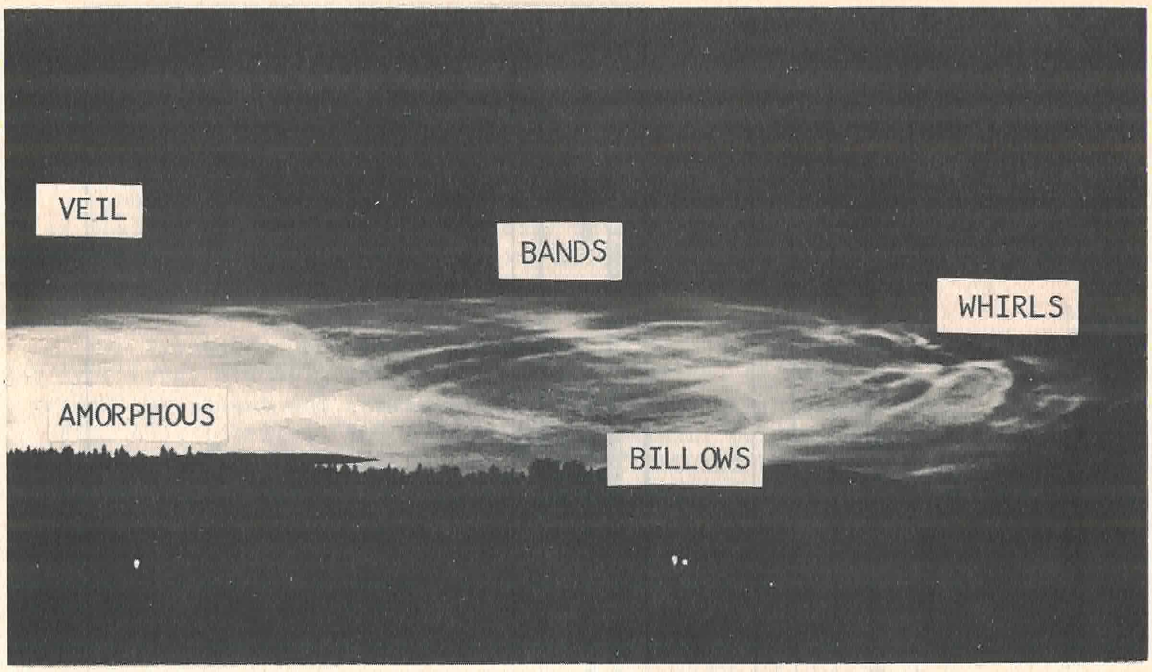


(A) NLC with Veil(Type I), Band(Type II.b), Billow(Type III.b), and Whirl(Type IV) forms. Intensity 3.

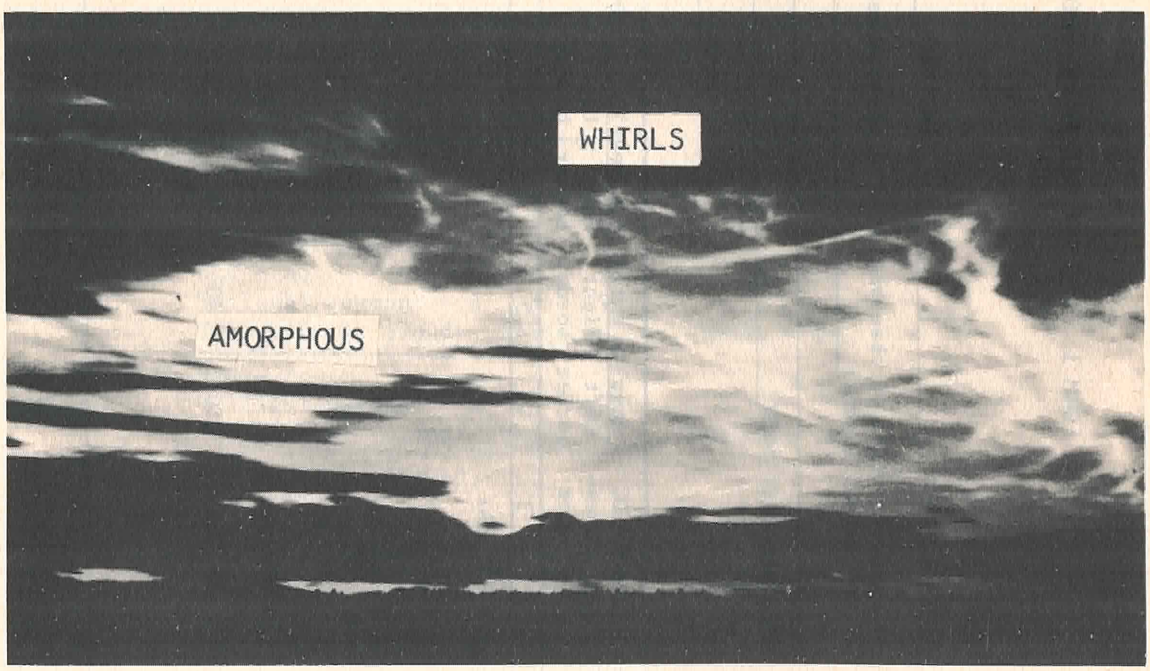


(C) NLC with Veil (Type I), Billow(Type III.a), Whirl (Type IV), and Amorphous (Type V) forms. Intensity 3.

Figure 20 - (A and C) Selected noctilucent cloud displays



(B) NLC with Veil(Type I), Band(Type II.b), Billow(Type III.b), Whirl(Type IV), and Amorphous (Type V) forms. Intensity 4.



(D) NLC with Whirl (Type IV) and Amorphous (Type V) forms. Intensity 5.

Figure 20 - (B and D) Selected noctilucent cloud displays

FORM 1: LOG FOR RECORDING GROUND-BASED VISUAL OBSERVATIONS OF NLC

Station Name:____________ Latitude__________ Longitude__________ Elev.________

Brief description of observation site (note observations of horizon in twilight sector and presence of any bright lights)____________________

____

Supplementary data____________________

Year________

Date-Local time	Time (UT)	NLC presence	Angular extent (degrees)				Brightness 5-point scale	Forms present	Tropospheric cloud cover		Remarks
			Left border	Right border	Lower border	Upper border			Twilight sector in letter form	General-in tenths	
1	2	3	4	5	6	7	8	9	10	11	12
25 July	22^h00^m	No									
	15	No									
	30	No									
	45	No									
	23 00	No									
	15	Yes	350	40	5	15	3	I, II-a	A	1 Ci	

APPENDIX 1: INSTRUCTIONS FOR RECORDING NLC OBSERVATIONS ON PUNCH-CARDS

A.1.1 Introduction

A major advantage of using punch-cards instead of the log for recording NLC data is that the data can be fed directly into computers for analysis at the data centres thereby saving time and reducing errors by eliminating the need to transcribe data from log forms to punch-cards.

Two types of punch-cards are needed to record NLC observational data. The first type (Fig. A1, A2), labelled "Presence of NLC", is used to record whether NLC are present or absent and information on the tropospheric cloud cover. The second type (Fig. A3), labelled "NLC Information", contains columns for recording the angular extent, brightness, and morphological forms of NLC and has to be filled out only when NLC are observed. These two cards together correspond to the log, and the same rules of recording the data apply to both the log and the cards. Since the punch-cards are processed by a computer, a soft graphite (number 2 or 3 B) pencil should be used in filling out the cards, and care should be exercised in handling and in mailing to avoid damage to or loss of the cards.

The method used in filling out the punch-cards is to strike out, using a soft graphite pencil, the oval(s) containing the answer that one wants to record. For example, if at one of the observing times NLC are not present and the tropospheric cloud cover is A, then one would cross out "No" under the NLC column and "A" under the twilight segment column. Other examples, given below, are shown on the sample cards in Figures A1, A2, A3.

Examples

(1) "Presence of NLC"
Month - July
Date - 13
Start - 21h15m

Presence of NLC:

1 NLC - no
Twilight segment - A
Tropospheric cloud: types - Ci; amount - 1;

2 NLC - no
Twilight segment - A
Tropospheric cloud: types - ; amount - ;

3 Observation omitted;

4 NLC - yes
Twilight segment - B
Tropospheric cloud: types - Ci; amount - 2;

5 NLC - yes
Twilight segment - B
Tropospheric cloud: types - Ci, Cc; amount - 3;

6 NLC - yes
Twilight segment - B
Tropospheric cloud: types - Ci, Cc; amount - 3;

7 NLC - no
Twilight segment - B
Tropospheric cloud: types - Ci; amount - 2;

8 NLC - no
Twilight segment - A
Tropospheric cloud: types - Ci; amount - 1;

9 NLC - no
Twilight segment - A
Tropospheric cloud: types - Ci; amount - 1;

10 -

11 -

No. of last observ. on card - 9;
Card number - 1;
Observation - cease;

(2) "Noctilucent Cloud Information"

Year - 1966
Month - July
Date - 13
Stard - 22h15m

Azimuth:

right border - 20°
left border - 345°

Elevation:

upper border - 15°
lower border - 5°
Brightness - 2
Morphological forms - I, IIa, IVa.

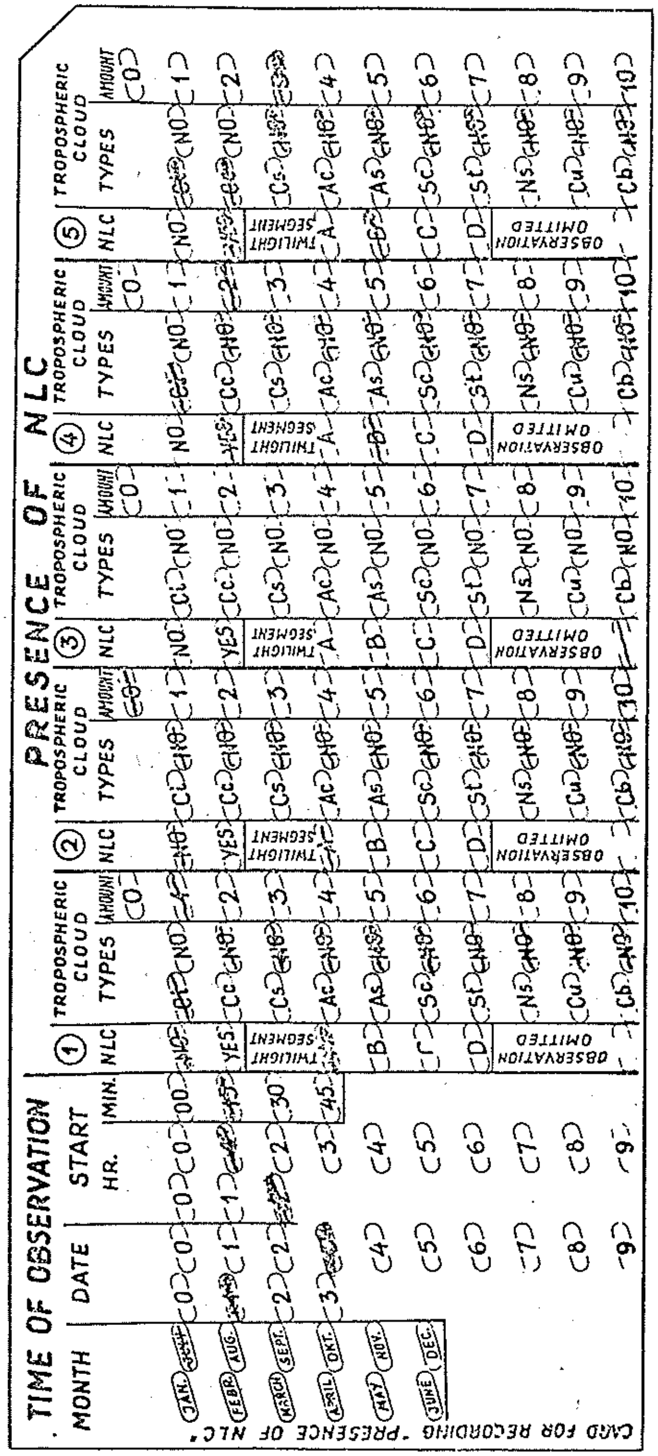


Figure A1 - Card for recording presence of NLC (front side)

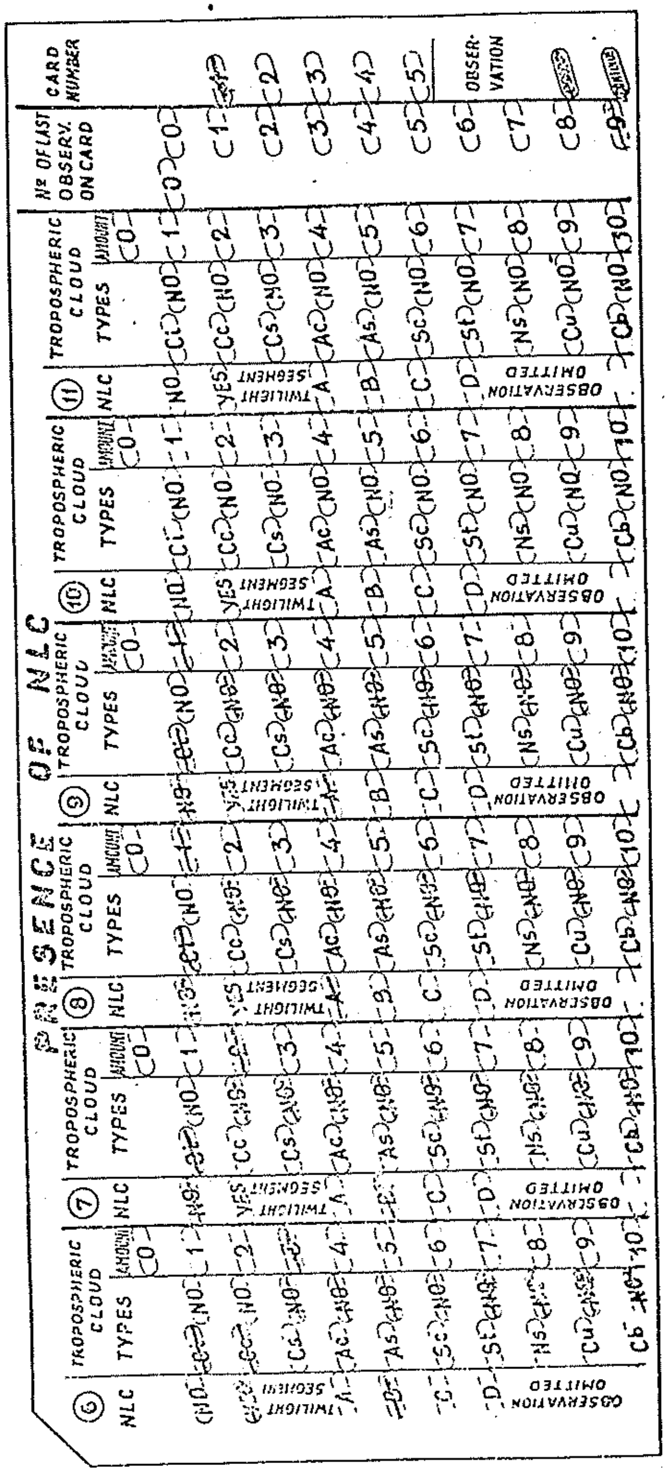


Figure A2 - Card for recording presence of NLC (reverse side)

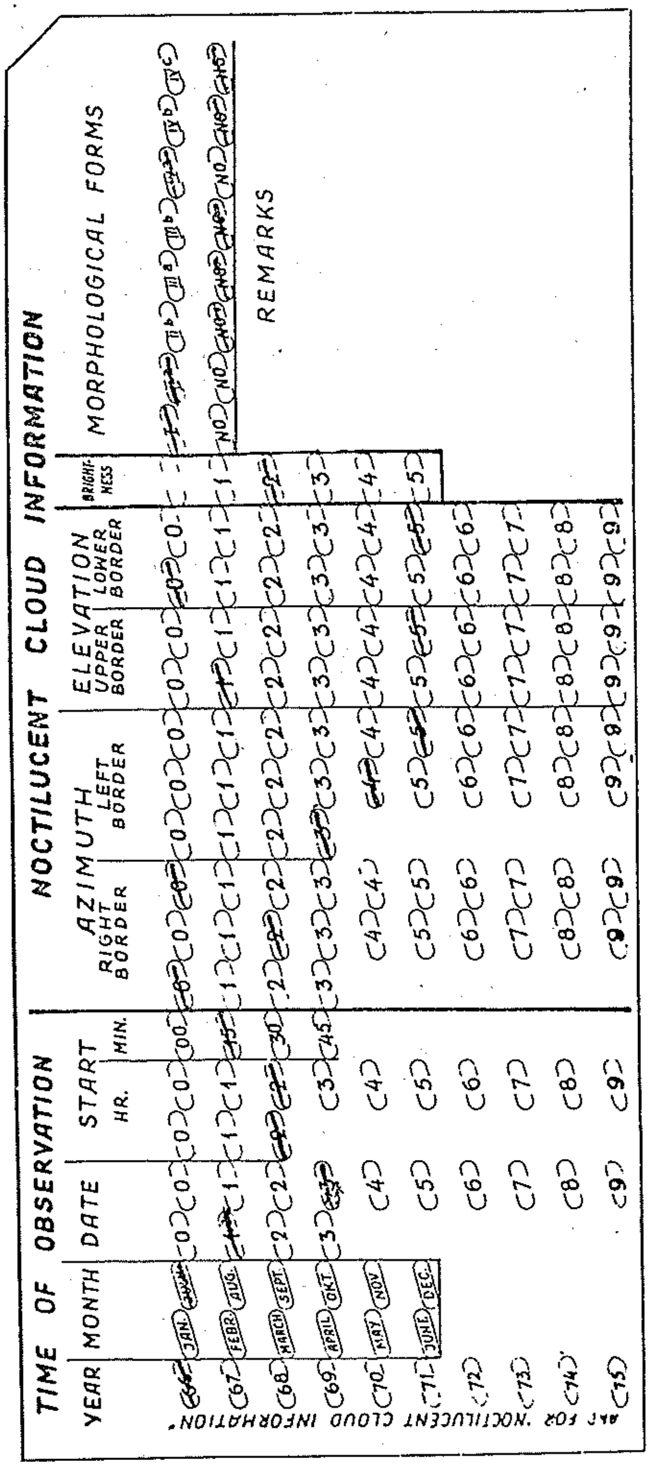


Figure A3 - Card for notilucent cloud information

APPENDIX 2: NLC PHOTOGRAPHY

Any camera which has provisions for time exposures can be used for NLC photography. The best cameras for this purpose are those with relatively "fast" (fl: 1 to fl: 2.8) lenses having a normal (approximately 35°) horizontal field of view. Cameras using 35 mm film are widely used in NLC photography and give good results, particularly when colour film is used. Cameras with larger film size are recommended for black and white photography of NLC.

It is best to use relatively high speed film (ASA rating of 160-400, DIN rating of 22-27, or 50-200 U.S.S.R. units) to avoid long exposure times which cause alterations in the colour balance of the film and also introduce the problem of reciprocity failure which requires even longer exposures. Experience in North America has shown that the colour film, High Speed Ektachrome (ASA 160, DIN 22), and the black and white film, PLUS X (ASA 160, DIN 22) are well suited for NLC photography. Colour photographs are preferable.

The camera should be mounted on a sturdy tripod and a cable release should be used to trigger the camera.

It is important for later analysis that all photographic observations be synchronized and that the pictures contain part of the horizon. Before taking photographs, the observer should first set his watch or clock to the correct time within an accuracy of a few seconds. Synchronized exposures should begin exactly on the quarter hour, for example:

n^h	00^m	00^s	Universal Time or Local Mean Time
"	15	00	
"	30	00	
etc.			

Observers taking photographs of NLC should record the pertinent data on a form similar to that shown in form A2.

Typical exposure times for NLC photography at different values of the solar depression angle (corresponding to different sky background intensities) are given below (Table A2) for several film speeds.

Form A2. Photographic Data Form

Date: 15 July 1968

Name and co-ordinates of observing station: Thompson, Manitoka (55°48'N, 97°51'W)

Photographer: John Doe

Camera used: Canon F

Lens, focal length and speed: 50 mm fl:1.4

Film size and type: 35 mm High Speed Ektachrome (ASA 160)

Exposure No.	Time (UT)	Exposure	Direction	Remarks
1	08^h15^m	2 sec @ f1.4	NNE	
2	08^h30^m	4 sec @ f1.4	NNE	aurora present
3	08^h45^m	4 sec @ f1.4	NNE	
4	09^h00^m	4 sec @ f1.4	NNE	
etc.				

Table A2. Exposure Times for NLC Photography

Film Speed SDA	ASA 50 DIN 18	ASA 100 DIN 21	ASA 200 DIN 23	ASA 400 DIN 27
6°	1/8 sec @ f2.8	1/15 sec @ f2.8	1/30 sec @ f2.8	1/60 sec @ f2.8
8°	2 sec @ f2.8	1 sec @ f2.8	1/2 sec @ f2.8	1/4 sec @ f2.8
10°	*15 sec @ f2.8	8 sec @ f2.8	4 sec @ f2.8	2 sec @ f2.8
12°	*60 sec @ f2.8	*30 sec @ f2.8	*15 sec @ f2.8	8 sec @ f2.8
14°	*240 sec @ f2.8	*120 sec @ f2.8	*60 sec @ f2.8	*30 sec @ f2.8
16°	- - - - - - - -	- - - - - - - -	*240 sec @ f2.8	*120 sec @ f2.8

* When the colour film is used, it is necessary to increase these exposures by one to three f-stops to correct for film speed changes at long exposures.

APPENDIX A

Information for Observers - Clarification of Manual

I Procedural and other important changes

(1) p. 8 Para. 1 and II.5.2:

(a) An observation begins the quarter hour closest to the expected time at which the solar depression angle at the station is 6°.

(b) In the event of no NLC being observed, then hourly observations will suffice.

(c) In the event of NLC being observed, observations shall be taken thereafter at 15 min. intervals.

(2) II.5.1 Month and the dates of the evening and morning twilights are entered in column i.

(3) Form I:'Brief description of Onservation Site,' latitude, longitude and elev. need only be written at the outset. Any changes thereafter should be added in 'supplementary date' space!

(4) 'Billows' have replaced 'waves', and 'amorphous' morphological form is added.

(5) Number of letter forms to describe tropospheric cloud cover in twilight sector is reduced to 4.

II Typographical errors and others requiring clarification:

1. p. I.3 Reference II.8 should be II.5.7
2. p. 7 (SMT)* Footnote is found on p. 8
3. p. 7 SMT (105) + LMT ...... should be SMT (105) = LMT.......
4. p. 8 II.5.2 UT and GMT are identical
5. p. 8 II.5.3 "see below" refers to II.5.10
6. p. 8 1st line and II.5.2 2nd line Preceding
7. p. 14 III.2(2) 1st line to read Canadian Meteorological Service
8. p. 39 Manitoba
9. Local mean time is equivalent to solar mean time in the Interim Manual.

STATIONS PARTICIPATING IN NOCTILUCENT CLOUD PROGRAM AND CORRESPONDING CO-ORDINATES AND TIME CORRECTION TO GREENWICH TIME

		LAT. N deg.	LAT. N min.	LONG. W deg.	LONG. W min.	TIME CORRECTION hrs.	TIME CORRECTION min.
1. **DND**							
Bagotville A, Que.	(72727)	42	20	71	00	4	44
Cold Lake A, Alta.	(74120)	54	25	110	17	7	21
Comox A, B.C.	(72893)	49	43	124	54	8	20
2. **HEADQUARTERS**							
Resolute A, N.W.T.	(72924)	74	43	54	59	6	20
3. **PACIFIC**							
Lytton, B.C.	(72891)	50	14	121	34	8	06
Prince George A, B.C.	(72896)	53	53	122	41	8	07
Terrace A, B.C.	(72951)	54	28	128	35	8	34
Vancouver Int,l A, B.C.	(72892)	49	11	123	10	8	13
Williams Lake, B.C.	(74104)	52	11	122	03	8	08
4. **WESTERN**							
Calgary A, Alta.	(72877)	51	06	114	01	7	36
Cambridge Bay A, N.W.T.	(72925)	69	06	105	07	7	20
Cape Parry A, N.W.T.	(72948)	70	10	124	41	8	19
Dawson, Y.T.	(72966)	64	04	139	26	9	18
Edmonton Int'l A, Alta	(74123)	53	19	113	35	7	34
Edson, Alta.	(72881)	53	35	116	25	7	46
Fort Chipewyan, Alta.	(72933)	58	43	111	09	7	25
Fort McMurray A, Alta.	(72932)	56	39	111	13	7	25
Fort Nelson A, B.C.	(72945)	58	50	122	35	8	10
Fort Reliance, N.W.T.	(74073)	62	43	109	06	7	16
Fort Simpson A, N.W.T.	(72946)	61	45	121	14	8	05
Fort Smith A, N.W.T.	(72934)	60	01	111	58	7	28
Grande Prairie A, Alta.	(72940)	55	11	118	53	7	56
Lethbridge A, Alta.	(72874)	49	38	112	48	7	31
Norman Wells A, N.W.T.	(74043)	65	17	126	48	8	27
Peace River A, Alta.	(74068)	56	14	117	26	7	50
Pincher Creek, Alta.	(72875)	49	30	113	57	7	36
Rocky Mountain House, Alta.	(72928)	52	23	114	55	7	40
Wagner, Alta.	(74069)	55	21	114	59	7	40
Watson Lake A, Y.T.	(72953)	60	07	128	49	8	35
Whitehorse A, Y.T.	(72964)	60	43	135	04	9	00
Yellowknife A, N.W.T.	(72936)	62	28	114	27	7	38

APPENDIX B (CONTD.)

STATIONS PARTICIPATING IN NOCTILUCENT CLOUD PROGRAMME AND CORRESPONDING CO-ORDINATES AND TIME CORRECTION TO GREENWICH TIME

		LAT. N deg.	LAT. N min.	LONG. W deg.	LONG. W min.	TIME CORRECTION hrs.	TIME CORRECTION min.
5. CENTRAL							
Armstrong A, Ont.	(72841)	50	17	88	54	5	56
Baker Lake, N.W.T.	(72926)	64	18	96	00	6	24
Broadview, Sask.	(72861)	50	23	102	35	6	50
Churchill A, Man.	(72913)	58	45	94	04	6	16
Coral Harbour A, N.W.T.	(72915)	64	12	83	22	5	33
Ennadai Lake, N.W.T.	(72923)	61	08	100	55	6	44
Thunder Bay A, Ont.	(72749)	48	22	89	19	5	57
Prince Albert A, Sask.	(72869)	53	13	105	41	7	03
Regina A, Sask.	(72863)	50	26	104	40	6	59
Saskatoon A, Sask.	(72866)	52	10	106	41	7	07
The Pas A, Man.	(72867)	53	58	101	06	6	44
Trout Lake, Ont.	(72848)	53	50	89	52	6	00
Winnipeg Int'l A, Man.	(72852)	49	54	97	14	6	29
Wynyard, Sask.	(72856)	51	46	104	12	6	57
Thompson A, Man.	(74079)	55	48	97	52	6	31
6. ONTARIO							
Mount Forest, Ont.	(72631)	43	59	80	45	5	23
7. QUEBEC							
Cape Dyer A, N.W.T.	(74094)	66	35	61	37	4	06
Chapais, Que.	(72822)	49	47	74	52	4	59
Fort Chimo A, Que.	(72906)	58	06	68	26	4	34
Frobisher Bay A, N.W.T.	(72909)	63	45	68	33	4	34
Hall Beach A, N.W.T.	(74081)	68	47	81	15	5	25
Montreal Int'l A, Que.	(72627)	45	28	73	45	4	55
Nitchequon, Que.	(72826)	53	32	70	54	4	44
Poste-de-la-Baleine, Que.	(72905)	55	17	77	46	5	11
Quebec A, Que.	(72714)	46	18	71	23	4	46
Schefferville A, Que.	(72828)	54	48	66	49	4	27
Val d'Or, Que.	(72725)	48	03	77	47	5	11
8. ATLANTIC							
Battle Harbour, Nfld.	(72817)	52	15	55	36	3	42
Gander Int'l A, Nfld.	(72803)	48	57	54	34	3	38
Goose A, Nfld.	(72816)	53	19	60	25	4	02

STATIONS PARTICIPATING IN NOCTILUCENT CLOUD PROGRAM AND CORRESPONDING

CO-ORDINATES AND TIME CORRECTION TO GREENWICH TIME

		LAT. N deg.	LAT. N min.	LONG. W deg.	LONG. W min.	TIME CORRECTION hrs.	TIME CORRECTION min.
9. ALASKA							
Anchorage	(70273)	61	10	150	01	10	00
Aniak	(70232)	61	35	159	32	10	38
Annette	(70398)	55	02	131	34	8	46
Barrow	(70026)	71	18	156	47	10	27
Barter Island	(70086)	70	08	143	38	9	34
Bethel	(70219)	60	47	161	48	10	46
Bettles	(70174)	66	54	151	31	10	06
Big Delta	(70267)	64	00	145	44	9	43
Cape Lisburne	(70104)	68	53	166	08	11	04
Cape Newenham	(70305)	58	39	152	04	10	08
Cape Romanzof	(70212)	61	47	166	02	11	04
Cold Bay	(70316)	55	12	162	43	10	51
College		64	54	148	06	9	52
Cordova	(70296)	60	30	145	30	9	40
Eielson	(70265)	64	37	147	04	9	49
Elmendorf	(70272)	61	15	149	48	10	00
Farewell	(70248)	62	32	153	54	10	16
Fort Yukon	(70194)	66	33	145	12	9	41
Galena	(70222)	64	42	156	54	10	28
Gulkana	(70271)	62	09	145	27	9	42
Gustavus	(70367)	58	25	135	42	9	03
Homer	(70341)	59	38	151	30	10	06
Iliamna	(70340)	59	44	154	57	10	20
Juneau	(70381)	58	22	134	35	8	58
Kenai	(70259)	60	34	151	15	10	05
Kotzebue	(70133)	66	52	162	38	10	50
Livengood		65	30	148	30	9	54
McGrath	(70231)	62	58	155	37	10	22
Minchumina	(70246)	63	53	152	17	10	09
Nenana	(70260)	64	33	149	05	9	56
Nome	(70200)	64	30	165	26	11	02
Northeast Cape	(70206)	63	19	168	58	11	16
Northway	(70291)	62	57	141	56	9	28
St. Paul Island	(70208)	57	09	170	13	11	21
Sitka	(70371)	57	04	135	21	9	02
Sparrevohn	(70235)	61	06	155	34	10	22
Stevens Village		66	00	149	06	9	56
Summit	(70264)	63	20	149	09	9	56
Tanana	(70178)	65	10	152	06	10	10
Talkeetna	(70251)	62	18	150	06	10	02
King Salmon	(70362)	58	41	156	39	10	27

APPENDIX B (CONTD.)

STATIONS PARTICIPATING IN NOCTILUCENT CLOUD PROGRAMME AND CORRESPONDING CO-ORDINATES AND TIME CORRECTION TO GREENWICH TIME

		LAT. deg.	N min.	LONG deg.	W min	TIME CORRECTION hrs.	min.
Tatalina		62	54	156	00	10	24
Tin City	(70117)	65	34	167	55	11	12
Unalakleet	(70207)	63	53	160	48	10	43
Yakutat	(70361)	59	31	139	40	9	19
10. GREENLAND							
Egedesminde	(04220)	68	42	52	45	3	31
Godhavn	(04218)	69	14	53	31	3	34
Holsteinsborg	(04230)	66	55	53	40	3	35
Prins Christian Sund	(04390)	60	02	43	07	2	52
11. ICELAND							
Eyrarbakki	(04038)	63	52	21	09	1	25
Graenas		64	00	22	36	1	34
Keflavik	(04018)	63	58	22	36	1	34
Reykjavik	(04030)	64	08	21	56	1	28