Statistical analysis of seismoelectromagnetic disturbances on whistler-waves propagation by using DEMETER data

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In this study promising results are obtained by time and space correlations of earthquakes (EQs) with anomalous whistler-waves collected by the Demeter mission. From the analysis of electromagnetic (EM) data concerning whistlers data collected by the RNF experiment on board of DEMETER, it has been developed an ad hoc method of investigation for the influence of seismic activity on whistler-waves propagation.

Data of whistler-waves propagation collected by ground-based observatories, have indicated that whistlers with anomalous dispersion coefficients are probably correlated with earthquakes occurring along the whistler propagation geomagnetic field line. Hayakawa et al., [1993] first pointed out a possible influence of seismicity on the propagation of magnetospheric whistler-waves at low altitudes. This result was obtained on the basis of long-term ground data detected at Sugadaira and Sakushima observatories during 1970-1978. By a statistical data analysis it has been found that number of anomalous whistlers, whose dispersion coefficient value is greater than twice the typical value, exhibits a substantial increase in coincidence with earthquakes occurring in the Japanese longitude sector.

The same authors also found that anomalous whistlers are detected mainly in summer, and never in winter when numerous normal whistlers are generally observed. On the contrary, it must be noted that there is no evidence of seasonal variations in the earthquakes occurrence.

These results are interesting and stimulating but need to be confirmed by further investigations. Our study aims at giving additional, and complementary information in the field on the basis of a statistical analysis of whistler data detected by RNF experiment on board of the Demeter satellite. It is the first time that correlation between seismic activity and whistlers occurrence is investigated by using satellite data. To perform a suitable whistler-EQ correlation, long time series of whistler data are requested together with EQ parameters, and information on magnetospheric perturbations caused by non-seismic sources. Unfortunately, contrary to the 9 year whistlers data of the previous study on ground based observations, in our case only three years (2005-2008) of data are available from RNF experiment. After having classified whistlers data into 19 classes as a function of the dispersion value, we have produced geographical maps in order to determine the normal background of spatial and temporal whistlers distributions. The expected value of number of whistlers \( w(\text{lat, long, t}) \) is obviously function of the temporal and spatial cells used to evaluate the whistler mean number. At this purpose whistlers maps have been constructed and represented for each one of the 19 whistler dispersion classes as a function of geographical position, monthly data collection, local time observation (divided in day- and night-time data, separately). The geographic whistler distributions have shown an increase at high magnetic latitudes near the VLF transmitters positions and at conjugate points. In order to study the influence of seismic activity on the whistler-wave propagation, we have looked for the existence of an anomalous variation of the whistlers number correlated with the occurrence of selected moderate and strong EQ (\( M > 4.8 \)).

At this purpose, we need to know the expected distribution of whistler averaging whistler data on a given area with homogeneous geographical and temporal conditions. This expected distribution
\[ < w(\text{lat}; \text{long}; t) >_{\text{cell}} \] was the background reference value we used to define the existence of an anomalous fluctuation of the whistler numbers. On the basis of the normal background of whistlers distributions it has been looked for possible space and time anomalous fluctuations of whistler data. At this purpose, two variables have been introduced in the study and defined as follows:

\[ \Delta w_r(\text{lat}, \text{long}, t) = \frac{w(\text{lat}, \text{long}, t) - < w(\text{lat}, \text{long}, t) >_{\text{cell}, 1\text{month}}}{\sigma(\text{lat}, \text{long}, t)|_{\text{cell}, 1\text{month}}} \]

\[ \text{hcum}_{\text{ratio}}(\text{lat}, \text{long}, t) = \frac{\text{hcum}(w(\text{lat}, \text{long}, t))}{\text{hcum}(< w(\text{lat}, \text{long}, t) >_{\text{cell}, 1\text{month}})} \]

First variable represents the standard score number of whistlers as a function of (lat, long, t). The second variable is the cumulative function of number of whistlers calculated at the observation point, normalized to the cumulative function of number of whistlers calculated at mean value. Values of these two parameters have been calculated for each class of whistlers. We stress the fact that the value of each variable has been calculated comparing the RNF observations with the mean value of observation, and day or night time condition separately. Distributions of the above-mentioned variables, constructed in this way, for each geographical cell, in each month, have been calculated for the whole period 2005-2008. In the analysis we have considered ducted whistlers propagation along the magnetic field line. For this reason data of whistlers detected by DEMETER have been selected inside a narrow band of longitude along the EQ magnetic field line and with latitude included between EQ latitude and latitude of EQ conjugated point (CP). Only whistlers which took place in a time window of +/- 48 hours, centered in the time of origin of the selected EQs, were taken into account. Moreover, since it has been demonstrated that geomagnetic disturbances with high Ap geomagnetic index value play an important role in the enhancement of the occurrence of whistlers and also of anomalous whistlers, only geomagnetically quiet periods have been included in the study.

The data set recorded during seismic events was mainly organized as a function of two parameters: \( \Delta t \), the difference between the time of satellite data and the time of earthquake (\( \Delta t = T_D - T_E \)) and \( \Delta \text{latmag} \), the difference between the magnetic latitude of satellite data and the magnetic latitude of the earthquake (\( \Delta \text{latmag} = \text{latmag}_D - \text{latmag}_E \)). Plots of \( \Delta w_r \) and \( \text{hcum}_{\text{ratio}} \) for each whistler dispersion classes as a function of (\( \Delta \text{latmag}; \Delta t \)) have been constructed. By considering that local time can significantly influence the whistler occurrence, we produced the maps for daytime, nighttime and day+night times, separately. What is observed is that maps of \( \Delta w_r \) and \( \text{hcum}_{\text{ratio}} \) vs \( \Delta \text{latmag} \) and \( \Delta t \) for the highest value of whistler classes, exhibit a band of anomalous fluctuations near the EQ epicentre and near the CP. It means that for high whistler dispersion values, number of whistlers close to earthquakes and conjugation points exhibits a greater increase than those detected along the magnetic field line. In particular this effect is evident for daytime maps. These two bands are independent from \( \Delta t \) values. The same bands of anomalous signals, are less evident in Nighttime maps. The existence of the two bands close to the EQ and to the CP region could indicate that seismic activity influences the whistler occurrence mainly for highest whistler dispersion values. On the contrary, no time dependence (\( \Delta t \)) is observed, indicating that any possible anomalous signal associated with an EQ can not be catalogued as pre-, co-, or post-seismic one, but only associated with time window of the seismic event as a whole. The presence of the two bands of anomalous signals only for highest dispersion classes is in agreement with the Hayakawa et al., [1993] result concerning the existence of anomalous increment of whistler of high dispersion value in coincidence with earthquake occurrence.
Nevertheless this is only an over-preliminary study, the existence of two bands could indicate the existence of a fluctuation in the number of whistlers with high D value induced by seismic activity near the EQ epicenter and its CP. Results seem to be promising for further applications. The study is still in progress in order to confirm and improve the quality of results. Further and deeper analyses are requested for a more exhaustive understanding of phenomena detected by DEMETER. Therefore, results of the study have to be considered as a first and preliminary contribution to the understanding of this very complicated matter.

References: