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# Novel non-linear processing methods of VLF signals for seismic-ionospheric precursor detection: Evaluation of Zhao-Atlas-Marks and Hilbert-Huang Transforms

Christos Skeberis (1), Zaharias Zaharis (1), Thomas Xenos (1), Sophia Theochari (2), Spyridon Spatalas (3), Dimitrios Arabelos (3), and Michael Contadakis (3)

(1) Department of Electrical & Computer Engineering, Aristotle University of Thessaloniki, Thessaloniki,Greece (cskeberis@auth.gr), (2) Civil Engineering Department, Aristotle University of Thessaloniki, 54006 Thessaloniki, Greece, (3) Department of Surveying & Geodesy, Aristotle University of Thessaloniki, Thessaloniki, Greece

This study investigates the application of three different methods of extracting spectra from VLF signals in order to detect disturbances that can be attributed to seismic-ionospheric precursor phenomena. The methods tested here are the Wavelet Transform (WT) as a benchmark method, the Hilbert-Huang Transform (HHT) and the application of Zhao-Atlas-Marks (ZAM) Distribution, which is a quadratic representation, to process the signals in question.
For the purpose of this paper, data acquired in Thessaloniki (40.59N, 22,78E) from the VLF station in Tavolara, Italy (ICV station Lat 40.923, Lon. 9.731) for over three years (December 2010 - December 2013) are used. The receiver was developed by Elettronika Srl and is part of the International Network for Frontier Research on Earthquake Precursors (INFREP).
A normalization of the received VLF signals is applied prior to their analysis. The efficacy of the processing methods and the results produced by these processes are then discussed. Finally, comparative spectra are presented along with an evaluation of the discrimination and detection capabilities of each method on disturbances of the received signals.
These methods provide different resolution and filtering capabilities. HHT provides frequency range filtering by making Intrinsic Mode Function (IMF) selection thus allowing us to focus on specific frequency ranges on the phenomena in question, whereas ZAM has an emphasis on improving frequency resolution and thus provides cross-term suppression, therefore this method gives clearer spectra without having the option of filtering that HHT provides.
Based upon the results, a suitable processing method can be chosen to further improve the current analysis method by using data produced by seismic-ionospheric precursor phenomena and also contribute to a real-time method for correlating seismic activity with the observed disturbances.