Noctilucent Clouds Connected to Greenhouse Gases

This article continues our series on current topics in arctic upper atmospheric research. Studies of noctilucent clouds, their connection to two major greenhouse gases, and the very detectable changes expected in the upper atmosphere due to these gases, are highly relevant to climate change research and to atmospheric science in general.

Because noctilucent clouds are optically thin, they can be observed only when the sun is 6-12º below the horizon. Under these conditions, the Earth's shadow is above the troposphere while the sun continues to illuminate the upper mesosphere. In this August 2000 photo taken in Valkeakoski, Finland (24° E, 61° N), the tropospheric clouds are dark bands on the horizon, and the noctilucent clouds are the white clouds above (photo by Tom Eklund).

In 1885, observers in northern Germany first reported the appearance of high, thin clouds that seemed to glow at dusk. By 1887, numerous observers had reported night luminous clouds over northern Europe. Data over the past 30 years indicate that the number of noctilucent cloud (NLC) occurrences has nearly doubled, and in the past few years, NLC have been seen over the central U.S. near 40° N—the lowest latitudes yet recorded.

Noctilucent clouds are the highest clouds in the Earth's atmosphere, forming in the upper mesosphere at an average altitude of 82 km. At most a few kilometers thick, NLC form in both polar regions during their respective summer months—typically from about 3-5 weeks before summer solstice to 7-9 weeks afterward.

The general circulation of the global mesosphere is characterized by upward winds in the summer hemisphere that cycle latitudinally to downward winds in the winter hemisphere. The expansion of gases caused by the upward winds results in summer temperatures at high latitudes in the upper mesosphere that are typically below 140 K (-133°C). As this pool of extremely low temperatures spreads from the "summer" pole to 50° latitude by late May and retracts again by late August, NLC form as mesospheric water vapor freezes on condensation nuclei. An active research topic, the most likely candidates for these nuclei are meteoric dust particles and proton hydrate ions. The radius of a cloud particle is typically less than 100 nm, but their particle size distribution and shape are still under investigation.

Connections to Global Change

The two main factors leading to NLC formation are an increase in water vapor and/or a decrease in the local temperature. Atmospheric methane and carbon dioxide levels directly affect NLC formation through these two factors. Methane is an important source of mesopheric water vapor. Tropospheric water vapor is prevented from dispersing into the mesosphere by the cold trap of the tropopause, while methane, once transported into the upper atmosphere, can form water vapor by interacting with atomic oxygen and hydroxyl radicals. Roughly speaking, each methane molecule leads to two water molecules. The two-fold increase in methane concentrations over the Industrial era may, therefore, partly explain the increase in NLC observations.

The fact that NLC were first reported in 1885, only 117 years ago (a relatively short time, considering the aurora has been observed for centuries), may be connected to the massive 1883 eruption of Krakatau. Presumably a great deal of water vapor injected into the stratosphere by the volcano was transported to the polar upper mesosphere within two years and introduced enough new material rapidly to bring the developing, but not yet detectable, NLC into visibility.

Models indicate that the expected doubling of carbon dioxide in the next 100 years will lead to a 10 K decrease in mesospheric temperature. This will increase the altitude region supporting NLC formation and extend the pool of low temperatures in which the clouds form to middle latitudes. Global change predictions also include increased tropospheric storm activity, which will transport more energy into the mesosphere region by buoyancy or gravity waves. These waves produce the much colder temperatures of the summer upper mesosphere, as the tropospherically generated waves breaking at mesosphere altitudes deposit momentum to the mesospheric wind system. Thus, an increase in gravity wave activity could decrease upper mesosphere temperatures further.

Science Support

A network of ground observers from North America to Asia has recorded NLC behavior on an organized basis for decades, providing invaluable information on NLC occurrence and structure (www.nlcnet.co.uk). Since 1970, satellite-borne optical instrumentation has allowed unobstructed views of NLC, improving knowledge of their global distribution and migration during the summer months.

The NSF Upper Atmospheric Research Section (www.geo.nsf.gov/atm/upper.htm) and NASA rocket and satellite programs (http://spacescience.nasa.gov) fund U.S. research on NLC, including novel remote sensing approaches and sophisticated rocket payloads. Ground stations, such as ALOMAR in Norway (www.rocketrange.no/alomar) and Søndrestrøm in Greenland (http://isr.sri.com), use radars, lidars and other optical instruments to study NLCs. Instrumentation on a NASA satellite called TIMED, launched in 2001 (http://www.timed.jhuapl.edu), will provide new insights into NLC and the mesosphere.

For more information, see http://lasp.colorado.edu/noctilucent_clouds/ or contact Jeff Thayer in Menlo Park, CA (650/859-3557; fax 650/322-2318; thayer@sri.com).