THE EUROPEAN RADIO NETWORK (INFREP) FOR STUDYING EARTHQUAKE PRECURSORS: STATUS AND PRELIMINARY RESULTS OBTAINED ON THE OCCASION OF THE DODECANESE ISLANDS EARTHQUAKES (JANUARY 30, 2020; MW=5.6 AND MW=5.7)

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PREFACE

The VLF radio signals lie in the 20-80 kHz frequency band. These radio signals are used for worldwide navigation support, time signals and for military purposes.

The LF radio signals lie in 150-300 kHz frequency band and are used for long way broadcasting by few (this type of broadcasting is going into disuse) transmitters located all over the world.

The VLF signals propagate in the earth-ionosphere wave-guide as channeled wave.

The LF signals are characterized by a ground-wave and a sky-wave propagation mode. The first one generates a signal that propagates in the channel ground-troposphere, while the second one generates a signal which propagates using the lower ionosphere as a reflector.

The ground wave and sky wave propagation mode is able also to simulate the propagation of VLF signals.

RADIO PRECURSORS

In the last 20 years, a research into the interaction between seismic activity and disturbances in radiobroadcasts has been carried out. Pre-seismic disturbances in VLF radio signals have been presented mainly by Japanese and Russian researchers; pre-seismic disturbances on LF radio broadcasts were proposed mainly by Italian researchers. We call these disturbances **radio precursors**.

Variations of parameters in the ground, atmosphere and ionosphere generate variations in the propagation medium of the radio-waves and so disturbances in their propagation can occur.

The radio precursors confirm the existence of a lithosphere-atmosphere-ionosphere coupling.

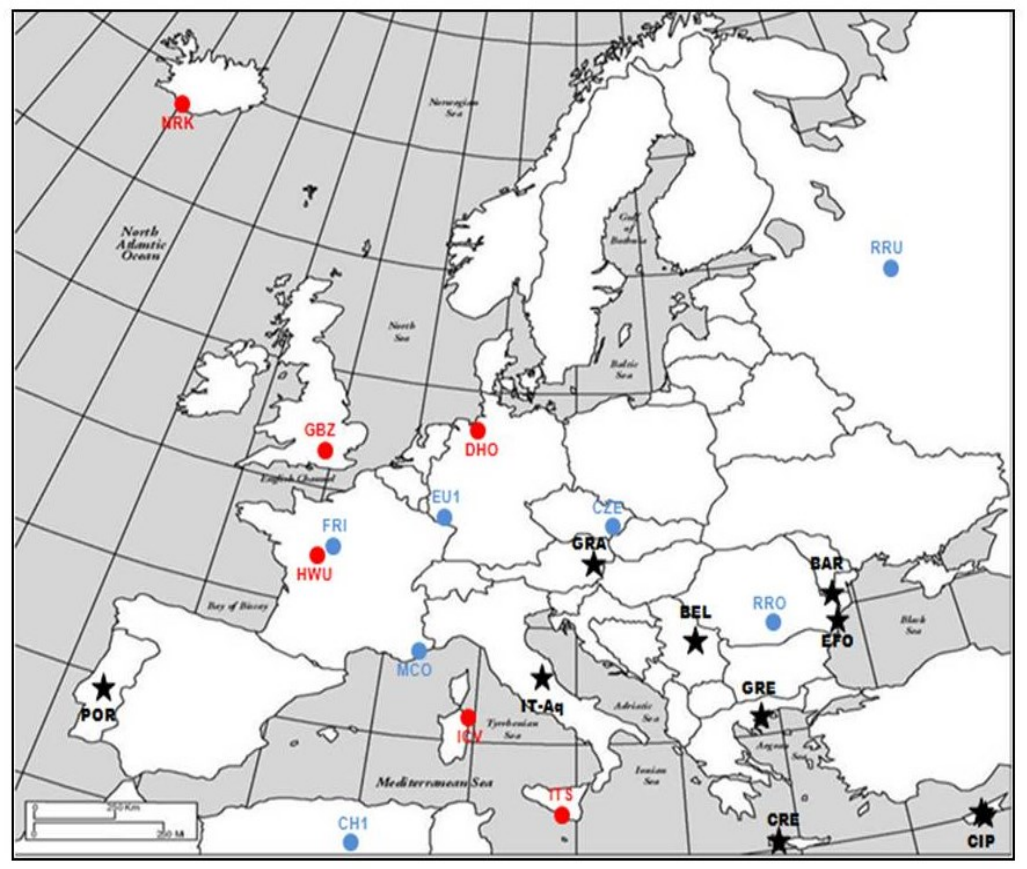
CURRENT STATUS OF THE INFREP RADIO NETWORK

In January 2009 a network of radio receivers able to measure the electric field intensity from various broadcasting stations existing in Europe, was installed. The network currently consists of nine receivers located as follows: two in Italy, Romania and Greece; one in Austria, Portugal and Cyprus.

The radio receivers were manufactured by an Italian factory and measure the intensity of 10 radio signals in the bands VLF (20-80 kHz) and LF (150-300 kHz), with 1 minute sampling rate.

The signals radiated by VLF-LF broadcasting stations located in Europe are used. Generally, each receiver collects 5 VLF and 5 LF signals; in any case, the selection of the signals to collect is based on the quality of local reception.

star = receiver
circle = transmitter
VLF (red) and LF (blue)



Labels and frequencies of the VLF-LF transmitters

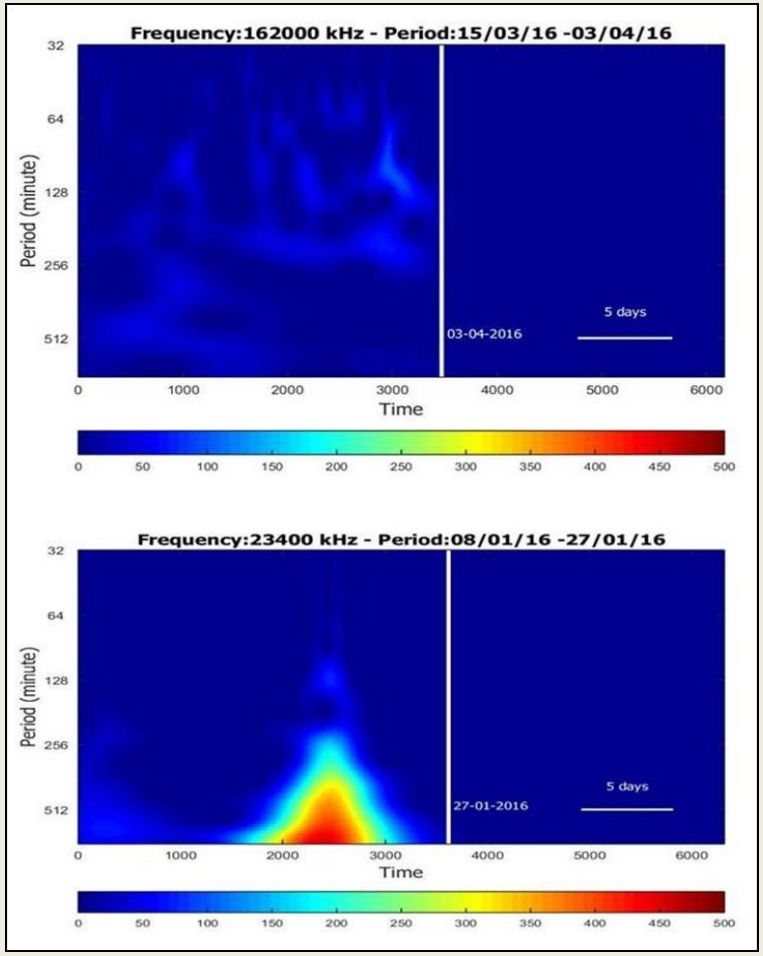
VLF	Frequency (kHz)	LF	Frequency (kHz)
GBZ	19.58	RRO	153
ICV	20.27	FRI	162
HWU	21.75	EU1	183
DHO	23.4	CH1	198
TBB	26.7	MCO	216
ICE	37.5	RRU	261
NSY	45.9	CZE	270

The data collected are transmitted by Internet, every day, to the server located at the Department of Physics of the University of Bari (Italy) that is the central node of the network.
An INFREP web site (http://www.infrep-network.eu/) was created showing the previous map with the paths (5th Fresnel zones) of the different signals for each receiver, the participant Teams and the main references. The different temporal trends (10 for each receiver) and the data bank in real time are protected by username and password.

In order to reveal possible radio precursors, the data had to be analyzed for discovering "anomalies", which differs from normal variations of the data trends.

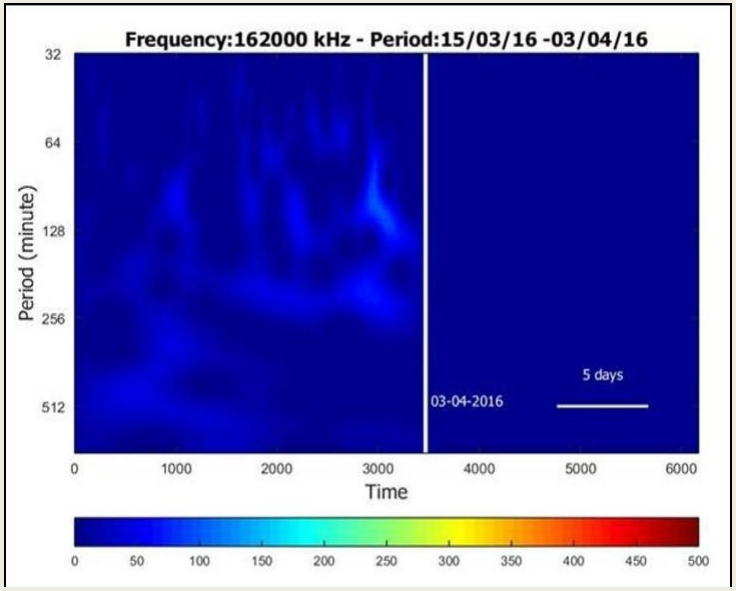
Generally, due to the absence of solar radiation, the VLF/LF radio signals are less disturbed during the night than during the day. So in INFREP, the analysis of the radio data is performed only on the night-time data for all VLF/LF radio bands, between 21.00 to 24.00 (UTC). Each day is therefore represented by 3 hours, that is, taking into account the 1 min sampling rate used, 180 data (minutes).

For the analysis of the data sets the Wavelet power spectra are used. A power spectrum is a two dimensions plot that, once properly normalized with respect to the power of the white noise, gives information on the strength and precise time of occurrence of the various Fourier components which are present in the original time series. Generally, color from blue to red indicates increase in the power strength; so, red zones define anomalies.



Two examples of Wavelet power spectra; at the top a normal situation; at the bottom an anomaly appears.

INFREP has implemented a software able to apply the Wavelet analysis on the radio data automatically at the end of each day. The analysis is performed on those 15 days [2700 data (minutes)] or 20 days [3600 data (minutes)] preceding each day; this day is indicated on the spectrum by a vertical white line; the part of the spectrum after the day is related to 15 days data without any frequency added to avoid border effects.

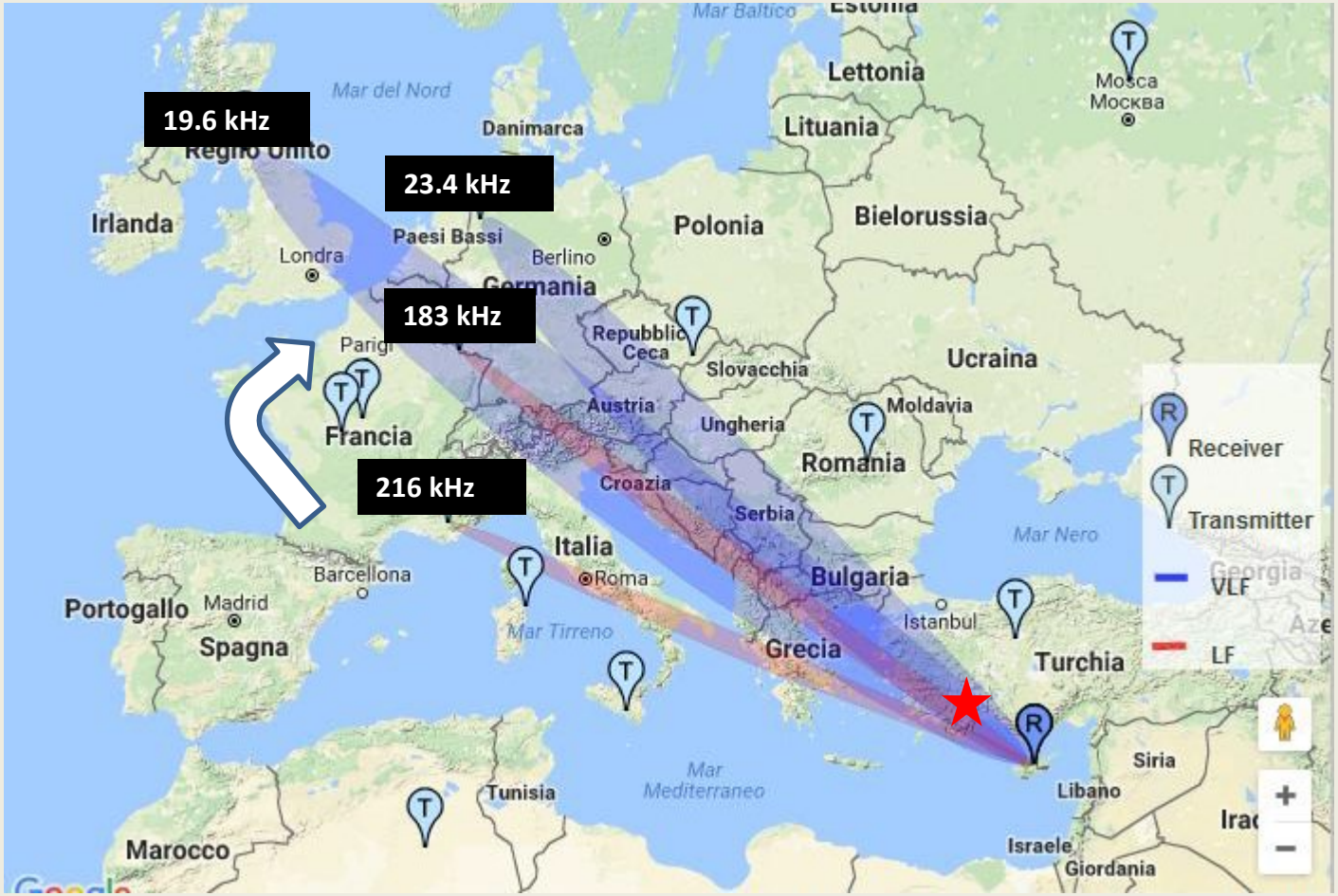


At the moment, the software operates on the night time data of four signals collected by each of the following receivers: CIP, CRE, GRE and IT-Aq. The results obtained with the Wavelet analysis are protected in the INFREP web site by a further username and password.

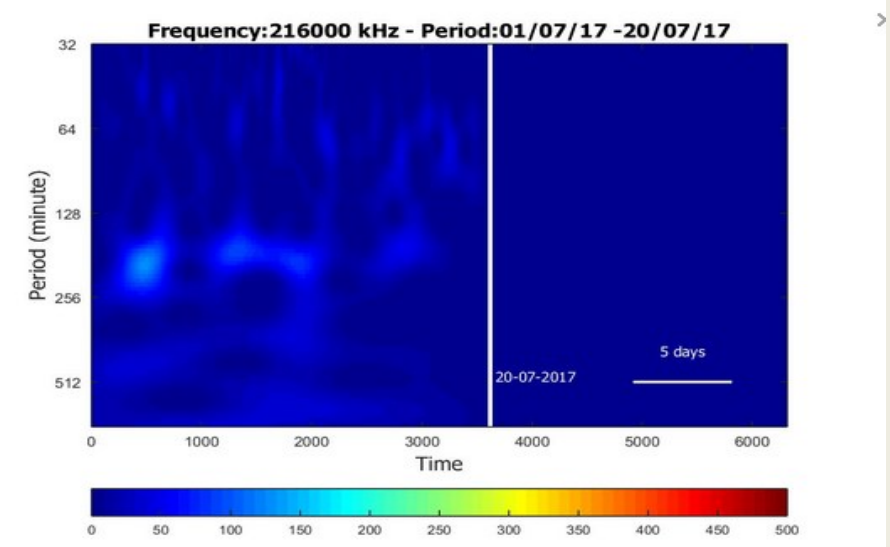
In order to identify radio precursors it is very important to take into account that, as well as the preparatory phase of earthquakes, other causes can produce disturbances in VLF/LF radio propagation: solar flares, anomalous geomagnetic activity and adverse meteorological conditions mainly around the receiver location. These effects can produce radio anomalies very similar to the pre-seismic ones; so, before to claim radio precursors it is necessary to check these effects.

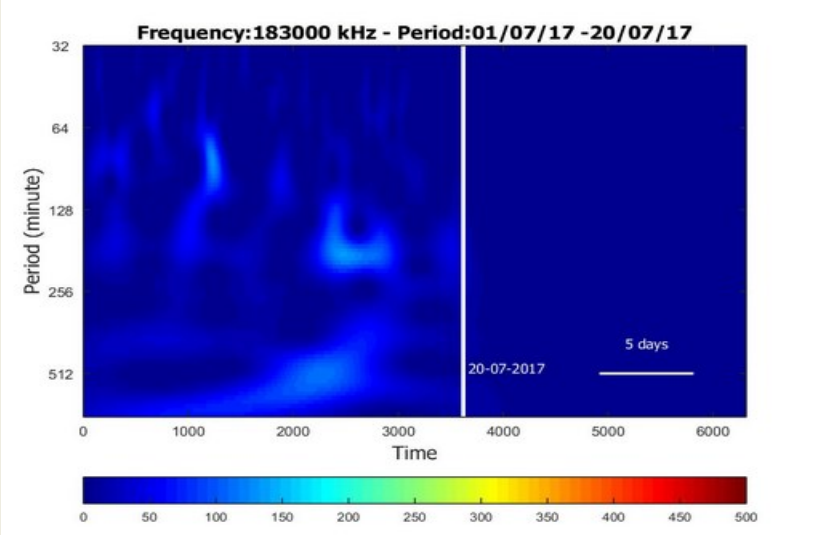
AN EXAMPLE

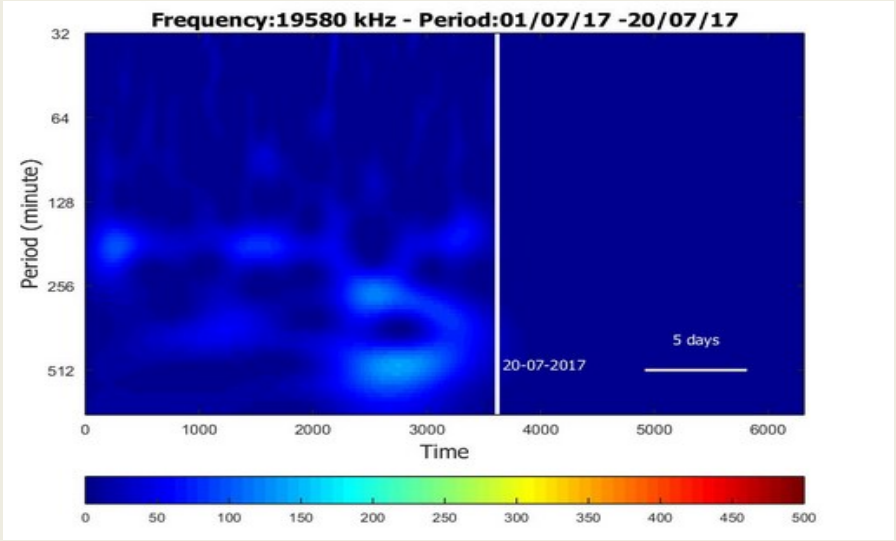
On July 20, 2017 a strong (M_w=6.7) earthquake occurred offshore (red star) near the coast of Turkey and the Kos island (Greece). The focal depth was 10 km.

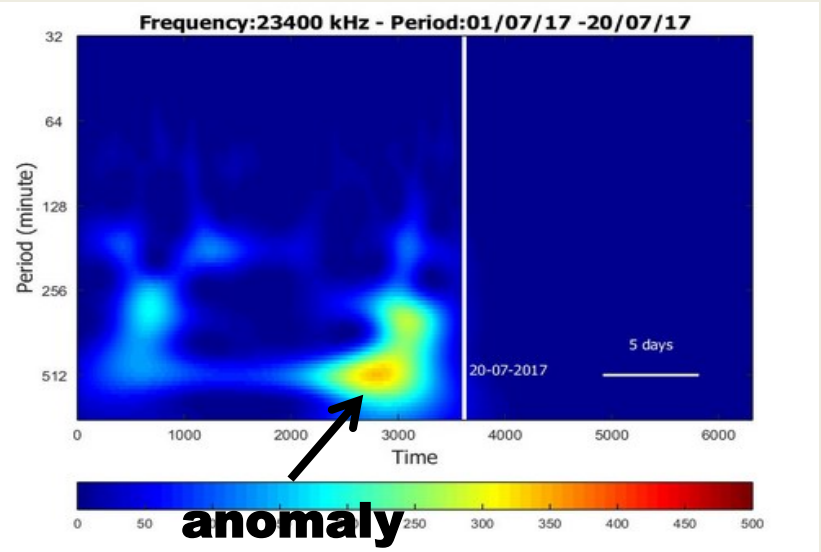


The Wavelet spectra of the indicated four signals automatically obtained at the earthquake day are shown clokwise in next slide


Frequency:216000 kHz - Period:01/07/17 -20/07/17
Period (minute)
32
64
128
256
512
20-07-2017
5 days
0
1000
2000
3000
4000
5000
6000
Time
0
50
100
150
200
250
300
350
400
450
500


Frequency:183000 kHz - Period:01/07/17 -20/07/17
Period (minute)
32
64
128
256
512
20-07-2017
5 days
0
1000
2000
3000
4000
5000
6000
Time
0
50
100
150
200
250
300
350
400
450
500

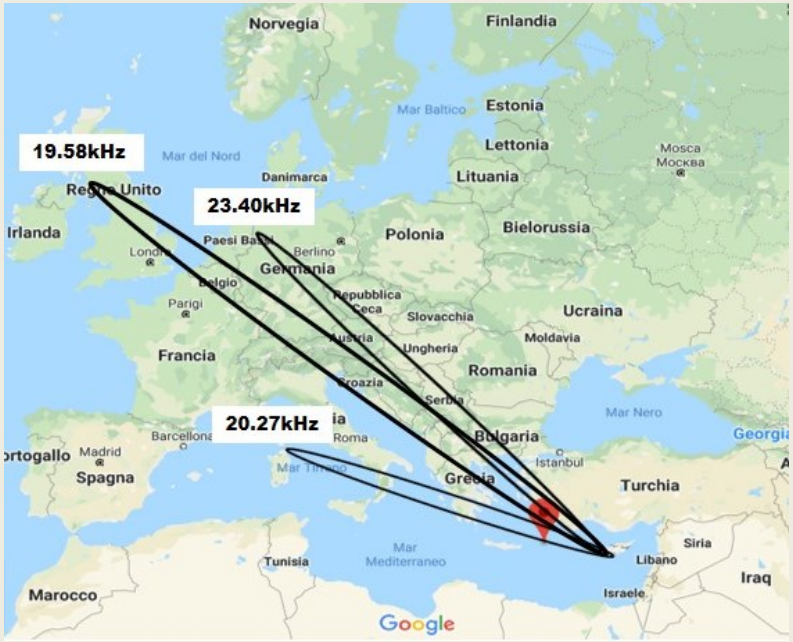

Frequency:19580 kHz - Period:01/07/17 -20/07/17
Period (minute)
32
64
128
256
512
20-07-2017
5 days
0
1000
2000
3000
4000
5000
6000
Time
0
50
100
150
200
250
300
350
400
450
500


Frequency:23400 kHz - Period:01/07/17 -20/07/17
Period (minute)
32
64
128
256
512
20-07-2017
5 days
0
1000
2000
3000
4000
5000
6000
Time
0
50
250
300
350
400
450
500
anomaly

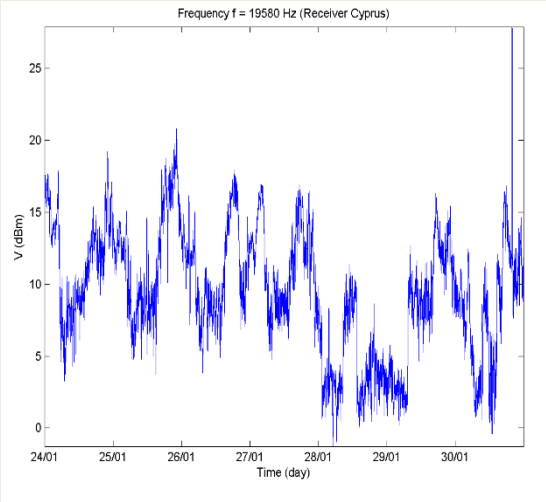
The possibility that the anomaly revealed in the 23.4 kHz signal collected by the Cyprus receiver is a precursor of the previous earthquake is convincing.
This anomaly is by the standards pointed out for the radio precursors, i.e:
a) a precursor time within ten days
b) a value of M_w equal or greater than 5.5
c) the epicentre located inside the 5th Fresnel zone of the radio signal near the receiver (most sensitive zone).

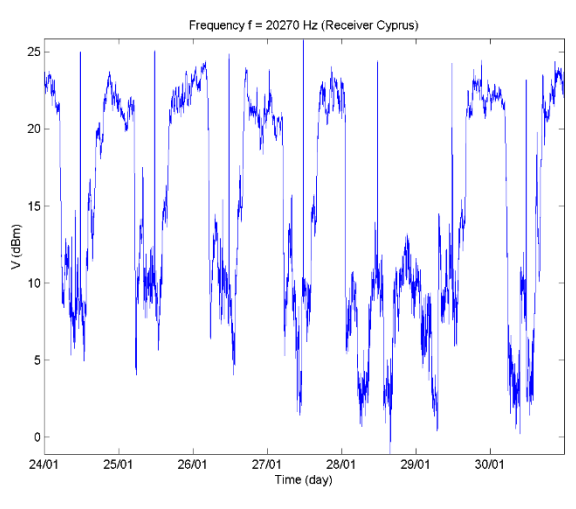
DODECANESE ISLANDS EARTHQUAKES (JANUARY 30, 2020)

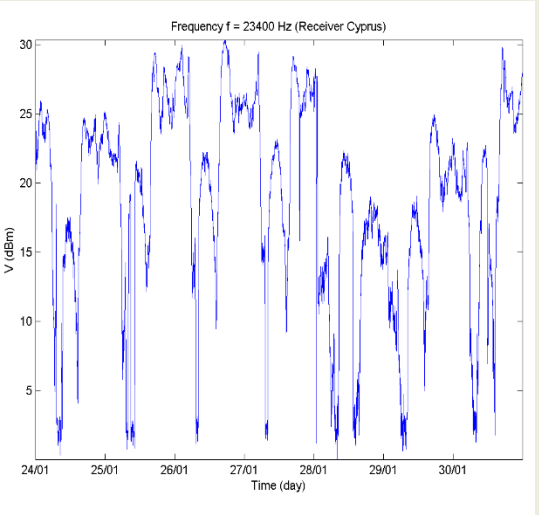
At the end of January 2020 an intense seismic activity occurred in Western Turkey and Dodecanneso Islands; the main events (M_w= 5.6 and M_w= 5.7) occurred on January 30. These seismic activities occurred in the "sensitive" zone of the Cyprus receiver of INFREP network.



In this occasion clear pre-seismic anomalies appeared on three VLF radio signals (19.58, 20.27, 23,40 kHz) collected by this receiver as it is shown in the Figures.







No anomalous geomagnetic activity or adverse meteorological conditions appeared in this period, so the possibility that the previous anomalies revealed in signals collected by the Cyprus receiver are a precursor of the previous earthquakes seems convincing.

CONCLUSIONS

The radio signals confirm their validity as earthquakes precursors.

The importance of using the data of a radio network clearly stands out from this presentation.

In any case in order to produce an earthquake forecast statistically significant one parameter is not sufficient. Only the simultaneous use of several different parameters could produce a success.