

A new VLF radio receiver in Greece for the detection of lower ionosphere anomalies before strong seismic events and the preliminary results for a strong (6.7 Mw) earthquake that occurred in Samos (Greece) on 30/10/2020

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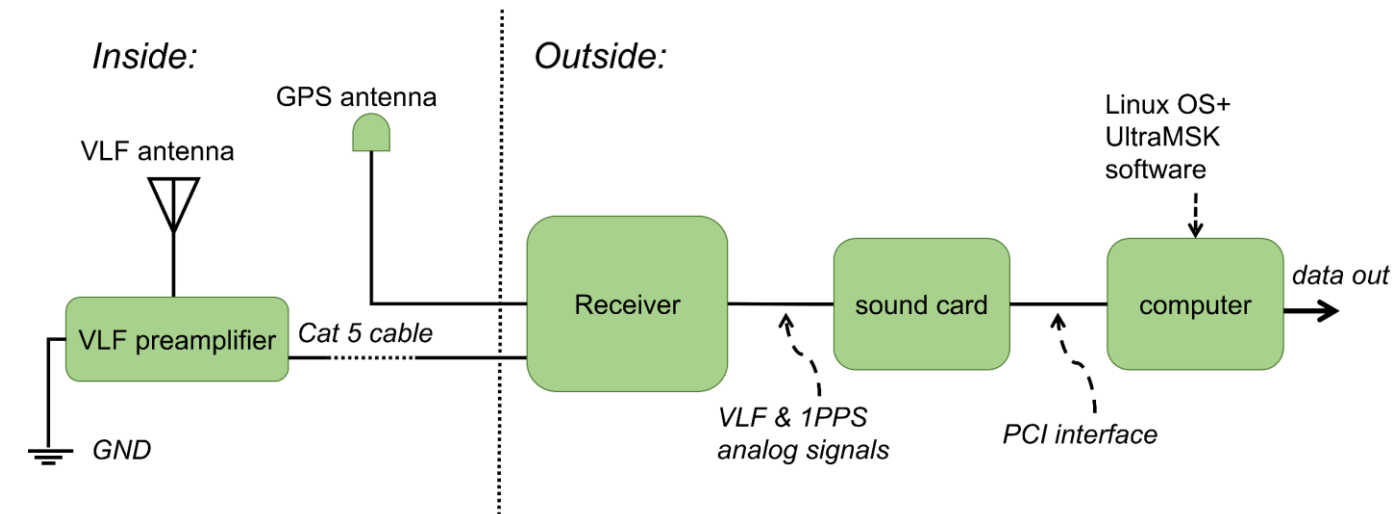
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Introduction:

In this study we used data from a new VLF radio station in the University of West Attica in Athens (Greece), which **is still operated in trial mode**. We focus on a very recent, strong (6.7Mw), shallow earthquake (EQ), that occurred in Greece on 30/10/2020, near to the Samos island, close to the Greece-Turkey borders, hereafter referred to as the 2020 Samos EQ. The VLF amplitude data were used from two transmitters, considering that the subionospheric propagation paths between the receiver and both transmitters could be disturbed from the location of the epicenter. The analysis of the amplitude data are done with the terminator time method (**TTM**), e.g. (*Molchanov et al., Phys. Earth Planet. Inter. 1998, 105, 239–248*), searching for shifts in the sunrise terminator time (**SRTs**) and sunset terminator time (**SSTs**) a few days prior to the EQ.

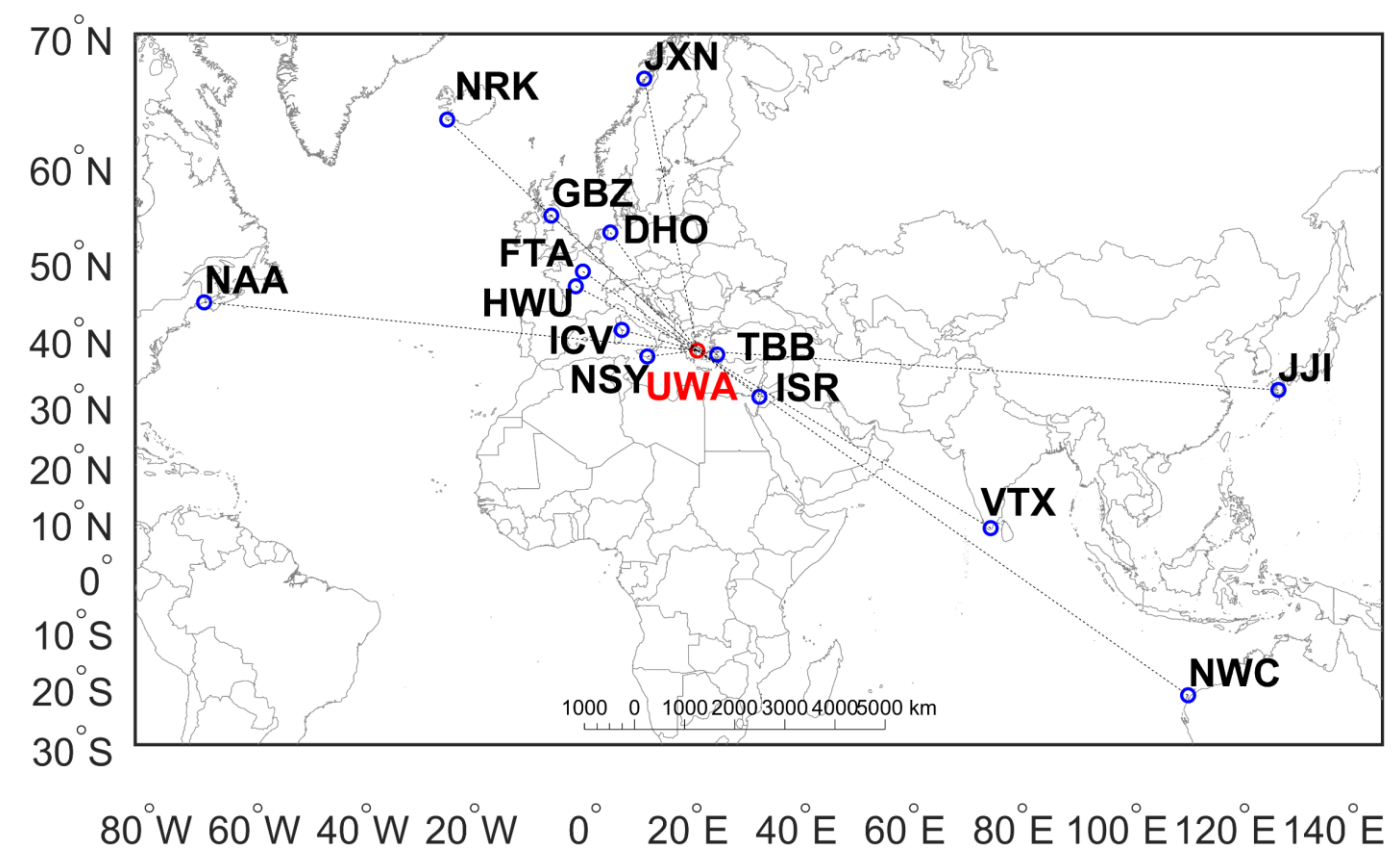
VLF Radio Station (An Overview):



Features of the station:

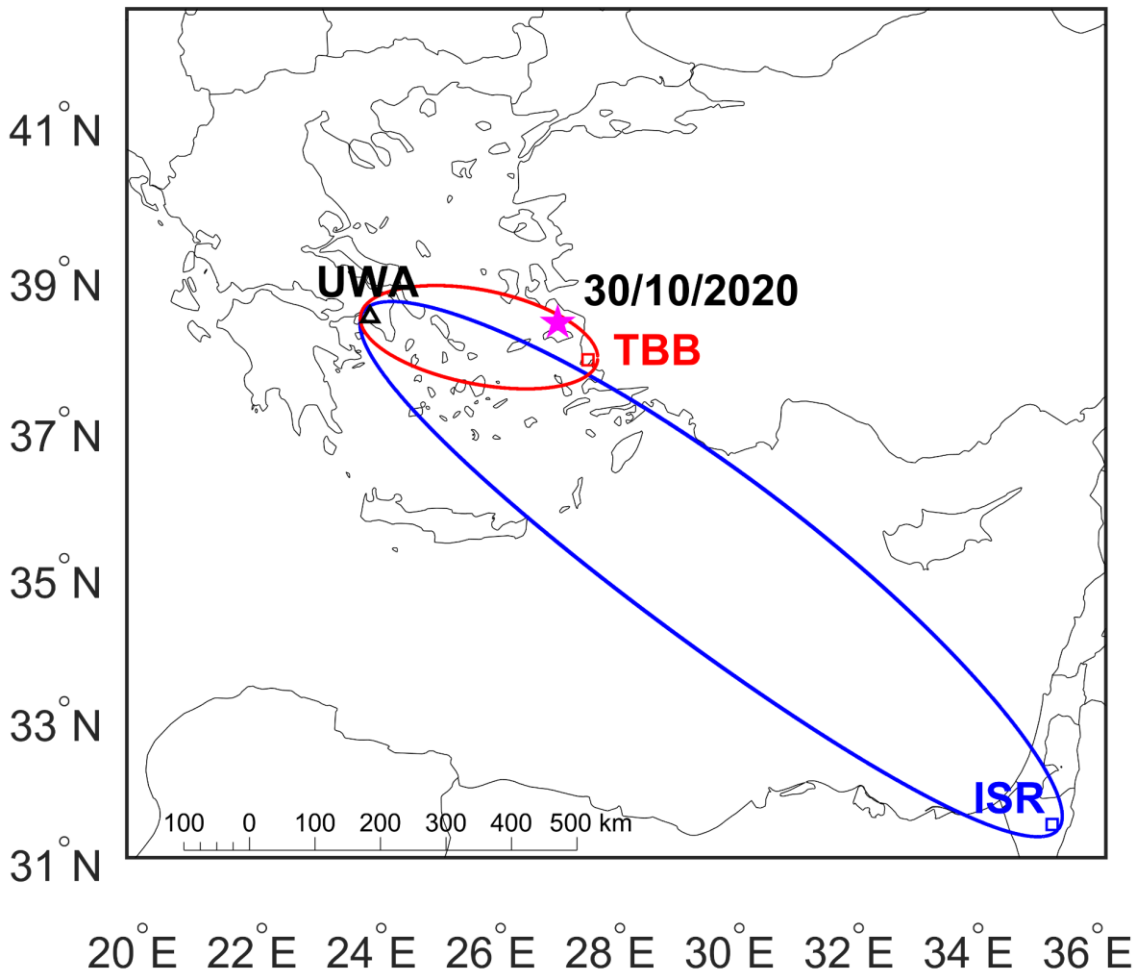
- Receiver designed by the Hayakawa Institute for Seismo-Electromagnetics (Hi-SEM)
- The station uses **a monopole VLF antenna** to capture the electric field.
- The sampling period of the recording data is **1 second**, which is synchronized from the **GPS signal (1 PPS)**
- The data (amplitude and phase data) are stored in to **text files** with time stamp in seconds from the computer via the sound card (DSP), using the **UltraMSK software**.
- The station, is able to record signals that are modulated mainly in minimum shift keying (**MSK**)
- The ground (**GND**) is used in order to avoid the electromagnetic interference of the noise.

Map showing the transmitters that are recorded from the station UWA in Athens and information about their recording frequencies.



Label	Country	Frequency (Hz)
DHO	Germany	23400
GBZ	Great Britain	19580
JXN	Norway	16400
FTA	France	20900
HWU	France	21750
ICV	Italy	20270
NSY	Italy	45900
TBB	Turkey	26700
ISR	Israel	29700
VTX	India	18200
NWC	Australia	19800
JJI	Japan	22200
NRK	Iceland	37500
NAA	United States	24000

Earthquake and VLF Subionospheric Propagation Data:



Map showing the wider area of eastern Mediterranean. The 5th Fresnel zones of propagation paths between the station (UWA) and each transmitter are indicated. The epicenter of the Samos EQ occurred on 30/10/2020 is indicated with magenta star.

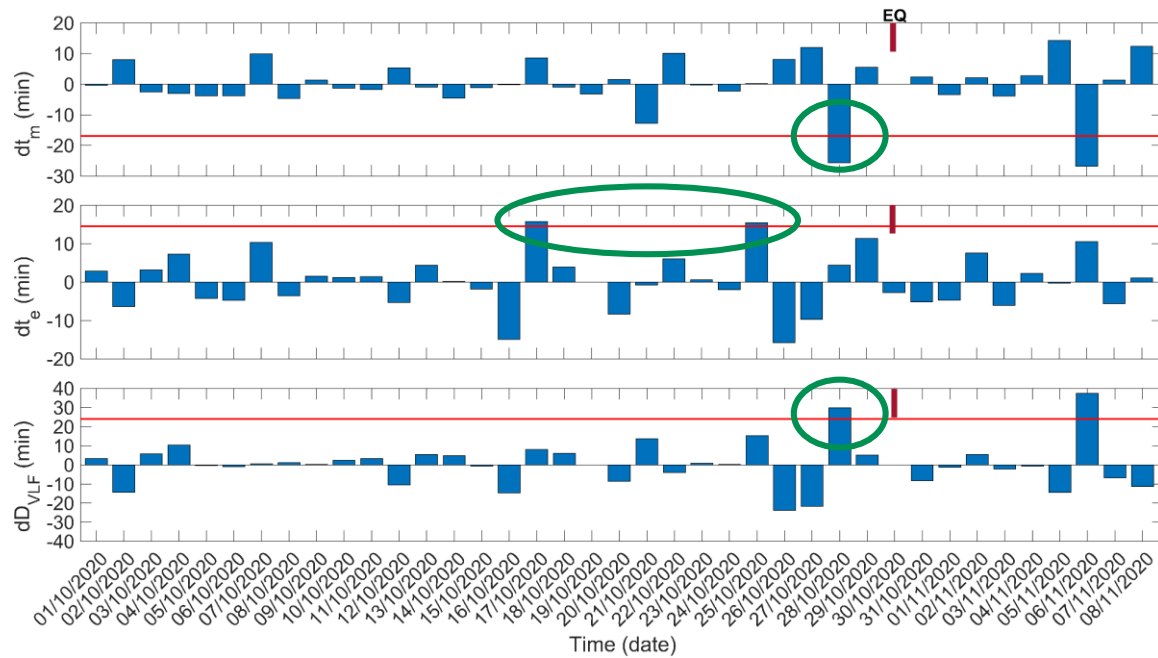
- TBB-UWA is a **very short** (~328 km) propagation path which the epicenter of the 2020 Samos EQ is **within** the 5th Fresnel zone and It is considered that the ground wave is stronger than the sky wave.
- ISR-UWA is a **short** (~1304 km) distance propagation path and the location of 2020 Samos EQ epicenter is in close distance to the borders of the 5th Fresnel zone, so that, considering the magnitude of the specific EQ, the corresponding propagation path could possibly be disturbed.
- We analyzed the VLF data by means of terminator time method (TTM) from 01/10/2020 until 08/11/2020, taking into account that **not any other ionosphere-influencing phenomena**, such as magnetic storms, solar flares or other EQs ($M \geq 5.5$), did occur on the aforementioned studying period or shortly (at least 1 month) after the mainshock.

We show the temporal evolution of the shifts in the **morning and evening TTs** ($dt_m = t_m - \langle t_m \rangle$, $dt_e = t_e - \langle t_e \rangle$), as well as, the “**VLf daylength**” ($dD_{VLF} = D_{VLF} - \langle D_{VLF} \rangle$) for the propagation paths TBB-UWA (left figure) and ISR-UWA (right figure) during the studied period from 1/10/2020 until 08/11/2020. For the calculation of the time series $\langle t_m \rangle$, $\langle D_{VLF} \rangle$, $\langle t_e \rangle$, a running mean window of 5 days is considered. The corresponding -2σ or $+2\sigma$ level, indicating the considered threshold for an anomaly, is also indicated in each panel.

In the TBB-UWA propagation path, a clear anomaly is observed very close (2 days prior to the mainshock) to the EQ (dt_m and dD_{VLF} , exceeding -2σ and $+2\sigma$, respectively), while two shifts appear on 17/10/2020 (>1 week before) and 25/10/2020 (5 days before the mainshock) in the evening TT (dt_e).

In the ISR-UWA propagation path there are shifts in TTs a few days (1-4 days) prior to the EQ on 26/10/2020 and 27/10/2020 for dt_{m1} and on 27/10/2020 for dt_{m2} , exceeding $+2\sigma/-2\sigma$ limit, while a shift in the evening TT (dt_e), exceeding $+2\sigma$ level, exists on 23/10/2020 (1 week prior to the EQ). However, a clear anomaly appears 2 weeks before the EQ, on 16/10/2020, where three anomalies are exhibited in morning (dt_{m2}) evening (dt_e) TT and daylength (dD_{VLF}), exceeding the $+2\sigma/-2\sigma$ limit.

TBB-UWA propagation path



ISR-UWA propagation path

