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SPORADIC E-LAYER AND MAGNETIC ACTIVITY AT SODANKYLÄ

by

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Abstract

The relations of Es and magnetic activity are studied by using 60 isolated substorms, which occurred during the IQSY and IASY. It is found that during the night time both foEs and fbEs start to increase at the beginning of the substorm or perhaps even a little earlier. The maximum in these parameters is reached within an hour after the onset of the substorm. The decay phase lasts 3–4 hours after which the statistical quiet time level is reached. The data used in this study do not give any definite answer if there are any relations between the daytime Es and magnetic substorms.

1. *Introduction*

The relation of the Es layer to magnetic activity has been a subject of numerous studies. The early results are summarized by THOMAS *et al.* [6]. By using the data from Sodankylä the correlation studies have been made by OKSMAN [4] and TURUNEN [7]. MAEHLUM [3] studied the Es data from several Norwegian stations.

It seems to be well documented that the overall correlation of Es layers to magnetic activity is positive in the auroral zone and slightly negative at middle latitudes. It is also clear that different types of Es layers have a different response to magnetic activity (MAEHLUM [3], OKSMAN [4], TURUNEN [7]). The correlation of retardation type Es is dependent very strongly on the distance between the statistical auroral zone and the measuring ionospheric station. In the auroral zone the correlation is mostly negative for this special type of Es, in the equatorward boundary of the auroral zone the correlation is positive at low levels of magnetic activity and negative at high levels of magnetic activity. The turning point is around the Q-index values 3–4 at Sodankylä (OKSMAN [4], TURUNEN [7]). At lower latitudes the correlation is positive, for example at Kjeller (MAEHLUM [3]).

Studies of that kind are not repeated in this paper but a closer connection between the auroral activity and Es phenomena is searched in terms of substorm. Although most of the geophysical phenomena relating to the auroral processes are explained in terms of substorms (AKASOFU [1]) similar behaviour for the Es phenomena seen in the auroral zone is not established. The present study, however, shows that the behaviour of Es layers in the auroral zone follows a systematic pattern during the auroral substorm and a term »sporadic E-layer substorm» could in some sense be justified. It is, however, probable that the Es substorm is not itself a primary process but a consequence of energetic processes present in the auroral ionosphere and atmosphere during a magnetic storm. In a detailed study of one magnetic storm TURUNEN and RAO [8] were able to show that even during a very complicated storm the frequency parameters of Es layers, the foEs and fbEs, reveal the individual substorms.

2. *Methods of the analysis*

The substorms used in this study are the same as used by BERKEY *et al.* [2] in a synoptic study of auroral absorption events. The total number of substorms is 60 and half of them occurred during IQSY and another half during IASY. No attempt is made to study the effects of the strength of the substorm but only the onset time of the substorm is used as a basic parameter. The timing is taken directly from the list of Berkey *et al.* and it must be realized that because they selected the substorms for the study of auroral absorption events it is possible that the substorms are slightly special. The substorms are well isolated and at least one hour before the onset of substorm is free from noticeable riometer absorption. The onset of the substorms has been defined on the basis of riometer absorption. Because the network of riometer stations in the northern auroral zone has been used, the onset is accurate perhaps within some minutes. For further information concerning the nature and timing of the substorms see the paper by Berkey *et al.*

The Es parameters are taken from the data bulletins of Sodankylä station and thus only hourly values are available. No rescaling or checking has been made. The ionosonde at Sodankylä had at that time automatic gain control, which used the noise level as a reference. In practice this means that the gain is very high. That makes the measurement possible during the absorption events and in practice numerical values were available in almost all cases. The parameters foEs and fbEs were used. The hourly values were arranged in time relative to the onset of the

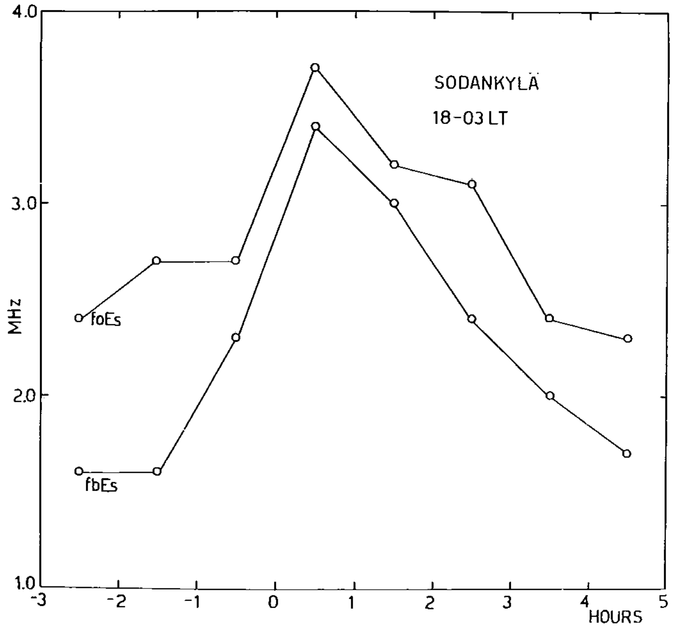

Fig. 1. Median behaviour of foEs and fbEs relative to the onset of magnetic substorm. The figure is based on the substorms having the onset time between 18 – 03 EET. The number of substorms is 28.

substorm. Three time intervals were studied separately, 18.00 – 03.00 LT, 03.00 – 09.00 LT and 09.00 – 18.00 LT. The number of cases in the first time interval was 28, in the second interval 23 and in the third interval only 9. The median value was counted both for foEs and fbEs. If no numerical value was given for fbEs because of total blanketing it was assumed that the value belongs to the upper quartile. The results are shown in the figures 1, 2 and 3.

3. *Results of the analysis*

It is seen in the Fig. 1 that in the local time sector 18.00 – 03.00 both foEs and fbEs start to increase during the hour preceding the onset of the substorm. The maximum is reached within one hour after the onset of the storm after which there is a continuous decrease to the pre-storm level, which is reached roughly in 3–4 hours. Just after the onset of the substorm the median level of fbEs is more than twice the level before and after the event. In foEs the change is slightly smaller but the overall behaviour is similar.

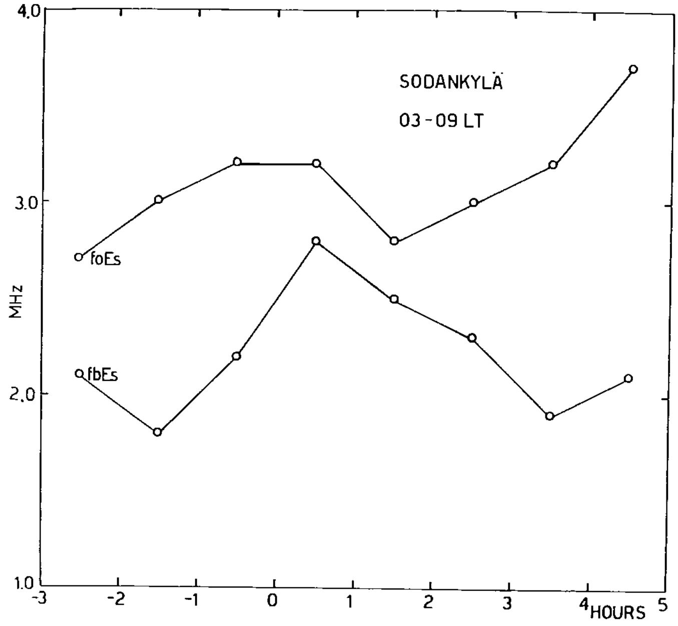

Fig. 2. Median behaviour of foEs and fbEs relative to the onset of magnetic substorm. The figure is based on the substorms having the onset time between 03 – 09 EET. The number of substorms is 23.

In Fig. 2 the results of the analysis for the interval from 03.00 to 09.00 LT are shown. The behaviour of the fbEs is the same as in Fig. 1 although the maximum after the onset is a little smaller. However, the foEs does no more follow the same pattern as in the previous time interval. Instead it shows a continuous increase all the time with a small but significant minimum 1–2 hours after the onset of the substorm.

The analysis of the third time interval from 09.00 to 18.00 local time is based only on nine cases and is thus somewhat unreliable. The results are shown in Fig. 3. The maximum in fbEs 1–2 hours after the onset of the substorm may be real, perhaps also the minimum in the foEs at the same time.

4. *Discussion*

One of the cases handled above is very simple, namely the time interval between 18.00 and 03.00 local time. At that time most Es layers belong into the auroral zone types at Sodankylä, and at that time the probability to have total

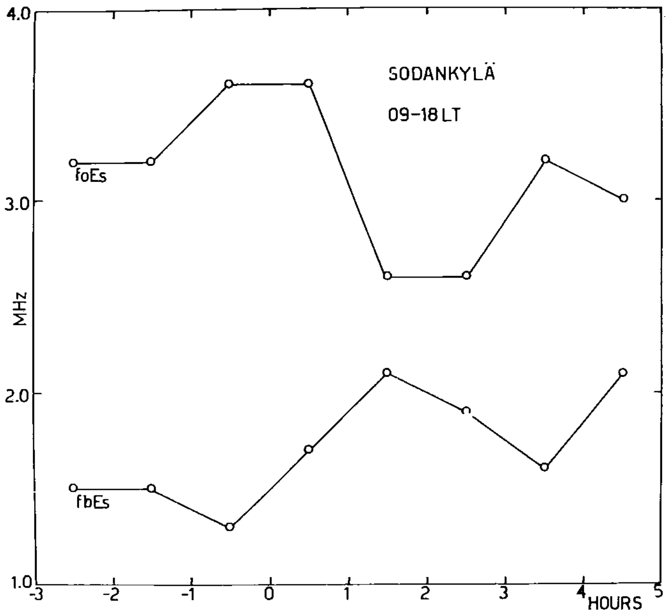

Fig. 3. Median behaviour of foEs and fbEs relative to the onset of magnetic substorm. The figure is based on the substorms having the onset time between 09 – 18 EET. The number of substorms is 9.

blanketing is highest. (TURUNEN and RAO [9]). This means that statistically it is already known that most of the Es layers at that time interval are certainly related to the auroral zone phenomena and that they are often strongly blanketing, which means that the maximum ionization density in the layers is high (see REDDY *et al.*, [5]). Furthermore this study shows that these layers start to form around the onset of substorms and that they reach maximum electron density within one hour after the onset of substorms, at least on the statistical basis. There is some indication in the data that the development of these layers starts a little before the onset of the substorms defined by BERKEY *et al.* [2], but this demands further study before the conclusion is certain. If the high electron density of the auroral zone Es layers is caused by particle precipitation, the energy of the ionizating electrons must be somewhere between 1 and 10 keV and in any case lower than the energies of the electrons causing the absorption. Thus, when an absorption substorm begins somewhere in the magnetic midnight sector, there is within a short time or even a little earlier soft particle precipitation in the late evening and midnight sector causing extra ionization at E-layer heights. Presumably after some redistribution of ionization an Es layer is formed and can be recorded by an ionosonde. It has a great variety of forms, which have different properties, but they all seem to be connected with substorms in the same way. The form and type of Es seen in the ionogram depends strongly on the relative position of the Es layer with respect to the measuring station.

In the morning a similar behaviour is seen in the fbEs but the foEs does not follow the pattern any more. The great difference between the foEs and fbEs may be explained by assuming that the Es layer is no more uniform, it is patchy, which quite well fits to the nature of auroral zone phenomena in the morning sector. There is, however, another reason, too, which makes the difference greater than in the evening – midnight sector. When very high gain is used there are already in the morning hours weak reflections seen, which are not blanketing and which have maximum in apparent foEs at noon. These echoes, which probably have no connections with auroral activity, cause the increase of median foEs with time in Fig. 2. Because the echoes are weak, they easily disappear if there is absorption over the station and this causes the minimum in foEs median 1–2 hours after the onset of the substorm. Thus it is clear that other phenomena than auroral activity are reflected in the foEs medians in Fig. 2, namely weak 1-type reflections modulated by absorption.

The same is true also in Fig. 3. Because of the limited number of cases at that time interval it is not possible to make other conclusion than that the increase in fbEs after the onset of the substorm is perhaps real.

In the evening and midnight sector when the Es layers have practically one to one relation to substorms, the Es event decays in 3–4 hours to the pre-storm level. This is clearly more than the mean decay time of absorption events at that time sector although an absorption substorm can last about that time. The energetic particle precipitation seems, however, to be located at other time sectors a couple of hours after the onset of the substorm (see BERKEY *et al.* [2]). Thus the explanation of the persistence of the substorm related Es layers demands that there are either slowly decaying soft precipitation component or ionization redistribution mechanism, or both, which are strong enough to maintain the Es layer or the long living metallic ions are responsible for the slow decay in a similar way as proposed in the case of midlatitude type Es layers. This latter explanation demands that during the active phase of the Es formation the ionization redistribution mechanism is able to form layers or other types of density enchancements of metallic ions. Which one of the proposed mechanisms, if any, is really important requires special experiments, and it seems that *in situ* measurements are needed.

5. *Conclusions*

Although the data used in this study are taken only from one auroral zone station it can be concluded that in the evening and midnight sector the enchancements in the Es activity seen as an increase in foEs and fbEs are closely related to substorms. This study is based on isolated substorms, but it was shown earlier (TURUNEN and RAO [8]) that the Es parameters respond to individual substorms even when the magnetic storm is very complicated. This proposes that the properly planned ionospheric sounding could be very helpful when analyzing magnetic storms. In the morning and daytime sector the influence of storms is smaller at least at Sodankylä, which is outside the auroral oval at those times. Because at those times other types of Es activity than the auroral zone type dominate, the results are difficult to interpret.

It is proposed that the auroral zone Es activity during substorms is caused by soft particle precipitation together with other processes active during the substorms. The long persistence of the layers proposes that long living ions may have an important role also in the maintenance of substorm related Es layers as in case of the midlatitude Es.

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