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OBSERVATION OF A POLAR STRATOSPHERIC CLOUD ABOVE MURMANSK ON 29 JANUARY 2008

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Abstract. The results of photographic observations of polar stratospheric (nacreous) clouds dynamics in Murmansk on January, 29, 2008 are presented. The heights of stratospheric clouds are determined and conditions of their formation are discussed.

Introduction

On January, 29, 2008 in Murmansk, Severomorsk, Loparskaya and Murmashy during the period from 10:30 UT till 13:50 UT it observed polar stratospheric clouds. Occurrence of such clouds in our latitudes is rare event. The similar phenomenon above Murmansk has been fixed on January, 16 1997 and on December, 3, 2003. Other cases of occurrence of stratospheric clouds [Roldugin et al., 1997] are known also. Interest to studying stratospheric clouds is connected to circulating processes both thermodynamic and dynamic conditions in the stratosphere. Last years this interest has amplified in connection with influence of stratospheric clouds on the total ozone content in the atmosphere. In this paper we shall present results of photographic and visual observations of stratospheric clouds and we shall define the lower border of a cloudy field.

Results of observations

In Murmansk (68.948ºN, 33.063ºE) on January, 29, 2008 approximately at 10:30 UT our attention has involved unusually bright cloud which was in a southwest part of the sky at height nearly 40º above horizon. The small cloud luminous by silvery-pink colour was roundish form with dimness in the center. During one hour we observed of changes of the form, the sizes, a luminescence and movement of this cloud, and then went to photographic observations which proceeded more than two hours. Photographing of this unusual cloud, to be exact clouds, was made on the digital equipment with an interval 1-3 minutes. The part of such pictures is submitted on Fig. 1.
From Figure it is visible, that appearance of observable clouds has some likeness to cumulus, stratocumulus, cirrus and cirrocumulus clouds with very strong irisation. At first clouds seem small, eventually they changed the form, painting and increased in sizes. Thus it was possible to make out additional structures of various scales as combs and strips. Some from these structures had a wavy kind. The luminescence of clouds had the diversified iridescent colours. In conditions of twilight colour of nacreous clouds seem unusual. At times clouds as though phosphoresced. Separate sites of the cloudy field became much brighter than others. In some minutes bright could appear the next sites. The lighting of the Earth's surface in Murmansk at 13:00 UT, created by the stratospheric cloud was stronger, than the lighting created by the full Moon. Clouds were visible until the dip angle of the Sun under horizon has not exceeded 10º. Shortly before it they have got an orange shade.

Height of stratospheric clouds

For definition of height of a stratospheric cloud it is necessary to find a trajectory of a light beam in the Earth's atmosphere. It is the easiest to make it when the atmosphere is considered a homogeneous medium. In this case the beam trajectory represents a rectilinear piece. In more complex cases effects of the refractive index changes with height are taken into account. In paper [Bronshten, Grishin, 1970] the statement of various methods which were at various times applied to definition of noctilucent clouds heights is given. One of methods is based that as noctilucent clouds are shined with the Sun, they should be outside of the Earth's shadow. Knowing a direction on the given point of the cloud and position of the Earth's shadow in the given direction, it is possible to find the necessary border of noctilucent clouds height. The theory of this method has considerably been advanced by Chamberlain [1961] in application to auroras. It had been received formulas, as for the general spatial case when the observable point does not lie in the Sun azimuth, and at the account of atmospheric shielding. With the help of these formulas we shall make calculation of heights of crossing of border of the terrestrial shadow h_e , which has been not deformed by the atmospheric refraction, with a sight beam. Results of such calculations are presented on Fig. 2.
At calculations of heights of crossing we have neglected a refraction of the light beam and considered that the shadow is absolutely sharp. From the graph it is visible, that at 13:50 UT the atmospheric regions located below 37

km, cease to be shined with the Sun. As calculations have been made for model of the homogeneous atmosphere for definition of true height of a cloud it is necessary to enter amendments on the refraction of light beams in the nonhomogeneous medium.

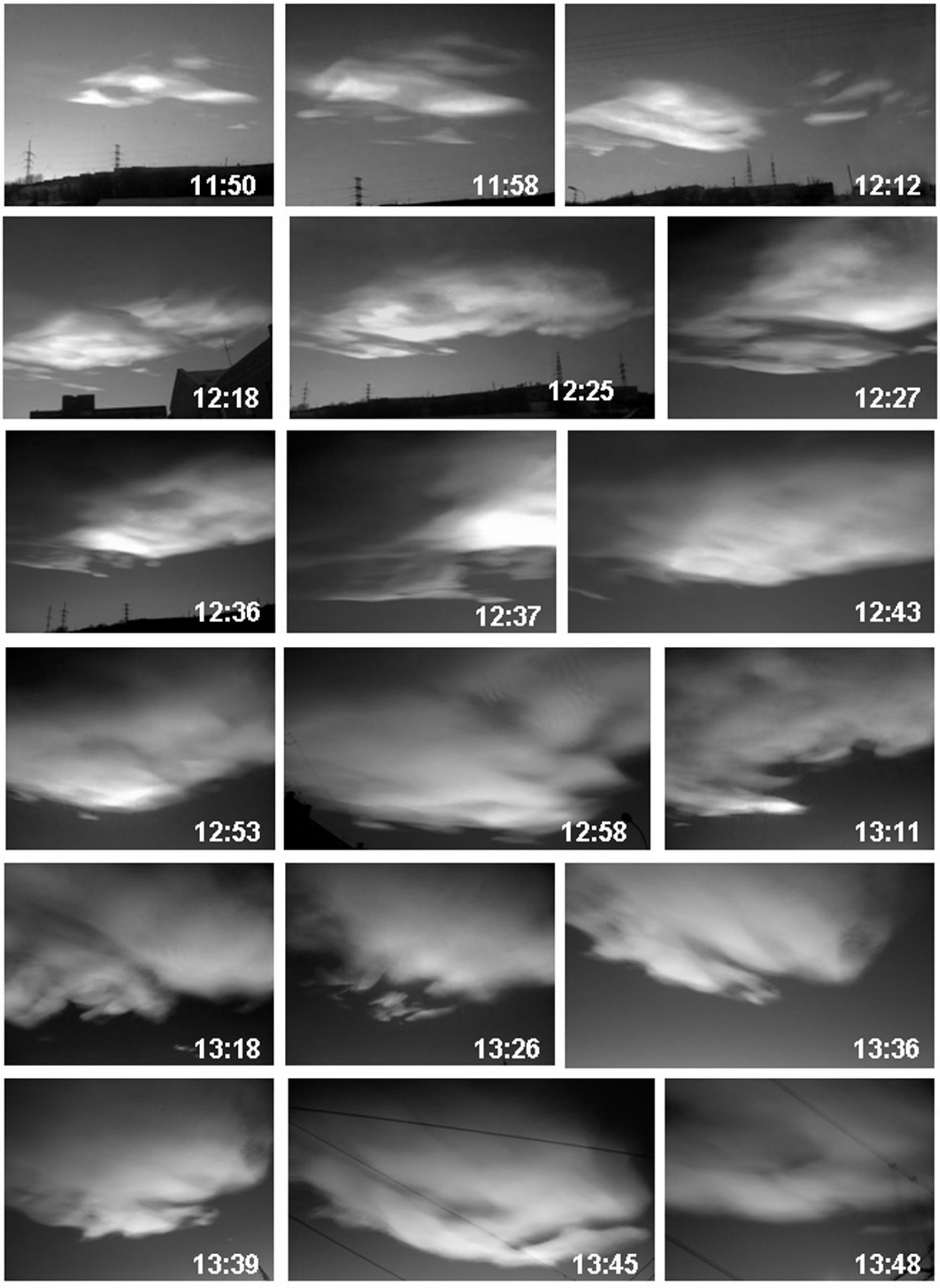

Fig. 1. Nacreous clouds above Murmansk

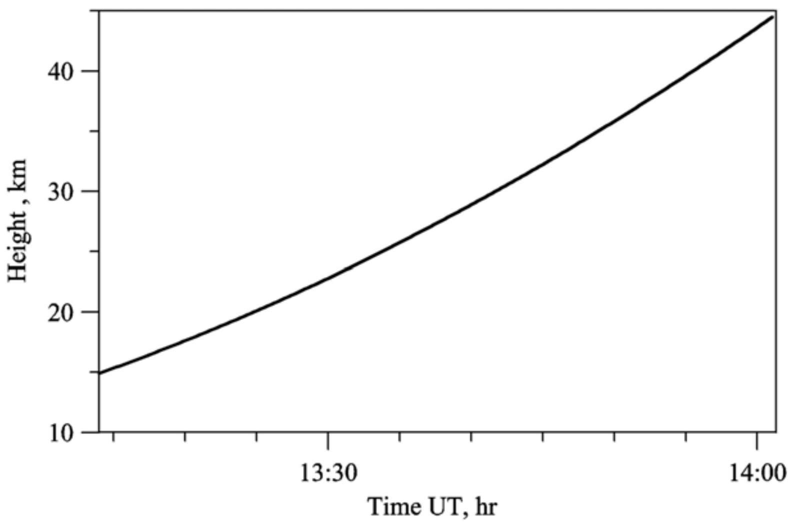

Fig. 2. Dependence of height of crossing of the Earth's shadow and beam of sight from time of observations

Refraction influence can be taken into account in the way based on use of equivalent Earth's radius [Wwedensky, 1973]. In this method the curvilinear ray path in the true atmosphere is replaced rectilinear in a fictitious atmosphere, but not above the real Earth of radius R, and above an imagined spherical surface with equivalent radius R_e. The real height of crossing of border of the terrestrial shadow with the sight beam h (cloud height) is defined from conditions, that a difference between curvature of the beam and curvature of the terrestrial surface, and also the beam length above the Earth in real and equivalent cases remains constants:

$$\frac{1}{\rho} - \frac{1}{R} = -\frac{1}{R_e}, \qquad h(h + 2R_e) = h_e(h_e + 2R), \tag{1}$$

where ρ is the radius of curvature of a light beam:

$$\rho = -\frac{n^2 r}{n_0 R \sin\varphi_0 (dn/dr)}. \tag{2}$$

Here n and n_0 are the refractive index of air at height h and at the Earth's surface, $r = R + h$ and φ_0 is the angle between the tangent to the beam and the perpendicular to the Earth's surface (the angle of exit).

At $\varphi_0 = \pi/2$ (the beam, tangential to the Earth) and concerning small h the formula (2) is reduced to

$$\rho = -\frac{n}{dn/dr} \approx -\frac{10^6}{dN/dr}, \tag{3}$$

where N is the index of tropospheric refraction.

From formulas (1) and (3) we find

$$h = kh_e = h_e \frac{R_e}{R} = \frac{h_e}{1 + 10^{-6} R(dN/dh)} \tag{4}$$

At the normal atmospheric refraction the vertical gradient of the index of refraction dN/dh in all thickness of troposphere will be equal -0.04 m^{-1}. Substituting this value, and also numerical value of the Earth's radius R = 6371 km in the formula (4), we shall find $h = 0.75h_e$. From here follows, that if cloud radiation is created by directly falling sunlight its height in case of the normal refraction will be equal 28 km.

Discussion

It is known, that polar stratospheric or nacreous clouds consist from crystals in the size from 1 up to 10 microns. The small particles are formed on dust nucleus of condensation water pair. Into microscopic structure of these particles enter: water, nitric acid, and sometimes both small amounts of chloric acid and sulphuric acid. Formation of polar stratospheric clouds needs very low temperature (about minus 85ºC at height of 25 km). Such low temperature in the polar stratosphere is observed in the winter when air weights because of lack of the sunlight do not mix up. It is one

of the reasons on which stratospheric clouds appear only in the winter and, basically, in high latitudes of both hemispheres of the Earth.
In conditions of polar night the substances polluting the atmosphere, are not exposed to destruction by ultra-violet light and freeze, forming the stratospheric clouds containing chlorine. Those clouds made the bright iridescent luminescence due to the dispersion of sunlight, the diffraction and interference of light waves, it is necessary, that small particles clouds were the identical size.
In the spring ultra-violet beams cause chemical reactions of the substances which have been saved up in clouds, transforming harmless substances into active free radicals (for example, chlorine monoxide), which react with ozone and cause reduction of its contents in the atmosphere.
Let's note, that brightly luminous formations observable after rocket start-up, have other nature and the form (Fig. 3 [Chernov, 1980]). The bright iridescent colours of these clouds grows out dispersion of the sunlight on small particles of the exhaust products which are taking place in special meteorological conditions [Roldugin et al., 1997].

Fig. 3. Extraordinary bright luminous formations above Apatity at 07:00 UT on December, 16, 1980

Formation, time of life and dynamics of cloudy systems in the stratosphere are determined by temperature and wind requirements and the contents in it of water pair. According to Murmansk management of the Hydrometeorological Service data [Semenov et. al., 2008] on January, 29 meteorological conditions of formation and transition of polar stratospheric clouds above Kola Peninsula were very favorable. In second half of this day in the vicinity of Murmansk slightly overcast weather without deposits was observed. The temperature of air at height of 22 km has made minus 85ºC. Relative humidity was very low (1-4 %). The wind was southwest, its velocity made 17-19 m/s.

Conclusions

Results of visual and photographic observations of polar stratospheric clouds dynamics in Murmansk on January, 29, 2008 are presented. The estimation of real height of stratospheric clouds is made on the basis of the concept of the Earth's equivalent radius. It is shown, that if the luminescence of the stratospheric cloud is created by directly falling the sunlight its height will be equal 28 km. It is marked, that occurrence of stratospheric clouds specifies extreme conditions in the atmosphere, leaders to the chemical processes promoting destruction of the natural ozone layer. Carrying out of complex researches on studying structure and thermodynamic processes in the stratosphere of the Earth at high latitudes therefore is necessary.

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