

Observations of mesospheric clouds in Latvia 1957-1983

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5 **Abstract.** Until the 20th century In the 1980s, there were very few instruments for studying the upper layers of the atmosphere. Therefore, great importance was attached for observation of noctilucent clouds (NLC) at an altitudes of about 82 km, including also for amateur observations. The reason for this is the observation of NLC in places where they have not been seen before, but especially the possible evidence of the connection of NLC appearance and parameters with the effects caused by climate change. Therefore, the study of the state and dynamics of the mesosphere and the analysis of long-term processes has again
10 become an urgent scientific task.

Long-term visual and photographic observations of NLC were carried out in the Latvian branch of the All-Union Astronomical and Geodesic Society. They started during the International Geophysical Year in 1957 and continued until 1983, that is, for 26 years. Observations were mostly carried out according to a uniform, internationally recognized methodology, which has made it possible to obtain a unique, methodically comparable series of observations in terms of duration. The article summarizes
15 information about the content of the archive materials and the information obtained from it about the observation points and the photographic technique used in them, as well as an overview of the materials obtained during the observations and their content. This archive has a reasonable importance of continuing work and performing in-depth data processing. The digitized observation logs and the text appendices are available in the LU e-resources repository at <https://dspace.lu.lv/dspace/handle/7/67137>¹.

20 1 Introduction

Noctilucent clouds (NLC) at mesospheric altitudes of about 82 km are among the few natural phenomena where, even nowadays, even very simple visual or photographic observations can make a significant contribution to the understanding of the phenomenon itself and the processes related to it. First of all, it is related to the statistics of NLC observability itself, which can be related to various processes both in the Earth's atmosphere and in outer space. After a some loss of interest in the second
25 half of the 80s, in the last decade the interest in observing NLC has increased dramatically. NLC observed in places where they were not visible before (Taylor et al., 2002; Nielsen et al., 2011; Ходоренко, 2020); there is also debatable evidence of the association of the appearance of NLC with the effects caused by climate change (Lübken et al., 2018). It should be noted that it is difficult to determine the actual long-term trends in NLC height changes, as they can be masked by trends inherent to

¹ The observation logs are in latvian, but there was successful experience with using of on-line translators.

the solar cycle. It should also be noted that the method of triangulation from photographs introduces its own error and may not be sufficiently accurate. Several authors (Kirkwood et al, Pertsev et al, 2014, Dalin et al, 2020) believe that such long-term trends have not been found, but these authors analyze NLC statistics and some physical parameters, while Lubken, among others, indicates this for the average height of the lower boundary of the NLC, which is clear downward trend, which has become significantly faster since the 1960s.

The study of the state and dynamics of the mesosphere and the analysis of long-term processes has therefore become an urgent scientific task (Fiedler et al., 2017), which, taking into account the nature of the phenomenon and the environment under study, can only be effectively carried out within the framework of international cooperation, and NLC observations from the ground are an important component of this task.

Long-term visual and photographic observations of this natural phenomenon were made in the Latvian branch of the All-Union Astronomical and Geodesic Society (AUAGS; since 1990 – Latvian Astronomical Society, LAS). They started during the International Geophysical Year (IGY) in 1957 and continued until 1983, i.e. 26 years. The observational materials accumulated in the LAS archive, which has been preserved as far as possible by the Museum of the University of Latvia (UL). The archive contains observation logs from the mentioned period and more than 2,000 large-size photo negatives. Some observation logs have unfortunately been lost because in the 1990s, it changed location and custodians several times. Photo negatives taken after 1967 have not survived, too.

Observations were mostly carried out according to a uniform, internationally recognized methodology (Гришин, 1957), which has made it possible to obtain a series of observations that is unique in terms of duration. With some minor modifications, this methodology is also used by modern citizen science all over the world (Ромейко, 1990; Romejko et al, 2003, Gadsden and Parvianien, 2006); the classification of morphological forms of NLC has been supplemented (WMO, 2022).

At the same time, it should be noted that these data have only been processed to a very small extent and published to an even smaller extent. The processing took place mostly in accordance with concrete, narrowly specific tasks of the IGY and AUAGS. Most of the results are found only in special reports, which are not published; the few publications (e.g. E. Mūkin's article on the results of NLC height determination) were in sources that are no longer available today and are known only from these same reports. However, the analysis of the series of obtained data and their details can provide important information about the processes observed in the mesosphere in the previous years, its dynamics, and the possible connection with the meteorological conditions on earth. Considering the peculiarities of current observations, there is reason to think that it is also possible to obtain information about the nature of climate change during the observation period, which in this context has become quite important in the literature (Gadsden and Taylor, 1994; Oliveira and Thomas, 2001). There are not many long lines of NLC observations (e.g., the one mentioned by (Romejko et al, 2003) – Moscow, 1962–2001. (Pertsev et al, 2014) and (Dalin et al, 2020) refers to later years at the same place since 1990. Therefore adding another one will in any case improve our knowledge of the long-term dynamics of the NLC and the mesopause.

2 Systematic observations of mesospheric clouds in Latvia

2.1 Sources

The historical evaluation of NLC observations made in Latvia is based on the following main groups of sources:

1. reports to the Central Council of AUAGS on the NLC observation work carried out by the Riga branch RB; later Latvia Branch LB,
2. field observation logs, in which the observers recorded the data required in the observation methodology directly and in real time: news about NLC, meteorological data and notes on the photographs taken;
3. archive of original photo negatives.

In the LAS archive, there are two reports on the observation of NLC in preparation for the IGY, as well as during the IGY (Дирикис М, 1957; Дирикис and Берзиньш Я., 1958). They are copies of the reports sent to the Central Board of the AUAGS, and they are typewritten in Russian. The reports contain information about the observation points and their equipment, they describe the observation season and the main results obtained during it. The information attached below about observation points and observations during the IGY is obtained directly from these reports.

2.2 Observation points

In the territory of Latvia, regular NLC observations within the framework of joint programs have taken place in four places: Baldone, Lielauce, Riga and Sigulda (Figure 1). The main information about observation points is added in Table 1. Observation log journals have survived from Riga, Baldone and Sigulda.

In Riga, the observations initially took place at 34 Gorkija (now Kr. Valdemāra) street, on the roof platform of a six-story residential building. However, in 1958, shortly after the beginning of the observation season, due to technical reasons, the observation site was moved to the Riga Palace, where the cultural center of the ideological children's organization "Pioneers" was located at that time. Observations in one of the palace towers began there in the middle of July 1958 and continued until at least 1960. In the later years, it was observed in Riga from the territory of the Astronomical Observatory of the UL (now the Satellite laser ranging station of the Institute of Astronomy UL; see figure 3). At the observation point there was a photo camera АФА-ИМ, binoculars, a wide-angle theodolite and a radio receiver for receiving accurate time signals. During the IGY, the work of the point was led by E. Grasbergs, a student at the UL. After 1966, systematically, but after 1969 – no sightings have taken place in Riga and all active activity takes place only in Sigulda.

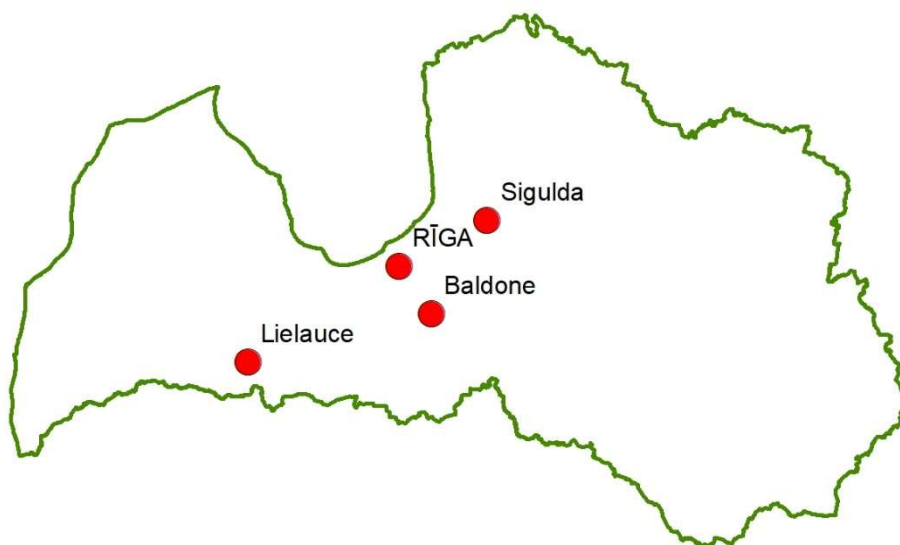


Fig. 1 Location of NLC regular observation points in Latvia during the IGY (figure in color)

In Sigulda, the observation point was located in the territory that used to be at the disposal of AUAGS Riga Branch. This
 90 territory was granted to the association for use by the decision of the local administration in 1956, and already that year a
 special pavilion for NLC observation was built there (figure 2). Observations began in 1957 and took place there until 1983.
 The observation point was well equipped. It housed aerial photo cameras АФА-ИМ and НАФА-3с on a masonry pillar with
 a deep, stable foundation. Other instruments include a light-capable wide-angle theodolite, a geodetic theodolite and
 binoculars. The needs of the weather service were served by a radio receiver for receiving precise time signals, marine
 95 chronometers and an aviation chronometer, and in the 80s also a quartz clock. During all observation periods, the activity of
 the point was managed by Matīss Dīriķis, a scientific associate of Astronomical Observatory at University of Latvia.

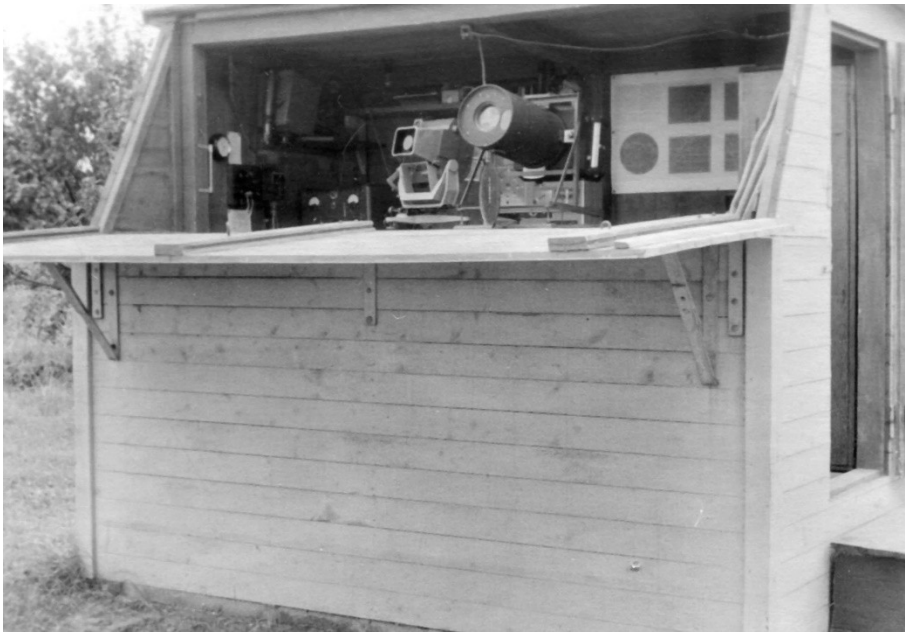
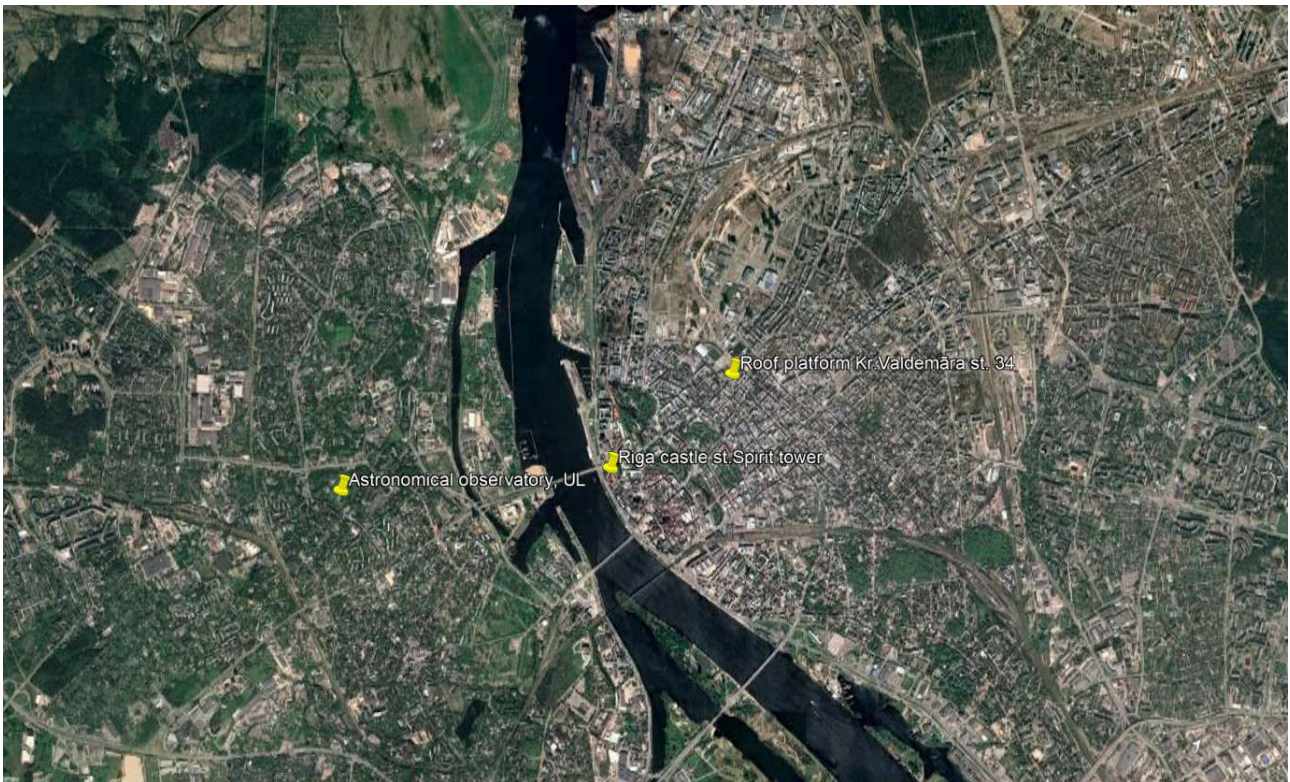


Fig. 2 NLC observation pavilion at AUAGS Riga Branch observatory in Sigulda. Photo by M. Dīriķis, 1958.



100 Fig. 3 Places where NLC observations took place in Riga. Background map: Geospatial information agency, Latvia.

In the center of the picture are wide film cameras АФА-ИМ and НАФА-3с. The thermometer and barometer used in the observations can be seen on the left side. The opening of the pavilion is oriented towards the north. The pavilion, also called the "Cloud Hut", remained until the end of the observatory's existence in 1993, but since 1988 it was no longer usable due to the deterioration of the wooden structures.

105 **Table 1. Main characteristics of NLC observation points**

Location	Coordinates in source	Real coordinates by ortophotos	Altitude above sea level, m	Address	Observation period
Baldone	56°46' N, 24°24' E	The exact place is unknown	≈75 (terrain)	Astrophysics laboratory of Academy of Science, Baldone, Riekstukalns	1958, 1959
Lielaucē	56°31'25" N, 22°54'08" E	56°31'22" N, 22°53'57" E (visual) 56°31'29" N, 22°54'05" E (photo)	115 (building) 100 (terrain)	Geodetic training ground of the Latvian Academy of Agriculture, Lielaucē	1957, 1958
Rīga	56°57'33" N, 24°07'14" E	56°57'32" N, 24°07'07" E	≈28 (building)	Gorkija (now Kr.Valdemāra) street 34, roof platform	1957 – 1958
Rīga	56°57'09" N, 24°06'04" E	56°57'03" N, 24°06'04" E	≈29 (building)	Pils square 3, Rīga palace St.Spirit tower	1958 – 1960
Rīga	No data	56°56'54" N, 24°03'33" E	8 (terrain)	Kandavas street 2, In the territory of the Astronomical Observatory of UL	1965 – 1969
Sigulda	57°09'38" N, 24°51'09" E	57°09'39" N, 24°50'58" E	100,5 (pillar)	Lāčplēša street 18, AUAGS RB (LB since 1961) People's Observatory	1957 – 1983

The Lielaucē observation point was located on the territory of the Latvian Agricultural Academy (LAA; now – University of Biosciences and technologies) geodetic training ground. The observation area was on the S bank of the lake, where the horizon was completely clear, but there was no pavilion. Therefore, visual observations were made from the balcony of the Lielaucē Castle (where the Latvian Agricultural Academy training base was located at that time), but in the event of the appearance of

110 MM, it was possible to get to the 250 m distant observation area within a few minutes, where it was possible to quickly install the АФА-ИМ camera. For this purpose, a brick post built for the geodesy polygon was used. Looking from the building, the horizon on the NW side was partially covered by the trees of the park, so a full-fledged observation point could not be installed there. The observers also had the geodetic instruments of the LLA training base at their disposal. The work at the observation point in 1957 and 1958 was led by LLA geodesy lecturer L. Ozols. There are no reports of sightings in this place after 1958.

115 Observation logs have not been preserved either, but in the Rīga logs we find notes that NLC were observed in Lielaucē.

Observations in Baldone took place in the territory of the Astrophysics Laboratory of the Academy of Sciences of the Latvian SSR (now – Baldone observatory of Institute of Astronomy, UL). An observation pavilion should have been built there already in 1957, but it has not been done. Therefore, in 1958, observations at this place were made only visually, and only during the period when observations in Riga were not possible. D. Melnāre was responsible for the observations and they were also carried out. In 1959, full-fledged (i.e. also photographic) observations took place there, but there is no news about later years. It was also not possible to identify the exact location of the observations, therefore its coordinates are known only with the accuracy mentioned in the reports up to a arcminute.

2.3 NLC observation logs and their digitization

In the archive of the LU museum, it was possible to find journals that testified to MM's observation work at observation points in Riga, Baldone and Sigulda. Riga observation logs were from 1957 to 1969, missing 1962. The records of the Sigulda observation point refer to the period from 1958 to 1983, missing 1957, 1968. and for 1970-1972. An observation point in Baldone is represented by one – 1959. In 1958, the log journal was started in Baldone, but the second half of the season was continued in Riga. Observation logs from Lielauce point have not been found.

The observation logs were digitized in the form of MS Excel tables; this work was done by the author of the article and volunteer assistants, students J. Stepanova and J. Biķis. In order to avoid arbitrary interpretations, a small instruction was prepared for the volunteers - explanations about the work to be done. A separate Excel file with 4 sheets was created for each year. Page 1 lists the data entrant, provides key information about the observation point, and provides explanations to help you understand the material that follows. Page 2 contains a list of observation nights and observers, information about clocks and their correction, as well as pre-processing data on the fact of NLC observation and the number of photographs taken. Page 3 contains a full record of night observations, including the fact of NLC detection, brightness, information on morphological forms, as well as meteorological parameters. Page 4 contains information about the photos taken.

Sometimes logs contain entries (notes) that are too long to fit comfortably in an Excel sheet cell. Therefore, only a reference to such notes has been placed in the relevant place, but they can be found in the appendix - in a text file.

Almost all observation entries in logs have been made in accordance with the requirements of the methodology (example in Figure 4). For reasons that are difficult to understand, the requirement to take notes of observations only in pencil was introduced of the time of IGY and later remained. Sometimes, probably due to the lack of experience of the observers, the parameters of the observed MMs (brightness, morphology) have not been fixed.

Initially (1957, partially until 1960) the notes were made in Russian. In these cases, the digitized version is a Latvian translation made by the author (the author is fluent in Russian). In some places, the use of the Cyrillic alphabet has caused difficulties for the observers, who in most cases have been Latvians: the letters "D" and "Д" are represented in the handwriting in the same way, but correspond to different degrees of covering of the twilight segment (respectively, D and E); the same applies to "B" and "Б". The latter clearly corresponds to the letter "B" of the Latin alphabet, but the first, which is written like the Latin "B", is the 3rd letter of the alphabet in Cyrillic and represents the grade C. The records of the Riga observation point for 1967-1969

are very incomplete. In 1967, it is obvious that they were carried out practically only on those nights when NLC were observed.
150 Regarding 1968 and 1969, it cannot be stated with certainty. In the first years, meteorological conditions were not recorded for some of the observations in Riga.

The image shows a handwritten observation log from 1976, consisting of two pages. The left page is headed 'VI 24/25' and 'Bulsa - 11.5'. It contains a table with columns for time (e.g., 23:30, 45, 0:00), NLC detection (e.g., 'nav'), brightness (e.g., 'B'), twilight visibility (e.g., 'A'), cloudiness (e.g., '0'), and atmospheric conditions (e.g., 'p=749', 't=16°'). The right page is headed 'AFA-M' and contains a table with columns for photo number (e.g., 3, 4, 5), time of capture (e.g., 0:47:00), camera azimuth (e.g., 100°), altitude (e.g., 15°), exposure time (e.g., 10s), and notes (e.g., 'Dumana = 1'). The log is signed 'Bulsa' at the bottom of the left page and 'A' at the bottom of the right page.

Fig. 4 Opening of the observation log with NLC and meteorological observation notes and information about the photos taken. 1976 year. Image of the author.

155 Explanation to fig.4. At the top of the page, the month and date of the observations, the clock used and its correction according to precise time signals are marked. On the right side, the observer's signature.

On the left: the first column - the time of observations, the second column - the fact of the NLC detection, columns 3 and 4 - the brightness of the NLC and morphological forms. Next, the visibility of the twilight segment (A - completely clear, F - completely obscured), total cloudiness (0 - completely clear, 10 - completely cloudy) and low clouds (0-10). In the last column,

160 atmospheric pressure, temperature and notes on weather conditions (rain, fog, etc.).

On the right: description of the photographs. Image no., time of capture, camera azimuth, altitude and exposure time. On the right side, there may be notes on the observation conditions, NLC features, etc.

Table 2 Sample of digitized observation log, same as in fig.4

Month	Date	Time	Depth of Sun, -deg.	Noctilucent clouds			Twilight segment	Cloudiness		Atmosphere		Notes
				Fact	Brightness	Types		Total	Low	pressure	temp. °C	

Jun	24	23:30	6.0	no			B	2	2	749		
Jun	24	23:45	6.8	no			B	3	3			Haze 1
Jun	25	00:00	7.5	no			B	2	2		16	
Jun	25	00:15	8.2	no			B	2	2			
Jun	25	00:30	8.6	no			A	1	1			
Jun	25	00:45	9.0	yes	1	1	A	0	0			
Jun	25	01:00	9.3	yes	1	1	A	0	0		14	
Jun	25	01:15	9.4	yes	1	1	A	0	0			
Jun	25	01:30	9.4	yes	1	1	A	0	0			
Jun	25	01:45	9.3	yes	2	1, 3b	A	0	0			
Jun	25	02:00	9.0	yes	3	1, 3a, 3b	A	0	0		11	
Jun	25	02:15	8.7	yes	2	1	A	0	0			
Jun	25	02:30	8.2	yes	1	1	A	0	0			Haze 2
Jun	25	02:45	7.6	no			B	1	1			
Jun	25	03:00	6.9	no			B	1	1		11	
Jun	25	03:15	6.1	no			B	1	1	749.5		

2.4 Visual observations

165 Systematic observations of NLC, which took place in the territory of Latvia in the period from 1957 to 1983, were mostly carried out in accordance with the methodology described in (Grishin, 1957) and (Bronstein and Grishin, 1970), observing some of the above-mentioned nuances and later additions.

Observations during the IGY season began in March and lasted until the end of October, and in the later period - on average from the beginning of June to August. The results of the observations were recorded in a certain sample journal, which was
170 arranged separately for each year (exceptions: Riga, where the 1966-1969 journals are in one volume, also Sigulda, 1981 and 1982).

In visual observations, the visibility and typology of NLC was recorded at the beginning of every quarter of an hour, with the time recorded to the minute. Clock correction, if used, was noted at the beginning of the observation session. The recording of the moments of time in Sigulda was ensured by the marine chronometer made by the company “J.Bruce&Sons” around 1900;
175 later also a similar “Thomas Mercer” instrument whose correction was marked by accurate time signals from dedicated AM band time signal transmitters. Sometimes the aviation chronometer was used in parallel. Since 1981, a “household” type quartz clock was used, and in 1983 – a quartz clock built by V. Gedrovics, an amateur astronomer and electronics engineer. At the other observation points, radio time signals were listened to, after which the hand (sports) stopwatch was started at the

beginning of the first full hour of observation. In observations at Kandavas Street 2, the observatory's time service quartz clock
180 was also sometimes used.

Air temperature and pressure were recorded only in observations in Sigulda, starting from 1964. Sometimes, if the weather
and its forecast in the evening have been “hopeless” – E/10/10 (see explanation at fig.4.), the observers have not been on duty
all night, but only noted such conditions for some periods at the beginning or even immediately and have not continued the
observations. In Riga, meteorological parameters have not been fixed at all for some years. Observers have sometimes made
185 logical errors in cloudiness estimation. For example, the total cloudiness is rated with a lower reading than the low clouds, or
at cloudiness indicators of 10/10, the cover of the twilight segment is rated as D. However, such errors are rare. In the early
observations in Riga, smoke from factory chimneys was quite often mentioned as a factor disturbing the observations: north
of the observation sites in the center of Riga is the industrial district of the Port of Riga. Here is an interesting conclusion about
atmospheric industrial pollution and air quality – for many years (at least since the mid-1980s; author's observation) nothing
190 similar has been observed in the city.

2.5 Photographic observations

2.5.1 Photo archive of NLC observations

Almost all images have a frame size of 180x130 mm; For 84 images, the format is 180x240 mm. There are a total of 2106
photo negatives in the archive. Of them, 271 were admitted in Riga from 1958 to 1964, 1482 were admitted in Sigulda from
195 1961 to 1967, 146 were admitted in Baldone in 1959 and 8 in Lielaucē in 1958. 106 pictures make up 53 pairs taken
synchronously in Sigulda-Riga and Sigulda-Lielaucē. Most of the images are placed in binders and organized by series of
observations. Each photographic negative is assigned a unique common identification number. The photo negatives are placed
one by one in an envelope made of a folded sheet of soft paper (Figure 5) and are annotated with a description of the shooting
conditions. All negatives are perfectly preserved. 186 mm wide aerial film was used for shooting.

200 Annotation for each photo includes:

- observation point code (initial letter of the name),
- personnel number (usually in the format XX-YYY, where XX is the last 2 digits of the year, and YYY is the serial number,
which starts from 1 every year),
- year, date and time of enrollment,
- 205 duration of exposure,
- camera direction (azimuth, height),
- the initials of the observers who made the frame.



Fig. 5 NLC 180x130 mm photo negative archive folder. Author's photo. (figure in color)

210 A semi-transparent paper template made during earlier processing is attached to some of the images, indicating the positions of the brightest stars in the frame and other marks.

It is planned to digitize these images at the Institute of Astronomy of the UL. It is intended to be done with a professional high performance scanner Epson 11000XL. Such scanners were used to digitize the 24x24 cm glass negative library of the 120/80 cm Schmidt telescope of the Baldone Observatory (Eglītis and Eglīte, 2016). An auxiliary device for accurate positioning of flexible photo negatives on the scanner glass was made at the Laser Location Station of Institute of Astronomy, UL.

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Photography was only performed if NLC were detected visually; the exception was some trial expositions.

2.5.2. Equipment

For serious photographic observations of NLC in the USSR, it was recommended to use aerial cameras with a frame size of at least 180×130 mm and a normal lens (focal length equal to the diagonal of the frame). The large size frame was chosen to allow for image processing with photogrammetry methods. The relevant cameras of the local branch of the AUAGS (usually they were decommissioned military aerial cameras) and special, ultra-fine-grained photographic materials could be obtained by ordering them from the Central Council of the AUAGS. It was not accessible to individual, “unorganized” observers.

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Aerial photo camera АФА-ИМ was used for NLC photography in Latvia (figure 6; Абрамов, 2022а). It was developed already in 1938 for the needs of the military department of the USSR. The camera used a four-lens anastigmatic lens Industar-51 with $f=210$ mm and aperture 1:4.5; the angular size of the frame was 46×30 degrees. Always used the largest aperture of the lens. A semi-automatic aerial photo camera НАФА-3с with a frame size of 180x240 mm was also used in Sigulda for a short time. The diagonal of the frame was 27 degrees of arc. The built-in lens was Industar-52 ($f=500$ mm, aperture 1:5) (Абрамов, 2022b). Not to be confused with the lens of the same name, which was widely used in the USSR for amateur small format cameras; it is a completely different device. This technically more developed camera was only used for a short time. The performance of the АФА-ИМ camera was recognized as sufficient and did not require special training, while the use of the НАФА-3с required certain skills. In later years, commercial 35 mm film-size cameras FED-3 and Viliya were also used in systematic observations. It should be noted that frames obtained with an amateur camera on 35 mm film cannot be used for photogrammetric analysis; they are also not found in archives.

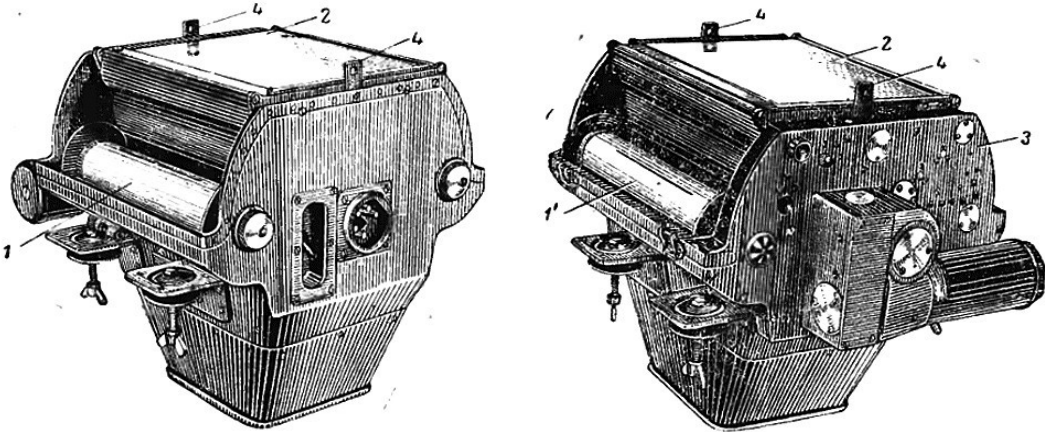


Fig. 6 Aerial photo camera АФА-ИМ with the cassette cover removed

1 – receiving coil, 1' – feeding coil, 2 – pressure glass, 3 – removable side part of the camera, 4 – cassette cover latches. Photographic observations took place in Riga, Sigulda and Lielauce. Panchromatic aerial photo film with optical density $D = 0.85$, contrast ratio $\gamma = 1.7 - 2.1$ and sensitivity 1000 – 1900 units of the state standard (ГОСТ) was used as photographic material. This special aviation film standard of the USSR is not directly comparable to the well-known ISO, ASA and DIN standards or soviet ГОСТ for civil industry products. Similar to ISO, it is in the arithmetic progression, but the conversion factor is unknown. The exposure duration was determined according to a special, experimentally obtained table (Table 3). The exposure depended on the depth of the Sun below the horizon, which made it possible to calibrate the brightness of the NLC depending on the degree of blackness of the exposed photo film, eliminating the subjective factor.

Table 3 Dependence of exposure times on sun depth

-h _s , arc deg	duration, s	-h _s , arc deg	duration, s	-h _s , arc deg	duration, s	-h _s , arc deg	duration, s
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6.0-6.6	1	8.2-8.4	6	10.3-10.8	20	12.4-12.6	60
6.7-7.2	2	8.5-8.7	8	10.9-11.0	25	12.7-12.9	80
7.3-7.5	3	8.8-9.3	10	11.1-11.4	30	13.0-13.2	100
7.6-7.8	4	9.4-9.6	12	11.5-11.9	40	>13.2	120
7.9-8.1	5	9.7-10.2	15	12.0-12.3	50		

245 In order to ensure synchronous photography of the same NLC field, exposures had to be carried out according to a specially determined time-direction table in the IGY observation programs in 1957-1959 (see Table 4). If the NLC is weak, without interesting shapes and significant details, then it is permissible to shoot only every full tenth minute. Observers continued to adhere to this scheme later, as long as there were systematic observations from at least two points, approximately until 1966. In later years, there was only a recommendation to do it at the beginning of a minute when choosing the starting moment of photography. The start of the exposure was determined by hearing, listening to the exact time signal and waiting for the full minute-long beep. For this purpose, DIZ (Germany, 4.525 MHz) special time signal broadcasting station was most often used; less often also some others. Observations were often hampered by the poor audibility of these signals in household radio receivers (then a stopwatch was visually used), but this did not interfere in Sigulda, where there was a precisely tuned military-type radio receiver with variable selectivity and an external antenna.

255 **Table 4 Mesospheric cloud synchronous capture program.**

Azimuth, degrees	150	Optionally	180	210	Optionally	240
Time, one minute after the start of each full hour	00	10	20	30	40	50
	02	12	22	32	42	52
	04	14	24	34	44	54
	06	16	26	36	46	56

3. Discussion

Briefly about the main results.

A brief overview of NLC observations in Latvia in the period from 1957 to 1983, which can be found in the observation journals, is attached in Tables 5 and 6. It can be seen that the mid-1960s and 1970s stand out with a particularly large number of NLC observations, but in 1957 there was only one and a dubious observation.

In Latvia, a very large amount of NLC observation material has been accumulated, the processing of which was carried out at the time did not nearly exhaust the potential hidden in it. A long series of observations about the fact of the appearance of MM, detailed (photographically) recorded topography and morphology of NLC can provide a lot of new information about the long-

term dynamics of NLC and its connection with climate change processes taking place in the troposphere. Specialists from Institute of Astronomy, UL, attracting students and volunteers, will continue to perform statistical processing of digitized information. Special attention should be paid to the rich photo archive, which can be digitized and processed in several directions. NLC height measurements should be taken first if possible. From 53 pairs of photographs, 53 measurements of NLC height could be derived, in the timeframe 1961-1964. Evaluating the results compared to those obtained, for example, in (Lübken et al., 2018), it is possible to confirm the assumption that they can serve as a large-scale indicator of climate change. Studies of NLC movement and morphology can provide valuable information about the dynamics of the upper atmosphere and its long-term changes, the relationship with the solar activity cycle and other factors, including the already mentioned climate changes. Among other things, an a priori statistical evaluation of the observations shows an apparent inverse relationship with the solar activity (Wolf number), but it will be clarified and substantiated in the further course of data processing. Observations in recent years, however, cast doubt on this assumption.

Table 5 Review of systematic observations of NLC in Latvia: Sigulda

Year	1958	1959	1960	1961	1962	1963	1964	1965
Observed, nights	153	76	52	64	55	48	83	81
Certain NLC sightings, times	4	8	3	8	3	16	15	15
Certain NLC sightings, hours	4.25	21.25	8.5	20.75	12.5	41.75	30	30.75
Average hrs at night when observed	1.06	2.66	2.83	2.59	4.17	2.61	2.00	2.05
Dubious observations	2	1	1	1	2	1	1	1
Taken photos	(113)	(338)	(78)	334	164	337	344	402
Year	1966	1967	1969	1973	1974	1975	1976	
Observed, nights	47	65	66	54	51	51	50	
Certain NLC sightings, times	8	20	9	5	10	16	11	
Certain NLC sightings, hours	18.25	39.25	15.5	12	25	36.75	24.75	
Average hrs at night when observed	2.28	1.96	1.72	2.4	2.5	2.3	2.25	
Dubious observations	3	0	1	2	1	3	4	
Taken photos ²	259	559	(94)	(19)	(80)	(124)	(88)	
Year	1977	1978	1979	1980	1981	1982	1983	
Observed, nights	58	41	40	37	28	35	42	
Certain NLC sightings, times	16	8	5	5	7	8	10	
Certain NLC sightings, hours	34	26.5	10.75	13.5	15.5	16.5	12.5	
Average hrs at night when observed	2.13	3.31	2.15	2.7	2.21	2.06	1.25	
Dubious observations	2	2	1	0	1	0	0	
Taken photos	(98)	(52)	(10)	(81)	(30)	(37)	(55)	

² In brackets are excerpts from images that have not survived.

Table 6 Review of systematic observations of NLC in Latvia: other observation points.

Year	1957	1958	1959	1960	1961	1963
Point of observation	Riga	Baldone	Baldone/Riga	Riga	Riga	Riga
Observed, nights	86	94	76	45	70	30
Certain NLC sightings, times	0	4	6	5	7	6
Certain NLC sightings, hours	0	5	16.25	7.25	12.5	15.75
Average hours at night when observed		1.25	2.71	1.45	1.79	2.63
Dubious observations	1	0	2	6	1	1
Taken photos	(2)	27	166	136	168	151
Year	1964	1965	1966	1967	1968	1969
Point of observation	Riga	Riga	Riga	Riga	Riga	Riga
Observed, nights	44	32	37	10	1	2
Certain NLC sightings, times	8	7	6	8	1	2
Certain NLC sightings, hours	15.24	15	12.75	13	2.75	2.25
Average hours at night when observed	1.91	2.14	2.13	1.63	2.75	2.25
Dubious observations	3	2	1	0	0	0
Taken photos	132	(115)	(72)	(160)	(15)	(9)

Competing interests

The author declare that they have no conflict of interest.

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