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Some possible correlations between electro-magnetic emission and seismic activity during West Bohemia 2008 earthquake swarm

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Abstract

There are long time lasting speculations about electro-magnetic emission phenomena (hereafter EME) connected with seismic activity. In the present work we study such relations in West Bohemia region during 2008 earthquake swarm. After brief characterization of the seismic region, we describe recording method and data analysis. We did not observe any direct link between EME and seismic events, however statistical analysis indicates that it could be some increase of EME activity in time 60 to 30 min before an event on periods 17–14 min, some gap in EME activity approximately 2 h after the event and a maximum 4 h after the events (note, that this result qualitatively correspond with observations from other seismic regions). Also global decrease of EME activity with the decay of the swarm activity was observed. However due to incomplete EME data and short time of observation these results must be understand as indication of possible correlation rather than reliable relation.

1 Introduction

Earthquakes, in the first approximation, purely mechanics phenomena, have been for a long time suspicious to generate not only mechanic seismic waves, but also to have some electro-magnetic effects. In the present article we describe an attempt of detection of such electro-magnetic phenomena in West Bohemia earthquake region during intensive earthquake swarm 2008. We give brief description of the earthquake region, performed measurements (seismic as well as electro-magnetic) and finally, we discus possible mutual correlations.

1.1 West Bohemia earthquake region

Seismic activity in West Bohemia region (hereafter W.B.) is definitely the most important seismic phenomenon in the territory of the Czech Republic. The activity is characterized by reoccurrence of rather weak earthquakes swarms. It was most recently affirmed by 2008 swarm, the strongest one for the last 3 decades. High activity lasted approximately from 10 October to 5 November 2008, more than 20 000 events ($Ml > -0.5$), about 100 events with $Ml > 2.0$, the strongest event with magnitude $Ml = 3.7$, were recorded (automatically identified and localized) – see Figs. 1 and 2.

The region is continuously monitored by WEBNET seismic network (Horálek et al., 2000) and the activity is consequently object of intensive studies (see among other e.g. Studia Geophys. et Geodet., 2000, 2008 and 2009).

In the beginning of modern instrumental investigation, which can be dated since 1985/86 swarm, the effort was focused on acquisition of basic seismic monitoring (i.e. seismic data recording by network of local stations, their collection, processing and archiving). In the last decade, in addition to the above mentioned "classical" seismic monitoring, it has arisen also various attempts to investigate non-seismic phenomena and their relation to the seismic activity (Špičák, 2000). It can be mentioned e.g. observation of CO_2 gas emanation, micro-network observation (Häge and Joswig, 2008), deep drilling projects, etc. We made an attempt to record electro-magnetic emission (here after EME) possibly excited by the seismic activity; the measurement and data mining is described below.

1.2 Possible binding of seismic activity and electro-magnetic emission

Binding of seismic activity and electro-mechanic phenomena is mentioned in the literature for a long time (see e.g. Eftaxias et al., 2001; Karakelian et al., 2002; Matsushima et al., 2002; Kapiris et al., 2003). However this references are either rather uncertain, or only unparalleled (with no repetition of observation of the phenomenon), or the observed conditions are not described in full details or the particular phenomenon can be hardly effectively handled in a quantitative way, etc. The description of the effects varies from the lights (e.g. St-Laurent et al., 2006; Losseva and Nemchikov, 2005), flashes and storms to the changes in ionosphere excited by large earthquakes (excitation is supposed to be transferred via Earth's surface vibrated by surface waves –

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Guglielmi et al. (2006a, b)). Exhaustive review of observation of electric and magnetic filed accompanying seismic and volcanic activity is given in Johnston (1997). Some laboratory experiments have been also performed. There are also speculations about electro-magnetic precursors or connection with material destruction during mechanical rupture in the earthquake source (Freund et al., 2006; Valliannatos et al., 2004).

2 EME observations

The arise of 2008 swarm activity (since 10 October 2008) was the final impulse to install for a long time intended EME measurement in West Bohemia region in addition to ongoing regular seismic registration. The instrument was installed in the course of 2008 swarm (14 October 2008) at the seismic station Nový Kostel (NKC) situated directly in epicentral zone. The instrument consists of coil antenna, amplifier and digitizer. Coil antenna contains of about 20 000 turns with permealoid core, the frequency range of the instrument is about 0.2–10 Hz with sampling rate 25 Hz, continuous registration. The antenna is sensitive to H component of electromagnetic field. The daily EME data volumes were regularly downloaded from NKC station.

3 EME data mining

Preliminary visual analysis of the recorded EME data shows strong correlation of EME signal and strong event (i.e. with Ml > 2.0), about 15 such cases were observed in the course of measurement. However comparison with seismogram discovers, that the strong EME signals are exactly correlated with P and/or S waves arrivals at the station and that the observed abnormalities are only so named “microphone effect” caused probably by movement of the antenna in a magnetic field, e.g. Earth’s magnetic field or in magnetic field of same metallic part of the construction of the station, etc.

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Providing that EME could be connected with earthquake rupture process we summed EME signals related to the relevant earthquakes in such a way, that the considered intervals of measurements were "centered" round their origin times.

$$\text{sum EME}_{(-dt,+dt)} = \sum_{i=1:N} \text{EME}_{(T0_i-dt,T0_i+dt)}, \tag{1}$$

where sum EME is the final summed signal of length $2*dt$, $T0_i$ is origin time of i-th event ($i=1:N$), $\text{EME}_{(T0_i-dt,T0_i+dt)}$ is particular interval of EME signal from time $T0_i-dt$ time to $T0_i+dt$. Neither such signal, nor its spectral or wavelet analysis respectively showed any (positive) correlations or abnormalities. Range of summed EME signals dt varied from 5 to 50 s, again only events with $\text{Ml} > 2.0$ were processed. Therefore we concluded that we did not observe any direct correlation between EME signal and seismic events.

3.1 Data summation extrems

To further statistical exploitation of EME data we adopted approach of Georgiadis et al. (2009), where data are transferred into minute average of amplitudes, which is, in fact, a sort of data filtration and decimation. Even if the quoted work process data from different frequency range (the original data are of 20 MHz sampling and are used for quick monitoring of activity in Greece) we applied it on our data set. Then we made again a summation given by Eq. (1). Considered time range dt was $+/-10$ h in this case. The final wavelet spectrum is on Fig. 3. It follows from that analysis: i) there is an increase of EME activity in the time from -3 to 0 h before the event with a maximum in time from -1 to -0.5 h before the event on periods 14–17 min. Note that this maximum is evocated by events with magnitude about $\text{Ml} \sim 2.0$ rather than by stronger events (this effect is not displayed in the figure). ii) There is a gap of EME activity in interval from $+1$ to $+2$ h after the event. iii) Finally, there is an important maximum in time about $+4$ hours after the event on periods 16 min. The stability of this maximum was tested and confirmed by Bootstrap test. These effects are hypothesized in the conclusions.

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As some anomalies were observed in wavelet spectra of the summed signal, we want to be sure that it is not again the influence of above mentioned "microphone effect". It would be possible e.g. in case that there is some prevalent period of event repetitions in course of the swarm. To test this possibility we constructed two another summed signals: i) we summed, in the same way as EME signals, seismic signals. For this analysis we used records of broadband instrument placed also at station Nový Kostel. Sampling frequency of this data (20 Hz) is similar to the EME record sampling (25 Hz). The corresponding wavelet spectrum is in Fig. 4b. ii) We supposed that EME anomalies could be effect of numerous week events, therefore we constructed cumulative graph of energy release. All bulletin events were included; standard equation

$$\log E = 1.5M_w + 11.8 \quad (2)$$

e.i. Gutenberg-Richter magnitude-energy was used. This value is grooving in the time course and its derivative also. Therefore we calculated second time derivation to obtain an oscillating signal. In such a way we obtain change of energy release velocity (or, figuratively, we can also speak about "energy acceleration"). Then the values were interpolated with equidistant time step and processed in the same way as EME signal. The wavelet analysis is on Fig. 4a. Neither analysis of seismic signal nor the velocity of energy release show correlation with the summed EME signal extremes. We therefore concluded, as it follows from Fig. 4, that observed EME anomalies are not provoked through any "microphone effect" by seismic waves.

3.2 Global trend

In the next analysis we calculate LTA/STA ratio of EME signal for whole swarm course (cca 3 months) and compare it with swarm earthquake activity – see Fig. 5. It is obvious from the figure, that frequency of LTA/STA picks generally decrease with decrease of the swarm activity. Origin of this EME spikes is not know and they can be even considered as disturbances according preliminary type analysis of the EME signal,

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however, as it has been said above and as it follows from the figure, their general course is obvious.

4 Conclusions

We started measurement of electromagnetic emission in the West Bohemia earthquake region and we were recorded data during part of the 2008 seismic swarm. It is a new non-seismic measurement in the region.

The data analysis showed:

- there is no direct correlation between earthquake origin time and EME record anomalies
- we observed statistical increase of EME activity from time −3 to 0 h before the event with a maximum in time −1 to −0.5 h on periods 14–17 min
- we observed statistical gap of EME activity in time +1 to +2 h after the event
- we observed statistical maximum of EME activity in time +4 h after the event
- we excluded possibility that maxima are caused by "microphone effect"
- we observed decrease of picks of LTA/STA ratio of EME signal during the swarm course, even if the origin of the abnormalities in EME signal is questionable

On the basis of previous laboratory experiments, we can speculate that the increase of EME activity before stronger event can be a preparation phase of the process. The after event gap can be a quiet phase of the relaxation. We have no such hypothesis for the maximum after the event and its explication would need to formulate a new idea of preparation and healing of an earthquake process.

All presented results must be understood like an advice to promising direction of future investigation rather than final fully confirmed facts (namely due to these points: the observation did not last during the whole the swarm and missed its stronger event, we also do not have EME data before the swarm, processed EME data were recorded during only one swarm and only at one point of observation, etc.). Nevertheless, it is remarkable that observed course of EME activity in relation with seismic activity (i.e. an increase before the event, a gap immediately after the event and then again an increase) quantitatively corresponds with observed magnetic field amplitudes tied with Loma Prieta earthquake ($M_S = 7.1$, 17 October 1989) of course in different time scale – see Fraser-Smith et al. (1990) and Fig. 6.

We consider all these results as promising and challenging and in dependency on financial and human support of the project, we plan: i) to continue in EME measurement, ii) extended range of recorded frequencies and iii) increase the number of points of observations including an out of region point to bee able to distinguish possible non-regional EME signals.

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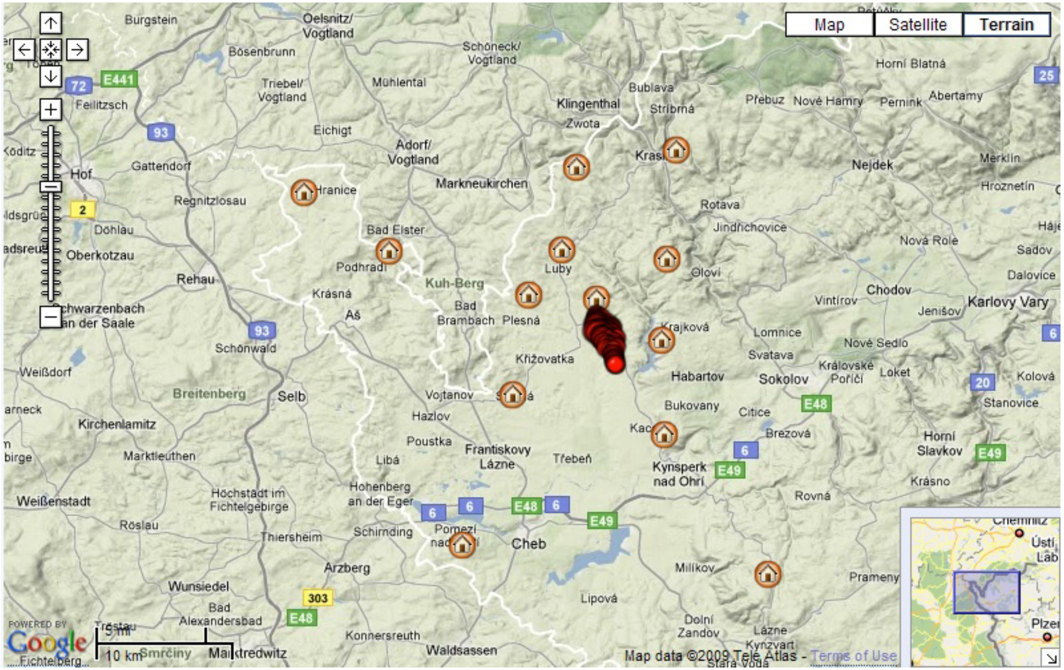

Fig. 1. Map of West Bohemia earthquake region. There are plotted stations of WEBNET network (symbol house) and 2008 earthquake swarm epicenters for Ml > 1.8 (red circle). Taken from Epicentre map (2010).

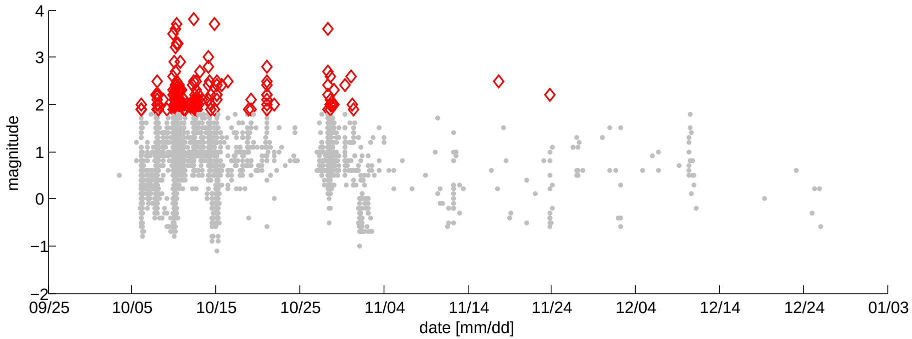

Fig. 2. Activity of 2008 West Bohemia earthquake swarm. There are plotted events' magnitudes versus time of all the bulletin events: $Ml > 1.8$ red diamond (events considered in the presented study), weaker events gray dots.

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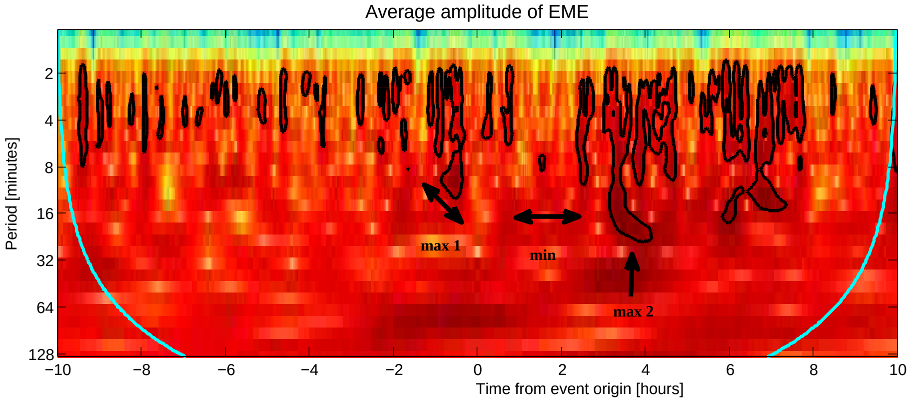

Fig. 3. Wavelet spectrum of summed EME signal (minute averages of time series are used) in range $dt = +/-10$ h round the origin time. 47 events (with Ml > 1.8) were processed. Algorithm designed by Torrence and Compo (1998) or Wavelet (1998) was used. The cyan lines determine zones of spectrum reliability, extremes with statistical significance >0.95 are marked by black lines. Increase of EME activity before the event is marked by double arrow and named "max 1", gap after the event is marked by double arrow and named "min", the following maximum is marked by arrow and named "max 2".

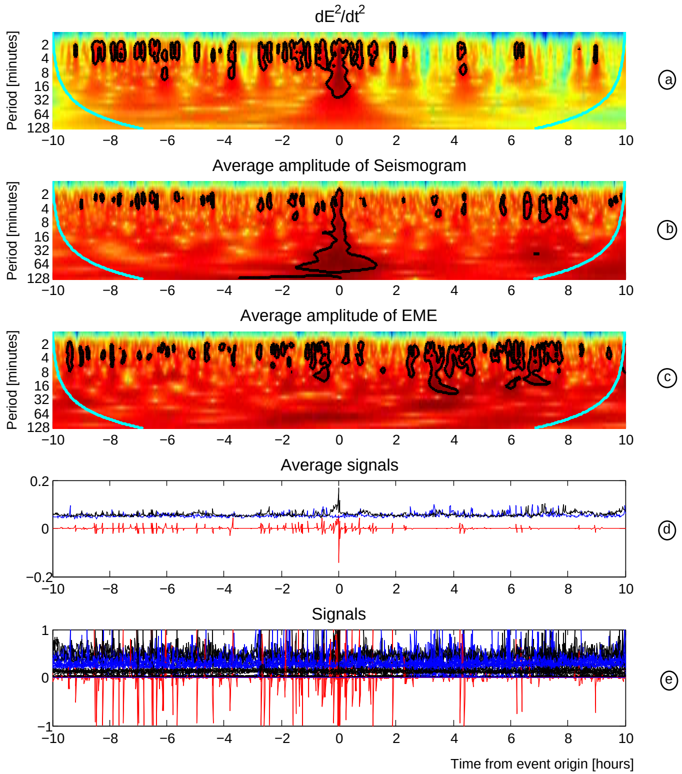

Fig. 4. Exclamation of "microphone effect". Wavelet spectra (from the top) of velocity energy release **(a)**, seismograms **(b)** and EME signal **(c)** – the same as in Fig. 3 are plotted. At the bottom there are normalized processed signals (**e** red - energy release, blue – EME, black – seismogram) and their averages (**d** in the same color as in (e)) – i.e. input data for wavelet analysis. The energy release and seismograms have maxima round the origin time (time = 0) as it can be expected and there is no correlation with extremes observed in EME signal. Therefore we concluded that extremes observed in EME signal are not caused by any "microphone effect" provoked by arriving seismic waves.

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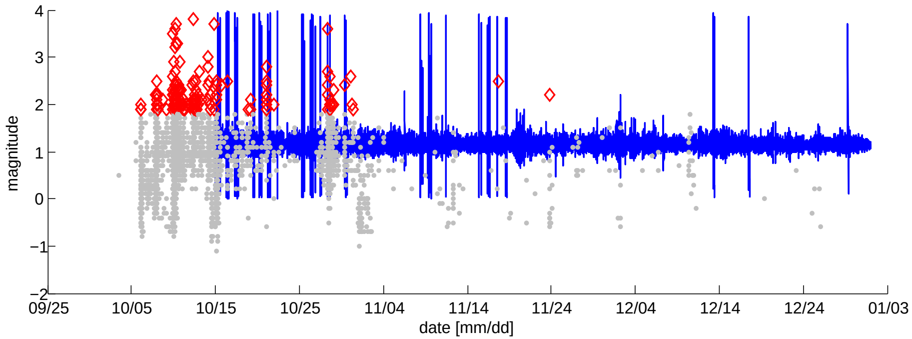

Fig. 5. Decrease of EME activity during the swarm course: the same as Fig. 2, but LTA/STA ratio of averaged EME signal is added (blue line). The decrease of LTA/STA EME signal picks with decrease of the swarm activity is obvious.

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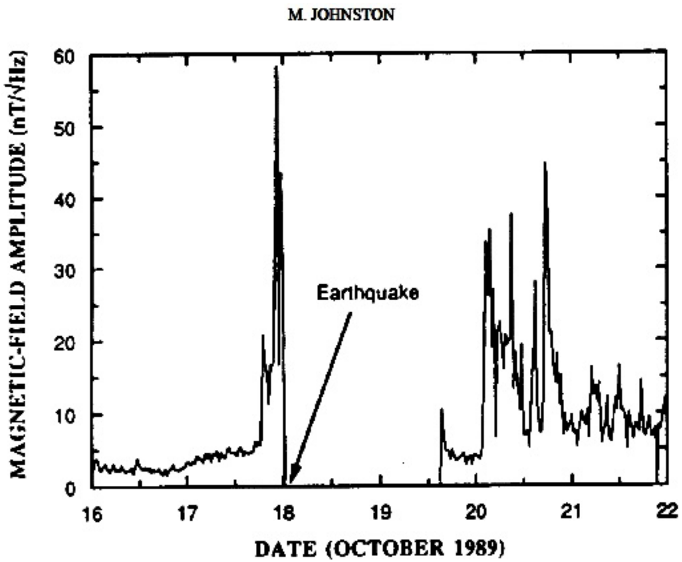

Fig. 6. Magnetic field amplitude as a function of time during the 2 days before and 4 days after the Loma Prieta earthquake (from Fraser-Smith et al., 1990, quoted also in Johnston, 1997). We consider the observed magnetic field amplitudes qualitatively similar to our results (cf. Fig. 3), of course in different time scale.