CONNECTION BETWEEN WHISTLERS AND Pc3 PULSATION ACTIVITY AT TIME PERIODS OF QUIET AND DISTURBED GEOMAGNETIC CONDITIONS

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We investigate the connection between whistlers and Pc3 pulsation activity. For our investigation we used magnetic data provided by the Nagycenk Geophysical Observatory (L $\sim$ 2) and whistler data from the nearby Tihany Geophysical Observatory recorded in year 2003. Both whistler and Pc3 pulsation data is hourly data. The whistler data provides the number of whistlers observed in one hour time period, while the Pc3 pulsation data presents the maximum amplitude value in the frequency range of Pc3 pulsations for the same time period. Our results show that in contrary to previous results (Verő et al., 1997) there is no visible correlation between the Pc3 pulsation intensity and the whistler occurance frequency. However, for the time periods of strong geomagnetic disturbances the appearance of whistlers in unusually large numbers is followed by Pc3 activity of large intensity.

Introduction

Two of the most important physical phenomena which are closely related to the plasma condition of the magnetosphere are the whistler waves and the Pc3 type geomagnetic pulsations. The practical advantage of whistlers and pulsations is that both can be studied by using ground measurements, therefore the data is more easily accessible than the data provided by sophisticated and expensive in-situ satellite measurements. Generally speaking, mid-latitude geomagnetic pulsations can be divided into two typical groups. While both types draw their energy from the so-called upstream waves (from now on: UW), the first type is driven directly by UW which are only slightly modified during their travel through the magnetosphere and as a consequence in the limited range of mid-latitudes they have practically the same period (and frequency). On the other hand, the second type is generated by a resonance mechanism of the geomagnetic field lines due to excitation by UW. The latter type of pulsation is called Field Line Resonance (FLR). The period (and the frequency) of FLR is a function of latitude. The variation of the FLR-type pulsation frequency with latitude is easy to understand if we take into consideration that the geomagnetic field line length changes with latitude. It is worth mentioning that the exact physical mechanism of energy transfer and coupling from the UW to the ground is not completely understood neither in the case of UW-type pulsation nor in the case of FLR. In order to be able to distinguish between UW and FLR type pulsations several meridional arrays were organised with the Nagycenk Observatory (NCK) in the center. In the first array, periods changed with latitude in roughly half of the events, sometimes smoothly, sometimes stepwise with latitude (Cz. Miletis 1980). Based on the results of the continuous studies became evident that by using data from a network of meridional array geomagnetic observatories FLR and UW type pulsations can be identified with high accuracy. A more comprehensive description of the results can be found in the review article by Verő (1986). The whistler waves have their source in terrestrial lightning. It is widely accepted the idea that at lightning a non-monochromatic very low frequency (VLF) wave package is generated which is (at least partially) able to step out into the magnetosphere. Afterwards this wave is traveling parallel mostly to the geomagnetic field lines and can be detected on-ground on the conjugate point of the field line on the other hemisphere. During its propagation in the magnetospheric region the wave package becomes highly dispersed. Maeda and Kimura (1956) were the first to show that propagation along the field lines would be impossible without 'ducts'. Smith (1960) and Smith et al. (1960) presented the theory for the propagation in ducts. Walker (1976), Laird and Nunn (1975) and Strangeways (1982) contributed significantly to this theory. Ducts have no sharp boundaries; they are more smoothly varying enhancements in electron density. Also it is known that the same whistler may propagate in numerous close ducts. However, the existence of these ducts still it is as open question. Multiple whistlers, which result from the same lightning, but propagate on different paths, support the idea of the existence of ducts. Lichtenberger (1994) determined the angle between the propagation of whistlers and the direction of the magnetic field. These angle values (10 to 15 degrees) also support the existence of ducts since without a duct the angle would be much larger. On the other hand, there are recently published new results which question the necessity of ducts in the propagation mechanism of whistlers (O. Ferencz et al. 2006). For a detailed discussion and description on whistlers see Cs. Ferencz et al. (2001).

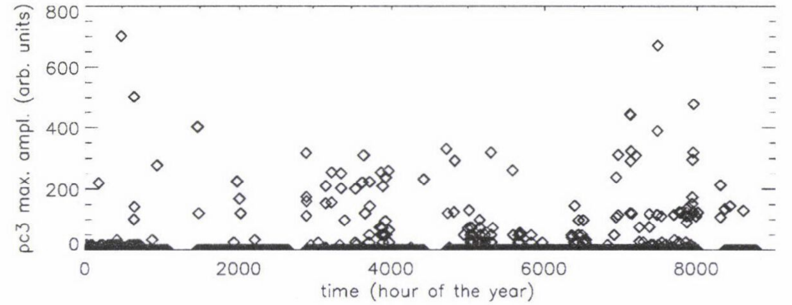

Fig. 1. Maximum amplitude in Pc3 activity versus time recorded in year 2003 at NCK. Each diamond-shaped symbol represents the maximum amplitude in Pc3 frequency range for the respective one-hour time period in a linear-linear scale. This method (i.e. taking the maximum value instead of an averaged value) gives back more accurately the intensity of the individual events

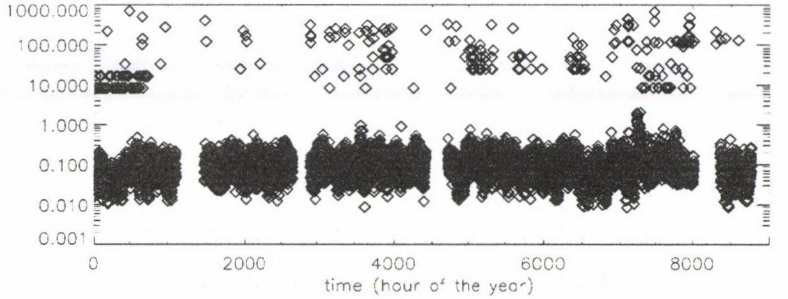

Fig. 2. Maximum amplitude in Pc3 activity versus time in lin-log scale

Verő et al. (1997) analyzed the supposition that whistler ducts and geomagnetic field line shells are closely connected with each other as they appear simultaneously with enhanced probability. They found a very close connection between the oocurance frequency of whistlers and geomagnetic Pc3 pulsation activity. According to their results the connection is nearly linear; if there are no whistlers, the pulsation activity is either extremely low or no pulsation activity exists. In our study we expand these earlier studies by verifying the connection between the Pc3 pulsation activity and whistlers. We approached the problem by using statistical methods, but we analyze individual events also.

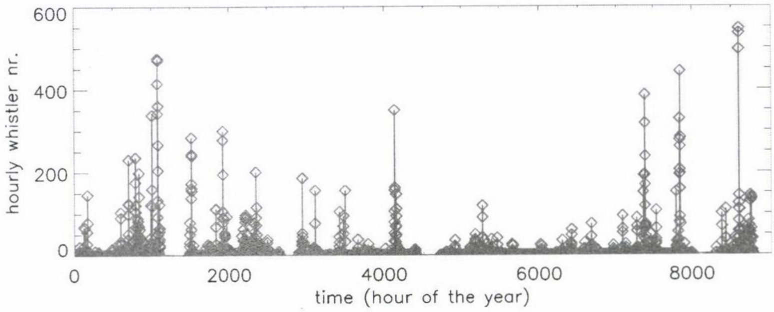

Fig. 3. Maximum amplitude in Pc3 activity versus time in lin-log scale.

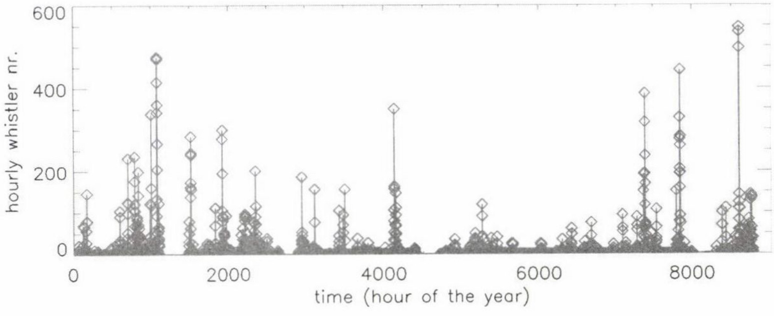

Fig. 4. Pc3 activity and whistler number versus time for the year 2003

Observations and Discussion

Statistical Results: General Behavior

For our investigation we used magnetic data provided by the Nagycenk Geophysical Observatory (NCK) situated at L$\sim$2 and whistler data from the nearby Tihany Geophysical Observatory (TGO) recorded in year 2003. Both whistler and Pc3 pulsation data is hourly data. The whistler data provides the number of whistlers observed in one hour time period, while the Pc3 pulsation data presents the maximum amplitude value in the frequency range of Pc3 pulsations for the same time period. This method (i.e. taking the maximum value instead of an hourly averaged value) gives back more accurately in our opinion the intensity of the individual events. Figure 1 presents the maximum amplitude in Pc3 pulsation activity (from now on: Pc3 activity) in arbitrary units versus time in linear-linear scale recorded in year 2003. Each diamond-shaped symbol represents the maximum amplitude in Pc3 frequency range for the respective one-hour time period. Figure 2 also presents the Pc3 activity versus time, but in a linear-logarithmic scale. It can be seen that

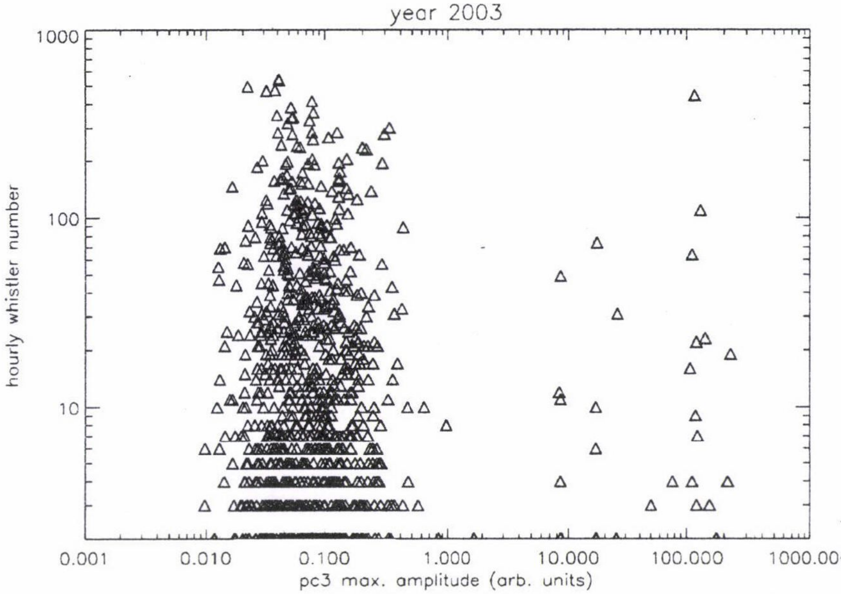

Fig. 5. Whistler number versus Pc3 activity for the year 2003 presented in log-log scale

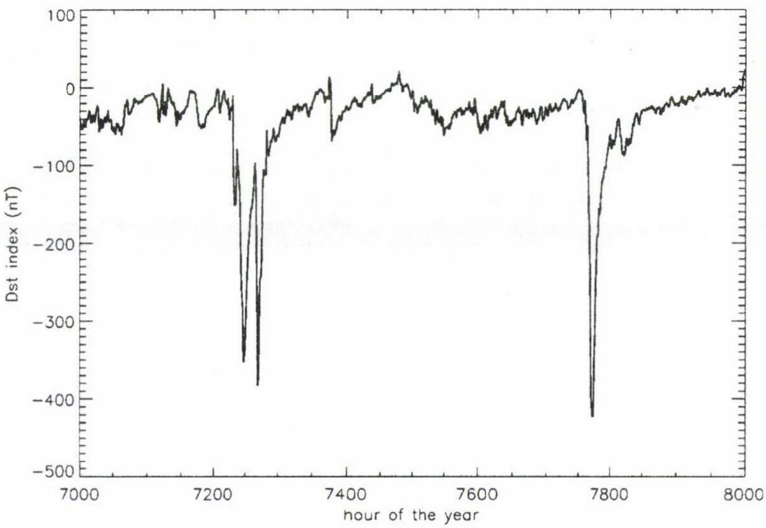

Fig. 6. Dst index versus time

besides the more quiet time periods there are to be found a significant number of events which are characterized with orders of magnitude higher Pc3 activity. The time gaps where the pulsation activity value is missing are due to lack of reliable

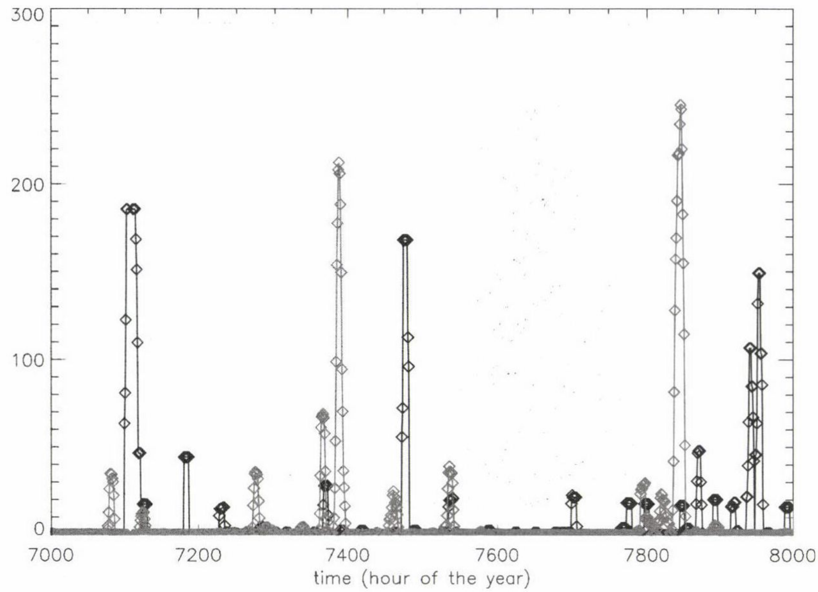

Fig. 7. Pc3 activity and whistler number versus time

data from the observatory records. Figure 3 presents the number of whistlers (i.e. the number of whistlers observed during one hour time period) versus time for the year 2003. It can be seen that there are events with very high whistler occurrence and it seems that these events appear more in groups rather than being scattered in time. In Figure 4 for better visibility we over plotted the Pc3 activity and the number of whistlers versus time in linear-linear scale. In order to investigate the connection between the whistlers and the Pc3 activity we plotted the hourly whistler number versus the maximum value of Pc3 activity for the same hour in Figure 5. It can be seen that the number of whistlers is not correlated with the Pc3 activity. Whistlers occur in high numbers during times of low Pc3 activity and high Pc3 activity does not necessary means the presence of whistlers in high numbers. This is in contradiction with the results by Verő et al. (1997), who found a clear, almost linear connection between the whistler number and the Pc3 activity. The explanation of the discrepancy between the previous and our results might be that for our investigation we used an hourly Pc3 activity, while Verő et al. (1997) used a daily pulsation index. The fact that by using an hourly Pc3 activity we were not able to reproduce the previous results shows the complexity of the problem. For an exact answer more investigation is needed. For now we can only conclude, that we found no evidence of correlation between the hourly occurrence frequency of whistlers and the hourly Pc3 activity.

Individual Events

In our study of individual events we focused on time periods of strong geomagnetic disturbances. We choose two events from the year 2003. when the geomagnetic Dst index indicates the occurrence of large geomagnetic storms. Figure 6 presents the Dst index versus time from the last period of year 2003. It can be seen that during this time period two major geomagnetic disturbance events occurred. Figure 7 presents the hourly whistler number and the Pc3 activity for the same time period. If we compare Figure 6 and with Figure 7 we can observe that after the strong geomagnetic disturbances (reflected in the Dst index) whistlers appear in an unusually high number, which is followed by intense Pc3 activity. The sequence of events is the same in both cases, however the time periods between them is not exactly the same. In our opinion this might be the consequence of changes in the value of plasma parameters in the near Earth environment. In order to completely understand the physical mechanism which leads to this chain of events further analysis is needed. In any case, our results are the first to suggest that a strong geomagnetic storm changes the near Earth plasma environment in such a way, that leads to an unusually high whistler occurance and enhanced Pc3 activity.

Acknowledgements

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