Research Note

A POSSIBLE INCREASE IN MID-LATITUDE SIGHTINGS OF NOCTILUCENT CLOUDS?

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ABSTRACT. The mesospheric phenomenon of noctilucent clouds (NLCs) has increasingly been observed from latitudes considered to be on the southern fringe of NLC visibility in North America. The increase in sightings and range, though partly attributable to heightened interest and knowledge of NLCs, may indeed be tied to an actual migration of NLCs to more southerly latitudes as a result of global climate changes.

RÉSUMÉ. Le phénomène mésosphérique de nuages noctiluques (NLCs) est de plus en plus observé dans les latitudes considérées à la marge sud des latitudes habituelles de visibilité de ces nuages en Amérique du nord. La croissance de ces observations et du rayon d'action, même si attribuable en partie à l'intérêt et les connaissances grandissants dans ce phénomène de nuages noctiluques, pourrait toutefois bien être lié à un mouvement réel vers les latitudes sud, à la suite des changements du climat global. SEM

Noctilucent clouds (NLCs) are mesospheric ice clouds that form over high latitudes in the months of May through August in the northern hemisphere as well as in the corresponding austral latitudes during their summer months. They are believed to be the product of a complex process involving the nucleation of water vapour upon meteoric dust and ions in the upper mesosphere under the typically cold conditions experienced there in the summer (Turco *et al.* 1982). Over the poles the clouds exist as a large, probably continuous veneer, and are known as polar mesospheric clouds, or PMCs (Olivero & Thomas 1986). When PMCs form in subarctic areas, at latitudes of 50°–65° N in the northern hemisphere, they are visible from the ground and are known by the more common term of NLCs. Usually NLCs can be seen between 3°–5° south of their area of evolution (Thomas 1996), but only in twilight through a combination of their optical thickness (typically much less than 0.001) and their great height (82–83 km), which allows them to remain sunlit long after sunset at ground level (Fogle 1966). Since the ice clouds scatter light from the below-horizon Sun, they appear as cirrus-like arrays of silvery-white strands, often tinged with blue because of absorption by stratospheric ozone.

In recent years there has been much speculation about why NLCs exist, why sightings of them appear to be increasing (Gadsden 1997), and whether or not such changes are signals of global climate change. Thomas *et al.* (1989) presented evidence indicating that about half of the water vapour existing in the mesosphere results from the transformation of methane, one of the so-called greenhouse gases, emitted from Earth's surface. Sources of methane are numerous and include bogs, rice paddies, cattle, and mining and petroleum production. Increased agricultural and industrial activity in the past two centuries has freed up large amounts of methane; the gas is transported into the upper atmosphere, and, in the stratosphere, breaks down into water vapour among other products. The attendant increase in water vapour has led to increases in both the number and size of ice particles; previously sub-visible clouds would then become visible, increasing the overall frequency of NLC sightings (Thomas 1996). The increase in sightings has, for the most part, taken place in the aforementioned latitudes where NLCs are now commonly seen. Thomas (1996) predicts that farther-reaching changes in the mesospheric environment will result in an encroachment of the evolved NLCs into more southerly areas where the phenomenon is now only very rarely observed.

The historical southern limit for NLC visibility in the northern hemisphere has been the 45° N parallel, although McConnell (1987) extended that limit somewhat, claiming that NLCs had been reported previously in the state of New York at a latitude of around 42° N. In a summary made ten years earlier, Bronshten & Grishin (1976) compared three different results: a Soviet study covering the period 1885–1956 that reported a most southerly NLC sighting at 46°.4 N, another Soviet study surveying the period 1957–59 that gave a similar value of 45°.0 N, and a North American survey conducted by Fogle & Haurwitz (1966) covering the years 1964–65 that reported a value of 45°.5 N. Fogle (1966) compared the percentage of clear nights during which NLCs could be seen at different latitudes and found that, during the height of NLC season in June and July, fully 10% of clear nights were NLC-active at a latitude of 45° N. Fogle also stated, however, that no reliable sightings of NLCs had been reported from immediately south of the 45th parallel.

A contour map derived from observations over the period 1988–92 by members of the North American surveillance network NLC CAN AM indicated, on the basis of lines of equal average seasonal NLC incidence, that there was a probability of seeing NLCs only once per year along the 49th parallel in the western half of the continent (Zalcik 1993). Ironically, also in 1993, aurora observer Jay Brausch from Glen Ullin, North Dakota (latitude 46°.8 N) reported an NLC in the pre-dawn sky on July 1 (Zalcik 1994). Photographs taken of the event (*e.g.* figure 1) show that the phenomenon was unmistakably a NLC. Until Brausch's sighting, the farthest south from which an NLC CAN AM report originated was Victoria, British Columbia (June 18, 1991; observer C. Spratt) at latitude 48°.4 N, nearly two degrees of latitude north of Brausch's location. In subsequent years, during

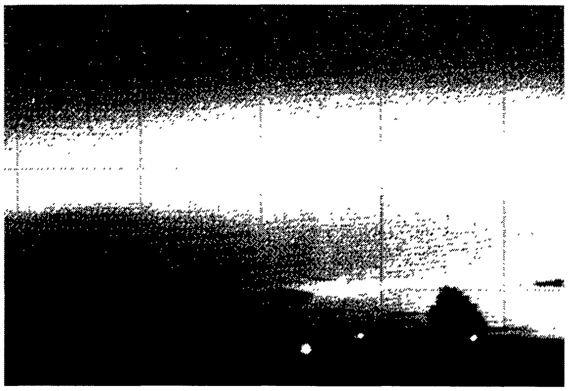

Fig. 1 — Photograph of a NLC (white patch near horizon) with auroral arc above in the morning sky at 09:10 UT (03:10 local time) on July 1, 1993. The Sun was 13°.2 below the horizon at the time the photograph was taken by Jay Brausch at Glen Ullin, North Dakota (latitude 46°.8 N).

which he maintained an earnest watch for NLCs, Brausch has seen them at least once per year; the 1995 season was remarkable with seven active nights from Glen Ullin (and another from Minnesota), a number similar to the average seasonal occurrence of NLCs from the high incidence zone (55°–60° N) a full ten degrees of latitude to his north.

On the morning of June 23, 1997, the author observed and photographed a display (figure 2) at Beaverhead National Forest in Montana (latitude 44°.7 N, longitude 113°.0 W). The site appears to be the farthest point south in North America from which NLCs have been photographed to date. Unfortunately, there were no sightings from other observers to corroborate the observation, although the recorded photographs appear to show a typical array of NLCs consisting of band-type clouds similar to those in instructional images in a recently-published NLC observing manual by Gadsden & Parvainen (1995).

Fig. 2 — Photograph of NLCs from Beaverhead National Forest, Montana (latitude 44°.7 N) at 10:30 UT (04:30 local time) on June 23, 1997. The Sun was 10°.5 below the horizon when the photograph was taken by Mark Zalcik.

The observed azimuths and altitudes of the NLCs seen by Zalcik can be used to establish the downrange position of the clouds. The NLCs were seen to cover a span of 25° in azimuth (at bearings ranging from 5° to 30°) at elevation angles of <5° to 10° above the horizon. Reference to graphs provided by Fogle (1966) yields downrange distances of 400 km for the southern or upper edges of the observed NLCs located 10° above the horizon. The clouds were, therefore, well south of the U.S. border, sitting over the area of Great Falls, Montana, near the 48th parallel. From how much farther south could the display have been seen? Reference to Fogle's graphs suggests that an observer located 200 km farther southwest on the Zalcik–NLC line of sight, near the Utah-Nevada border around the 43rd parallel, would have seen the same clouds ~5° above the local horizon. In general, if one observer sees NLCs, it is possible that observers farther south can see the same display. Such a possibility takes on new significance here, where we are examining the equator-ward edge of the range of NLC visibility.

The locations of Beaverhead National Forest and Glen Ullin, the site of Jay Brausch's observations, are shown in figure 3, which is a contour map of NLC sightings that updates the information in the earlier map by Zalcik (1993) and covers the eight-year period 1988–95 (climatological data are listed in Table I). Glen Ullin appears as an anomalous island of high NLC activity on the basis of Brausch's 1994 and 1995 observations, and it is difficult to explain why NLC frequency in the American mid-west should be so high. There is clearly a need for more NLC-watching at such latitudes to determine if the Glen Ullin anomaly is real or if instead it is likely that NLCs may be more commonly seen in the 45°–50° N latitude range than was previously believed.

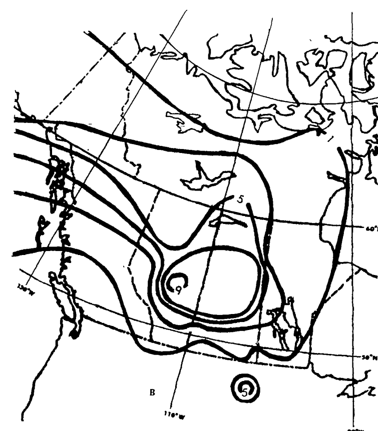

Fig. 3 — A contour map showing lines of equal average seasonal NLC incidence in western North America during the period 1988–95. The five-display iso-line in the U.S. south of the Saskatchewan-Manitoba border denotes Glen Ullin, North Dakota, observing site of Jay Brausch. The letter "B" denotes Beaverhead National Forest, where the author observed NLCs on June 23, 1997. NLC detections decrease to the south as a consequence of their southern limits of evolution, to the north as a result of the shorter lengths of polar nights in summer (and hence the intervals during which NLCs may be seen), and to the east, possibly because of tropospheric cloudiness over Hudson Bay.

Another sighting of a NLC from NLC CAN AM records (Lohvinenko & Zalcik 1991) stands out, namely that by amateur observer Steve McKinnon in Oakville, Ontario (latitude 43°.3 N) on the evening of July 15, 1988. As with the author's June 23, 1997, observation referred to above, there were no corroborative sightings. Since 1988 there have been a few other reports of mid-latitude NLC CAN AM observers who may have seen NLCs but were unable to make a definitive designation and, moreover, were not supported by confirming observations by others nearby. Conversely, some southerly observers, notably Michael Boschat in Halifax, Nova Scotia (latitude 44°.6 N), have not seen any NLCs since 1988.

Recent mid-latitude sightings of NLCs have not been confined to North America. At Alma-Ata (latitude 43°.2 N) in Kazakhstan, Victor G. Tejfel of the Fessenkov Astrophysical Institute reported the detection of NLCs on June 17 and June 24, 1996, and on June 6, 1997 (note the lack of a corrrelation with the June 23, 1997, sighting from Beaverhead), after never seeing NLCs from that location in the preceding four decades (Tom McEwan, personal communication, 1997).

Could these mid-latitude NLCs have been mistaken for something else? Positive detection of NLCs can be a challenge, especially for someone who has never seen them; other types of clouds, such as cirrus clouds illuminated by moonlight or distant low clouds illuminated by artificial lighting, can mimic NLCs.

It is nonetheless apparent that it has indeed been possible to see NLCs from the upper to mid forties of north latitude over the past decade, if not before then. What is unclear is whether or not the clouds are truly evolving with increasing frequency at the southern edge of their range, or if their range is extending equator-ward. With the latter comes the potential for NLCs to be a new feature of the summer twilights in the lower forties of latitude. The situation is analogous to that at the end of the last century, prior to which NLCs had *never been seen*. Only in 1885 was the existence of the phenomenon confirmed; exhaustive efforts by, for example, Gadsden (1985) have found no older sightings. Only in 1933, nearly half a century later, were they first reported in North America (Vestine 1934). Did the clouds merely evade detection or did they simply not exist prior to 1885? Thomas *et al.* (1989) suggest that the very debut of NLCs is explained by the gradual increase in NLC brightness past the threshold of naked eye visibility as historical methane levels, and hence mesospheric water vapour concentrations, have climbed.

One must wonder, over a century later, though the phenomenon is now a regular sight in the twilight skies of the southern subarctic, why there is now a steadily increasing tally of NLC reports from those areas farther south where NLCs have rarely, if ever, been seen before. Perhaps the clouds are indeed on the equator-ward march as a consequence of global increases in the greenhouse gases: methane, which in turn increases water vapour concentrations in the mesosphere, and carbon dioxide, which lowers mid-latitude mesospheric temperatures, or perhaps we simply have a more enlightened global regiment of skywatchers.

Table I
Summary of North American Sightings of Noctilucent Clouds, 1988–1995

Site	N Lat.	W Long.	Type[a]	Number of Sightings 1988	1989	1990	1991	1992	1993	1994	1995	Years	Displays	Displays Per Year
Baker Lake	64°.3	96°.1	F	..	..	..	..	..	1	0	3	3	4	1.33
Winnipeg	49°.9	97°.2	I	..	2	1	1	0	..	..	..	4	4	1.00
Lynn Lake	56°.9	101°.1	F/W	..	..	..	..	..	2	4	2	3	8	2.67
The Pas	54°.0	101°.1	F	1	8	3	3	..	1	4	6	7	26	3.71
Glen Ullin	46°.8	101°.8	I	..	..	..	..	..	..	4	7	2	11	5.50
Broadview	50°.4	102°.7	W	2	3	1	0	0	..	..	..	5	6	1.20
Estevan	49°.2	103°.0	W	..	..	2	0	1	..	..	..	3	3	1.00
Wynyard	51°.8	104°.2	W	6	8	..	..	..	..	..	..	2	14	7.00
Cambridge Bay	69°.1	105°.1	W	..	0	0	0	0	0	..	..	5	0	0.00
La Ronge	55°.2	105°.3	F	..	..	10	9	7	7	8	8	6	49	8.17
Swift Current	50°.3	107°.7	F	1	2	..	..	..	..	..	..	2	3	1.50
Ft. Reliance	62°.2	109°.2	W	1	9	2	..	..	..	..	..	3	12	4.00
Lethbridge	49°.6	112°.8	W	7	3	0	1	0	..	..	..	5	11	2.20
Edmonton	53°.7	113°.5	I	12	8	8	12	3	9	16	..	7	68	9.71
Slave Lake	55°.3	114°.8	W	7	8	5	1	..	..	..	..	4	21	5.25
Whitecourt	54°.1	115°.8	F	..	..	..	..	..	4	3	4	3	11	3.67
Vancouver	49°.2	123°.2	W	..	..	1	0	0	0	0	..	5	1	0.20
Cape Parry	70°.2	124°.7	W	1	0	..	..	..	..	..	..	2	1	0.50
Watson Lake	60°.1	128°.8	F	4	6	5	4	..	..	..	..	4	19	4.75
Cape St. James	51°.9	131°.0	W	..	..	..	2	0	..	..	..	2	2	1.00

Notes:[a] Notation for Types: W = Atmospheric Environment Service Weather Station, F = Transport Canada Flight Service Station, I = Individual Observer: Todd Lohvinenko (Winnipeg), Brausch (Glen Ullin), Zalcik (Edmonton).

The sites are listed in order of increasing longitude. Missing entries indicate years in which no observing was conducted or that data for the year were not used in the analysis. Criteria for site selection included observing for at least two years during the survey period, observing through most of the three month season from May through August, and completeness of the written reports. The paucity of sightings in 1992 is believed to be the result of mesospheric changes brought about by the Mount Pinatubo eruption a year earlier (Gadsden 1997).

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References

Bronshten, V. A. & Grishin, N. I. 1976, Noctilucent Clouds (Keter House: Jerusalem)
Fogle, B. 1966, Noctilucent Clouds, Geophys. Rep. UAG R-177, University of Alaska, College
Fogle, B. & Haurwitz, B. 1966, Space Sci. Rev., 6, 279
Gadsden., M. 1985, in Historical Events and People in Geosciences, ed. W. Schröder (Lang: Bern, Frankfurt), p. 131
Gadsden, M. 1997, Adv. Space Res., 20, 2097
Gadsden, M. & Parvainen, P. 1995, Observing Noctilucent Clouds, International Association of Geomagnetism and Aeronomy
Lohvinenko, T. W. & Zalcik, M. S. 1991, Arctic, 44, 328
McConnell, D. 1987, Astronomy, 15, 42
Olivero, J. J. & Thomas, G. E. 1986, J. Atmos. Sci., 43, 1263
Thomas, G. E. 1996, Adv. Space Res., 18, (3), 149
Thomas, G. E., Olivero, J. J., Jensen, E. J., Schroeder, W. & Toon, O. B. 1989, Nature, 338, 490
Turco, R. P., Toon, O. B., Whitten, R. C., Keesee, R. G. & Hollenbach, D. 1982, Planet. Space Sci., 30, 1147
Vestine, E. H. 1934, JRASC, 28, 249
Zalcik, M. 1993, Clim. Bull., 27,165
Zalcik, M. 1994, Sky & Telescope, 88, 76

APPENDIX I.

NLC CAN AM participants during the years 1988–1997.

Amateur observers: Michael Boschat, Halifax, NS; Jay Brausch, Glen Ullin, ND; Peter Brown, Sheila Callan, Michael Gabriel, Helen Hawes, Robert Howell, Brian Tkachyk, Ft. McMurray, AB; Bill Burton, Reston, VA; Gaetan Chevalier, Ste.-Foy, PQ; Martin Connors, Alister Ling, Bruce McCurdy, Murray Paulson, Don Thacker, Larry Wood, Mark Zalcik, Edmonton, AB; David Dawson, Broad Brook, CT; Bob Fischer, Fairbanks, AK; Susan French, Scotia, NY; L. Geelan, Cochrane, AB; Gary Hargreaves, Vancouver, BC; Richard Huziak, Gord Sarty, Saskatoon, SK; Randall Janssen, West Lafayette, IN; Dale Johnson, Muskegon, MI; Lucian Kemble, Lumsden, SK; Glen LeDrew, Cape Parry, NT; Todd and Stan Lohvinenko, Winnipeg, MB; Wayne Madea, Mapleton, ME; Larry Manuel, Calgary, AB; Cheryl Matsugi, Raymond, AB; Steve McKinnon, Oakville, ON; Adrienne Morris, Buffalo, NY; Dave Parkhurst, Anchorage, AK; John Rousom, Arva, ON; Art and Joan Seabury, Jr., Norris Point, NF; Chris Spratt, Victoria, BC; G. E. Thomas, Boulder, CO; Ron Thompson, Wynyard, SK; Oscar Van Dongen, Vermilion, AB; Allen Walker, Plato, SK; Karren Webb, Freeport, MI.

Airline pilots: Stuart Beresford, Bob Fearn, and Frank Kosalla.

Canadian weather and flight service stations: Alert, NT; Baker Lake, NT; Broadview, SK; Cambridge Bay, NT; Cape Parry, NT; Cape St. James, BC; Churchill, MB; Cold Lake, AB, Cree Lake, SK; Edson, AB; Estevan, SK; Ft. McMurray, AB; Ft. Reliance, NT; Gander, NF; Goose Bay, NF; La Ronge, SK; Lethbridge, AB; Lynn Lake, MB; Meadow Lake, SK; Montreal, PQ; Moose Jaw, SK; Moosonee, ON; Peace River, AB; Pickle Lake, ON; Red Lake, ON; Schefferville, PQ; Sept-Îles, PQ; Sioux Lookout, ON; Slave Lake, AB; Swift Current, SK; The Pas, MB; Thompson, MB; Vancouver, BC; Wabush, NF; Watson Lake, YT; Whitecourt, AB; Whitehorse, YT; Wynyard, SK; Yellowknife, NT.

U.S. weather station: Fairbanks, AK.

MARK S. ZALCIK is the amateur astronomer who founded the Noctilucent Cloud Canadian-American (NLC CAN AM) surveillance network in 1987 and who has served as its co-ordinator since then. He holds diplomas in chemical technology from the Northern Alberta Institute of Technology and in mineral resources/prospecting from the Saskatchewan Institute of Applied Science and Technology. He has been a participant in a variety of meteorite search efforts (see JRASC, *91, 248-249, 1997). His interests include astronomy, meteorites and impact craters, and backpacking.*