Study on Irregularity of Electron Density in Polar Summer Mesopause

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Abstract

The volume reflectivity and the irregularity of electron density occurring Polar Mesosphere Summer Echoes (PMSE) have close relation. A preliminary result is given by analyzing the data obtained from the experiment of ECT-02. The small-scale structure of electron density caused by charged dust particles may have some great effect on PMSE.

1. Introduction

Polar mesosphere summer echoes (PMSE) are very strong radar echoes primarily studied in the VHF wavelength range. In 1979, Ecklund and Balsley observed this phenomenon for the first time with the MST radar at Poker Flat, Alaska. The altitude occurring PMSE is about 80-90km, the strongest echoes usually lie in the height about 86km[1] Many scientists being engaged in space physics and dusty plasma physics have paid much attention to PMSE, and gain lots of research accomplishments[2-4].

There exist a lot of charged dust particles in the polar mesopause. The presence of dust particles occurring PMSE has been confirmed by launching the rockets into polar mesopause to detect them[5-6]. The preliminary understanding about how PMSE occur was obtained when the irregularity of electron density was found by the heating experiments of PMSE[7-9]. But the problem about how the irregularity of electron density is generated is not solved until now. In most cases, the study on the PMSE is carried out under the condition that the irregularity of electron density already exists in polar mesopause. The inherent relation between irregularity of electron density and the intensity of radar echoes still an open scientific question[10-11].

In the paper, with the experimental results of ECT-02, we obtain the profile of the square of the electron density perturbation. A lot of charged dust particles in mesopause affect electron distribution, and the irregularity of electron density will occur. When electromagnetic waves meet the irregularity of electron density, anomalous radar echo will be observed. The dusty plasma and small-scale perturbation of electron density theory are valuable tools to study PMSE.

2. Experiment Analyses about Irregularity of Electron Density

The small-scale structure of electron density created by charged dust particles is introduced to study PMSE in this section. Radar waves are scattered at irregularities in the radar refractive index at mesopause altitudes, which is effectively determined by the electron number density. For efficient scatter, the electron number density must reveal structures at the radar half wavelength (Bragg condition for monostatic radar). The question how such small-scale electron number density structures are created in the mesopause region has been a longstanding open

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scientific question for almost 30 years [12-13].

In the period July 25 to August 12, 1994, the international campaign ECHO-94 was conducted at Andøya Rocket Range (ARR; 69°N, 16°E), Norway, to study noctilucent clouds (NLC) and PMSE. During the campaign, the EISCAT VHF (224 MHz) radar outside Tromsø, Norway, and the ALOMAR SOUSY VHF (53.5 MHz) radar located at ARR were used to detect the presence of PMSE, while the NLC condition was established by ground-based observers in southern Sweden as well as two Rayleigh lidars located 2 km apart (one at ARR and the other at the ALOMAR observatory). This campaign is the first detection of charged dust particles in the Earth's polar mesosphere when occurring PMSE[5].

The first salvo (salvo 1; July 28-29, 1994) during ECHO was launched in the presence of strong PMSE detected by both VHF radars. No visible NLC was detected by the two Rayleigh lidars. The result was named as ECT-02. By analyzing the experiment of ECT-02, the atmosphere density of neutral particles, electron density, dust charge density, ion density, and temperature are got in the range of height is 82-90 km. At the same time, the signal to noise ratio (SNR) was observed in the campaign of ECT-02 with ALOMAR-SOUSY VHF radar when the rocket detected the polar mesosphere occurring PMSE[4].

By analysing the irregular profiles of electron density, we obtain the square of electron density perturbations. Fig. 1 gives the profile of the square of electron density perturbations.

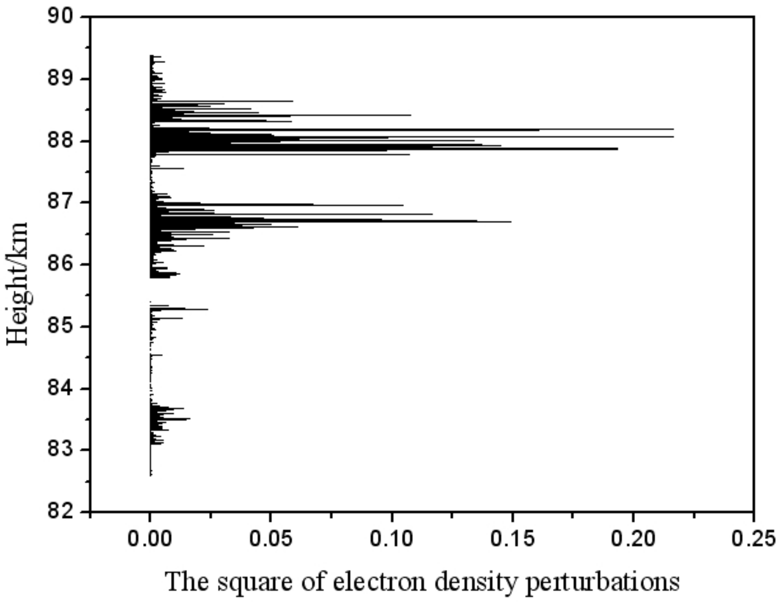

Figure 1. Profile of the square of electron density perturbations.

By comparing the profiles of SNR in paper [4] and the square of electron density perturbations in Fig. 1, three parts that the electron density irregularity and SNR change much sharper can be found. By analyzing each part of the overall electron density perturbation in Fig. 1, we can find that the minimum electron density perturbation lie in 83-84km, stronger perturbation in 86-87 km, the strongest perturbation in 87-89km. SNR also has three peaks, the smallest peak lies in the bottom, the second peak is in the middle, the largest peak lie on the top at the corresponding height. The heights of the three peaks of SNR and electron perturbation intensity almost lie in the same height by comparing the results in paper [4] and Fig. 1.

The difference of SNR between the largest peak and the smallest peak is about 12dB. The difference of perturbation intensity between the largest peak and the smallest peak is big too. Others, we found that the intensity of radar echoes in the smallest area of electron density is very weak. Comparing the strongest echoes region with the weakest region, the difference of SNR is more than 20 dB, so we can assure that PMSE don't occur when the electron density is small. Because when the electron density is too small to generate stronger irregularity of electron density, PMSE cannot occur in mesopause.

At the height of 85-86km and 87-88km, the electron density perturbation is relatively small. Due to the presence of a large number of dust particles in this region, numerous electrons are adsorbed by dust particles, the electron density sink are generated. When the electron density is small, the absolute value of electron density perturbation is relatively small; the generation mechanism of PMSE in the two regions may disagree with the normal generation mechanism. It will be very valuable for us to solve the generation mechanism in the two regions in the future.

In short, these exists three large areas of the square of the electron density perturbation, corresponding to the SNR profiles. When the disturbance is stronger, the local echo is stronger. The results show that the electron density perturbation and the formation of PMSE are closely linked; the radar reflectivity is corresponding to the square of the electron density perturbation.

3. Conclusion

In this paper, the relation between reflectivity and irregularity of electron density is analyzed by introducing small-scale perturbation of electron density. According to the experimental data of ECT-02 and SNR profile observed by SOUSY VHF radar, the profile of the square of the electron density perturbation is got. The results show that the electron density perturbation is stronger; the radar echo is stronger, which is consistent with the profile of SNR respectively. So PMSE and electron density perturbations must closely be linked, the irregularity of electron density may be an important method to explain the generation mechanism of PMSE.

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5. References

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