Ray paths of VLF/LF transmitter radio signals in the seismic Adriatic regions

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Abstract

We analyze the radio wave propagations of VLF/LF transmitter signals along sub-ionospheric paths using two different reception systems localized side by side at the Space Research Institute (IWF) of the Austrian Academy of Sciences (ÖAW) in Graz (Austria). Those systems allow the simultaneous detection of more than fifteen transmitter signals emitting in the northern (i.e. France, Germany and United Kingdom) and southern (i.e. Italy and Turkey) parts of Europe. In this work, we investigate the transmitter radio wave propagations associated with two earthquakes (EQs) which occurred, at two occasions, in nearly the same Croatian regions (Geo. Long.=16°E; Geo. Lat.=45°N). The first and second EQs happened, respectively, on March 22 and December 29, 2020, with magnitudes M_w equal to 5.4 and 6.4. The use of two complementary reception systems, i.e. INFREP (Biagi et al., *Open Journal of Earthquake Research, 8, 2019*) and UltraMSK (Schwingenschuh et al., *Nat. Hazards Earth Syst. Sci., 11, 2011*), and the proximity to the epicenters lead us to characterize the behavior of the transmitter signal amplitudes particularly above the Croatian seismic regions. We analyze the amplitude variation for a given transmitter frequency starting few weeks before the earthquakes occurrences. We discuss the observed anomalies in the transmitter signals which may be considered as precursors due to the ionospheric disturbances of the transmitter ray paths above the earthquakes preparation zones.

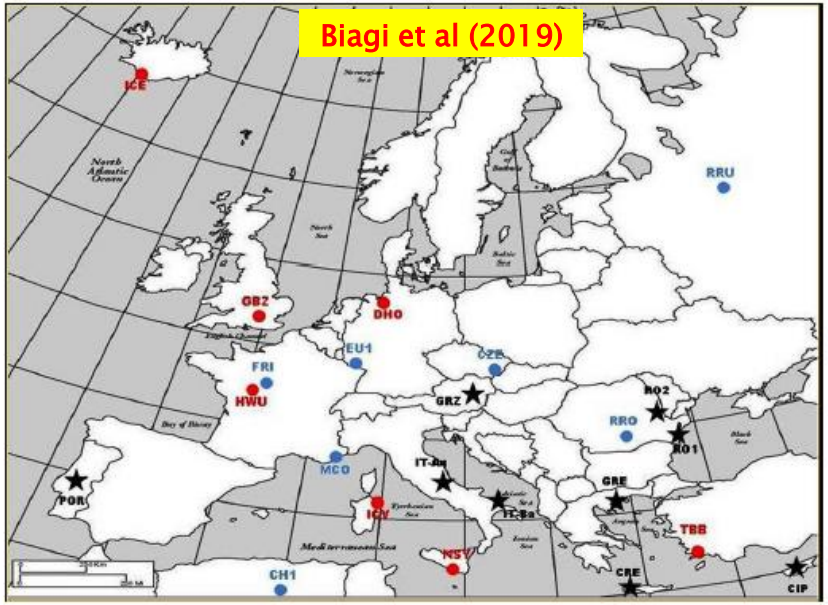
Earthquakes Events

Event1
2020-03-22 05:24
45.87N 16.02E 10 6.4
CROATIA

Event2
2020-12-29 11:19:54.6
45.46N 16.31E 10 6.4
CROATIA

VLF and LT Transmitters in Europe

VLF
ICV (Italy)
ITS (Italy)
HWU (France)
DHO (Germany)
GBZ (GB)
ICE (Island)



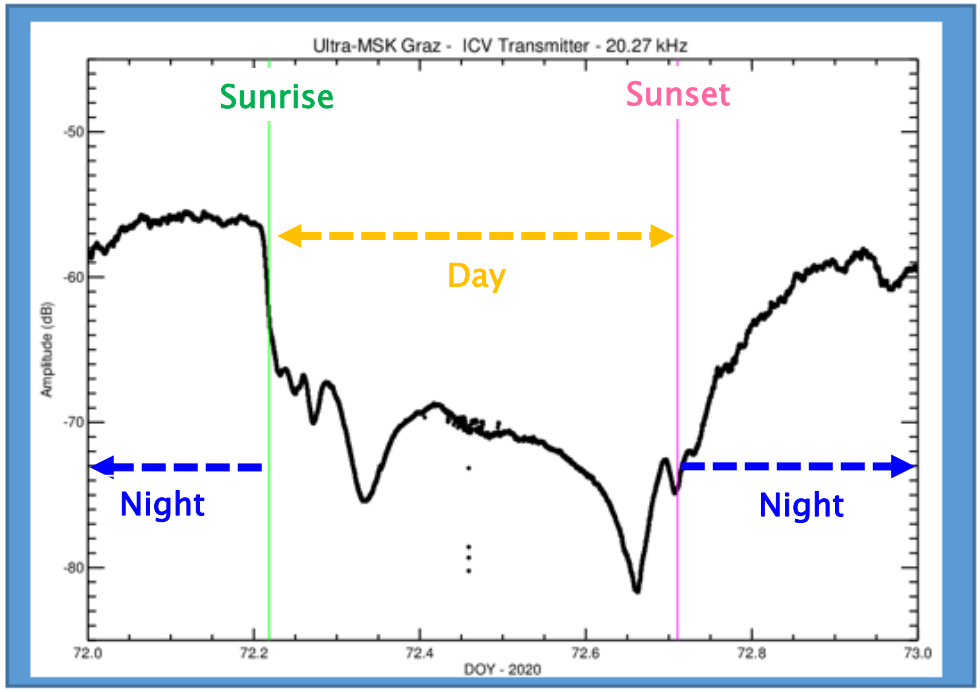
LF
(Czech) CZE
(Rumania) RRO
(Algeria) CH1
(Turkey) TBB
(France) FRI
(Luxembourg) EU1
(Monte-Carlo) MCO

Two VLF/LF reception systems

- Ultra-MSK VLF — Schwingenschuh et al (2011)
- Elettronika VLF/LF — Biagi et al (2011)

Methodology and VLF/LF signal analysis

1. Diurnal variations of transmitteur signal ampltitudes
2. 50 days before EQs occurrences
   - Event1: from 13 Feb. to 24 March 2020
   - Event2: from 21 Nov. to 31 Dec. 2020
3. Terminator Times (TTs): Sunrise and Sunset **Hayakawa et al (1996)**



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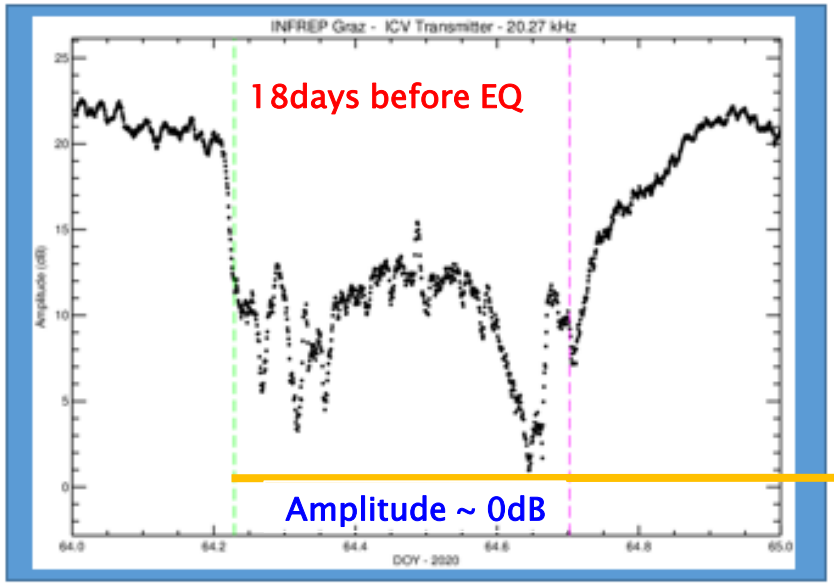
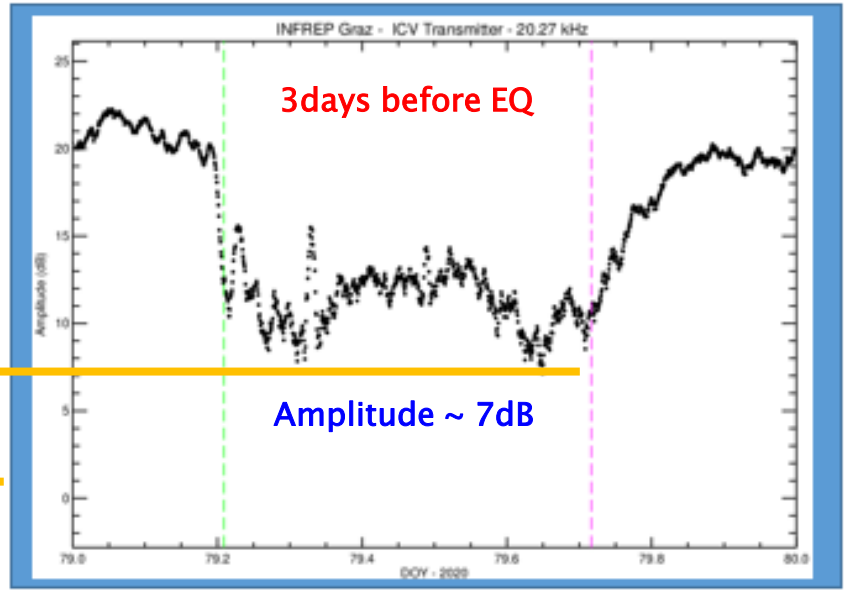
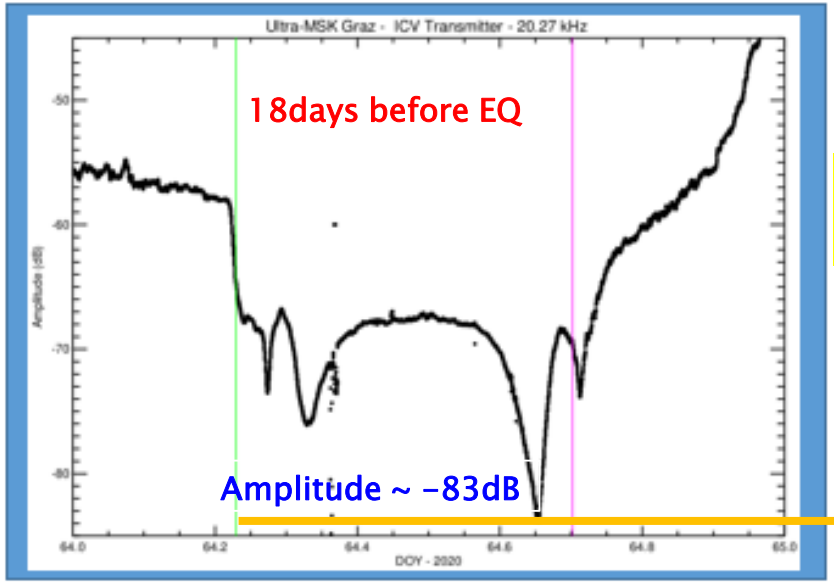


Event1

INFREP VLF-ICV (One Day)

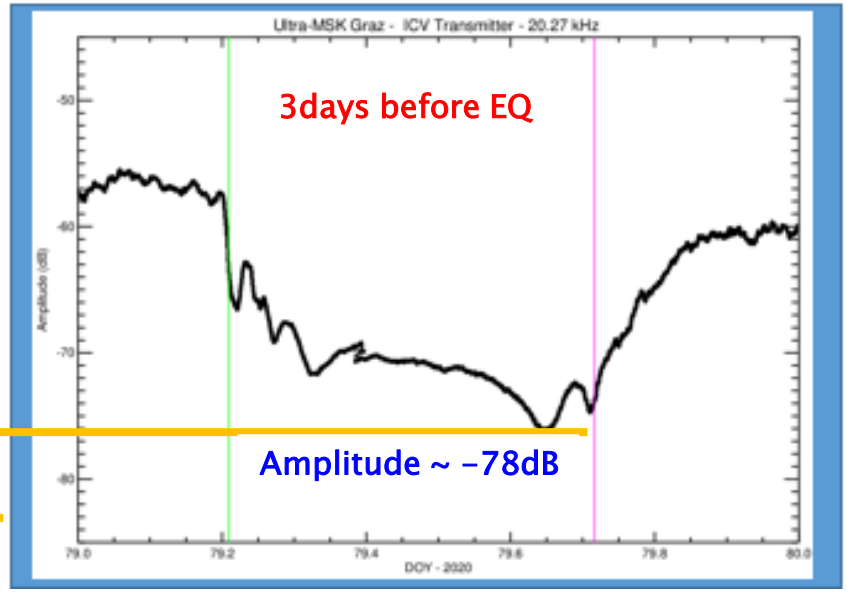
~ 7dB



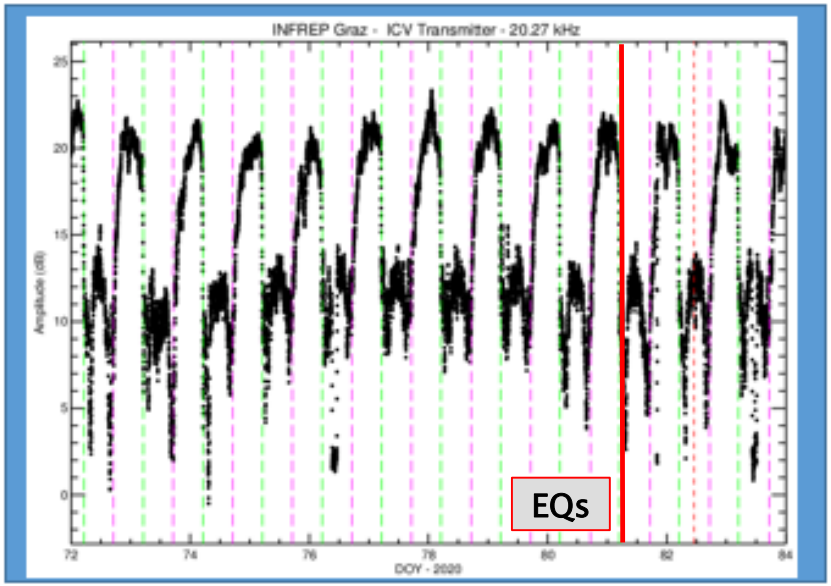


Utra-MSK VLF-ICV (One Day)

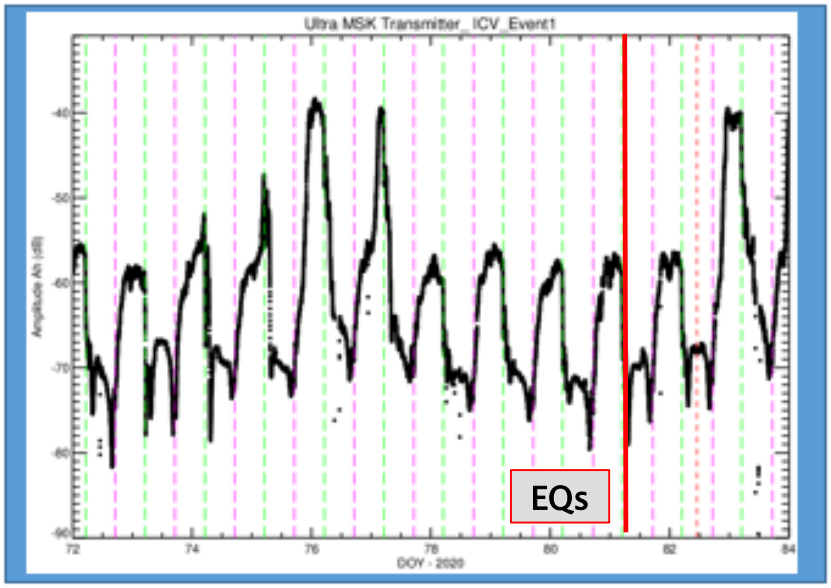
~ 5dB



INFREP VLF-ICV (14 Days)

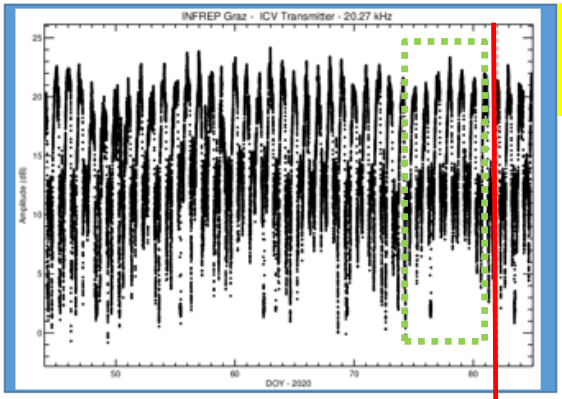


Utra-MSK VLF-ICV (14 Days)



Event1

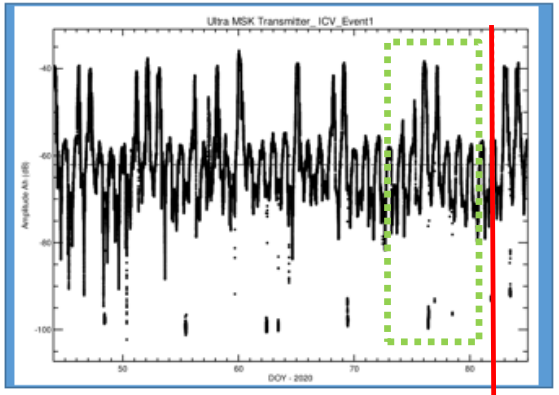
1. EQs vertical red lines
2. 10 days before EQs occurrence
3. Increase of TT signal amplitudes
4. Recover of TT amplitudes after EQs



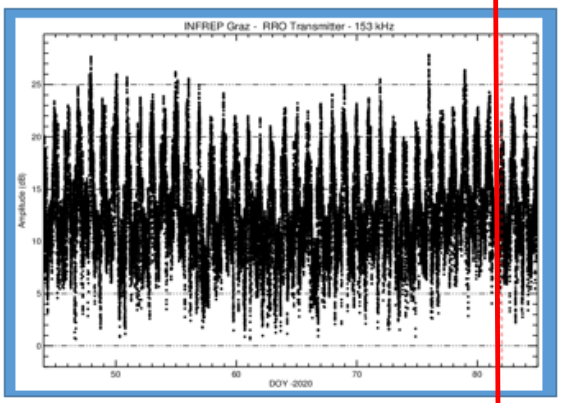
INFREP VLF-ICV (50days)

Event1

Ultra-MSK VLF-ICV (50days)

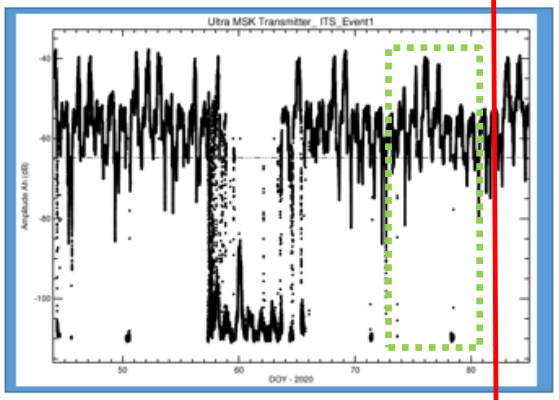


1. EQs Vertical red lines
2. Green boxes increase in TT amplitudes

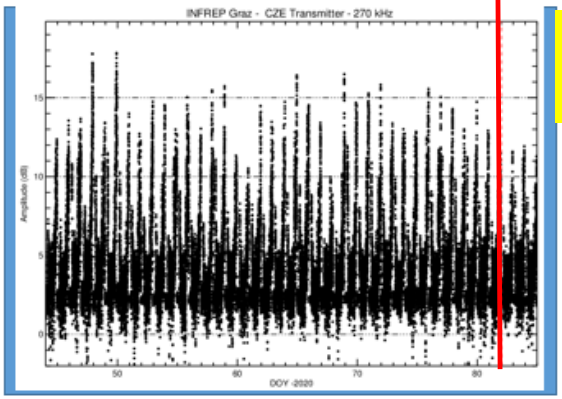


INFREP LF-RRO (50days)

Ultra-MSK VLF-ITS (50days)

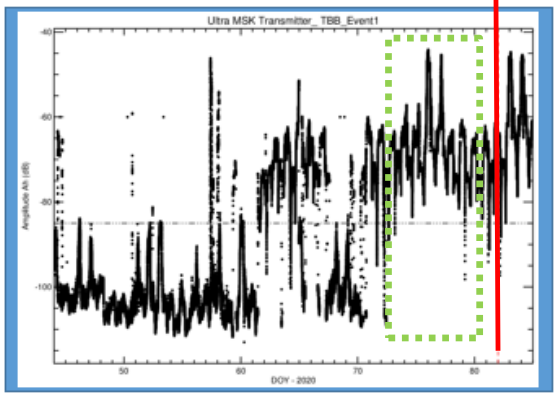


3. Signal increase
   - VLF/ICV transmitter
   - VLF/ITS transmitter
   - VLF/TBB transmitter



INFREP LF-CZE (50days)

Ultra-MSK VLF-TBB (50days)



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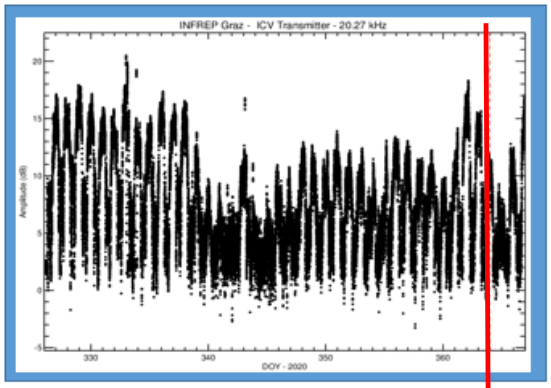
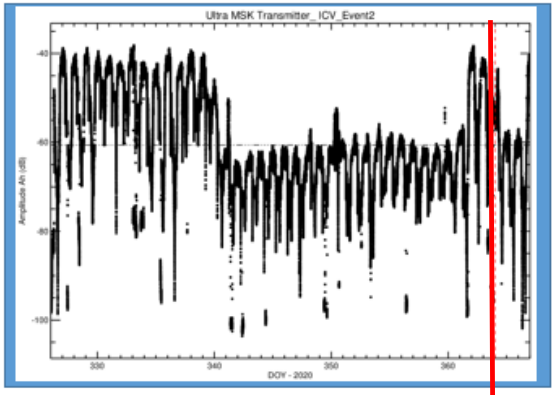


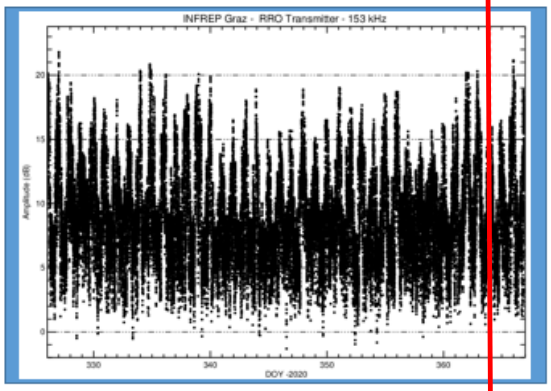
INFREP VLF-ICV (50days)

Event2

Ultra-MSK VLF-ICV (50days)

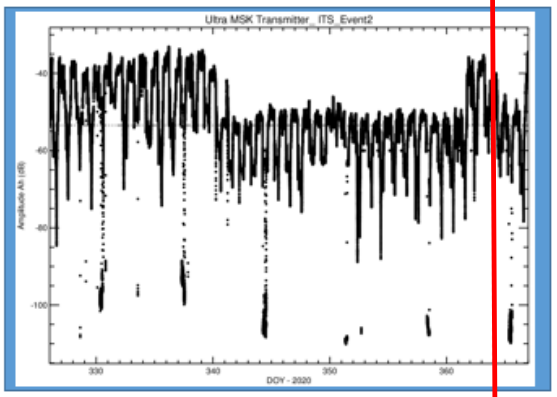


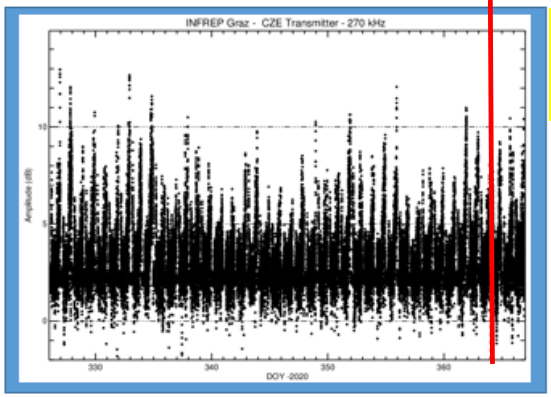
1. Vertical red line = EQs day
2. No `anomalies´ in TT amplitudes



INFREP LF-RRO (50days)

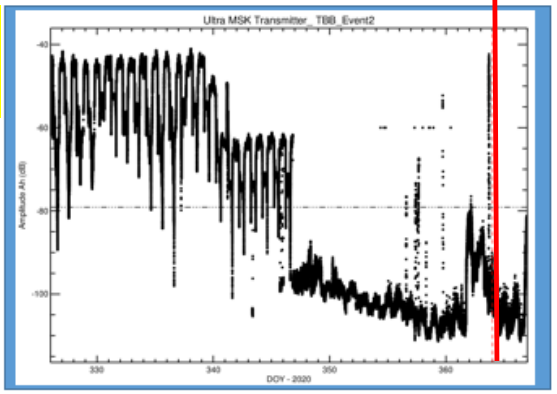
Ultra-MSK VLF-ITS (50days)





INFREP LF-CZE (50days)

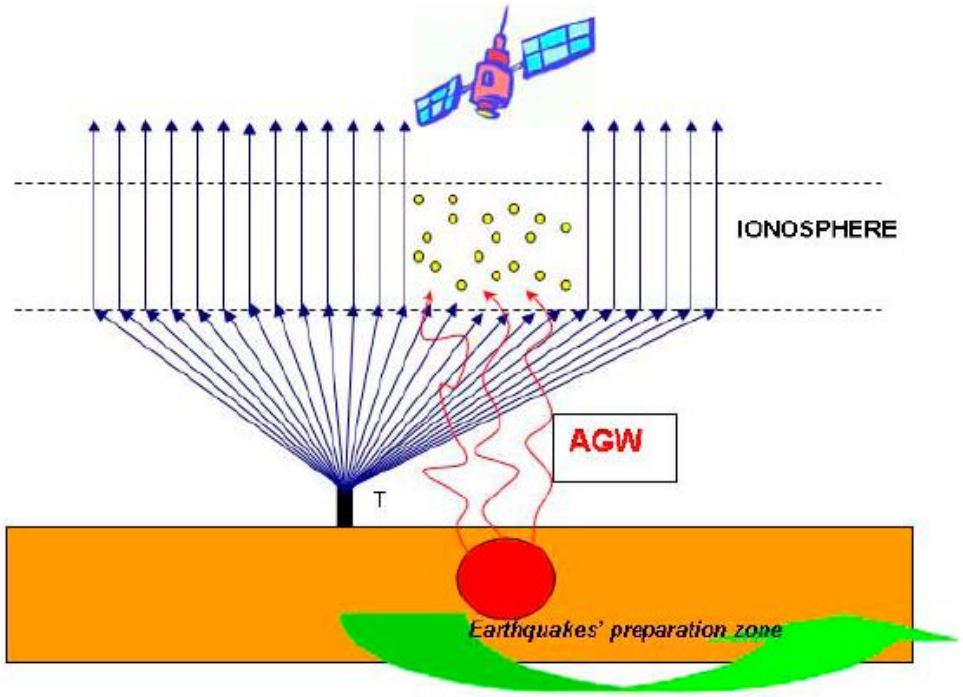
Ultra-MSK VLF-TBB (50days)



Physical Model

Physical mechanism at the origin of TT amplitude variations **Molchanov et al (2006)**

1. Phase1: Increase of strain energy in the preparation seismic region
2. Phase2: Come up of atmospheric gravity waves (AGW) above the preparation zone
3. Phase3: Arise of ionospheric turbulence linked to AGW



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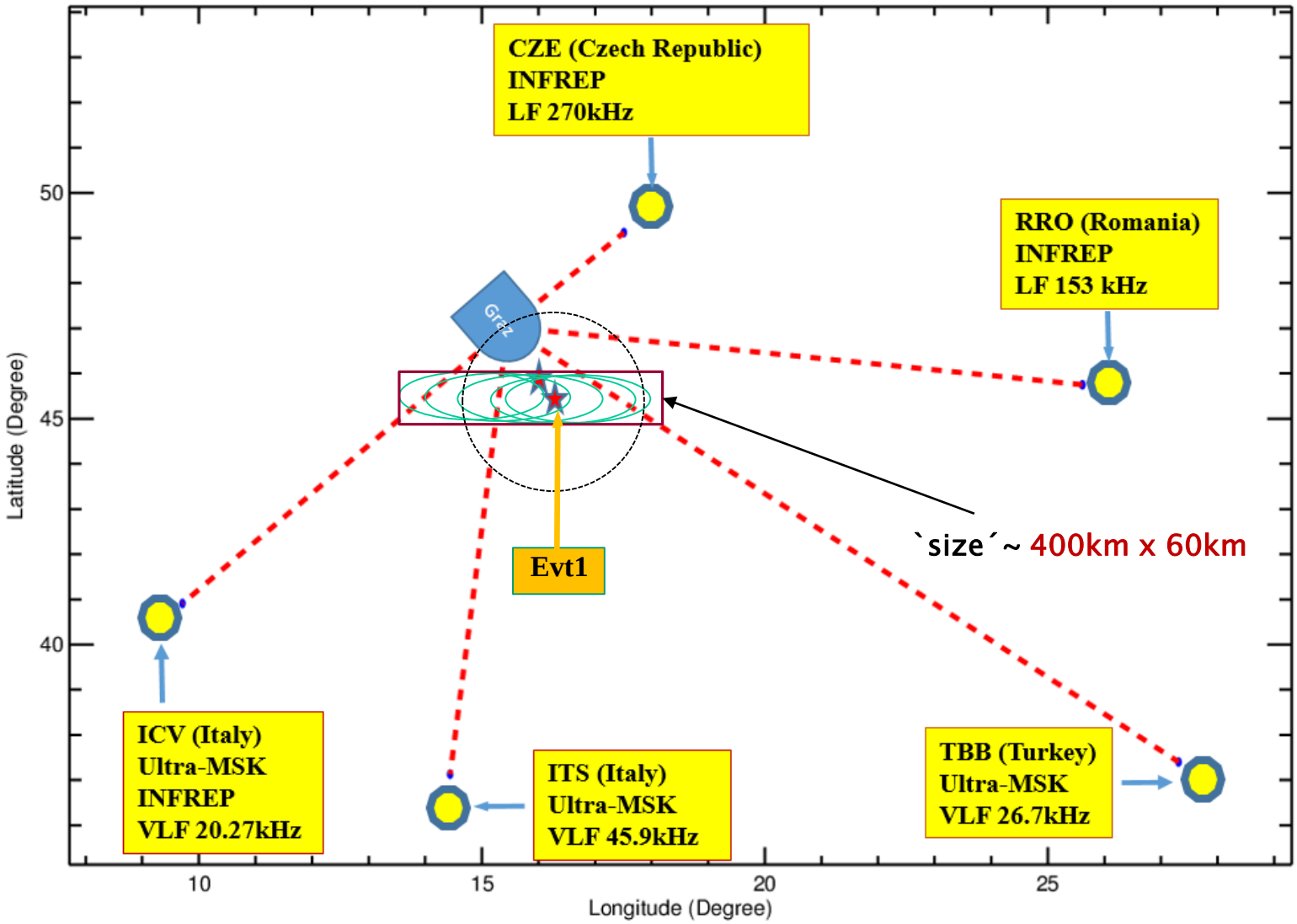

Summary

1. Two seismic events have been investigated which occurred in Croatia on 22nd March 2020 (Event1) and 29th Dec. 2020 (Event2)
2. Distances to Graz (Austria) were, respectively, of about 136km and 186km for Event1 and Event2
3. Terminator Times (TTs) method has been used to study the amplitude signal variation at sunset and sunrise

4. From this preliminary study, we find precursor signals:
   - Increase of TT amplitude signals only for Event1
   - Enhancement only in the case of VLF transmitters: ICV (Italy), ITS (Italy) and TBB (Turkey)
   - No effect on LF transmitters: RRO (Rumania) and CZE (Czech Republic)

5. Probable physical mechanism is related to AGWs linked to preparation zone appearing about 10 days before earthquake occurrence.

6. Such AGWs generate disturbances in the ionospheric region above the pre-seismic region

7. Ionospheric disturbance region characteristics are:
   - 'Source size' of about 400kmx60km
   - Extended in longitudinal directions and narrow in latitudinal ones
   - Elongated more on west-side of the EQs region

Thank You