"Physics of Auroral Phenomena", Proc. XXII Annual Seminar, Apatity, pp.77-78, 1999

Polar Geophysical Institute

EISCAT RADAR REFLECTION FROM THE VICINITY OF A NOCTILUCENT CLOUD

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Abstract. The signal backscattered profile received with the EISCAT VHF radar during a noctilucent cloud event of 3-4 August 1997 is discussed. The processing of the radar signal was standard. A strong signal reflected from the 83-88 km altitude was observed for three hours without abnormal ionization above this layer. The layer descended with a velocity of 0.5-3 km/hr. Sometimes it was stratified into two layers, the ionosphere between the layers being undisturbed. The scattered signal strength was as strong as would be expected from an electron density reaching 10^{11} el/cm^3. Simultaneously the MST radar in Esrange revealed the occurrence of PMSE at the same heights. A case of strong reflected signal for the MST radar from a 62 km altitude during the Solar Proton Event of 2 May 1998 is also discussed.

In August 1997, the Polar Geophysical Institute (PGI) carried out observations of noctilucent clouds (NLCs) in Karelija, Russia. The place is named Shala with geographic coordinates λ = 36° E, φ = 62° N. Noctilucent clouds have been seen on 3 August at 2230–2330 UT interval. The sun dive below the horizon was 9.8 – 7.8°. Several photographs were obtained. The NLCs had band structure and occupied all the azimuthal interval between 320° and 350°. They elevated from 8.5° to the very horizon, so we can suppose that the area of EISCAT radar was into the NLCs in this event. It is well known that NLCs are related to polar mesospheric summer echoes (PMSE), [see e.g., the review of Cho and Rottger, 1997]. PMSE may be registered by the MST radar, situated in ESRANGE near Kiruna, Sweden. Really, this radar recorded the PMSE occurrence at that time. The picture of signal-to-noise of the MST radar for 3 August 1997 is shown in Fig. 1. One can see that PMSE appeared in the evening at 2100 UT and lasted all the night at altitudes between 81 and 88 km. Accordingly to the MST radar, the azimuthal velocity of the wind at this altitude oscillated between ±20 m/s, the meridional one was directed southward and equal to 50 m/s, and the vertical component was in limits of ±2 m/s.

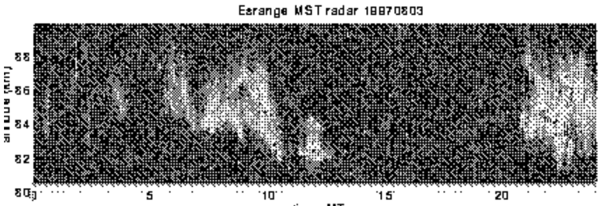

Fig. 1. The MST radar time-altitude picture of the signal-to-noise ratio during PMSE event of 3 August, 1997.

We processed the VHF EISCAT data for this night with the help of the standard method to obtain the height profile of electron density. The result is shown in Fig. 2. A strong signal reflected from 83-88 km altitude was observed for three hours without abnormal ionization above this layer after 2230 UT. The layer descended with velocity of 0.5–3 km/hr. After 2340 UT it was stratified into two layers, the ionosphere between the layers being undisturbed. The scattered signal strength was as strong as would be expected from electron density reaching 10^{16} el/m^3. The maximal "electron density" amounted to 2×10^{17} el/m^3 at 2343 UT at the altitude of 85 km.

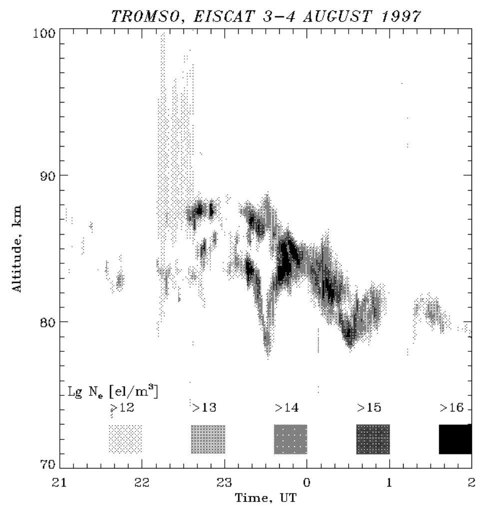

Fig. 2. The effective electron number density (in el/m^3), calculated by the standard method from EISCAT data during the noctilucent cloud event of 3-4 August, 1997.

The considered case of preposterous values of electron density in the mesopause is not unique. Such values were observed also in both neighboring nights. Fig. 3 shows the EISCAT "electron density" for the night of 2–3 August 1997. In the time interval 0000–0200 UT, the values exceeded 10^{12} el/m^3 with peak 3.2×10^{18} el/m^3 at 0039 UT. We have no observations of NLC this night due to weather conditions. The MST radar detected PMSE although it was weak, see Fig.1. In the night of 4–5 August, the maximal value was 3×10^{14} el/m^3 at 2336 UT when PMSE arose at 86 km.

Certainly, the absurd values of electron density in the mesopause (10^{17} el/m^3 which is 7 orders higher than typical density at the 85 km altitude), received by the standard processing of EISCAT data, are not caused by abnormal ionization. The EISCAT measures not electron density at PMSE or NLC volume, but only the power of a backscattered signal. Usually the scattered signal is incoherent and proportional to electron density. In PMSE it depends also on gradients of plasma density caused by turbulence, and other factors.

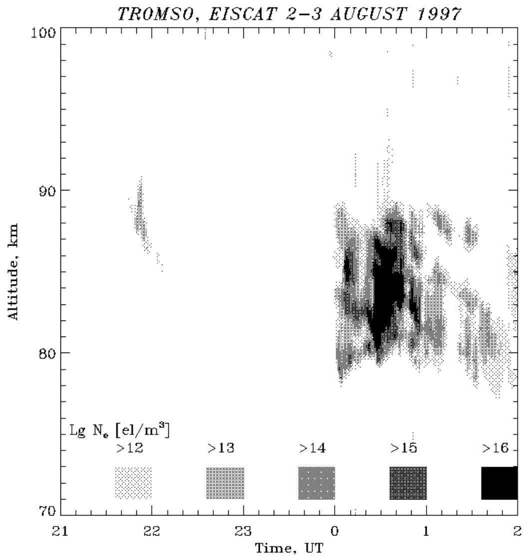

Fig. 3. The same as Fig. 2 for 2-3 August, 1997.

The NLC origin is vague. Some authors relate NLC to cosmic dust [e.g., Soberman, 1969]. There are also theories of NLC particle formation by water condensation on charged nucleus [Hesstvedt, 1969; Christie, 1969]. We suppose that the NLC particles include metallic dust of cosmic origin. These condensation nuclei are charged and under special conditions become cluttered with ice. Apropos, Witt [1969] hypothesized hydrated metal ions as condensation nucleus. Maybe, the big intensity of the scattered signal is due to reflection from the metal core of the particles.

Under the influence of the gravity the specks fall down. Its velocity can be estimated if we suppose that the potential energy of a speck is spent on dragging of air in its vicinity. Assume that the speck consists of a heavy nucleus surrounding a light shell (wings). The energy conservation law can be written in the following approximate form

$$\frac{d}{dz} m_{nucl} g z = \rho_{air} a_{wing}^2 v^2 \qquad (1)$$

where z is the height, m_{nucl} is the mass of the nucleus, ρ_{air} is the surrounding air density, g is the gravity acceleration, a_{wing} is the size of the light shell playing a role of wings or parachute slowing down a drop. The mass may be estimated as follows

$$m_{nucl} = \rho_{nucl} a_{nucl}^3 \qquad (2)$$

where ρ_{nucl} is the density of the speck core, a_{nucl} is the core size (we suppose that main mass of spec is in its core). Substitution of (2) into (1) yields

$$v = \sqrt{g \frac{\rho_{nucl}}{\rho_{air}} \frac{a_{nucl}^3}{a_{wing}^2}} \ . \qquad (3)$$

In his rocket experiment Witt [1969] determined diameter of NLC speck near $2 \cdot 10^{-5}$ cm. It seems to be underestimated by the order. Really, in contrast to polar stratospheric clouds, the noctilucent clouds are not iridescent at all, Mie scattering is not essential. So the size of particles must exceed 10 times the wavelength of light and be equal to a_{wing} = 50,000 Å = 5×10^{-4} cm. According to Soberman [1969], the most frequent sizes of micrometeoroids are between 0.1 and 0.01 μ, and so $a_{nucl} = 5 \times 10^{-6}$ cm = 500 Å. Let us take ρ_{nucl} = 10 g/cm^3, $\rho_{air} = 10^{-8}$ g/cm^3, then the velocity of subsidence is v ≈ 0.8 km/hr, which is in accordance with the observation.

The picture of the MST radar in Fig. 1 is typical for PMSE events. The destination of this 52 MHz radar is to measure three components of wind velocity. But sometimes it registers strange signals. For example, during the solar proton event of 2 May 1998 the strong reflection was observed from 62 km altitude, see Fig. 4. Its beginning at 1500 UT coincides with the beginning of precipitation of protons with energy >100 MeV.

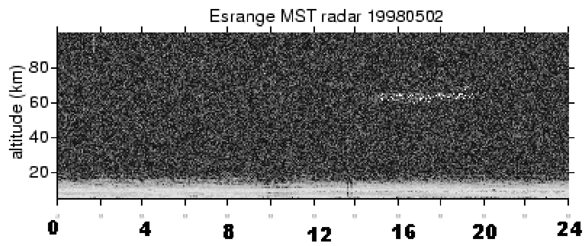

Fig. 4. The MST radar time-altitude pattern of the signal-to-noise ratio during the solar proton event of 2 May, 1998.

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