An Earlier Lidar Observation of a Noctilucent Cloud above Logan, Utah (41.7°N)

Joshua P. Herron  
*Utah State University*

Vincent B. Wickwar  
*Utah State University*

Follow this and additional works at: https://digitalcommons.usu.edu/atmlidar_post

Part of the Atmospheric Sciences Commons, and the Physics Commons

**Recommended Citation**

An Earlier Lidar Observation of a Noctilucent Cloud above Logan, Utah (41.7°N)

Joshua P. Herron and Vincent B. Wickwar
Center for Atmospheric and Space Sciences, Utah State University

Abstract
The Atmospheric Lidar Observatory (ALO) Rayleigh-scatter lidar has been operated for 11 years on the Utah State University (USU) campus (41.7° N 111.8° W). During the morning of 22 June 1995 a noctilucent cloud (NLC) was observed with the lidar well away from the twilight periods when NLCs are visible. It lasted for approximately one hour. This observation and a second in 1999 [Wickwar et al., 2002] are very significant because they show the penetration of NLCs equatorward of 50°, which may have important implications for global change. Temperature profiles calculated at hourly intervals were at least 20 K cooler than the 11-year June climatological average for ALO near the NLC altitude. These cool temperatures arose, in part, because of a major temperature oscillation.

Observations & Discussion
The observations were carried out with the Rayleigh-scatter lidar at ALO. The system, consisting of a Spectra Physics Nd:YAG operating at 50 Hz with 600-800 mJ per pulse at 332 nm and a 44-cm diameter Newtonian telescope, has a power-aperture product of 2.77 Wm². The range bins are 250 ns or 37.5 m. The sampling time is 2 minutes corresponding to 3600 laser pulses.

During the early morning of 22 June 1995 a NLC was observed for approximately an hour. This detection is shown in terms of backscatter ratio in Figure 1. The backscatter ratio, R, is one for pure Rayleigh-backscatter, and is greater than one when and where Mie scatter is present. Where S₀ is the Rayleigh-scattered signal and S₀ is the Mie-scattered signal. The Rayleigh-scatter signal was calculated from the average of the observations excluding the profiles containing the NLC.

The main body of the NLC spanned from 83 to 85 km and lasted for ~1 hour starting at 0748 UT. The profiles consist of 10-minute averages in time and 150-m averages in altitude. The averages are performed every 2 minutes and were used to make the contour plot, Figure 1. The peak in the backscatter ratio descended at a rate of 1.9 km/h. A second enhancement occurred at 0930 UT and is most likely another portion of the NLC that was transported into the lidar’s field of view.

The maximum backscatter ratio reached during the night was ~8 as illustrated in Figure 2(b). When compared to other NLC observations, this is a relatively weak NLC. Observations from higher latitudes have reported backscatter ratios > 200 [e.g., Langer et al., 1995]. The altitude of the density equivalent to the NLC peak is ~70 km, Figure 2(a).

In addition to the lidar, a BOMEM Michelson Interferometer was operated at USU during the same time period [Espy, 2004]. Nightly OH temperature measurements from ~87 km, Figure 5, show a cool period from 20 to 26 June 1995 averaging 160 K with the night of 22 June 1995 being significantly cooler (148 K). In addition, the temperatures on average were cooler in 1995 than for the same period in 1996.

To calculate temperatures from the relative density profiles the return signal can only be comprised of Rayleigh-scattered photons, which are proportional to density. To remove the Mie-scattered component caused by the NLC, a fourth order polynomial was fitted across the density gap occupied by the NLC, Figure 3.

The Rayleigh-scatter lidar requires an initialization temperature to derive the temperatures from the relative densities. For the ALO lidar the temperature climatology from the CSU sodium lidar was used [She et al., 2000]. However, these temperatures can be significantly different from the temperatures on a given day. Using the BOMEM temperature for initialization at 87 km gave slightly cooler results, but at NLC altitudes they were within the measurement uncertainty of each other.

15-minute temperature measurements from the BOMEM are given in Figure 6 for the night of 22 June. They show that the temperatures for short periods were much cooler than the nightly average. Because of a short data gap, OH temperatures at 87 km are not available when the NLC appeared at 83-85 km. However, the lowest temperatures occurred two hours earlier. This might have been related to the formation of the NLC at a higher altitude and its subsequent descent as the particles grew large enough to be detected. Alternatively, this very cold period might have given rise to an undetected NLC.

The hourly temperature measurements from the BOMEM were calculated for the lidar returns on an hourly basis. Of the 5 hourly profiles, 4 used the curve fits to remove contributions from the NLC. These hourly temperatures are shown in Figure 4 along with the June temperature average from the ALO climatology for comparison [Herron, 2004].

The hourly temperature measurements from the lidar near 85 km are significantly lower than the June average from the ALO climatology. The minimum temperature was 142 ± 5 K. This is well within the range 130-154 K reported in the NLC temperature survey by Lübken et al. [1996].

In addition to the lidar, a BOMEM Michelson Interferometer was operated at USU during the same time period [Espy, 2004]. Nightly OH temperature measurements from ~87 km, Figure 5, show a cool period from 20 to 26 June 1995 averaging 160 K with the night of 22 June 1995 being significantly cooler (148 K). In addition, the temperatures on average were cooler in 1995 than for the same period in 1996.

The Rayleigh-scatter lidar requires an initialization temperature to derive the temperatures from the relative densities. For the ALO lidar the temperature climatology from the CSU sodium lidar was used [She et al., 2000]. However, these temperatures can be significantly different from the temperatures on a given day. Using the BOMEM temperature for initialization at 87 km gave slightly cooler results, but at NLC altitudes they were within the measurement uncertainty of each other.

15-minute temperature measurements from the BOMEM are given in Figure 6 for the night of 22 June. They show that the temperatures for short periods were much cooler than the nightly average. Because of a short data gap, OH temperatures at 87 km are not available when the NLC appeared at 83-85 km. However, the lowest temperatures occurred two hours earlier. This might have been related to the formation of the NLC at a higher altitude and its subsequent descent as the particles grew large enough to be detected. Alternatively, this very cold period might have given rise to an undetected NLC.

The hourly temperature measurements from the BOMEM were calculated for the lidar returns on an hourly basis. Of the 5 hourly profiles, 4 used the curve fits to remove contributions from the NLC. These hourly temperatures are shown in Figure 4 along with the June temperature average from the ALO climatology for comparison [Herron, 2004].

The occurrence of the NLC is presumably related to the unusually cold temperatures found at 83-85 km on 22 June 1995. However, comparison of the temperature profiles to the climatological mean profile, Figure 7, provides more information about this event. It shows that the low temperatures are related to a large temperature oscillation with a low value near 85 km and a high value near 75 km. The largest temperature difference from the mean was ~25 K.