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INVESTIGATION OF PMSE CHARACTERISTICS BY PARTIAL REFLECTION RADAR AT 2.7 Mhz

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1. Introduction

PMSE (Polar Mesospheric Summer Echoes) are strong radar echoes in the polar summer mesosphere (80-90 km) first observed by the MST radar in Alaska [*Balsley et al.* 1980], but now observed on a fairly regular basis by other 50 MHz radars such as SOUSY and CUPRI. EISCAT has also observed these echoes at 224 MHz and 933 MHz, while Sonderstrom radar has seen echoes at 1.29 GHz. During MAC/SINE campaign (1987) a partial reflection experiment was operated in Ramfiordmoen (69.6^{0}N, 19.2^{0}E) near Tromso. There were simultaneous observations with the EISCAT VHF radar [*Hoppe et al.*, 1990]. *Hoppe et al.* [1990] have performed a detailed comparison between the echoes observed with EISCAT and those observed with PRE, but they found no relationship, neither in time nor in amplitude. The distribution of PRE echoes shows general increase of occurrence from 75 to 95 km, with no significant peaks. The authors conclude that either relation between PMSE and PRE echoes is weak or it does not exist.

Many papers concerning the observation of PMSE have been published. PMSE research is currently very active, and there are excellent reviews by *Rottger* [1993], *Cho and Kelley* [1993] and *Rottger* [1994].

The major questions about PMSE are concerned with how such echoes occur, and if they are related to local turbulence. Furthermore the presence of charged aerosols is likely to be a key condition for PMSE occurrence [*Cho et al.*, 1992]. Gravity waves can produce local minima in the vertical temperature profile where enhancement of electron recombination, water cluster formation, and nucleation of ice aerosols can take place. These are all the questions that have brought the summer mesopause to the forefront as an exciting topic for study.

At present we can not give the real definition of PMSE in terms of physical processes. Therefore, any physical parameters measurable at mesospheric heights during PMSE are very interesting for investigation of physical nature of PMSE.

2. Partial reflection radar of Polar Geophysical Institute (PGI-PRE radar)

The PGI-PRE radar is located in Tumanny (68.9^{0}N, 35.8^{0}E) near Murmansk (Russia). Partial reflections from ionospheric scatters at heights below E-region (60-100 km) are received at the ground and are resolved into two components: the ordinary (O) and the extraordinary (X) modes. The PRE system operates at 2.7 MHz with the pulse peak power about 100 kW. The radar is controlled by a computer. The amplitude of reflected signal is stored on a magnetic tape. The data can later be analysed with the all-purpose computer by a variety of programs. The pulse is transmitted from antenna array composed of 8x8 folded dipoles, spaced at 41 m and suspended 16 m above the ground. The system parameters are shown in the table.

Table 1.

	PGI-PRE	ALOMAR-SOUSY	EISCAT-VHF
Coord.	68.9°N, 35.8°E	69.3°N, 16.0°E	69.6°N, 19.2°E
Peak power	100 kW	150 kW	1.5 MW
Frequency	2.7 MHz	53.5 MHz	224.0 MHz
Height range	81-90 km	77-95 km	72-95 km
Height resolution	1 km	150 m	300 m
Time resolution	1 min, 1sec	36 sec	2 sec
Beamwidth	17°	6.5°	1.7° N-S, 0.6° E-W

The parameters of EISCAT and ALOMAR-SOUSY radars are also shown in the table. We use PRE-system for measurements of mesospheric winds by the spaced antenna method. We used only the O-mode for analysis of winds because the X-mode signals are stronger absorbed at the day time and during auroral absorption events than the those of the O-mode.

3. The basic characteristics of PR signals during PMSE events

During the NLC-91 campaign two radars EISCAT-VHF (224 MHz) and PGI-PRE (2.7 MHz) were operated simultaneously from 26 July till 06 August. PR data were collected for the range of scattering heights from 80 to 91 km in 1 km steps. The two radars are separated by the distance of 677 km. It is very difficult to make conclusions about simultaneous observations, because variations of PRE and EISCAT signals can be connected with the spatial variations of the atmosphere parameters. During PMSE events observed by EISCAT, PGI-PRE radar occasionally detected thin layers (1-2 km) of the PMSE kind. The main features of the observed layers are summarised as follows (see Fig.1):

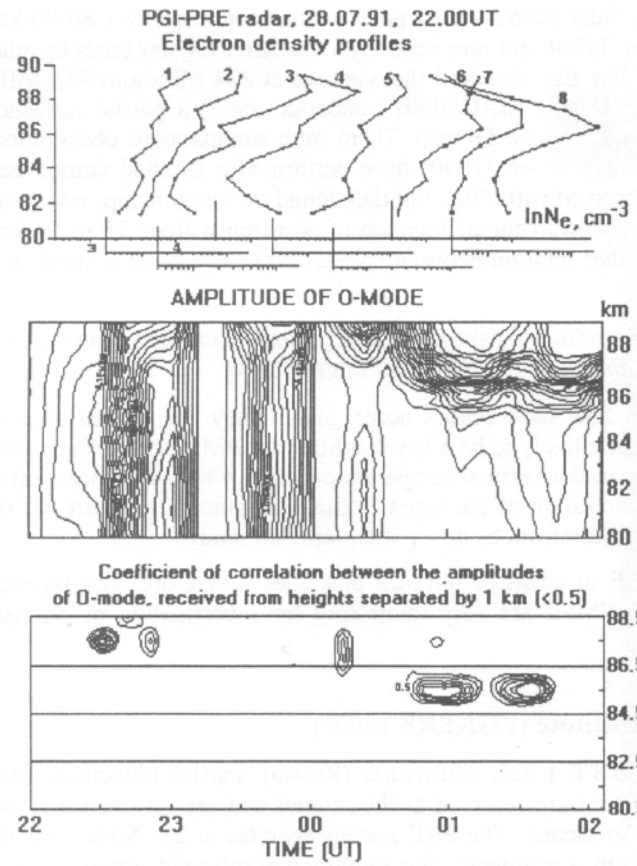

Fig.1

- the electron densities calculated by the standard method have the maximum at the heights of these layers (Fig.1 shows electron density profiles average over 30 minutes, 1 - 22.00-22.30UT, 2 - 22.30-23.00 etc.),
- the altitude of maximum electron density descends approximately 0.3 m/s (the descents of the layer altitude with time is a common feature of PMSE),
- the amplitude variations at the adjacent range gates, separated by 1 km have a low level of correlation,
- at the heights of these layers the amplitude of scattered signals has a very strong gradient.

All these features of partial reflection signals could be regarded as an evidence to events of the PMSE kind.

During the ECHO-94 campaign the PGI-PRE radar was operating from 24 July till 10 August to detect Polar Mesosphere Summer Echoes. PR data were collected for the heights of 81-90 km in 1 km step. Simultaneously with the PGI-PRE radar the detection and investigation of PMSE were carried out using the 53.5 MHz ALOMAR-SOUSY radar at Andenes and the 224 MHz EISCAT VHF radar at Tromso.

In Fig.2 the EISCAT and the PGI - PRE data are shown obtained simultaneously over four hours of 30 - 31 July. We can see good spatial and time similarity of these radars data. The strong IR echoes, the sharp gradient of PRE amplitude and the patches of the deep decrease of the level of correlation between the amplitude variations at the adjacent range gates are observed at the same altitude range of 84 - 86 km. We see also temporal descent of examined altitude level in the data of both radars. The low correlation coefficient between amplitudes of PR signal received from 84 and 85 km changes with the period of 20-30 minutes. That may be the effect of gravity waves propagation through the mesosphere. Many papers have been published concerning the observation of gravity wave influence on PMSE intensity [*Williams et al.*, 1989; *Miller et al.*, 1993]

The spectral analysis of PRE data was carried out to learn what kind of the amplitude fluctuation peculiarities cause the decrease in the level of correlation. In this analysis we used 1-second time resolution of amplitude fluctuation data. Power spectrum estimation was calculated by means of the direct Fourier transformation of the autocorrelation function of 120 s data series. The spectral window with the bandwidth of 0.03 Hz was used.

Power spectra of partial reflection amplitude fluctuations for ten separate altitude levels (top spectrum for 90 km and down by the step of 1 km till 81 km) are represented at the bottom of Fig.3. The three time intervals of the seance on 26 July (12 40 UT is the beginning of the time-axis) were examined. These moments (marked by arrows) correspond different situations in the spatial-temporal pattern of the level of correlation between the signals received from neighbouring altitudes. At the first moment (12.52 UT) the patch of the correlation decrease (below 0.5) is at 86 -87 km. At the next moment (13.00 UT) the level of correlation is greater than 0.5 at all altitudes. And at the third situation the patch of the correlation decrease is at 84 -85 km.

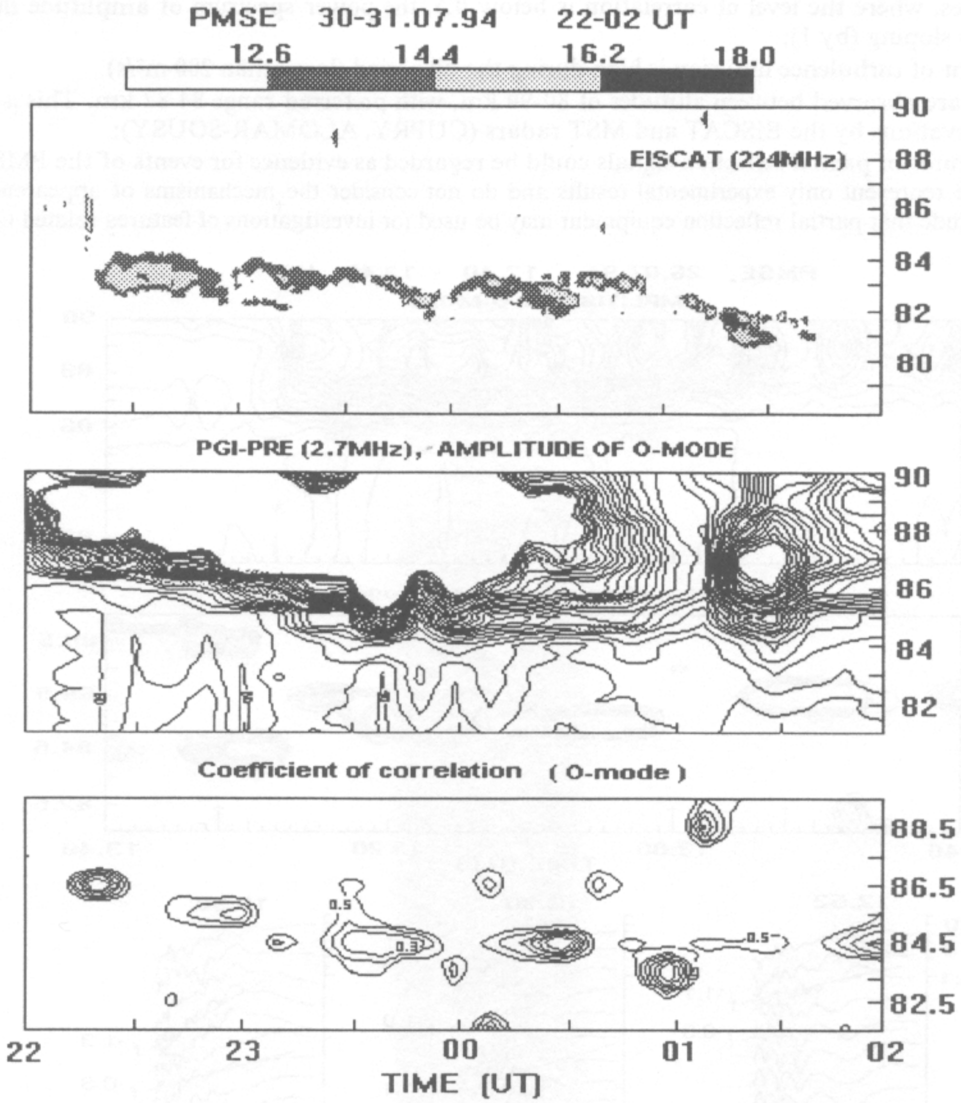

Fig.2

In Fig.3 we can see that the slope of the power spectrum and its certain details change in the region of altitudes where the patch of the deep decrease correlation is located. And the changes in the spectral slope are negligible outside the patch region. We see that the relative intensity of high frequency amplitude fluctuations in spectrum increases in the patches of the deep decrease of the level of correlation between different altitudes as well.

4. Conclusion

The partial reflection equipment of the Polar Geophysical Institute (PGI-PRE radar) worked during summer 1991-1994. Simultaneous observations with the EISCAT incoherent scatter radar were made. During PMSE events, the PGI-PRE radar occasionally detected thin layers (1-2 km) of the PMSE kind. The main features of the observed layers are summarised as follows:

- the electron densities calculated by the standard method (from ratio of amplitudes of ordinary and extraordinary components) have the maximum at the heights of these layers;
- the altitude of maximum electron density descends approximately 1 km per hour (0.3 m/s). The descent of the layer with time is a common feature of PSME;
- sometimes two layers are present, with similar features at different heights;
- at the heights of these layers the amplitude of scattered signals has a very strong gradient;
- the amplitude variations at the adjacent range gates, separated by 1 km, have lower level of correlation than at the heights upper and below;
- the evolution of the level of correlation has a periodical (10-30 min) structure;

- in the patches, where the level of correlation is below 0.5, the power spectrum of amplitude fluctuations becomes less sloping (by 1);
- the coefficient of turbulence diffusion is high during the all period (large than 200·m²/s)
- these layers are observed between altitudes of 80-90 km, with preferred range 84-87 km. This is similar to PMSE observations by the EISCAT and MST radars (CUPRY, ALOMAR-SOUSY);
- all these features of partial reflection signals could be regarded as evidence for events of the PMSE kind;

In this report we represent only experimental results and do not consider the mechanisms of appearence of these layers. We conclude that partial reflection equipment may be used for investigations of features related to PMSE.

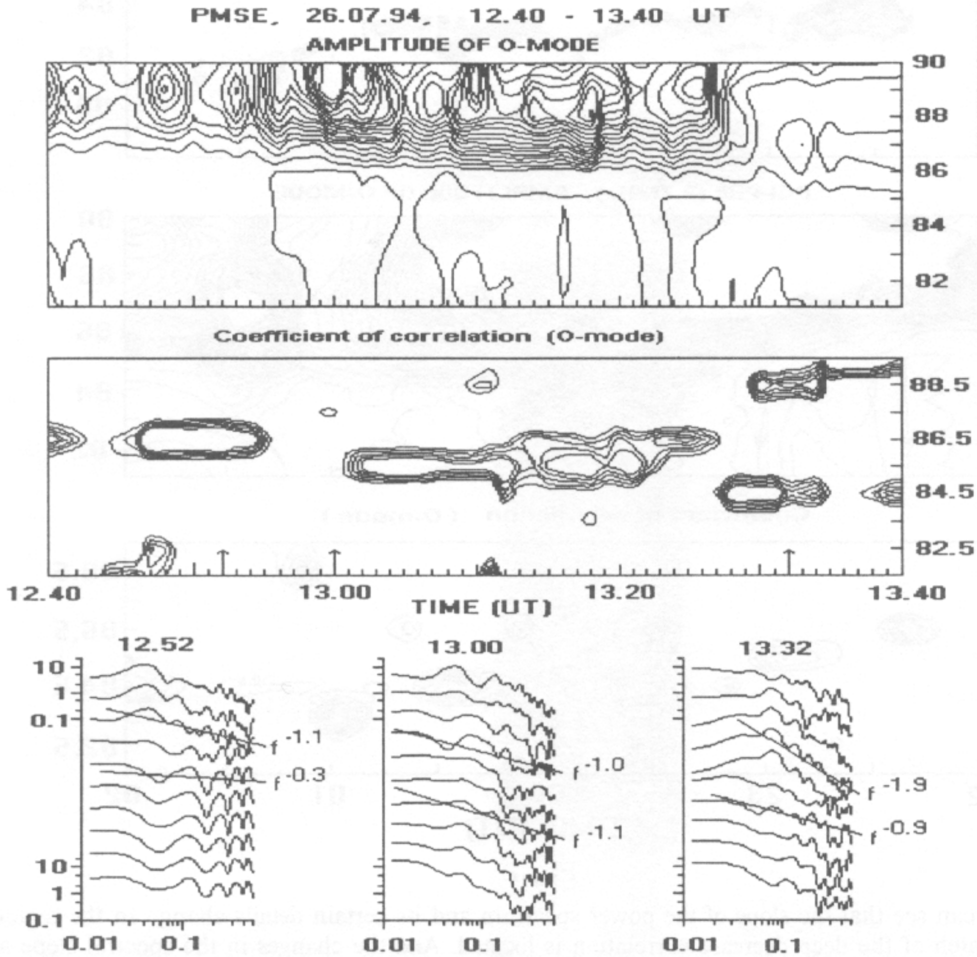

Fig.3

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