

= Noctilucent cloud =

Night clouds or noctilucent clouds are tenuous cloud @-@ like phenomena that are the " ragged edge " of a much brighter and pervasive polar cloud layer called polar mesospheric clouds in the upper atmosphere , visible in a deep twilight . They are made of ice crystals . Noctilucent roughly means night shining in Latin . They are most commonly observed in the summer months at latitudes between 50 ° and 70 ° north and south of the equator . These clouds can be observed only when the Sun is below the horizon for the observer , but while the clouds are still in sunlight .

They are the highest clouds in Earth 's atmosphere , located in the mesosphere at altitudes of around 76 to 85 kilometres (47 to 53 mi) . They are normally too faint to be seen , and are visible only when illuminated by sunlight from below the horizon while the lower layers of the atmosphere are in the Earth 's shadow . Noctilucent clouds are not fully understood and are a recently discovered meteorological phenomenon ; there is no record of their observation before 1885 .

Noctilucent clouds can form only under very restricted conditions ; their occurrence can be used as a sensitive guide to changes in the upper atmosphere . They are a relatively recent classification . The occurrence of noctilucent clouds appears to be increasing in frequency , brightness and extent .

= = Formation = =

Night clouds or noctilucent clouds are composed of tiny crystals of water ice up to 100 nm in diameter and exist at a height of about 76 to 85 km (47 to 53 mi) , higher than any other clouds in Earth 's atmosphere . Clouds in the Earth 's lower atmosphere form when water collects on particles , but mesospheric clouds may form directly from water vapour in addition to forming on dust particles .

Data from the Aeronomy of Ice in the Mesosphere satellite suggests that noctilucent clouds require water vapour , dust , and very cold temperatures to form . The sources of both the dust and the water vapour in the upper atmosphere are not known with certainty . The dust is believed to come from micrometeors , although particulates from volcanoes and dust from the troposphere are also possibilities . The moisture could be lifted through gaps in the tropopause , as well as forming from the reaction of methane with hydroxyl radicals in the stratosphere .

The exhaust from Space Shuttles , which was almost entirely water vapour after the detachment of the Solid Rocket Booster at a height of about 46 km , was found to generate minuscule individual clouds . About half of the vapour was released into the thermosphere , usually at altitudes of 103 to 114 km (64 to 71 mi) . In August 2014 , a SpaceX Falcon 9 also caused noctilucent clouds over Orlando , FL after a launch .

The exhaust can be transported to the Arctic region in little over a day , although the exact mechanism of this very high @-@ speed transport is unknown . As the water migrates northward , it falls from the thermosphere down into the colder mesosphere , which occupies the region of the atmosphere just below . Although this mechanism is the cause of individual noctilucent clouds , it is not thought to be a major contributor to the phenomenon as a whole .

As the mesosphere contains very little moisture , approximately one hundred millionth that of air from the Sahara desert , and is extremely thin , the ice crystals can form only at temperatures below about ? 120 ° C (? 184 ° F) . This means that noctilucent clouds form predominantly during summer when , counterintuitively , the mesosphere is coldest , therefore they can 't be observed (even if they are present) inside the Polar circles because the Sun is never low enough under the horizon at this season at these latitudes . Noctilucent clouds form mostly near the polar regions , because the mesosphere is coldest there . Clouds in the southern hemisphere are about 1 km (0 @.@ 62 mi) higher than those in the northern hemisphere .

Ultraviolet radiation from the Sun breaks water molecules apart , reducing the amount of water available to form noctilucent clouds . The radiation is known to vary cyclically with the solar cycle and satellites have been tracking the decrease in brightness of the clouds with the increase of ultraviolet radiation for the last two solar cycles . It has been found that changes in the clouds follow

changes in the intensity of ultraviolet rays by about a year , but the reason for this long lag is not yet known .

Noctilucent clouds are known to exhibit high radar reflectivity , in a frequency range of 50 MHz to 1 @. @ 3 GHz . This behaviour is not well understood but a possible explanation is that the ice grains become coated with a thin metal film composed of sodium and iron , which makes the cloud far more reflective to radar , although this explanation remains controversial . Sodium and iron atoms are stripped from incoming micrometeors and settle into a layer just above the altitude of noctilucent clouds , and measurements have shown that these elements are severely depleted when the clouds are present . Other experiments have demonstrated that , at the extremely cold temperatures of a noctilucent cloud , sodium vapour can rapidly be deposited onto an ice surface .

= = Discovery and investigation = =

Noctilucent clouds are first known to have been observed in 1885 , two years after the 1883 eruption of Krakatoa . It remains unclear whether their appearance had anything to do with the volcano eruption , or whether their discovery was due to more people observing the spectacular sunsets caused by the volcanic debris in the atmosphere . Studies have shown that noctilucent clouds are not caused solely by volcanic activity , although dust and water vapour could be injected into the upper atmosphere by eruptions and contribute to their formation . Scientists at the time assumed the clouds were another manifestation of volcanic ash , but after the ash had settled out of the atmosphere , the noctilucent clouds persisted . Finally , the theory that the clouds were composed of volcanic dust was disproved by Malzev in 1926 . In the years following their discovery , the clouds were studied extensively by Otto Jesse of Germany , who was the first to photograph them , in 1887 , and seems to have been the one to coin the term " noctilucent cloud " , which means " night @-@ shining cloud " . His notes provide evidence that noctilucent clouds first appeared in 1885 . He had been doing detailed observations of the unusual sunsets caused by the Krakatoa eruption the previous year and firmly believed that , if the clouds had been visible then , he would undoubtedly have noticed them . Systematic photographic observations of the clouds were organized in 1887 by Jesse , Foerster , and Stolze and , after that year , continuous observations were carried out at the Berlin Observatory . During this research , the height of the clouds was first determined , via triangulation . The project was discontinued in 1896 .

In the decades after Otto Jesse 's death in 1901 , there were few new insights into the nature of noctilucent clouds . Wegener 's conjecture , that they were composed of water ice , was later shown to be correct . Study was limited to ground @-@ based observations and scientists had very little knowledge of the mesosphere until the 1960s , when direct rocket measurements began . These showed for the first time that the occurrence of the clouds coincided with very low temperatures in the mesosphere .

Noctilucent clouds were first detected from space by an instrument on the OGO @-@ 6 satellite in 1972 . The OGO @-@ 6 observations of a bright scattering layer over the polar caps were identified as poleward extensions of these clouds . A later satellite , the Solar Mesosphere Explorer , mapped the distribution of the clouds between 1981 and 1986 with its ultraviolet spectrometer . The clouds were detected with a lidar in 1995 at Utah State University , even when they were not visible to the naked eye . The first physical confirmation that water ice is indeed the primary component of noctilucent clouds came from the HALOE instrument on the Upper Atmosphere Research Satellite in 2001 .

In 2001 , the Swedish Odin satellite performed spectral analyses on the clouds , and produced daily global maps that revealed large patterns in their distribution .

On April 25 , 2007 , the AIM satellite (Aeronomy of Ice in the Mesosphere) was launched . It is the first satellite dedicated to studying noctilucent clouds , and made its first observations on May 25 , 2007 . Images taken by the satellite show shapes in the clouds that are similar to shapes in tropospheric clouds , hinting at similarities in their dynamics .

On August 28 , 2006 , scientists with the Mars Express mission announced that they found clouds of carbon dioxide crystals over Mars that extended up to 100 km (62 mi) above the surface of the

planet . They are the highest clouds discovered over the surface of a planet . Like noctilucent clouds on Earth , they can be observed only when the Sun is below the horizon .

Research published in the journal Geophysical Research Letters in June 2009 suggests that noctilucent clouds observed following the Tunguska Event are evidence that the impact was caused by a comet .

The United States Naval Research Laboratory (NRL) and the United States Department of Defense Space Test Program (STP) conducted the Charged Aerosol Release Experiment (CARE) on September 19 , 2009 , using exhaust particles from a Black Brant XII suborbital sounding rocket launched from NASA 's Wallops Flight Facility to create an artificial noctilucent cloud . The cloud was to be observed over a period of weeks or months by ground instruments and the Spatial Heterodyne IMager for MEsospheric Radicals (SHIMMER) instrument on the NRL / STP STPSat @-@ 1 spacecraft . The rocket 's exhaust plume was observed and reported to news organizations in the United States from New Jersey to Massachusetts .

= = Observation = =

Noctilucent clouds are generally colourless or pale blue , although occasionally other colours including red and green occur . The characteristic blue colour comes from absorption by ozone in the path of the sunlight illuminating the noctilucent cloud . They can appear as featureless bands , but frequently show distinctive patterns such as streaks , wave @-@ like undulations , and whirls . They are considered a " beautiful natural phenomenon " . Noctilucent clouds may be confused with cirrus clouds , but appear sharper under magnification . Those caused by rocket exhausts tend to show colours other than silver or blue , because of iridescence caused by the uniform size of the water droplets produced .

Noctilucent clouds may be seen by observers at a latitude of 50 ° to 65 ° . They seldom occur at lower latitudes (although there have been sightings as far south as Paris , Utah , Italy , Turkey and Spain) , and closer to the poles it does not get dark enough for the clouds to become visible . They occur during summer , from mid @-@ May to mid @-@ August in the northern hemisphere and between mid @-@ November and mid @-@ February in the southern hemisphere . They are very faint and tenuous , and may be observed only in twilight around sunrise and sunset when the clouds of the lower atmosphere are in shadow , but the noctilucent cloud is illuminated by the Sun . They are best seen when the Sun is between 6 ° and 16 ° below the horizon . Although noctilucent clouds occur in both hemispheres , they have been observed thousands of times in the northern hemisphere , but fewer than 100 times in the southern . Southern hemisphere noctilucent clouds are fainter and occur less frequently ; additionally the southern hemisphere has a lower population and less land area from which to make observations .

The clouds may show a large variety of different patterns and forms . An identification scheme was developed by Fogle in 1970 that classified five different forms . These classifications have since been modified and subdivided .

They may be studied from the ground , from space , and directly by sounding rocket . Also , some noctilucent clouds are made of smaller crystals , 30 nm or less , which are invisible to observers on the ground because they do not scatter enough light .

= = Connection to climate change = =

It has been proposed that the relatively recent appearance of noctilucent clouds , and their gradual increase , may be linked to climate change . The author of this study , atmospheric scientist Gary Thomas of the Laboratory for Atmospheric and Space Physics at the University of Colorado has pointed out that the first sightings coincide with both Krakatoa and the nascent Industrial Revolution , and they have become more widespread and frequent throughout the twentieth century , including an uptick between 1964 and 1986 . The connecting of global warming and noctilucent clouds however , remains controversial . Gary Thomas may have penned his paper after Wilfried Schröder , who might hold the distinction of being the first to explain noctilucent clouds as " indicators " for

atmospheric processes (Gerlands Beiträge zur Geophysik , 1971 , Meteorologische Rundschau 1968 ? 1970) . Most recently in 2012 Lonnie Cumberland 's physics PhD work supported viewing noctilucent clouds as a possible Miner 's Canary for climate change as her third conclusion as a sign of increasing the presence of water in the high atmosphere . NASA scientists speculate that methane may be driven higher into the mesosphere where noctilucent clouds form by climate change and through reactions that end up producing water at such altitudes .

Climate models predict that increased greenhouse gas emissions cause a cooling of the mesosphere , which would lead to more frequent and widespread occurrences of noctilucent clouds . A complementing theory is that larger methane emissions from intensive farming activities produce more water vapour in the upper atmosphere . Methane concentrations have more than doubled in the past 100 years .

Tromp et al. also controversially suggest that a transition to a hydrogen economy would result in an increase in the free hydrogen concentration of the atmosphere by 1 ppm , which would increase the number of noctilucent clouds .