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VLF wave attenuation in the ionosphere observed by the DEMETER spacecraft in the vicinity of earthquakes

D. Píša (1,2,3), F. Němec (1), M. Parrot (2), O. Santolík (3,1)

(1) Charles University in Prague, Faculty of Mathematics and Physics, Praha, Czech Republic (david.pisa@mff.cuni.cz), (2) LPC2E/CNRS, Orléans, France, (3) Institute of Atmospheric Physics, Academy of Science of the Czech Republic, Prague, Czech Republic

We present a statistical study of VLF electromagnetic wave perturbations in the upper ionosphere based on almost 6.5 years of DEMETER satellite data. This spacecraft was operating between 2004 and 2010 at an altitude of $\sim$ 660 km. We have processed all available data measured 0-4 hours before the time of the main shocks. we have selected data recorded when the satellite projection on the ground was within 440 km from the epicenters to large earthquakes. Altogether, data related to more than 9000 earthquakes selected from the USGS earthquake catalog with a magnitude larger or equal to 5 and a depth lower than 40 km have been analyzed. We have used a two-step data processing, which allows us to compare these data with an unperturbed background distribution based on data collected during the whole DEMETER mission. We confirm the previously reported results of a significant decrease of the wave intensity at a frequency of about 1.7 kHz. Two statistical tests show that this effect is unlikely to be random. Earthquake parameters needed to observe the phenomenon are discussed.