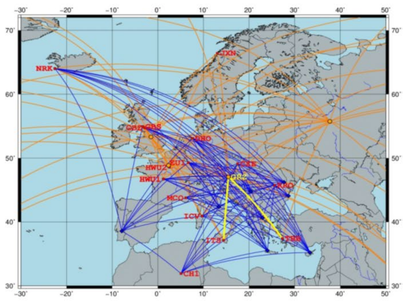
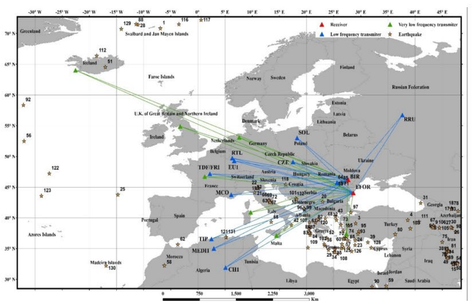
NH4.4 - Multi-parametric Short-Term Seismic Hazard monitoring and Physical and Statistical Models for Earthquake Risk assessment

Poster number X3.50 / Abstract Number EGU25-10351

EGU General Assembly 2025

INFREP VLF/LF EUROPEAN NETWORK 2009 - PRESENT





INFREP Receivers	Information
R1 – IT-Aq	L'Aquila, Italy lon_Aquila=13.40 lat_Aquila=42.36
R2 - BEL	Belgrade, Serbia lon_Belgrade=20.40 lat_Belgrade=44.80
R3 - CRE	Chania, Crete, Greece lon_Chania=24.03 lat_Chania=35.51
R4 – BAR	Barlad, Romania lon_Barlad=27.67 lat_Barlad=46.22
R5 - EFO	Eforie Nord, Romania lon_EforieNord=28.63 lat_EforieNord=44.08
R6 - GRA	Graz, Austria lon_Graz=15.44 lat_Graz=47.06
R7 - CIP	Nicosia, Cyprus lon_Nicosia=33.37 lat_Nicosia=35.19
R8 – GRE	Thessaloniki, Greece lon_Thessalonica=22.95 lat_Thessalonica=40.63
R9 - POR	Lisbon, Portugal

The Romanian Receivers of INFREP

Grafic 3D pentru frecventa - 21750Hz (Anul 2023 - zile an: 304)

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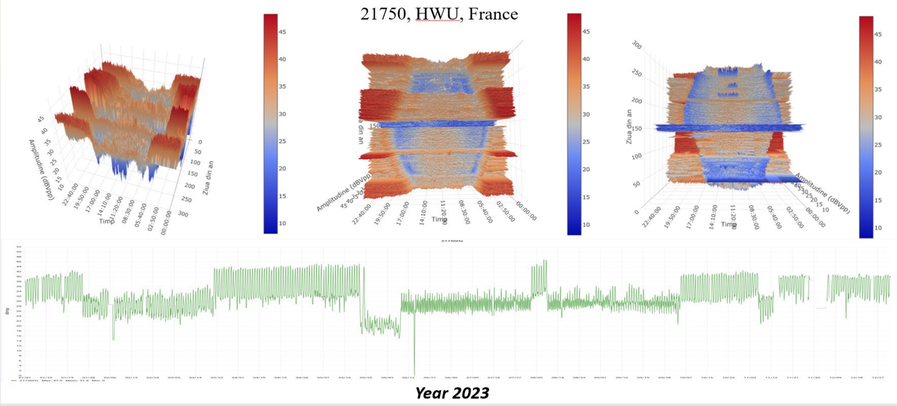
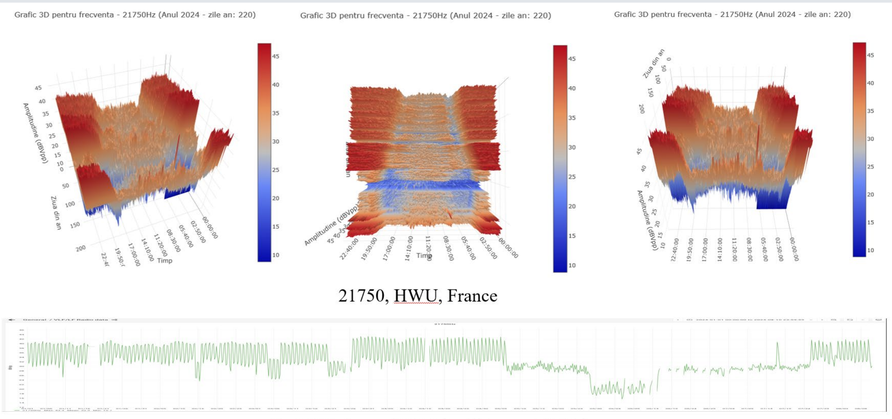


Year 2023

Grafic 3D pentru frecventa - 21750Hz (Anul 2024 - zile an: 220)

Grafic 3D pentru frecventa - 21750Hz (Anul 2024 - zile an: 220)

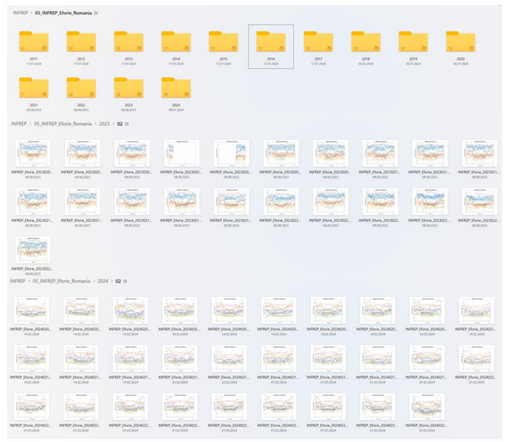
Grafic 3D pentru frecventa - 21750Hz (Anul 2024 - zile an: 220)



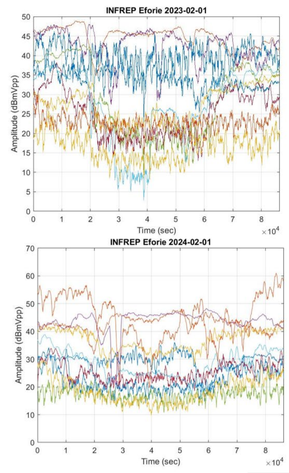
First 220 days of 2024 (until August 2024)

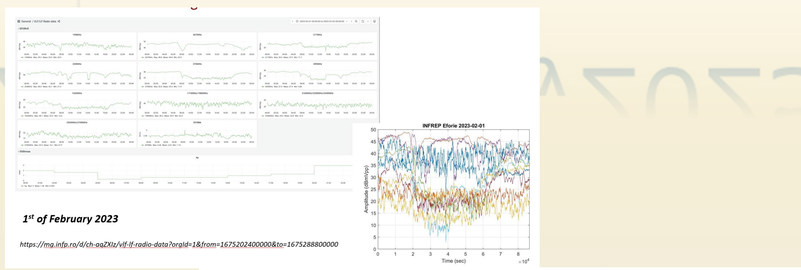
INFREP VLF/LF EUROPEAN NETWORK

2D and 3D near real time signal visualization



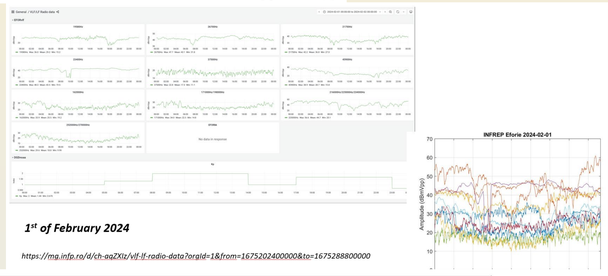
https://infrep.iwf.oeaw.ac.at/data-access/





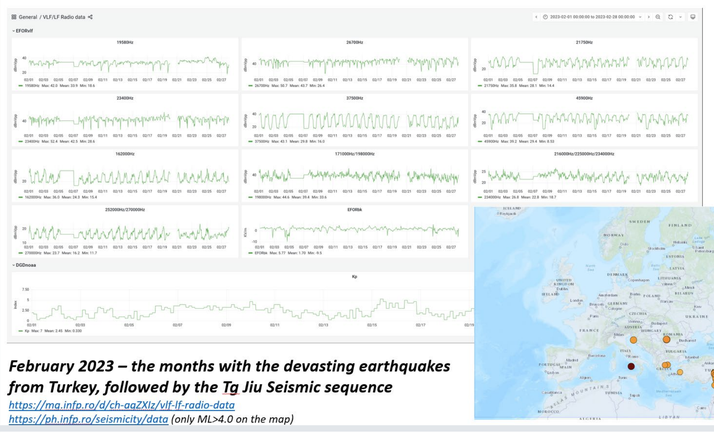
1st of February 2023

https://mg.infp.ro/d/ch-aqZXIz/vlf-lf-radio-data?orgId=1&from=1675202400000&to=1675288800000



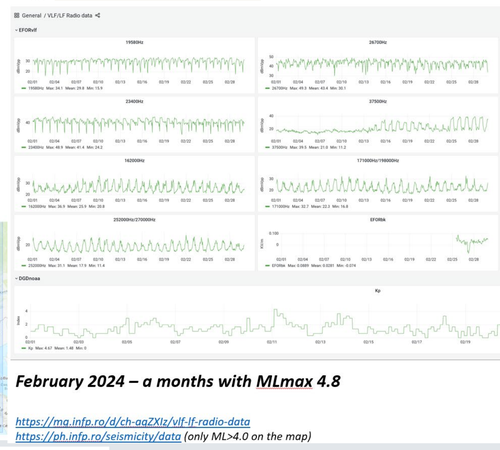
1st of February 2024

https://mg.infp.ro/d/ch-aqZXIz/vlf-lf-radio-data?orgId=1&from=1675202400000&to=1675288800000



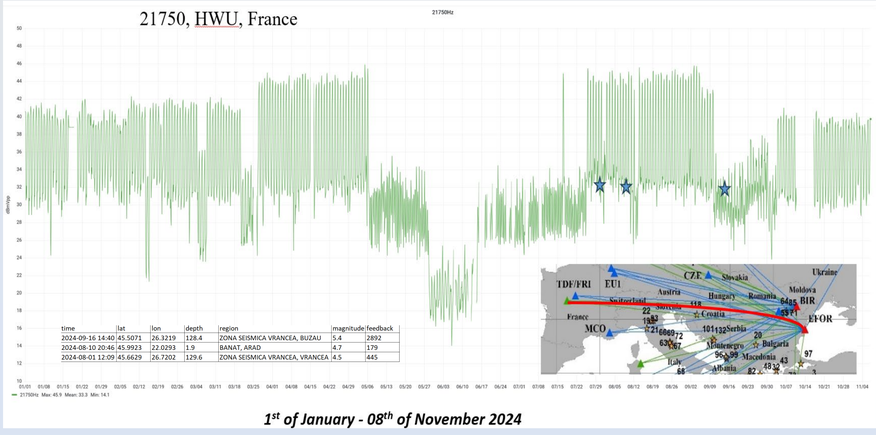
February 2023 – the months with the devasting earthquakes from Turkey, followed by the Tg Jiu Seismic sequence

https://mg.infp.ro/d/ch-aqZXIz/vlf-lf-radio-data
https://ph.infp.ro/seismicity/data (only ML>4.0 on the map)



February 2024 – a months with MLmax 4.8

https://mg.infp.ro/d/ch-aqZXIz/vlf-lf-radio-data
https://ph.infp.ro/seismicity/data (only ML>4.0 on the map)



time	lat	lon	depth	region	magnitude	feedback
2024-09-16 14:40	45.5071	26.3219	128.4	ZONA SEISMICA VRANCEA, BUZAU	5.4	2892
2024-08-10 20:46	45.9923	22.0293	1.9	BANAT, ARAD	4.7	179
2024-08-01 12:09	45.6629	26.7202	129.6	ZONA SEISMICA VRANCEA, VRANCEA	4.5	445

1st of January - 08th of November 2024

CONCLUSIONS

Wavelet analysis of LF data from the European Radio Network has shown earthquake-related anomalies, especially within 300 km, indicating high sensitivity of this method for detecting local disturbances in the "preparation zone." While Fresnel cases had mixed results, with two successes and one failure, this variation—particularly in summer—suggests lower sensitivity for seismic effects in Fresnel zones during this season.

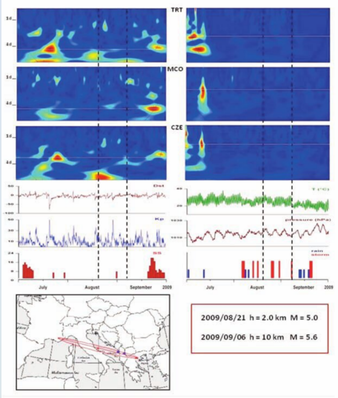
The study of solar terminators on VLF/LF waves characteristics suggest potential precursors in the shifts of VLF/LF transmitter – receiver propagation characteristics.

To validate and enhance these findings, future studies will apply additional methods, including residual dA/dP analysis, principal component analysis, and detrended fluctuation analysis. Multi-parametric observations shall also complement the methods.

To achieve robust results INFREP VLF/LF network will be maintained and upgraded with other receivers. We need to involve researchers with skills and expertise in EM waves transmission , radio amateurs, engineers.

POSSIBLE PRECURSOR SEISMIC ANOMALIES

Wavelet analysis of the LF radio signals

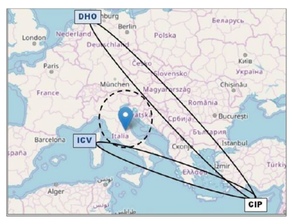


Night-time (TOP left) **and day-time** (TOP right) **spectrograms of three LF transmitters** TRT (180 kHz), MCO (216 kHz) and CZE (270 kHz) transmitter **radio signals collected by the Thesaloniki (GRE) receiver**, together with the geomagnetic/solar and the (local) meteorological data, **from July to September 2009**. Top panels: Spectrograms of the night-time (left) and day-time (right) radio signals. Continuous horizontal lines, delimitation of the region of the wavelet spectra in which edge effects become important (Torrence and Compo, 1998). Centre panels: Dst and Kp geomagnetic indices and solar burst numbers (SS) (left), and air temperature, air pressure and occurrence of rain and storms (right). Bottom: map showing the 5th Fresnel zone of the GR/MCO path, showing the epicentres of the **August 21 and September 6, 2009, Albania earthquakes** that occurred inside these zones. Vertical dashed lines, time of occurrence of these earthquakes.

(Righetti et al., 2012)

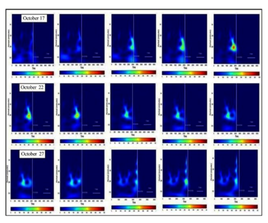
POSSIBLE PRECURSOR SEISMIC ANOMALIES

Wavelet analysis of the LF radio signals

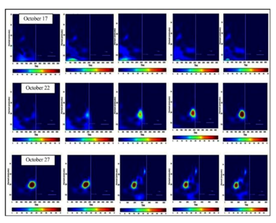


Location of the Norcia (Central Italy) earthquakes occurred at the end of October 2016. The dashed line encloses the Dobrovolsky area of the main shock (**M w = 6.5, October 30, 2016**); the ellipses define the 5 th Fresnel zones of the two radio paths.

(Biagi et al., 2019)



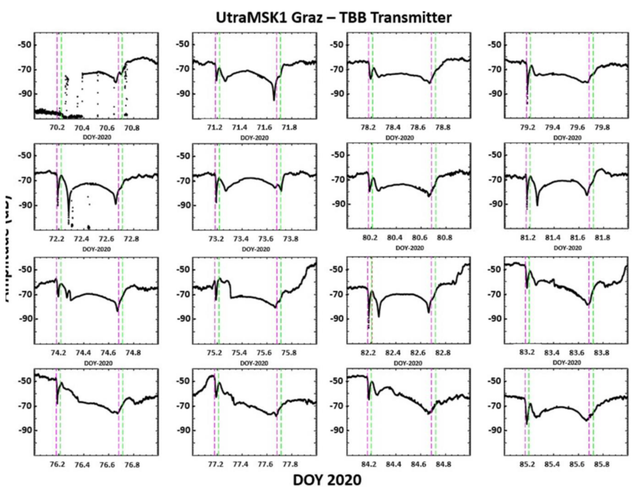
The power spectra of the DHO (23.4 kHz) radio signal collected by CIP receiver from 17 th to 31 st of October 2016. In the time interval between **17 th and 28 th October 2016**, the Wavelet analysis is performed on the 15 days [2700 data (minutes)] preceding the reference day (vertical white line); in the last three days, analysis is performed on the 20 days [3600 data (minutes)]



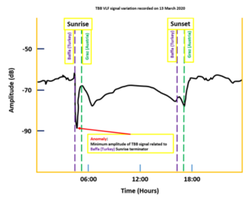
The power spectra of the ICV (20.27 kHz) radio signal collected by CIP receiver for the time interval between the **17 th and 31 st of October 2016**. In the time interval between the 17 th and 28 th of October, the Wavelet analysis is performed on the 15 days [2700 data (minutes)] preceding the reference day (vertical white line); in the last three days the Wavelet analysis is performed on the 20 days [3600 data (minutes)].

POSSIBLE PRECURSOR SEISMIC ANOMALIES

Terminator time method



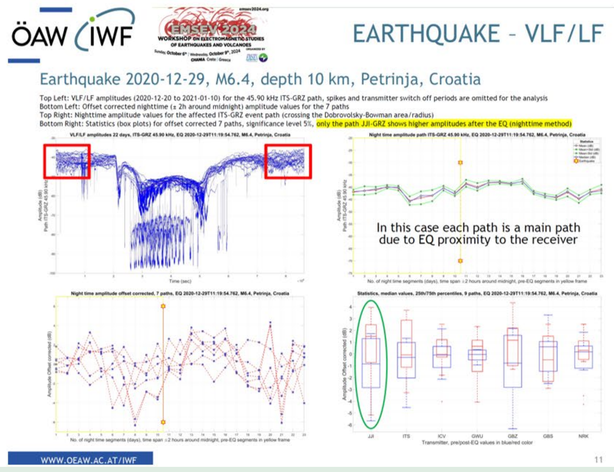
TBB transmitter signal variations recorded by the Ultra-MSK system from 10 to 25 March 2020, which correspond, respectively, to 70 DOY and 85 DOY. The horizontal and vertical axes indicate the time (24 h) and the amplitude from −110 dB to −40 dB. The vertical lines designate the sunrises and sunsets at the TBB transmitter location (violet dashed vertical lines) and the sunrises and sunsets at the Graz VLF/LF facility (green dashed vertical lines). **The EQ occurred on 22 March 2020 (82 DOY) at 05:24 UT, ML5.8 in Croatia, near Zagreb.** (Boudjada et al., 2024)

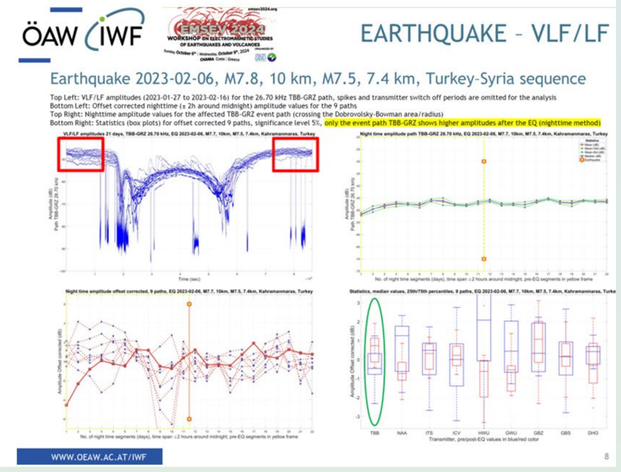


POSSIBLE PRECURSOR SEISMIC ANOMALIES

Night time amplitude method

(Eichelberger et al., 2024)





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Boudjada MY, Biagi PF, Eichelberger HU, Nico G, Galopeau PHM, Ermini A, Solovieva M, Hayakawa M, Lammer H, Voller W, et al. Analysis of Pre-Seismic Ionospheric Disturbances Prior to 2020 Croatian Earthquakes. *Remote Sensing*. 2024; 16(3):529. https://doi.org/10.3390/rs16030529

Eichelberger, Hans U., Mohammed Y. Boudjada, Konrad Schwingenschuh, Bruno P. Besser, Maria Solovieva, Pier F. Biagi, Patrick H. M. Galopeau, Aleksandra Nina, Giovanni Nico, Manfred Stachel, Wolfgang Voller, Irmgard Jernej, Werner Magnes , Combined Natural Hazards Investigations With Sub-ionospheric Vlf/Lf Electric Fields And Satellite Magnetic Measurements , EMSEV 2024 - Workshop on Electromagnetic Studies of Earthquakes and Volcanoes

Righetti, F., Biagi, P. F., Maggipinto, T., Schiavulli, L., Ligonzo, T., Ermini, A., Moldovan, **I. A., Moldovan**, A., Buyuksarac, A., Silva, H. G., Bezzeghoud, M., Contadakis, M. E., Arabelos, D. and Xenos, T. (2012) "Wavelet analysis of the LF radio signals collected by the European VLF/LF network from July 2009 to April 2011", *Annals of Geophysics*, 55(1). doi: 10.4401/ag-5188.

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