Application of Self Adaptive Unsupervised Neural Networks for Processing of VLF-LF signals to detect Seismic-Ionospheric Precursor Phenomena.

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Introduction

The earthquake activity contributes to ionospheric variability.

Extensive studies point to the conclusion that the Earth’s lithosphere interacts with the atmosphere prior to a strong seismic event, resulting in the generation of an anomalous electric field that affects the electron content of the ionosphere.

Introduction

However, the seismo-ionospheric interaction is considered a local event, in the sense that only a certain area over the ground is affected by the earthquake, and its size is a function of the magnitude of the event.

On the contrary, solar activity, which is the primary contributor to ionospheric variability, affects the ionosphere as a whole, producing more global effects compared to the localized phenomena of seismo-ionospheric coupling.

The challenge therefore is to distinguish between the seismic-generated D-layer fluctuations and the fluctuations attributed to solar activity.

The problem becomes more and more complicated when other smaller magnitude disturbances of undefined origin appear in the received signal, characterized as geophysical or ionospheric noise .

Introduction

As such, different sources can produce multiple disturbances.

Therefore the need to provide an adaptive robust method of distinguishing points of interest and provide a preliminary discrimination of disturbances.

That method should aim to alleviate the requirement for human observations and interpretations as well as provide a fast method due to the large amount of data gathered.

Scope

To provide a self adaptive unsupervised method for detecting disturbances that can be attributed to seismic-ionospheric precursor phenomena using VLF radio signals.

Procedure:

A normalization of the VLF signals received is applied prior to their analysis by the Empirical Mode Decomposition; then it is followed by the application of artificial neural networks (ANN) based on Predictive Modular Neural Networks (PREMONNs)

Scope

- Predictive Modular Neural Networks(PREMONNs) have been developed for time series classification and prediction and through that for source switching detection in a time series

- They are constituted of a self adaptive unsupervised neural network that is continuously trained with current samples and can provide objective results in real time.

- Thus the neural network can handle new unknown types of disturbances.

Data and measurements

VLF Transmitters:

Frequency (Hz)	Station Call	Location	Country	Lat/Lon
19.580	GBZ	Anthorn	UK	54.912, -3.277
20.270	ICV	Tavolara	Italy	40.923, 9.731
21.750	HWU	Le Blanc	France	46.708, 1.241
37.500	ICE	Keflavik	Iceland	63.959, -22.542

Receiver: Thessaloniki, Greece (40.69N 22.78E) developed by Elettronika Srl

Part of the International Network for Frontier Research on Earthquake Precursors (INFREP)

Data and measurements

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- The VLF stations have been monitored over a period of two years.
- A database with samples of a period of a year (1/10/2010 to 3/10/2011) is chosen for the processing.

Method and Analysis/steps

A normalization of the VLF signals received is applied.

Goal:

1. the impact of the attributes of the ionosphere on the disturbance of VLF waves are brought forth
2. the detected disturbances across multiple stations of different characteristics (such as the transmitted power and the distance between transmitter and receiver) are brought in line .

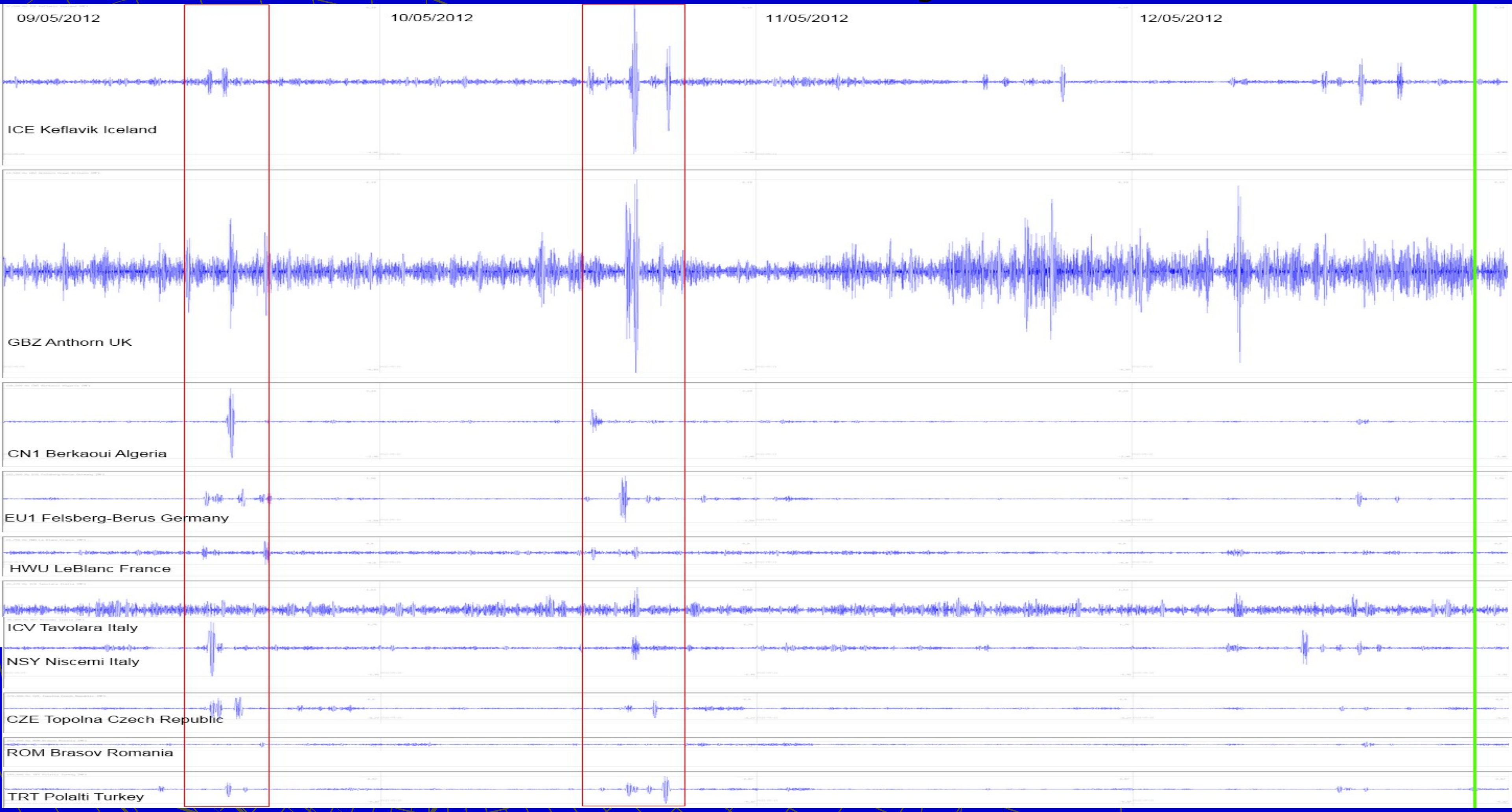
Method and Analysis/EMD

The normalized signals are analyzed by the Empirical Mode Decomposition

It is an adaptive method for processing non-linear and non-stationary signals.

EMD decomposes a real signal into its functional components,which are known as Intrinsic Mode Functions (IMF)

Method and Analysis/EMD



The red squares denote areas of interest across all stations due to the proximity of the event. Green line denotes the seismic event (earthquake on the 12 May 2012 Greece, 48.58 N 22.85 E Mw=4.0 http://www.emsc-csem.org/)

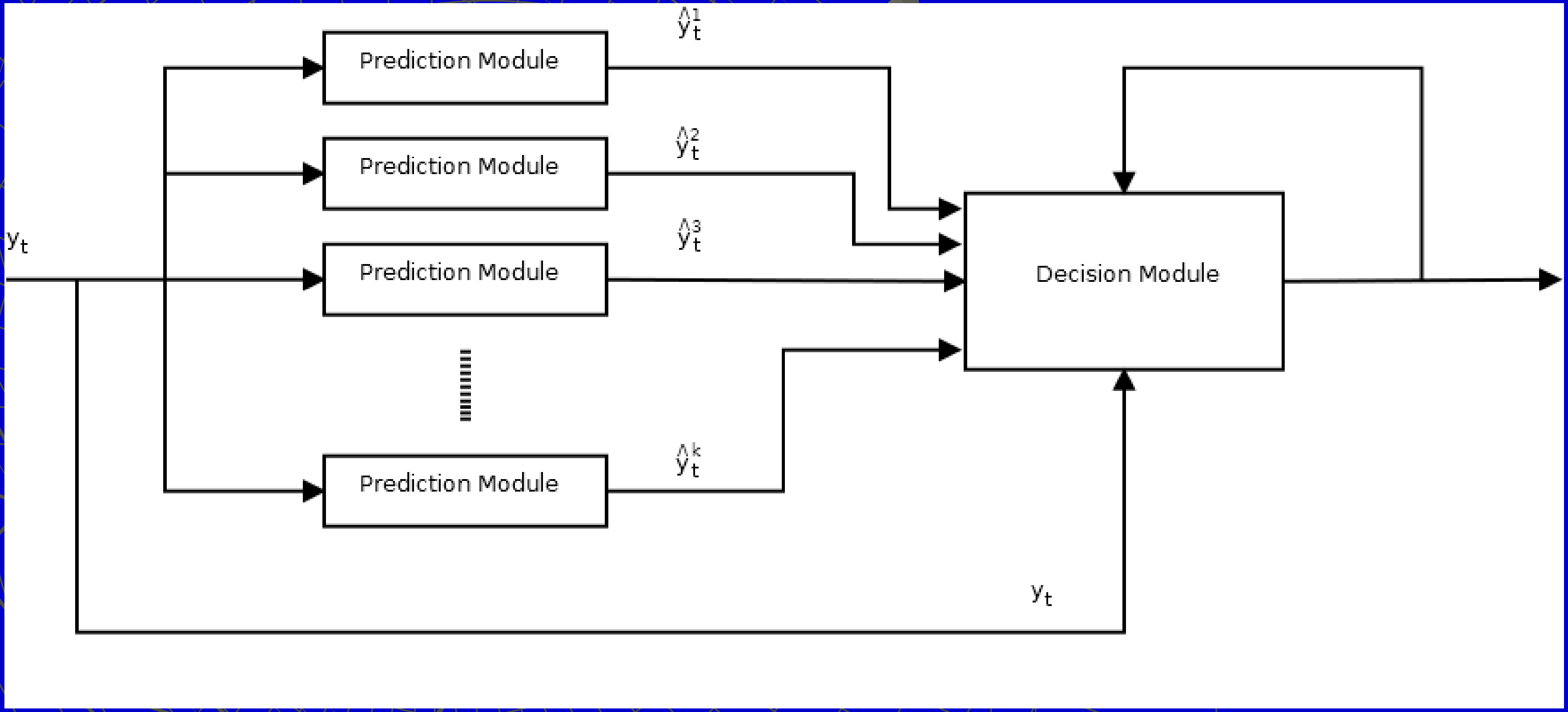
Method and Analysis/ANN

PREMONNs are constituted by two modules in a two tier architecture.
The first tier is a module consisting of a dynamic array of neural networks following the data stream in order to predict the next value of a time series.

The second tier is a decision one utilizing a Bayes probability equation (or any other appropriate cost function) to decide on source switching. That module is responsible for electing and appropriately training the closest fitting NN or switching to a new NN if a source switch is apparent.

Method and Analysis/ANN

PREMONNs are constituted by two modules in a two tier architecture.



Method and Analysis/Steps

The first tier:

1.Monitors the time series in data segments of a set number of samples

2. The full array of ANNs try to predict the next step in the series individually and provide their best estimation.

The second tier:

1.Compares all the predictions of the array of ANNs and the actual next step in the series.

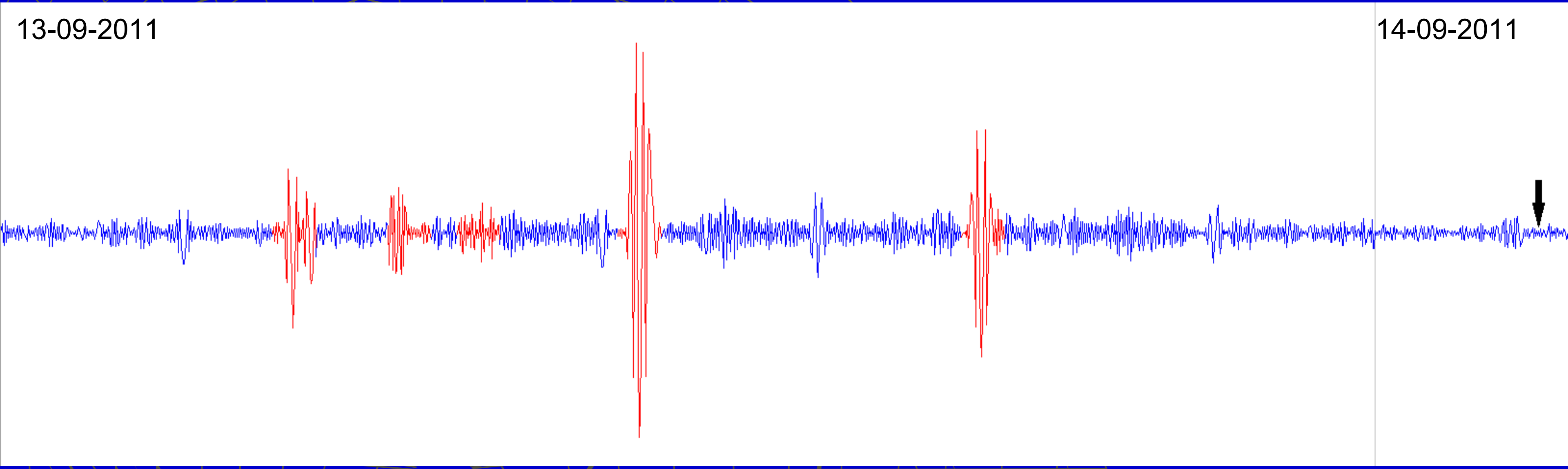
2.Decides on a winner, based on a set cost function

3.Commands the winner of the predictions to be further trained for a few iterations with the newest sample.

4. If there are no close winners, it creates a new ANN which is closely trained with the given sample and is added to the array for the next cycle of decisions.

Observations

Disturbance on the IMF1 diagram on the ICV station Tavolara, Italy 19.58kHz recorded on 13-09-2011

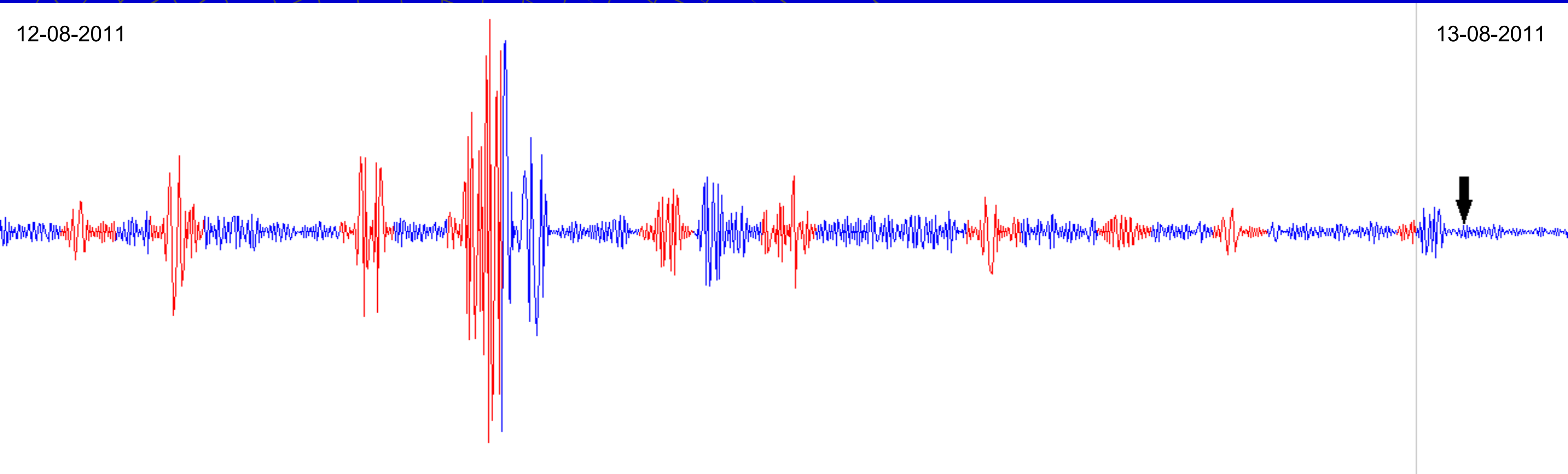


Red denotes the points of interest as produced by the ANN
The black arrow denotes the seismic event

(earthquake on the 14 September 2011 Greece, 37.2 N 22.05 E Mw=4.9 http://www.emsc-csem.org/)

Observations

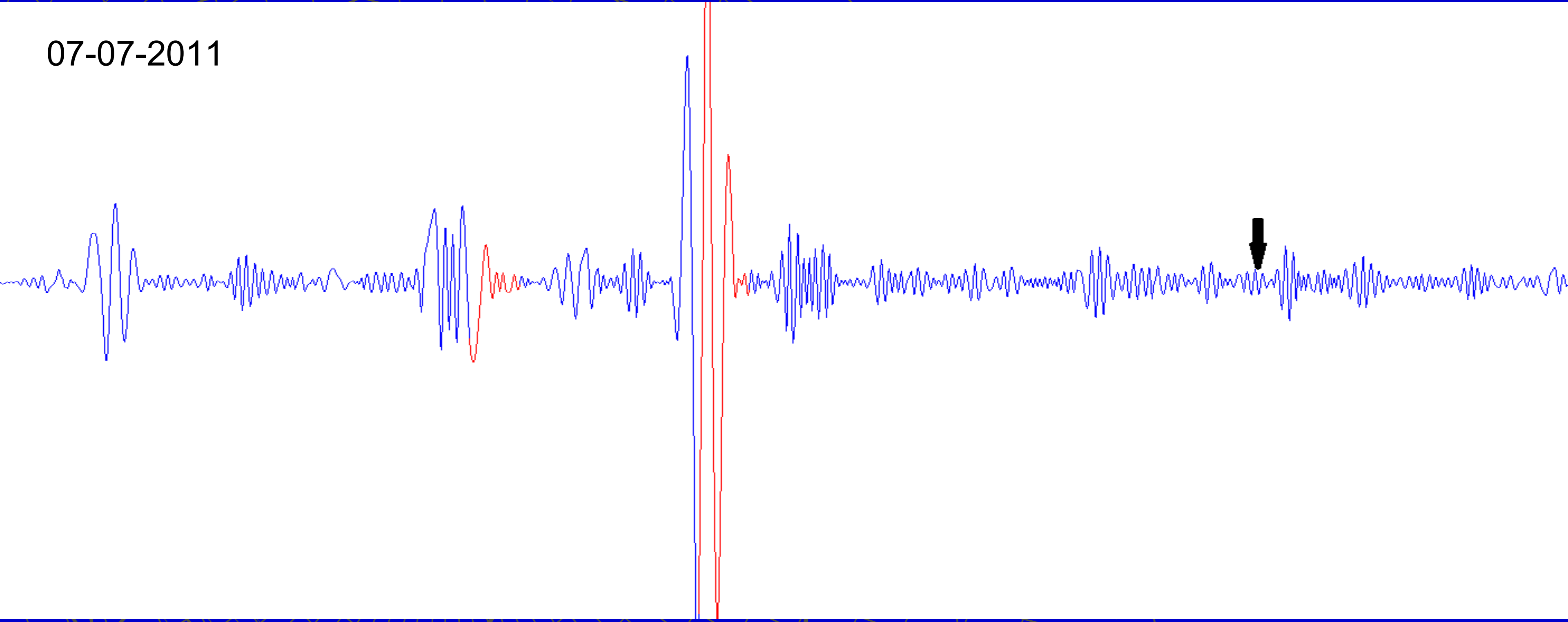
Disturbance on the IMF1 diagram on the ICV station Tavolara, Italy 19.58kHz recorded on 13-08-2011



Red denotes the points of interest as produced by the ANN
The black arrow denotes the seismic event
(earthquake on the 14 August 2011 Greece, 37.27 N 22.02 E Mw=4.8 http://www.emsc-csem.org/)

Observations

Disturbance on the IMF2 diagram on the ICV station Tavolara, Italy 19.58kHz recorded on 07-07-2011



Red denotes the points of interest as produced by the ANN
The black arrow denotes the seismic event
(earthquake on the 07 July 2011 Mediterranean Sea, 42.06 N 7.60 E Mw=5.3 http://www.emsc-csem.org/)

Further processing

- The output from the PREMONN is developed to be used to train a Self-Organizing Classifier based on Self-Organizing Maps (SOM/Kohonen Networks).

- The unsupervised classifier can in real-time compare and correlate disturbances to prior established disturbances and can report similarities to previous events.

Conclusions

- An automated system based on the PREMONN can provide an adaptive robust method of distinguishing points of interest and provide a preliminary discrimination of disturbances.

- Those areas of interest can be the basis for either human observations of disturbances accorded to events

or

- Paired with an unsupervised classifier it may provide a real-time method for correlating seismic activity with the observed disturbances.

Thank you