Geomagnetic control of polar mesosphere summer echoes

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Abstract. Using observations with the ALOMAR SOUSY radar near Andenes (69.3°N, 16.0°E) from 1994 until 1997 polar mesosphere summer echoes (PMSE) have been investigated in dependence on geomagnetic K indices derived at the Auroral Observatory Tromsø (69.66°N, 18.94°E). During night-time and morning hours a significant correlation between the signal-to-noise ratio (SNR) of the radar results and the geomagnetic K indices could be detected with a maximum correlation near midnight. The correlation becomes markedly smaller in the afternoon and early evening hours with a minimum near 17 UT. This diurnal variation is in reasonable agreement with riometer absorption at Ivalo (68.55°N, 27.28°E) and can be explained by the diurnal variation of ionization due to precipitating high energetic particles. Therefore, a part of the diurnal PMSE variation is caused by this particle precipitation. The variability of the solar EUV variation, however, has no significant influence on the PMSE during the observation period.

Key words: Ionosphere (auroral ionosphere) – Magnetospheric physics (energetic particles, precipitating) – Radio science (remote sensing)

Introduction

After the first detection of polar mesosphere summer echoes (PMSE) at Poker Flat, Alaska, in 1979 by Ecklund and Balsley (1981) investigations of this phenomenon have been made with different radars at different places. However even 20 years after the detection of these unexpectedly strong radar echoes at altitudes between about 80–90 km, during summer months at polar latitudes, not all the details of this phenomenon are fully understood. Radar scatters from the mesosphere are caused by inhomogeneities in the electron density having spatial scales of about half the radar wavelength. Such small-scale electron density fluctuations are normally smoothed by diffusion. Large charged particles (water cluster ions, aerosols or ice particles) are necessary to reduce the electron diffusivity and maintain these scales as proposed by Kelley et al. (1987). The occurrence of large particles is markedly supported by the low mesospheric temperatures during polar summer months. A detailed review of existing PMSE observations and theories can be found in Cho and Röttger (1997).

Until now there have only been a few investigations concerning the geomagnetic influence upon backscattered mesospheric radar echoes during polar summer conditions. Whereas Rishbeth et al. (1988) reported a connection between geomagnetic field variations and backscattered echo power during one special event, Röttger et al. (1990) did not find such a connection when investigating another PMSE. Using EISCAT observations at 224 MHz in summer 1991 Bremer et al. (1995) estimated a negative correlation between the PMSE occurrence and the geomagnetic K index of Tromsø.

There are also only very few investigations between PMSE and riometer absorption. These absorption data derived at polar latitudes can be used as a good indicator of enhanced ionization near 80–90 km (Harangreaves, 1979) due to precipitation of energetic particles. Czechowsky et al. (1989) found a small positive correlation of 0.26 between 240 samples of 30 min mean values of the PMSE peak echo power and corresponding riometer data from observations at Andenes in June 1984.

During the summer months of 1994 to 1997 PMSE observations have been carried out with the ALOMAR SOUSY radar (53.5 MHz, 150 kW peak power, range resolution 300 m, time resolution about 1 min) at the
international ALOMAR facility near Andenes. Details of the ALOMAR observatory are described by von Zahn et al. (1995), and more information about the radar can be found in Singer et al. (1995). In this work the large amount of PMSE data obtained during the 4 years are used to investigate the connection between the backscattered radar echo power (characterized by the signal-to-noise ratio, SNR) and the geomagnetic activity expressed by the 3-h geomagnetic K values of the Auroral Observatory Tromsø.

Experimental results

As shown in detail by Hoffmann et al. (1999) the PMSE season at Andenes starts normally near the middle of May and lasts until the end of August. To exclude the strongly variable parts of this seasonal PMSE variation, only the months June and July have been investigated here. In Fig. 1 the daily values of the geomagnetic activity (daily sum of the eight 3-hourly K values, \( \Sigma K \)) and of the solar radio flux \( F_{10.7} \) are presented for the years 1994–1997. The dashed horizontal lines are the mean values of both parameters over the 2-month periods. The geomagnetic and solar activity are relatively small with highest mean values in 1994 (\( \Sigma K = 24.2, F_{10.7} = 78.9 \)) and smallest values in 1996/97 (\( \Sigma K = 15.6/15.8, F_{10.7} = 69.2/71.4 \)). The years investigated are relatively near the solar minimum and, therefore, the geomagnetic and solar activity conditions are mostly quiet or only slightly disturbed.

The SNR values of the PMSE used in the correlation analyses are mean values for the height range 83.0–87.5 km and 3-hourly intervals according to the geomagnetic K values. In Fig. 2 one example is shown for the correlation between such mean SNR and the K values for the time interval 0–3 UT. Whereas SNR is positively correlated with K (Fig. 2a), between SNR and daily \( F_{10.7} \) values no marked correlation could be found (Fig. 2b). The thick lines are the regression lines calculated from the individual data (circles).

The results of the correlation analyses in dependence on time (UT) are summarized in Fig. 3. In the upper part (Fig. 3a) the correlation coefficients \( r(\text{SNR}, K) \) are presented together with the significance levels of 99% (dotted lines, estimated after Fisher’s F-test, for details see Taubenheim 1969), in the lower part (Fig. 3b) the corresponding correlation data \( r(\text{SNR}, F_{10.7}) \) are shown. Here the results of simple correlation analyses are used instead of partial correlation coefficients.

![Fig. 1. Variation of geomagnetic activity (daily sum of eight 3-hourly K values, \( \Sigma K \)) of Tromsø (left) and of solar 10.7 cm radio flux (right) for the months June and July 1994–1997. The dashed lines are the mean values for the two-month intervals](image-url)