Electromagnetic Ionospheric Anomalies Related to the Central Italy Earthquakes

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INTRODUCTION

The Good Friday Alaska earthquake on March 24 of 1964 gave the beginning of the seismo-ionospheric coupling studies (Moore, 1964; Davies and Baker,1965).

Ionospheric parameters were studied related to the Tashkent earthquake in 1966 (Antselevich, 1971; Datchenko et al., 1972)

What is the time interval between the anomaly ionospheric variations and the earthquake occurrence?

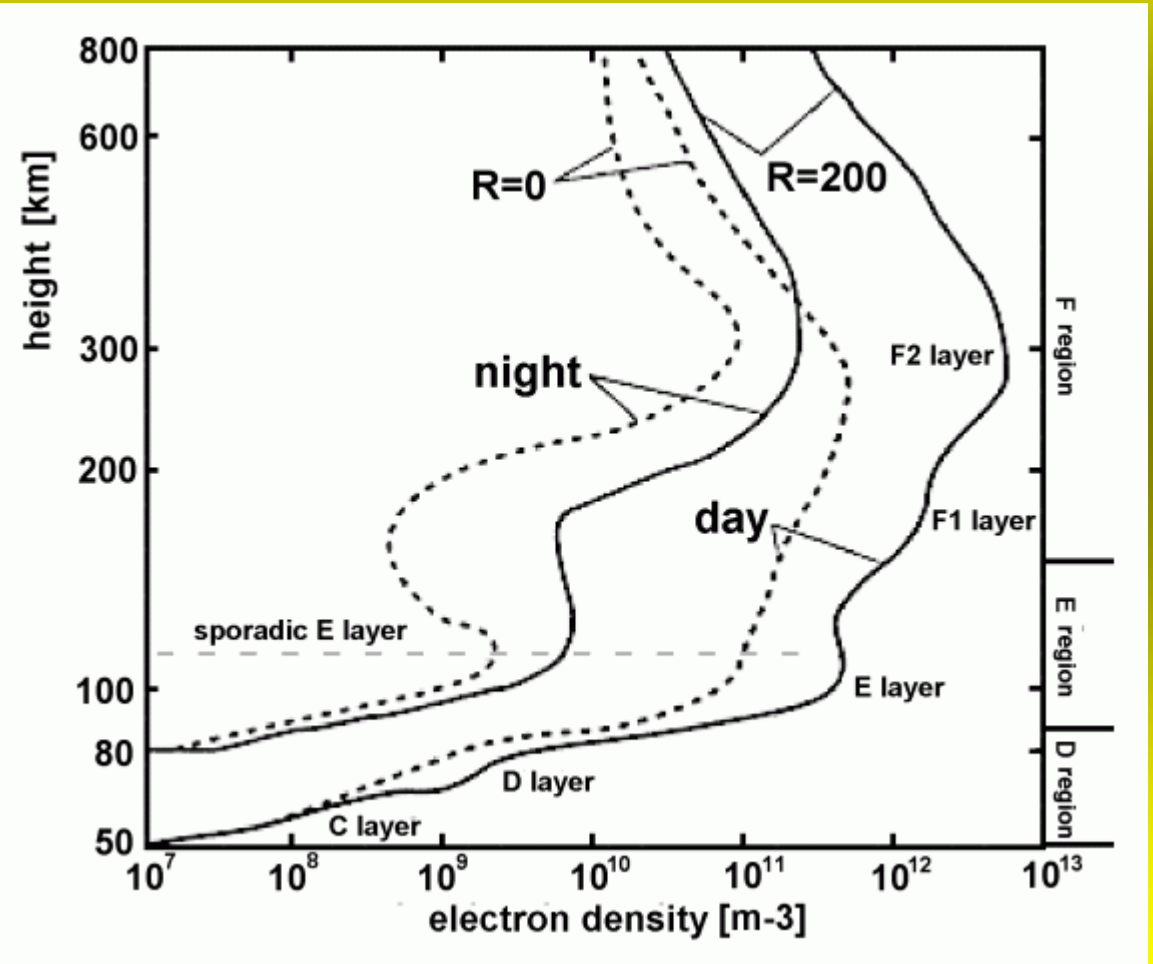
Middle - term precursors
up to one month in advance (Dubas et al., 2007; Korsunova and Khegai, 2006; Hao, 2000)

Short-term precursors
some hours to one day (e.g. Pulinets, 1998)

What is the spatial extension of this anomaly?

The ionospheric station is within the preparation zone of earthquake ($r \leq 10^{0.43M}$, km, where r is the radius of the preparation zone and M is the magnitude (Dobrovolsky, 1979).

Ionosphere


height [km]
800
600
300
200
100
80
50
R=0
R=200
night
day
F2 layer
F1 layer
E layer
D layer
C layer
sporadic E layer
F region
E region
D region
10^7
10^8
10^9
10^{10}
10^{11}
10^{12}
10^{13}
electron density [m-3]

Which ionospheric layers are considered?

1. Es Layer

Kim et al. 1993,1994) have shown that electric field above the preparation zone of the future earthquake can penetrate in to the ionosphere to form a dense Es layer. So the ionospheric parameters related to Es layer are used. (Silina et al. 2001;Ondoh, 2003; Ondoh and Hayakawa, 2006, Korsunova and Khegai,2006)

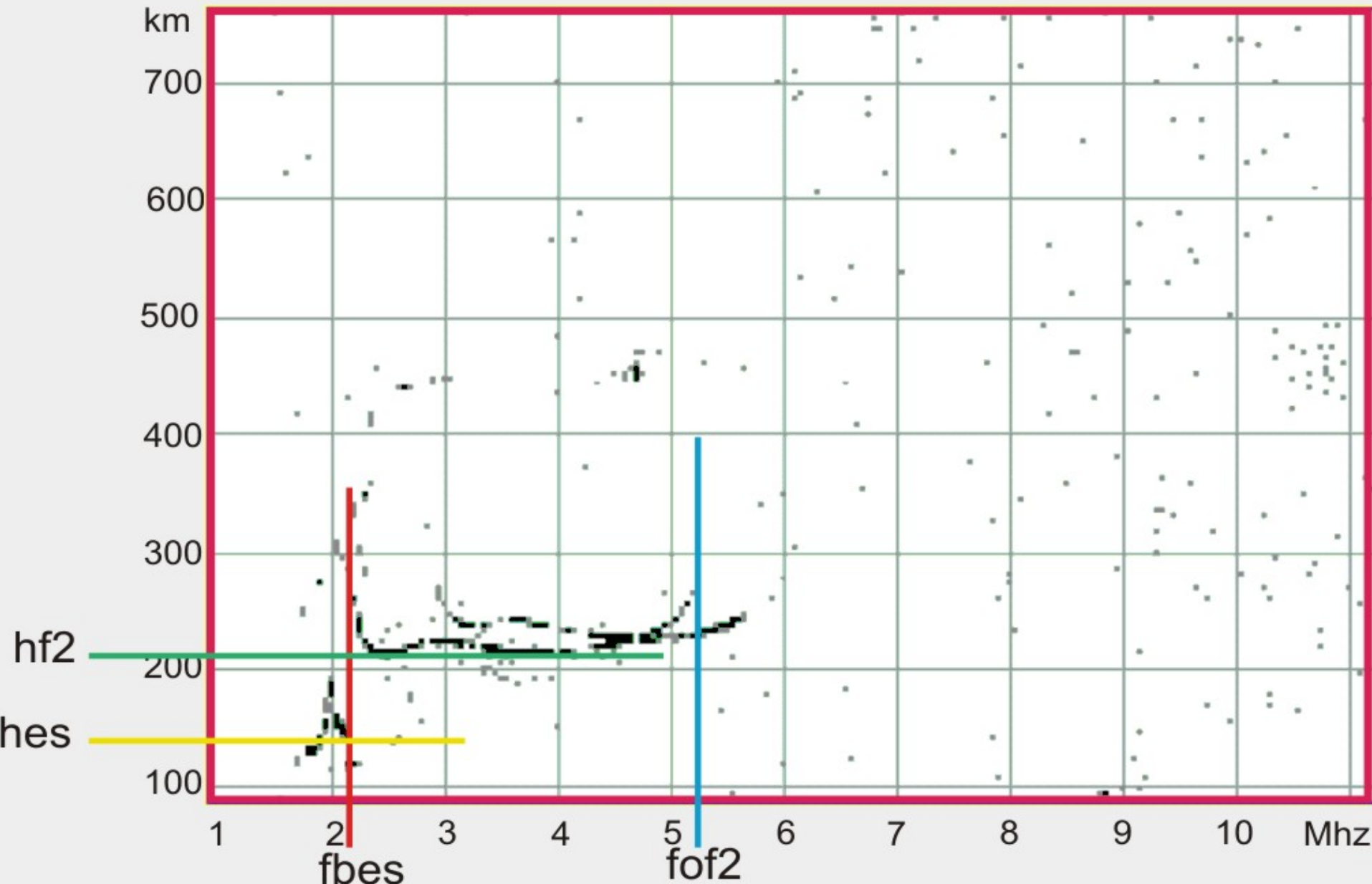
- **F2 layer**

Variations of foF2 during seismo-active periods are considered in many papers, as foF2 observations are usually available from ground-based ionosondes (Hobara and Parrot ,2005; Ondoh, 1998, 2000; Liu, 2006).

Stazione del sondaggio: Roma

Data del sondaggio: 03 03 2009

Ora del sondaggio: 06:30



The aim of the present analysis is:
to check if the earlier obtained results for powerful crustal Japanese earthquakes with M >6.5 can be applied for analysis of moderate earthquakes observed in the central Italy

Method Description

A new feature of the Korsunova and Khegai (2006, 2008) method is a multiparameter approach to earthquake analysis.

1. The occurrence of abnormally high Es layer with
$\Delta h'Es = (h'Es - (h'Es)med) \geq 10$ km

2. $\delta fbEs = fbEs - (fbEs)med / (fbEs)med \geq 20\%$

3. $\delta foF2 = foF2 - (foF2)med / (foF2)med \geq 10\%$

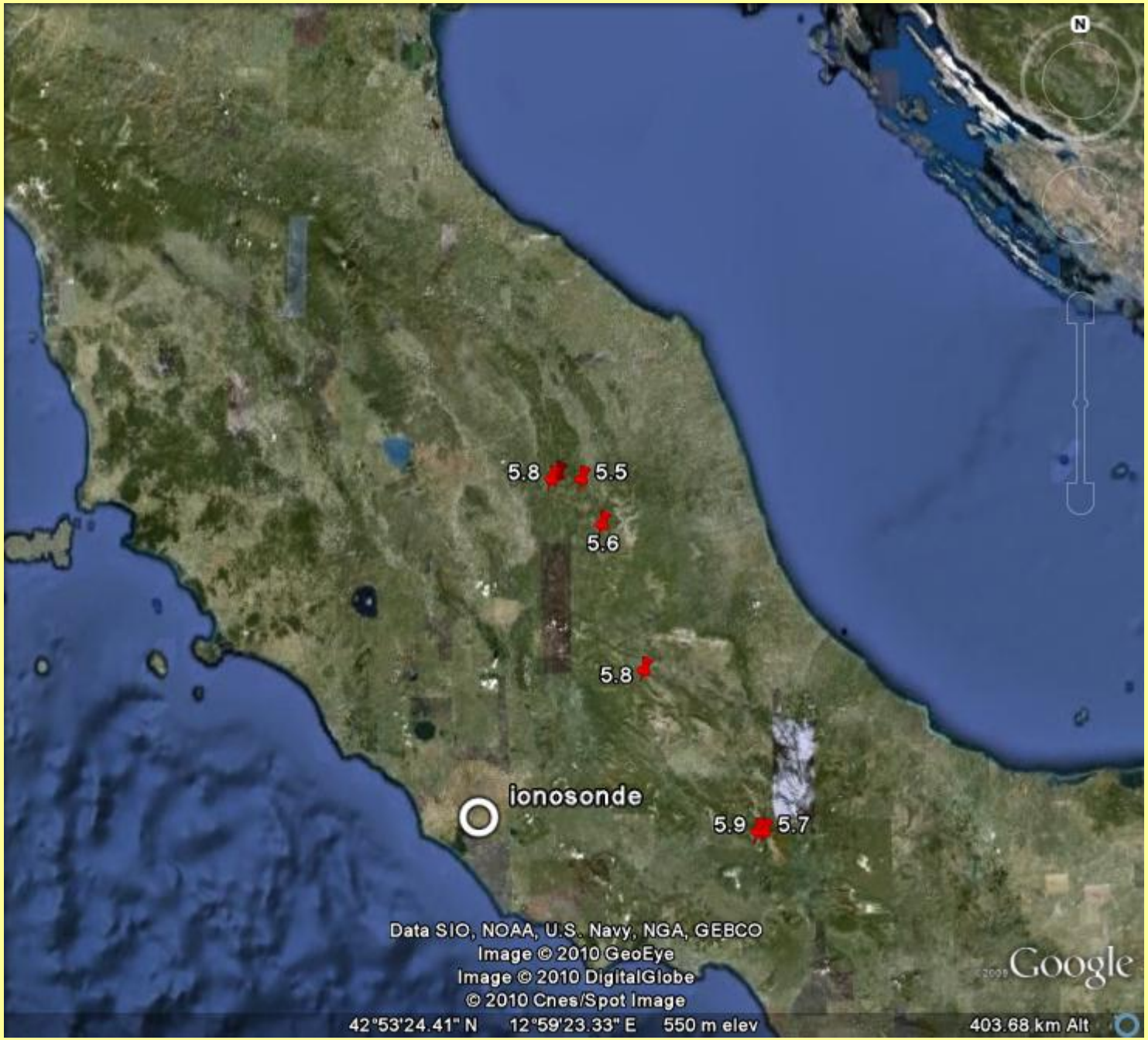
Following each other within one day for 2-3 hours.
($\delta fbEs$ follows $\Delta h'Es$, but $\delta foF2$ shift depends on M)

Where fmed - 27 day running mean median calculated over quiet days ($Ap \leq 15$)

Initially we considered all crustal earthquakes with magnitudes M > 5.0 and the epicenter depth < 50 km, but we could not reveal significant precursors for weak and distant from the ionosonde station Rome events.

Therefore only strong ($M \geq 5.5$) earthquakes with the epicenter distance $R \leq 140$ km were analyzes.

For all these events Rome is located in the preparation zone according to the formula by Dobrovolsky et al. (1979).


N
5.8
5.5
5.6
5.8
ionosonde
5.9
5.7
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2010 GeoEye
Image © 2010 DigitalGlobe
© 2010 Cnes/Spot Image
Google
42°53'24.41" N 12°59'23.33" E 550 m elev
403.68 km Alt

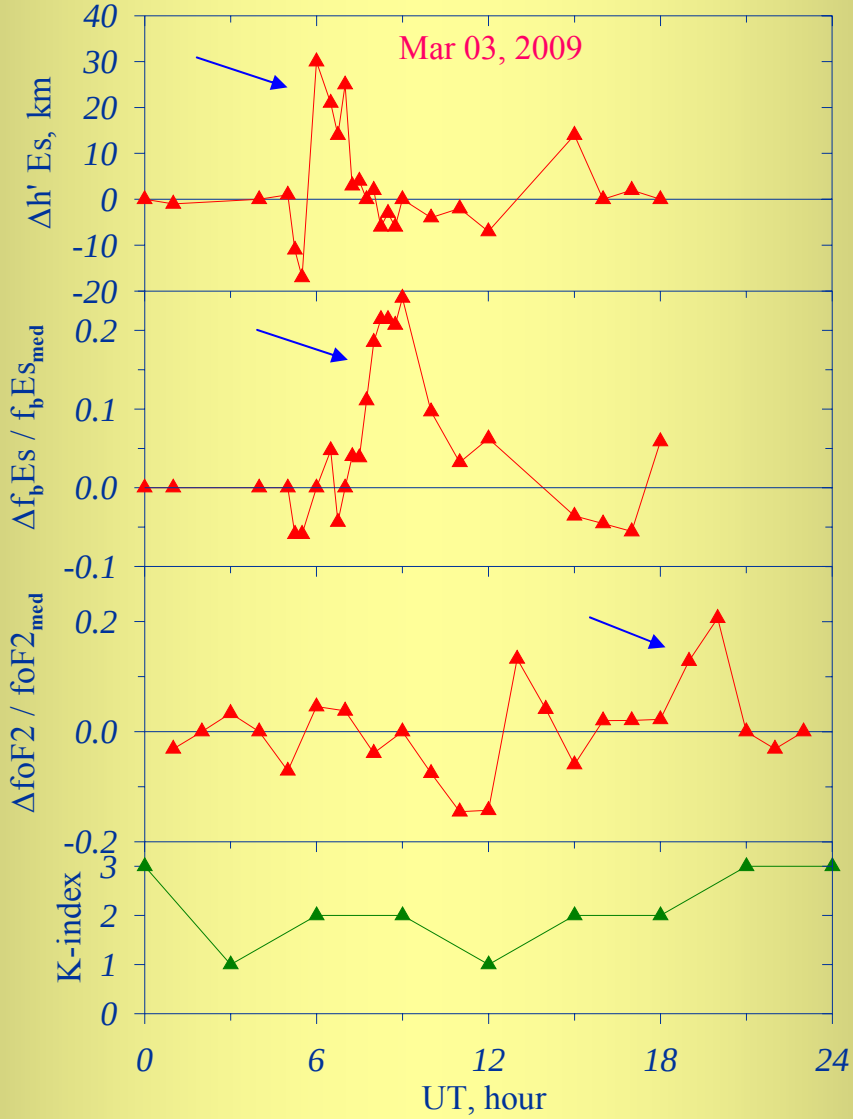
According to Liu et al. (2006, Taiwan earthquakes) only the events within 150 km and with $M \geq 5.4$ produce significant ionospheric effects in the F2-layer.

On the other hand, the analysis of the precursors in the nearest to the epicenter zone is the most important from practical point of view.

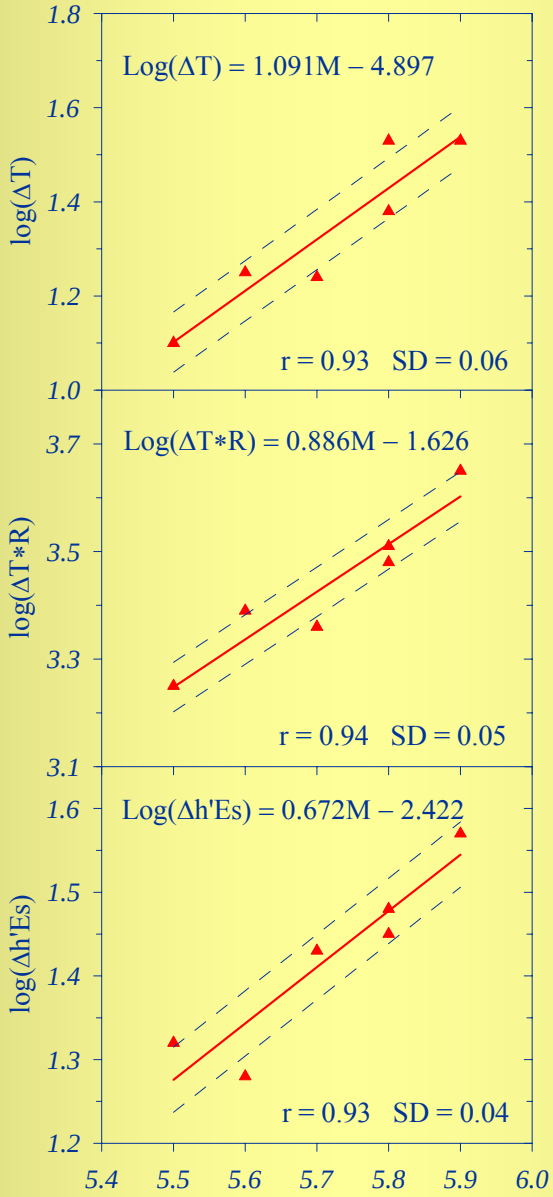
The Events Selected for Analysis

Date of the earthquakes	UT, h	M	lat	long	R(km)	Zone
7/05/84	17:49	5.9	41.7	14.1	133	Appennino Abbruzzese
11/05/84	10:41	5.7	41.7	14.1	133	Appennino Abbruzzese
26/09/97	09:40	5.8	43.0	12.9	137	Appennino Umbro-Marchigiano
26/09/97	00:33	5.6	43.0	12.9	137	Appennino Umbro-Marchigiano
14/10/97	15:23	5.5	43.0	13.0	140	Appennino Umbro-Marchigiano
6/04/09	01:32	5.8	42.3	13.3	86	Aquilano

The Precursor Identification for the 06.04.09 Earthquake (as an example)



Observed Log(ΔT), Log(ΔT*R), Log(Δh'Es) versus M



Notice that inclusion of the epicenter distance R improves to some extent the dependence (although R≈ constant in our case)

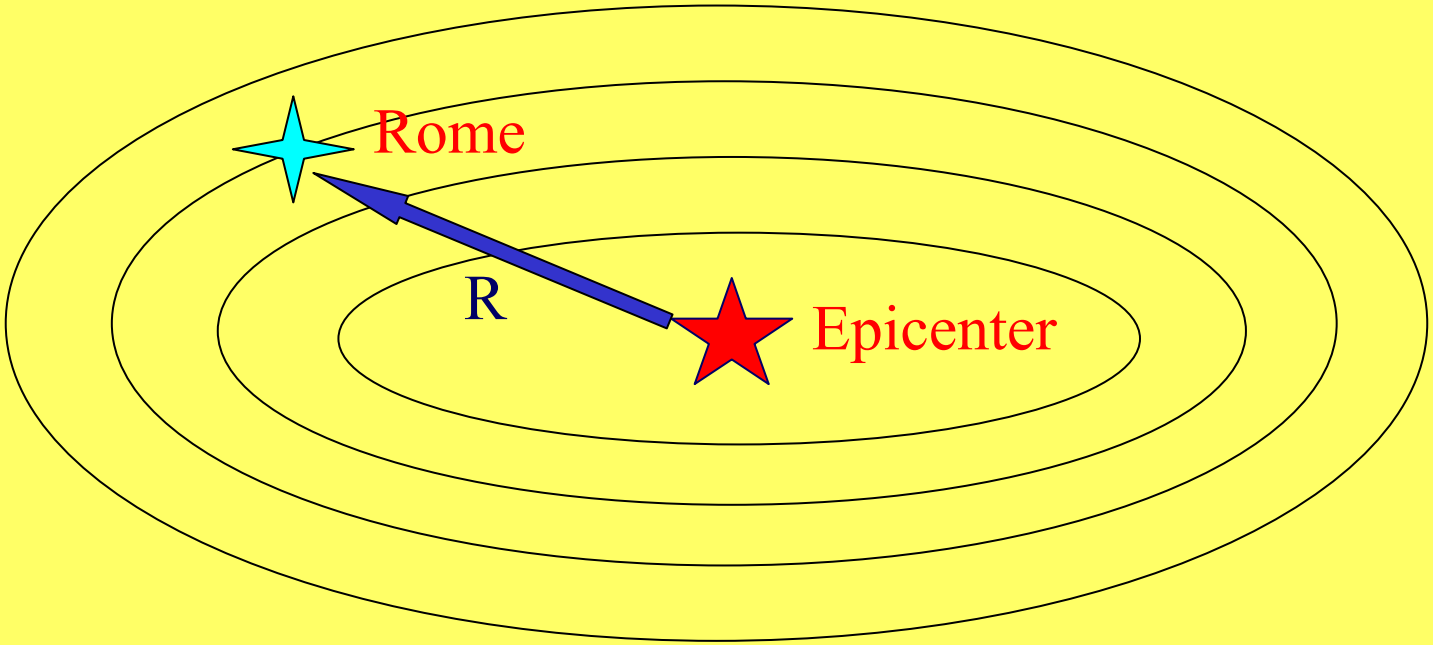
A Comparison of (ΔT*R) versus M relationships

$\log(\Delta T*R) = 1.14M - 4.72$ Japanese earthquakes (Korsunova)

$\log(\Delta T*R) = 0.72M - 0.72$ Ground observations (Sidorin)

$\log(\Delta T*R) = 0.89M - 1.63$ Present results

The stronger earthquake (M), the larger lead time (ΔT) for the precursor to occur at a given distance R



Ionospheric anomalies not related to earthquakes

We have checked three years 1984, 1997, 2002.

$\Delta h'Es$, $\delta fbEs$, and $\delta foF2$ deviations were calculated for 24 UT moments of all days and all months of the three years.

Using the relations it is possible to find

from

$\log(\Delta h' Es) = 0.672M - 2.422$

The magnitude M

from

$\log(\Delta T) = 1.091M - 4.897$

The lead time ΔT

from

$\log(\Delta T * R) = 0.886M - 1.626$

The distance R

Ionospheric anomalies not related to earthquakes

n/n	Date of the false precursor	UT hour	Δh'Es	δfbEs	δfoF2	M	ΔT days	R km
1	21.04.97	06-08	28	0.58	0.33	5.8	24	124
2	20.05.97	02-03	25	0.92	0.27	5.7	20	128
3	22.11.97	13-14	30	0.21	0.71	5.8	27	121
4	2.02.84	10-11	24	0.48	0.23	5.7	19	130
5	19.03.84	16-17	39	0.25	0.17	6.0	41	112
6	20.09.84	09-10	24	0.53	0.12	5.7	19	130
7	7.08.02	05-06	22	0.30	0.22	5.6	16	134
8	21.09.02	07-09	30	0.437	0.18	5.8	27	122
9	27.12.02	07-08	31	0.41	0.12	5.8	28	120

Conclusions

1. The method earlier used for powerful Japanese earthquakes was shown to be applicable for moderate ($5.5 \leq M < 6.0$) earthquakes observed in central Italy.
2. The simultaneous deviations in $\Delta h'Es$, $\delta fbEs$, and $\delta foF2$ above the corresponding thresholds for 2-3 hours following each other within one day are considered as a middle-term ionospheric precursor.

Conclusions

3. The observed ionospheric precursors result in the dependence relating the lead time ΔT with the earthquake magnitude M and the epicenter distance R.

4.The dependence indicates the process of spreading the disturbance from the epicenter of future earthquake towards periphery during the earthquake preparation process.

Conclusions

5. The similarity of dependences obtained in different parts of the world (Japan, Middle Asia, Italy) tells us about the uniformity of the processes during the earthquake preparation period both for powerful and moderate earthquakes.

6. There are ionospheric anomalies not related to the earthquakes. They are not numerous, but their number is comparable and are not distinguished from the ionospheric anomalies linked to the earthquakes.

THANK YOU