# Observing noctilucent clouds from Hungary with NLC wakeup application

Alexandra Kálmánczhelyi-Farkas, András Barta

*Environmental Optics Laboratory, Eötvös Loránd University, Budapest, Hungary*

**Abstract**

*The bluish noctilucent clouds are observable only during the time of summer solstice. They are most commonly observed at latitudes between 50 and 70 degrees, but there is evidence that corroborates their gradual increase which may be linked with the slow climate change. We summarize the discovery of noctilucent clouds after the eruption of volcano Krakatoa. We also describe their formation and types, then demonstrate the Noctilucent Cloud (NLC) WakeUp Android application developed by us. This tool can help us to calculate automatically the detection windows of noctilucent clouds depending on the date and the solar elevation angle.*

# Observing Noctilucent Clouds from Hungary with NLC WakeUp Application

**Alexandra FARKAS**[1], **András BARTA**[1,2]

1: Laboratory of Environmental Optics, Department of Biological Physics, Physical Institute, Eötvös University, H-1117 Budapest, Pázmány sétány 1, Hungary

2: Estrato Research and Development Ltd., H-1121 Budapest, Mártonlak utca 13., Hungary

**The bluish noctilucent clouds (NLCs) are observable only during the time of summer solstice. They are most commonly observed at latitudes between 50 and 70 degrees, but there is evidence that corroborates their gradual increase which may be linked with the slow climate change. We present the discovery of noctilucent clouds after the eruption of volcano Krakatoa. We also describe their formation and types, then demonstrate the Noctilucent Cloud (NLC) WakeUp Android application developed by us. This tool can help us to calculate automatically the detection windows of noctilucent clouds depending on the date and the solar elevation angle.**

**Figure 1**: Noctilucent clouds observed by A. Farkas from Mogyoród (47° 36' 10" N, 19° 14' 31" E), Hungary, on 29/30 June 2007, on 22/23 July 2009 and on 30/31 June 2013.

| Date | Time (UT+2) | Observed NLC Forms | Brightness | Maximum elevation |
|---|---|---|---|---|
| **2007** | | | | |
| June 15/16. | 21:40-22:10 | IIab, IIIab, IVa, P, V | 5 | |
| June 28/29. | 22:00-22:45 | IIab, IIIa | | |
| June 29/30. | 21:35-23:00 | IIab, IIIa, S, P, | 5 | |
| June 14/15. | 22:30 | IIab, IIIa | 2 | |
| **2008** | | | | |
| July 1/2. | 04:17-04:55 | IIa, IIIa, IVa | 2 | 8° |
| July 7/8. | 03:15-03:40 | IIa, IVa | 4 | 10° |
| July 18/19. | 03:40-04:20 | IIa, P, V | 3 | 13° |
| **2009** | | | | |
| June 13/14. | 22:00-22:23 | IIab | 3 | 10° |
| June 13/14. | 03:30 | IIb | 2 | 5° |
| June 14/15. | 03:45 | IIb | 2 | 10° |
| June 16/17. | 03:00-03:15 | IIIb | 3 | 10° |
| June 18/19. | 22:09-22:27 | IIab | 2 | 5° |
| June 20/21. | 03:30-03:45 | I, IIb, P | 2 | 5° |
| June 25/26. | 22:00-22:30 | IIb, IIIb, P | 4 | 10° |
| July 7/8. | 03:30-03:45 | IVa | 3 | 10° |
| July 8/9. | 22:15-22:30 | | | |
| July 11/12. | 22:00 | IIa, IIIa, P | | |
| July 12/13. | 21:20-22:20 | IIa | 4 | 20° |
| July 13/14. | 21:15-22:20 | IIb, IIIb, P | 4 | 20° |
| July 13/14. | 03:20-03:40 | I, IIab | 2 | 5° |
| July 14/15. | 21:30-22:05 | IIb, P | 2 | 5° |
| July 16/17. | 03:40-03:50 | IIb, IIIb | 3 | 15° |
| July 19/20. | 21:30-22:10 | IIa, IIIb, IVc | 3 | 10° |
| July 21/22. | 21:30-22:10 | IIab | 4 | 10° |
| July 21/22. | 03:00-05:00 | IIab, IIIb, IVbc, S, P | 5 | 20° |
| July 25/26. | 21:30-21:40 | IIa, IIIa | 1 | 5° |
| **2010** | | | | |
| June 14/15. | 03:00-03:15 | IIa | 2 | 3° |
| June 23/24. | 03:05-03:15 | IIa | 2 | 10° |
| June 28/29. | 22:05-22:25 | IIa, IIb, IIIa | 3 | 10° |
| June 29/30. | 22:10-22:25 | I | 2 | 5° |
| July 10/11. | | IVc | 4 | 5° |
| **2011** | | | | |
| June 15/16. | 22:10-22:30 | IIa, IIIa | 2 | 5° |
| July 9/10. | 03:25-04:40 | IIa, IIIb, IVb | 2 | 55° |
| **2012** | | | | |
| June 11/12. | 21:55-22:30 | IIa, IIIa | 3 | 15° |
| June 13/14. | 03:00-05:10 | IIb, IIIb, IVc, P, S | 4 | 35° |
| June 14/15. | 02:55-04:20 | I, IIab, IIIa, IVab | 3 | 20° |
| June 16/17. | 22:15-23:00 | I, IIa | 1 | 10° |
| June 16/17. | 02:35-03:45 | I, IIab, IIIb | 2 | 20° |
| June 17/18. | 22:00-22:30 | IIab, IIIa | 1 | 10° |
| June 17/18. | 02:50-04:10 | I, IIa, IIIa | 1 | 15° |
| June 22/23. | 02:35-03:40 | I, IIa, IIIa | 1 | 8° |
| June 26/27. | 22:30 | I | 1 | 5° |
| June 26/27. | 03:00 | IIab | 3 | |
| June 22/23. | 03:50 | IIab | 1 | 3° |
| **2013** | | | | |
| June 16/17. | 02:45-03:30 | IIab | 3 | 12° |
| June 26/27. | 22:05-22:50 | IIab, IIIab, IVb, S | 3 | 8° |
| June 30/31. | 22:00-23:00 | I, IIab, IIIb, S, V | 5 | 15° |

**Table 1**: Observed noctilucent clouds from Hungary between 2007-2013.

## Occurrence and Observation of Noctilucent Clouds

The generally bluish noctilucent clouds (NLCs) or night-shining clouds are spectacular atmospheric optical phenomena which appear only around the summer solstice in the vicinity of the northern horizon. They are made of tiny water ice crystals 150 nm in diameter and formed in the mesosphere (around 83 km), higher than any other clouds in Earth's atmosphere. They become visible from the surface only during the deep twilight when they are illuminated by sunlight from below the horizon. NLCs are most commonly observed between the 45°- 80° latitudes, but the most and the brightest NLCs are observed around the 60° latitudes (Kokhanovsky, 2005; Gadsden *et al.*, 2006). Interestingly, since the recent past more and more people observe it from lower latitudes also. The first NLCs of the given year in the Northern Hemisphere usually occur in May, however Hungarian observers can look for the NLCs only from mid-June until the end of July (**Table 1, Figure 1-2**).

Their formation is linked to the summer solstice period because the temperature of the mesosphere is the lowest during that time instead of winter (below 130 K), which is ideal for the formation of these clouds besides the very low humidity (von Zahn, 1989; Thomas, 1991). The ice-forming nuclei and water vapor necessary for the creation of ice clouds can be found in the troposphere in practically unlimited quantities in contrast to the mesosphere, which is the rarest and driest layer of the atmosphere, therefore their possible presence and resources are must be discussed separately.

## Sources of Water Vapor and Ice Nuclei

Connection with NLCs detected after the catastrophically and highly destructive eruption of Krakatoa in 1883 or after the Tunguska event in 1908, we can mention volcanic eruptions and water-rich asteroids as the natural sources of water (Fogle, 1967; Schröder, 1999; 2001; Longo, 2007). A part of water vapor is appended to the mesosphere due to the reaction of methane with hydroxyl radicals or due to complex reactions of methane. The methane molecules can fall apart between 40 km and 70 km due to the effects of sunlight, thereafter water molecules can form in the reaction of hydrogen with atmospheric oxygen (Thomas *et al.*, 2001). This chemical process is negligible in the troposphere, but a key in the extremely dry mesosphere. In addition water vapor can be added to the mesosphere as a result of anthropogenic influences, because during the combustion of space rocket fuels water is also formed among other materials. The amount of mesospheric water vapor is constantly decreasing as a result of the photodissociation and the intensity of this reaction is strongly dependent on the solar variation (Nicolet, 1984; Sonnemann *et al.*, 2005; Grygalashvyly *et al.*, 2006). Up to 30% - 40% more water molecules remain in the mesosphere during the sunspot minimum (Chandra *et al.*, 1997, DeLand *et al.*, 2007). It is likely that a large number of NLCs detected from Hungary in 2009 (**Table 1**) can also be associated with an unusually long sunspot minimum. Ice nuclei may be added to the mesosphere with slow air flows or they can originate from meteorites (Shafrir *et al.*, 1967; Turco *et al.*, 1982; Rapp *et al.*, 2003; Apfelbaum *et al.*, 2009).

## Multifarious Morphology of Noctilucent Clouds

The NLCs have great diversity in morphology: four basic types (I, II, III, IV) with sub-groups (a, b, c) and four complex forms (S, P. V, O) are known. The veil (I) is the simplest form, which is generally present in the background of other types and similar to the tropospheric high-level clouds. Bands (II) are often occurring in groups arranged roughly parallel to each other. IIa bands are with blurred and IIb bands are with clearly visible boundary edges. Waves or billows (III) and whirls (IV) with ring structure can also appear. In most cases, two or more types can simultaneously observed. The brightness of NLCs is classified according to a 5-point scale (1-5), where 1 means a very weak and 5 means an extremely bright and illuminating phenomena (Gadsden *et al.*, 2006).

## Long-term Increase

The discovery of NLCs in 1885 had enormous importance in the meteorological and geophysical research. The descriptions and instrumental analyses of observation networks uncovered several details from that unknown part of the atmosphere. Based on long-term observations it is also revealed that NLCs appear more often and more brighter and they are observable from more and more southern latitudes over time. These can be associated with the changes of the mesospheric temperature and the increasing water vapor concentration. These long-term changes may be connected to the global climate change and human activities (Thomas *et al.*, 1989; 2001; 2003; Klostermeyer, 2002; von Zahn, 2003). These grounds are still uncertain, further research is needed to explore the accurate formation and behaviour of NLCs. In addition to investigating this phenomenon with the AIM spacecraft (Aeronomy of Ice in the Mesosphere), it is important to conduct terrestrial visual observations which may help to answer the open questions (Farkas, 2011). Although, for those researchers who regularly observe NLCs, it is very time consuming to search for or calculate from day to day that exactly when they need to monitor the northern horizon. We developed an Android application which can make it easier for observers.

## The services of the NLC Wake Up application

The NLC Wake Up application was developed primarily for research purposes and for photographers who would like to observe NLCs. As a first step, the application determines the locations of the observers, based on the GPS service of their smart phone, thereafter it calculates the current elevation angles of the Sun (**Figure 3**). After the evening Sun was setting and the solar elevation reached -6° below the horizon (when the observation window opens), the application plays an arbitrary ring tone, namely it alerts the researcher or the photographer in order to have the opportunity to observe NLCs. Unfortunately, the phenomenon can not be predicted, so the observer is forced to look for the NLCs through the whole possible observation period and measurements can only be performed if they really appear. The NLC Wake Up application provides the same alerts even when the solar elevation reached -16° below the horizon (when the possible visibility period ends), thus the application indicates the researcher that it is not worth to continue the monitoring. These alarms repeated in the early hours as well. The application can also use the data of an online weather monitoring service, in which case the observer is alarmed only when the sky conditions are appropriate for observing NLCs. It would be useless to get up at night and look for this mesospheric phenomena if they are being covered by lower tropospheric clouds.

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**Figure 2**: Noctilucent clouds observed by A. Farkas from Mogyoród, Hungary, on 22/23 July 2009.

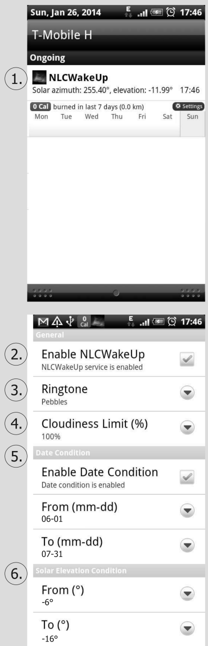


**Figure 3:** Screens of the NLC Wake Up Android application. 1) The activated application shows the current solar azmith and elevation angles. 2) The check mark indicates that the service is enabled. The user can set 3) an arbitrary ring tone, 4) a cloudiness limit, above which the application omits the alarm, 5) a date period and 6) a range of solar elevation when the alarm application operates.