UNIVERSITY OF ATHENS
Faculty of Geology & Geoenvironment
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MOMENT MAGNITUDES FOR SMALL AND INTERMEDIATE EARTHQUAKES

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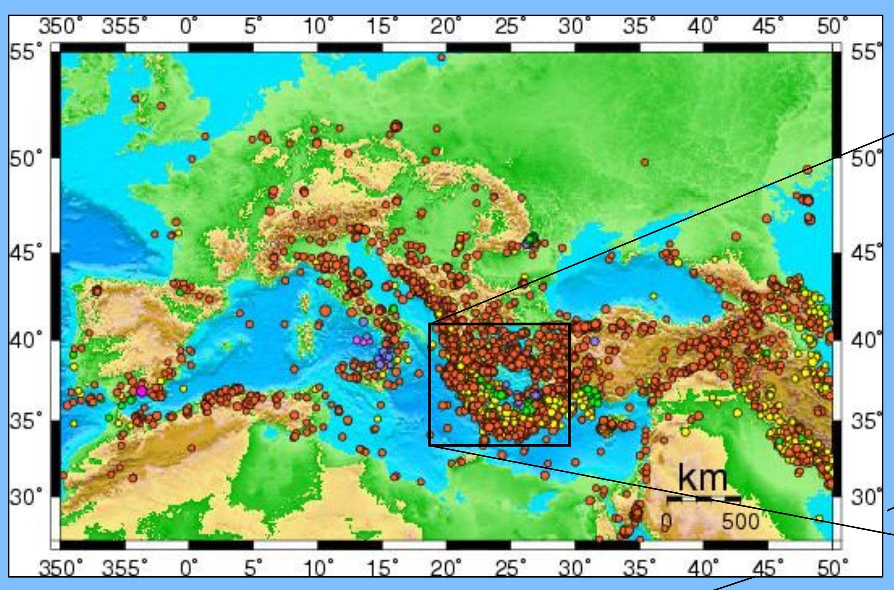
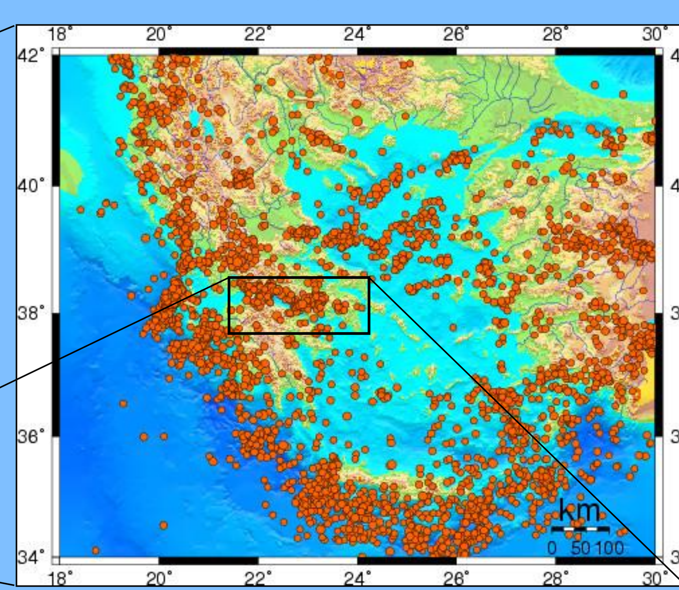
ABSTRACT

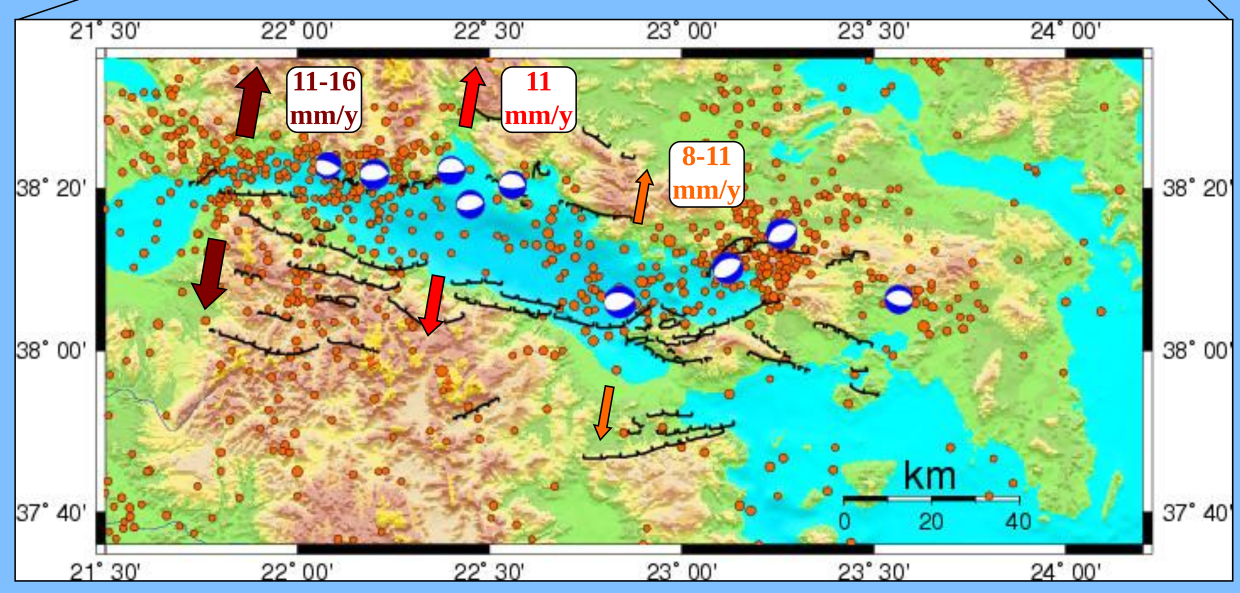
Data recorded by the Cornet network, a permanent network of the Geophysics – Geothermics Department of the University of Athens, are used in the present study to obtain reliable moment magnitudes. This network was installed around the Eastern Gulf of Corinth, which is one of the most seismic regions of Greece and Europe and has suffered from disastrous earthquakes since the antiquity. The morphology of the Gulf is mainly due to repeated earthquakes that occurred on north-dipping normal faults. In a previous study a relation for the calculation of the duration magnitude M_D was obtained using a multiple linear regression technique. In the same work the moment magnitude was determined using spectral analysis for events with $M_D \geq 3.0$. In the present study more data were processed for the same magnitude range, but for another time period, to test the reliability of the obtained magnitude relations, as well as to ameliorate their precision, by reducing the statistical errors. It is worth noticing that the same relation was obtained in both studies between the moment and the duration magnitude, which were both calculated using recordings of the Cornet Network. Furthermore, the moment magnitude, which is considered to be the most reliable magnitude scale, was calculated for smaller events with $M_D<3.0$. After the determination of the moment magnitude M_W for both magnitude ranges, relationships were obtained between M_W and the duration magnitude M_D that was calculated for the same dataset. Finally, relationships between the moment magnitude M_W, the local magnitude M_L, calculated by the National Observatory of Athens, and the body wave magnitude m_b, calculated by the ISC, are presented.

Seismicity of the Mediterranean



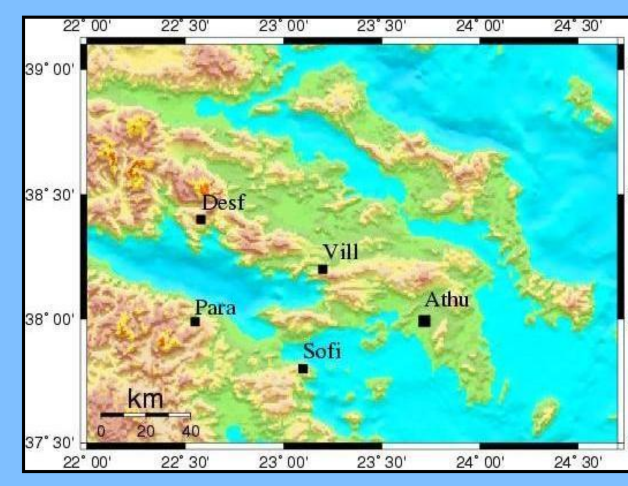
Seismicity of Greece





The Gulf of Corinth is considered as one of the most active tectonic rifts around the world. The high level of seismicity (Makropoulos and Burton, 1984), the quaternary local faulting and the 10 to 15 mm/year approximately N-S extension rate, imply that the Gulf of Corinth is a key place in Europe for the study of various physical processes related to the origin of earthquakes. Seismological and tectonic studies (Rigo et al., 1996) indicate that the morphology of the Gulf of Corinth is mainly due to repeated earthquakes that have occurred on 40° to 60° north-dipping normal faults. The Gulf is characterized by the long term subsidence of the northern coast and upward displacement of the main footwalls. Several large historical earthquakes have destroyed cities in the Gulf, the most well-known of which is the Heliki earthquake of 373 B.C., but only few of them have provided information about the faults that produced them. Recent large events are characterized by normal faulting with an approximately E-W direction, while their focal depths are about 10 km.

Cornet Network



The Seismological Laboratory of the Geophysics – Geothermics Department of the University of Athens installed since 1995 the Cornet permanent telemetric network around the Eastern Gulf of Corinth. The area was chosen due to its high seismicity and the absence of permanent seismological stations. The network initially consisted of 5 stations, but due to hardware limitations only 4 stations operated. At the beginning 3 seismometers of 1Hz were installed at each station. Following, they were replaced with 3D 5 sec Lennartz seismometers. The main goal of installation of the network was the recording of all local events and the accurate determination of their source parameters.

Determination of Duration Magnitude M_D

The duration magnitude M_D is one of the most commonly used magnitude scales for local networks and is calculated using the formula: $M_D = \alpha + \beta \cdot \log D + \gamma \cdot \Delta$

where D is the total signal duration in seconds (until the signal to noise ratio is equal to 1), Δ is the epicentral distance in kilometers and α, β, γ constants.

The first step for a reliable duration magnitude was the determination of the constants α, β, γ. The selected dataset consisted of earthquakes for which both the Local Magnitude (M_L), calculated by the Geodynamic Institute of the National Observatory of Athens, and the body wave magnitude m_b, calculated by the ISC, were available. The epicentral distances of these events were smaller than 200 km.

Following, software was developed for the determination of the constants α, β and γ using linear multiple regression. The values of the constants α, β, γ, standard deviation s and coefficient of determination (goodness of fit) R^2 for each station and for the whole Cornet Network are:

Station	α	β	γ	s (Richter)	R^2	Observations
Desf	-1.1	2.34	0.0012	0.029	0.988	92
Para	-1.1	2.36	0.0012	0.027	0.991	98
Sofi	-1.1	2.34	0.0012	0.028	0.991	89
Vill	-1.1	2.35	0.0012	0.025	0.992	73
CORNET	**-1.1**	**2.35**	**0.0012**	**0.027**	**0.991**	**352**

Whence the obtained formula is:

$$M_D = -1.1 + 2.35 \log D + 0.0012\,\Delta$$

Moment Magnitude M_W – Relation with Duration Magnitude M_D for events with $3.0 \leq M_D$ in previous study

After the independent calculation of both the Moment Magnitude M_W and the Duration Magnitude M_D using 101 events that were recorded by the Cornet network in the time period 1996 - 1997 a relationship between them was obtained (Kaviris et al., 2007), using linear regression:

$$M_W = 0.99\,M_D + 0.61 \quad \text{for } 3.0 \leq M_D \leq 4.5$$

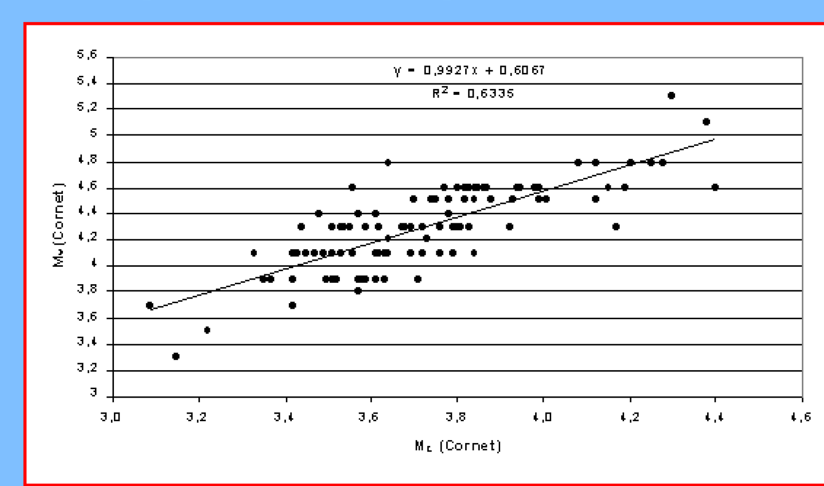
This equation is similar to the one obtained by Papazachos et al. (1997) for Greece:

$$M_W = 0.97 \cdot M_L + 0.58 \qquad M_L = M_D$$

The relation obtained in the framework of the present study can be replaced by the following:

$$M_W = M_D + 0.6 \qquad \text{for } 3.0 \leq M_D \leq 4.5$$

which is more practical and gives the same results.



Moment Magnitude M_W – Relation with Duration Magnitude M_D for events with $3.0 \leq M_D$ in the present study

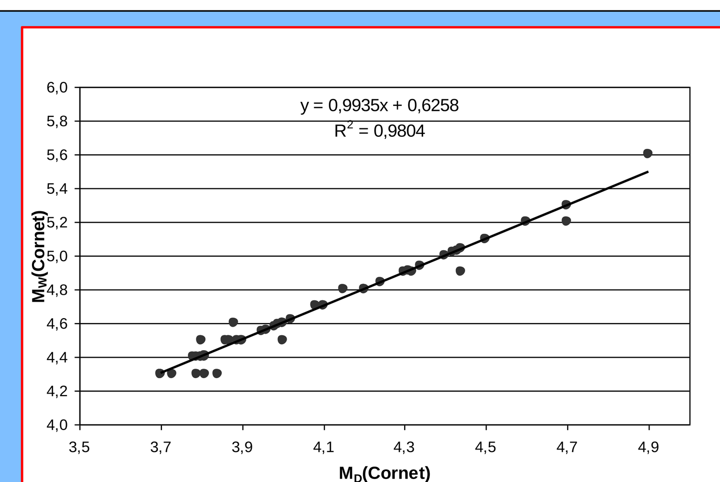
In the present study, 81 events were processed for $3.0 \leq M_D$ (same magnitude range with the previous study) that occurred during 1998. A similar relation was obtained:

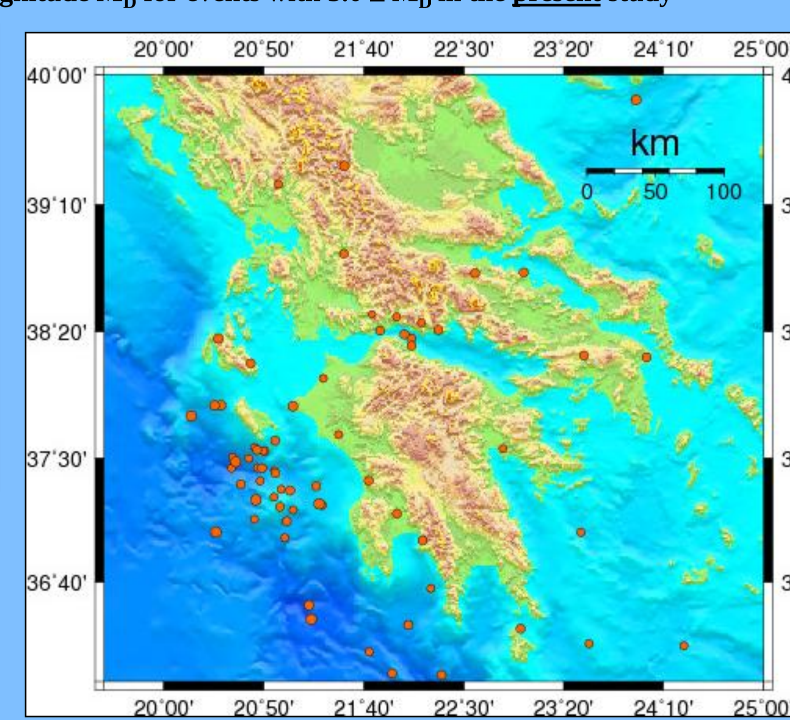
$$M_W = 0.99\,M_D + 0.63 \qquad \text{for } 3.0 \leq M_D$$

The coefficient of determination (goodness of fit) R^2 was found equal to 0.98 (98%), almost equal to 1 (100%). This very satisfactory value guarantees that the Moment Magnitude M_W calculated by the Cornet Network is reliable.

The relation obtained in the framework of the present study can also be replaced by the:

$$M_W = M_D + 0.6 \qquad \text{for } 3.0 \leq M_D \leq 6.0$$





Events with $3.0 \leq M_D$ used in the present study

Determination of Moment Magnitude M_W

The next goal was the determination of the moment magnitude M_W. This is considered to be the most reliable magnitude scale, since it is not saturated and does not depend on the frequency window.

The calculation of the seismic moment M_0 was performed using spectral analysis, through the equation :

$$M_0 = 4\pi\rho\beta^3\Omega_0 R/0.85$$

The Moment Magnitude M_W is calculated as:

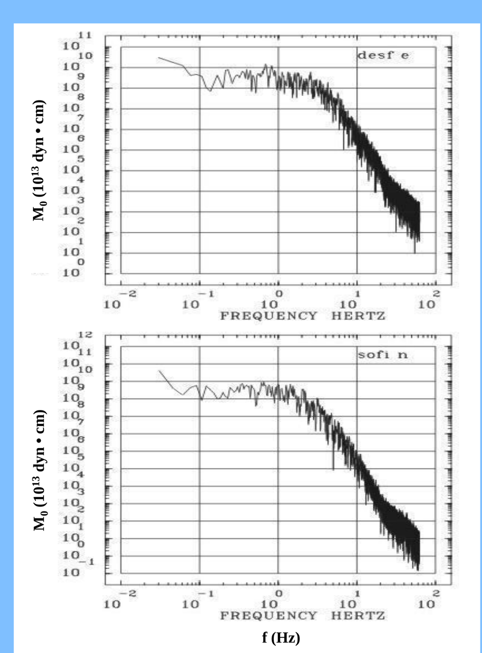
$$M_W = \frac{2}{3}\log M_0 - 10.73$$

It is worth noticing that the moment magnitude M_W is calculated by directly processing digital data.

The response spectra of the Desf (component E-W) and the Sofi (component N-S) stations for the same earthquake (1-6-96) are presented, respectively, as an example.

After the determination of the spectral amplitude Ω_0, the value of the seismic moment M_0 was found equal to $M_0=4 \cdot 10^{22}$ dyn•cm, resulting a moment magnitude $M_W=4.2$.

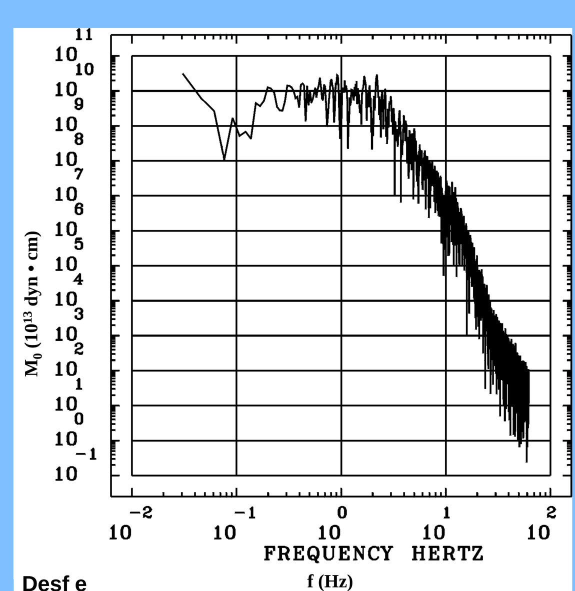
Furthermore, the corner frequency is $f_0=3$ Hz.

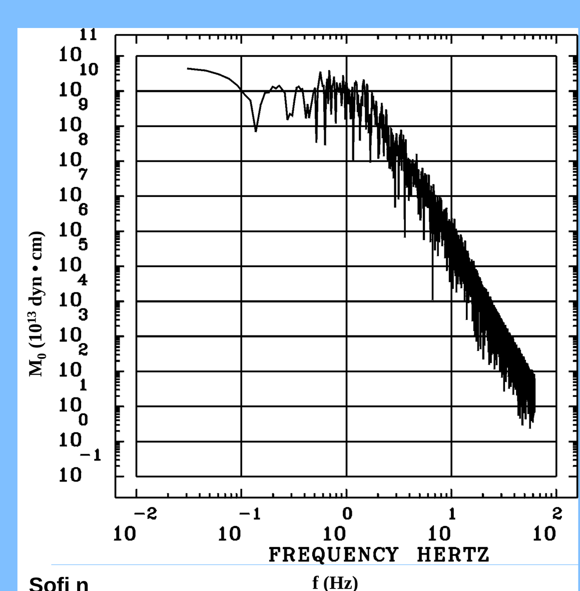


As another example, the response spectra of the Desf (component E-W) and the Sofi (component N-S) stations for the same earthquake (17-2-98) are presented.

After the determination of the spectral amplitude Ω_0, the value of the seismic moment M_0 was found equal to $M_0=1.5 \cdot 10^{23}$ dyn•cm, resulting a moment magnitude $M_W=4.7$.

Furthermore, the corner frequency is $f_0=2.5$ Hz.





Moment Magnitude M_W – Relation with Duration Magnitude M_D for events with $M_D < 3.0$

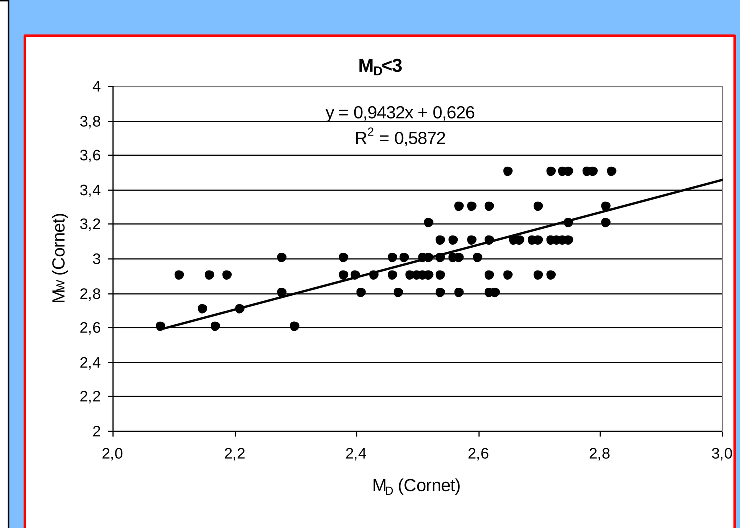
The moment magnitude, which is considered to be the most reliable magnitude scale, was also calculated for smaller events with $M_D<3.0$, using the above mentioned procedure. After the determination of the moment magnitude M_W via spectral analysis, and of the duration magnitude M_D for the same dataset, the following relation was obtained using linear regression:

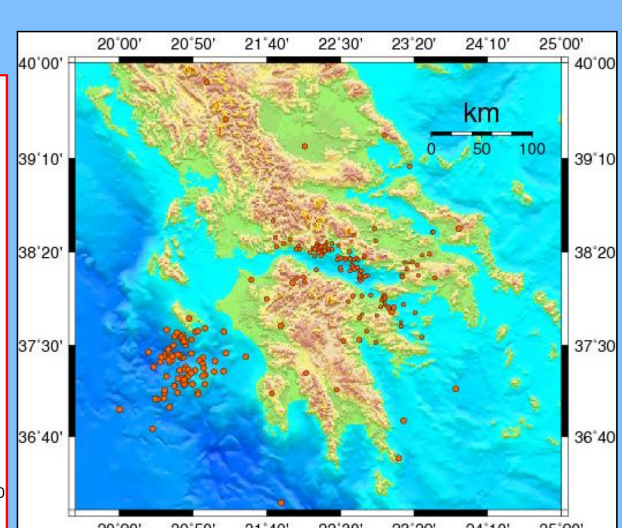
$$M_W = 0.94\,M_D + 0.62 \quad \text{for } M_D < 3$$

The relation obtained in the framework of the present study can be replaced by the:

$$M_W = M_D + 0.5 \quad \text{for } M_D < 3$$

which is more practical and gives the same results





Events with $M_D < 3.0$ used in the present study

Moment Magnitude M_W – Relation with Duration Magnitude M_D in both studies

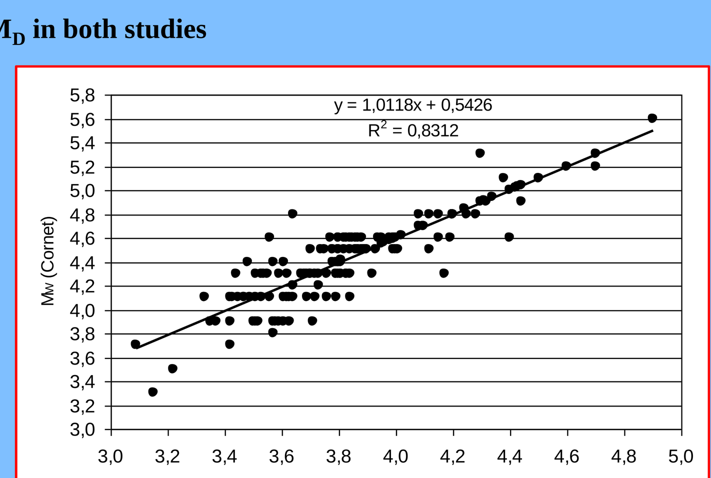
Using linear regression, a relationship was obtained between the moment magnitude M_W and the duration magnitude M_D for all the 185 events with $M_D \geq 3$ that were analyzed (years 1996-1998):

$$M_W = 1.01\,M_D + 0.54 \quad \text{for } M_D \geq 3$$

The relation obtained in the framework of the present study can be replaced by the:

$$M_W = M_D + 0.6 \quad \text{for } M_D \geq 3$$

It is worth noticing that the same results were obtained in both studies between the moment and the duration magnitudes, which were both calculated using recordings of the Cornet Network.

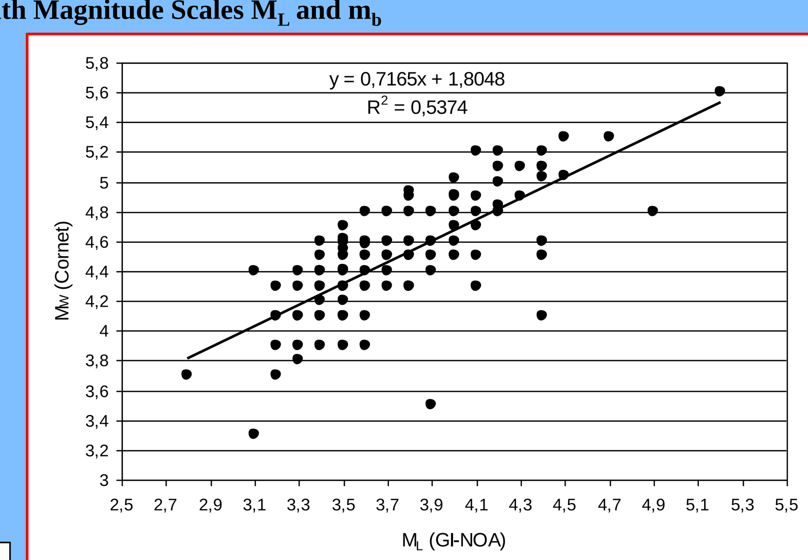


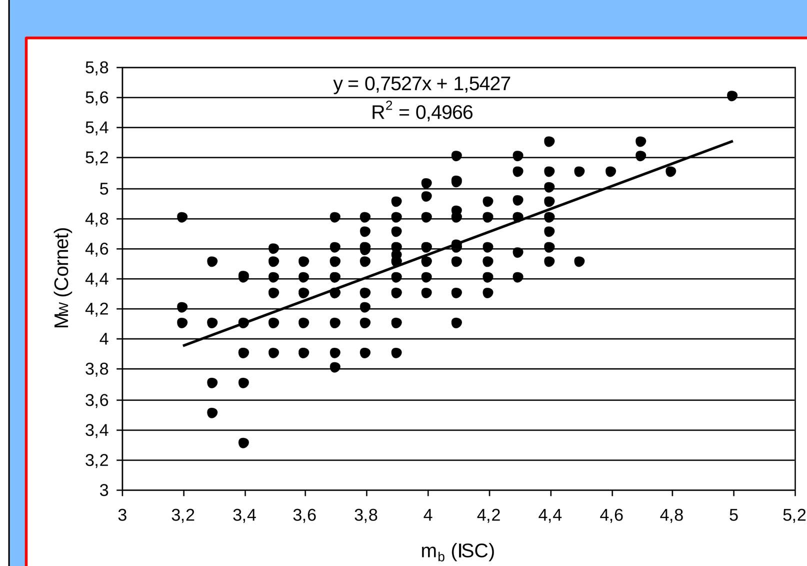
Moment Magnitude M_W – Relations with Magnitude Scales M_L and m_b

For the same data set (1996-1998), relations between the moment magnitude M_w, the local magnitude M_L (Geodynamic Institute of the National Observatory of Athens) and the body wave magnitude m_b (ISC) were obtained using linear regression :

$$M_W = 0.72\,M_L + 1.8 \quad \text{for } 2.8 \leq M_L \leq 5.2$$

$$M_W = 0.75\,m_b + 1.54 \quad \text{for } 3.2 \leq m_b \leq 5.0$$





Conclusions

The Gulf of Corinth is an asymmetrical active tectonic rift, characterized by normal faulting in an almost E-W direction. The Gulf has suffered destructive earthquakes since the antiquity and is an area of high tectonic, geodetic and seismological interest. The permanent Cornet network was installed since 1995 around the Eastern Gulf of Corinth.

After the determination of a reliable duration magnitude M_D, the moment magnitude M_W was calculated using spectral analysis. This is considered to be the most reliable magnitude scale and a catalogue was created. The obtained relation for events with $3.0 \leq M_D$ between the two magnitude scales calculated by the Cornet Network (1996-1998) reveals that the moment magnitude M_w is systematically 0.6 larger than the duration magnitude M_D, while it is systematically 0.5 larger for events with $M_D<3.0$.

References

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