Πρακτικά	6ου Συνεδρίου		Μάϊος 1992
Δελτ. Ελλ. Γεωλ. Εταιρ.	Τομ. XXVIII/3	σελ. 181-192	Αθήνα 1993
Bull. Geol. Soc. Greece	Vol.	pag.	Athens

RECENT ACTIVITY ON EARTHQUAKE PREDICTION RESEARCH CARRIED OUT BY THE SEISMOLOGICAL INSTITUTE (NATIONAL OBSERVATORY OF ATHENS)

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ABSTRACT

The Seismological Institute of the National Observatory of Athens is the responsible center in Greece to carry out continuously the routine seismic observations. The material collected gave the opportunity to perform earthquake prediction research by examining seismicity patterns in a systematic way with the help of some modern techniques.

The ν-value method is used to discover temporal changes in the present seismicity level as well as the technique proposed by Matsu'ura to investigate anomalous seismicity changes before the occurrence of the large aftershocks.

Attention has been also given to earthquake prediction which is characterized as intermediate-term. For this research the M8 algorithm is used. This algorithm examins several seismicity patterns in order to define the Time of Increased Probability (TIP).

The algorithm M8 has been successfuly tested for the earthquakes of M>7.0 which occurred in Greece from 1973 till 1983 and the applicability of this algorithm for smaller earthquakes was explored. This application is considered to be of practical importance for the area of Greece due to their frequent occurrence. After that the algoritm M8 used to diagnose current TIP's for the area of Greece by using recent complete data.

The Seismological Institute will continue the research on earthquake prediction by using these methods among others.

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ΠΕΡΙΛΗΨΗ

Στο άρθρο αυτό παρουσιάζεται η πρόσφατη δραστηριότητα του Σεισμολογικού Ινστιτούτου του Εθνικού Αστεροσκοπείου Αθηνών σχετική με την πρόγνωση σεισμών στην Ελλάδα και η οποία στηρίζεται στον έλεγχο χαρακτηριστικών της σεισμικότητας.

Η περιοχή αυτή χαρακτηρίζεται απο πολύπλοκο γεωδυναμικό καθεστώς που δίνει την ευκαιρία να εξετασθούν ανεξάρτητες μεταξύ τους μέθοδοι ελέγχου της σεισμικότητας σε διαφορετικές περιοχές της χώρας.

Οι μέθοδοι που χρησιμοποιήθηκαν παρουσιάζονται συνοπτικά και αναπτύσσονται περιληπτικά τα αποτελέσματά τους.

INTRODUCTION

Greece is one of the most seismically active countries in the world and the most active region in the Mediterranean. The tectonic structure of this area is the results of the comlex interaction of different geodynamic processes, not all of which can be assigned to a simple plate tectonic model.

The Seismological Institute of the National Observatory of Athens is the responsible center in Greece to carry out continousely the routine seismic observations.

Recently the Institute completed the installation of a modern, real time, telemetric network (Papanastassiou et al., 1989a) which results in a better detectability of earthquakes and in more accurate determination of their parameters. The material collected gave us the opportunity to perform earthquake prediction research by examining seismicity patterns in a systematic way and these have been interpreted as precursory earthquake phenomena.

SEISMICITY PATTERNS

Amongst the various earthquake precursors, seismicity patterns have played one of the predominant roles in earthquake prediction studies (Rikitake 1981). Many papers have been published by Greek researchers concerning seismicity patterns such as seismic quiescence, seismic gap, migration of seismicity etc. (Papazachos and Comninakis 1982, Karakostas et al., 1985, Papadimitriou and Papazachos 1985, Papadopoulos 1986, 1988). These studies were based on historical and instrumental data and employed only large or moderate earthquakes. Thus the obtained results are strongly dependant on the available seismological data. This was pointed out by Drakopoulos et al., (1989) [illegible] earthquake prediction research along the southeastern part of the Hellenic arc, by using different sources of seismological data. For this reason great attention must be given at any observation and interpretation of seismicity patterns.

In order to have a complete and homogeneous data set we used only the earthquake parameters as they are listed in the monthly bulletins of the Seimological Institute from 1971 and afterwards. Our research focused on some modern techniques in earthquake prediction research. Firstly the algorithms were tested retrospectively for earthquakes that occurred in the area of Greece and afterwards they were applied.

The employed algorithms and the obtained results are presented briefly bellow.

I. Real time prediction methods

a). Papanastassiou et al., (1989b) used the ν-value method to discover temporal changes in seismicity. The ν parameter is defined by Matsumura (1982,1984) as (mean $(\tau))^2$/ mean(τ^2) where τ is the time interval between two successive earthquakes in time and space. When the ν-value is greater than 0.5 the earthquake sequence is characterized as periodical, when it is equal to 0.5 as random and, when is smaller than 0.5 as clustered.

This method was initialy applied to the earthquake sequence of March 25, 1986 (Aegean earthquake). This sequence mainly consisted of seven significant shocks with magnitude range between 4.6 and 5.3.

Calculating the ν-value for the period Dec 1982 - July 1986 it was found that a decrease of the parameter ν (ν<0.5) occured before the initiation of the sequence and the occurrence of the large earthquakes (Fig. 1).

Moreover Papanastassiou et al., (1989c) analysed 5 different earthquake sequences which occurred in various regions of Greece with different seismotectonic characteristics (Magnessia, Jul. 1980; Alkyonides, Feb. 1981; Central Aegean sea, Dec. 1981; Ionian sea, Jan. 1983; North Aegean sea, Jan. 1982 and Aug. 1983). They observed that almost all the significant events of these sequences were preceded by small ν-values (ν<0.5). The decrease in ν-value started some hours or a few days before the occurrence of the seismic events (Fig. 2).

b). It is well known that in an earthquake sequence after the occurrence of the main shock an aftershock may follows which may be as large and destructive as the main one.

Matsu'ura (1986), proposed a method to investigate whether, in an aftershock activity, there exists any anomalous change from the level expected from the modified Omori formula (Utsu 1961) before the occurrence of a large aftershock.

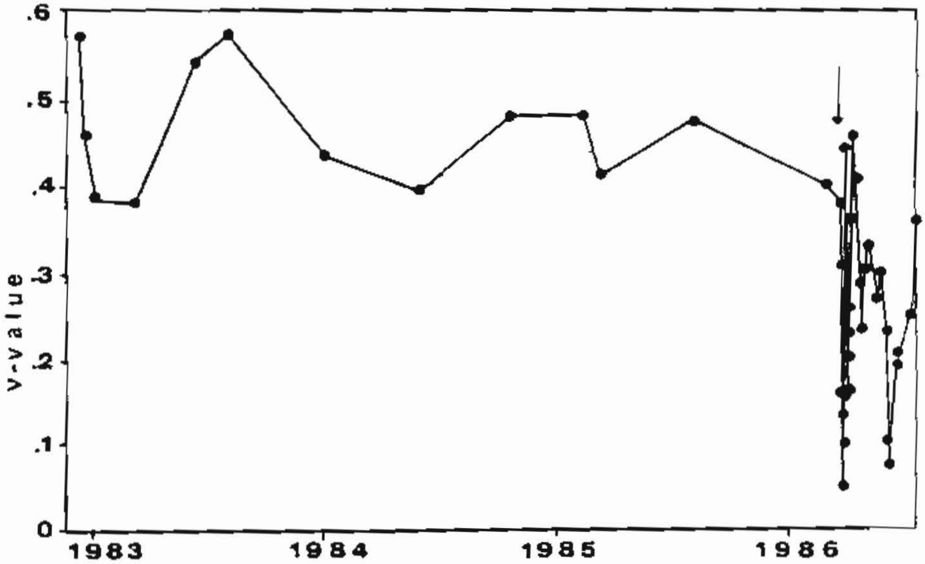

Fig. 1. *Changes of ν-value for the period December 198 through July 1986. The ν-values were calculated for groups of 30 successive shocks which are moved by a window of 10 shocks. The vertical arrow shows the beginning of the sequence (25 March 1986).*
(Papanastassiou et al., 1989b).

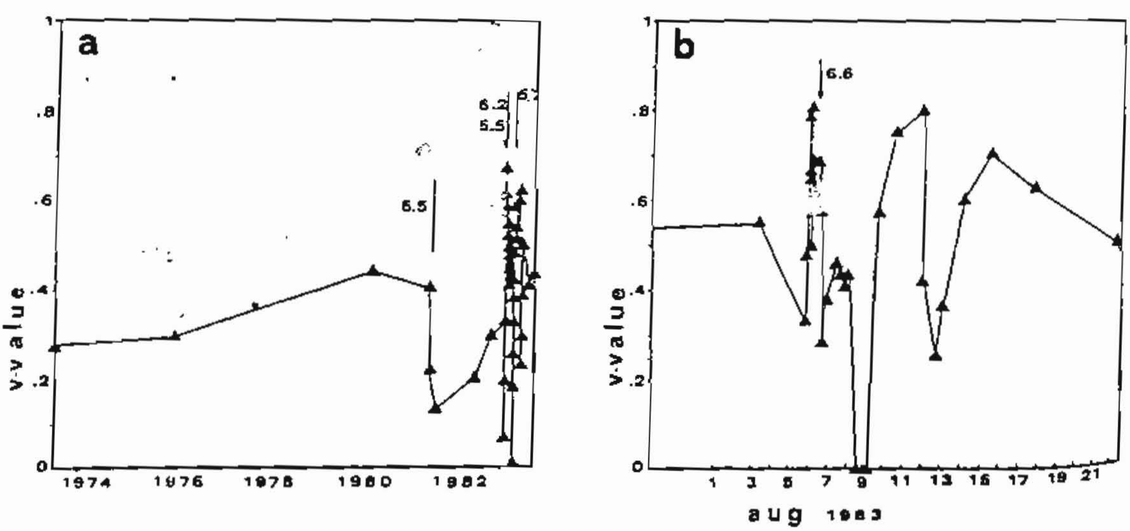

Fig. 2. *Changes of ν-value:* **(a)** *The Ionian sea sequence.* **(b)** *The north Aegean sea sequence, (August 1983).*
(Papanastassiou et al., 1989c).

This technique has been applied by Latoussakis et al., (1991a) to some earthquakes sequences, with significant aftershock activity, which took place in different seismotectonic regions in Greece, (Alkyonides, Feb. 1981; Central Aegean sea, Dec. 1981; Ionian sea, Jan. 1983; Central Aegean sea, Mar. 1986). It has been recognized that before the occurrence of such large aftershocks the activity decreased and the whole aftershock area became quiescent. Subsequently the aftershock activity recovered to the normal level or increased beyond it prior to the occurrence of the large aftershock (Fig. 3) which followed the secondary aftershock activity.

It is worth to mention that this pattern is not recognized in aftershock activities which are not accompanied by large aftershocks. The anomalous change in activity (decrease then increase) prior to a large aftershock is larger than statistical fluctuations irrelevant to large event.

Although the aforementioned "predictions" obtained after the occurrence of the relevant earthquakes, the above two methods seem to be promising and the obtained results are quite encouraging for a successful prediction in areas where dense seismograph network is established and the seismological data are observed in real time.

II. Intermediate - term prediction methods

An earthquake prediction is characterized as intermediate-term when the occurrence time of the coming earthquake is given as long as five years or less.

For this research two algorithms are common: the CN (California - Nevada) and the M8.

The first one has been applied by Allen et al., (1987) to earthquakes occurred in California - Nevada in order to diagnose a Time of Increased Probability (TIP), and the second one by Keilis-Borok and Kossobokov (1986) for the same purpose but they used a simpler criterion of diagnosis and included smaller events in their catalog.

These algorithms includ the most frequently used seismicity patterns as: the current level of seismic activity, the deviation of the seismic activity from a long-term linear trend, the concentration of main shocks in space, the clustering of earthquakes etc.

A TIP is decleared when extremely large values of the previous seismicity patterns are clustered in a sufficiently narrow time interval (six months).

Based on the results obtained by applying these two algorithms in different regions of the world it is believed that M8 is appropriate for a quantitative investigation and recognition of the seismic patterns.

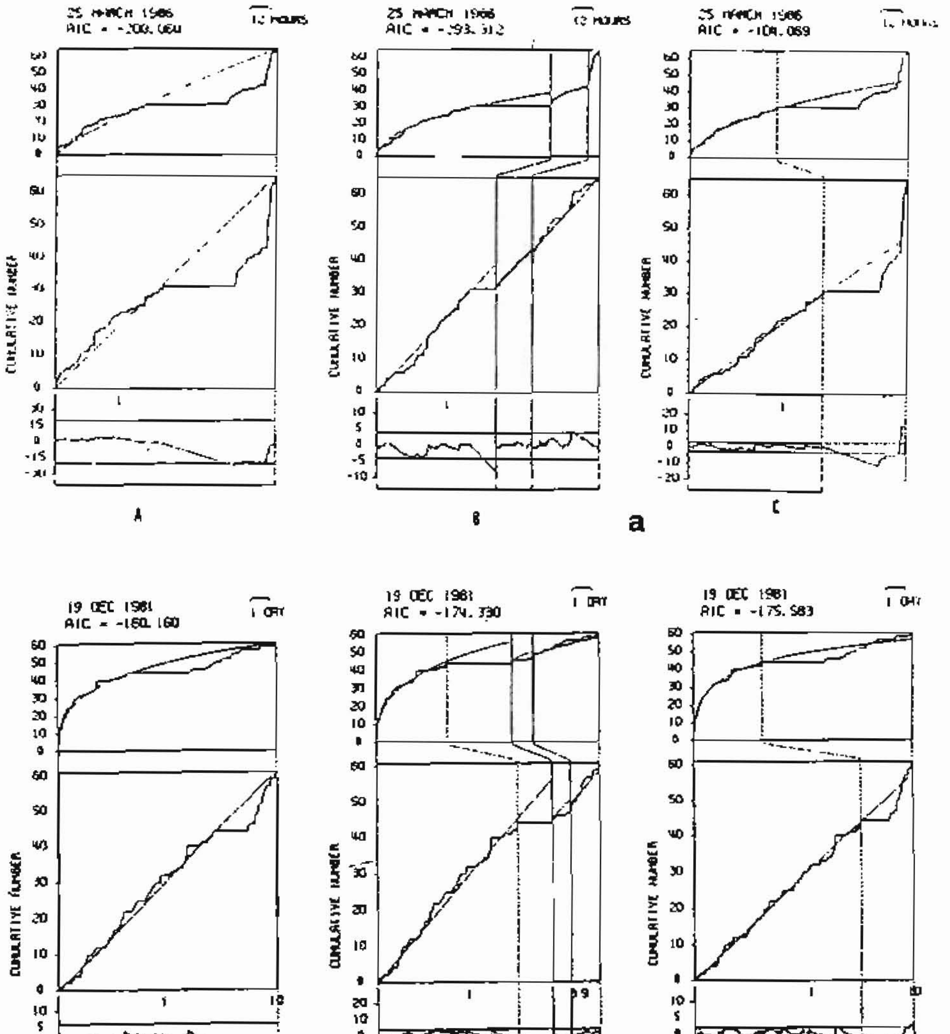

Fig. 3. *Top and middle figures show the cumulative number of aftershocks against ordinary time and FLT, respectively. The bottom of the figure magnifies the difference of the observed cumulative number from the calculated one on the same time scale as the middle. The large aftershock occurred at the right end of the time scale.*
(A) *The frequency-linearized time from all data.* **(B)** *The best fitted model from all data.* **(C)** *FLT from data prior to the occurence of the large aftershock.*
(a) *The 1986 cental Aegean sea earthquake,* **(b)** *The 1981 central Aegean sea earthquake.*
(Latoussakis et al., 1991a).

The algorithm M8 has been tested for the earthquakes of M>7.0 which occurred in Greece from 1973 till 1983 in order to examine whether these large shocks were preceded by TIP's (Latoussakis and Kossobokov, 1990). The results indicate that the three events of M_s>7.0 (Cen· ›l Aegean sea, Dec. 1981; Ionian sea, Jan. 1983; North Aegean sea, Aug. 1983) took place within TIP's (Fig. 4).

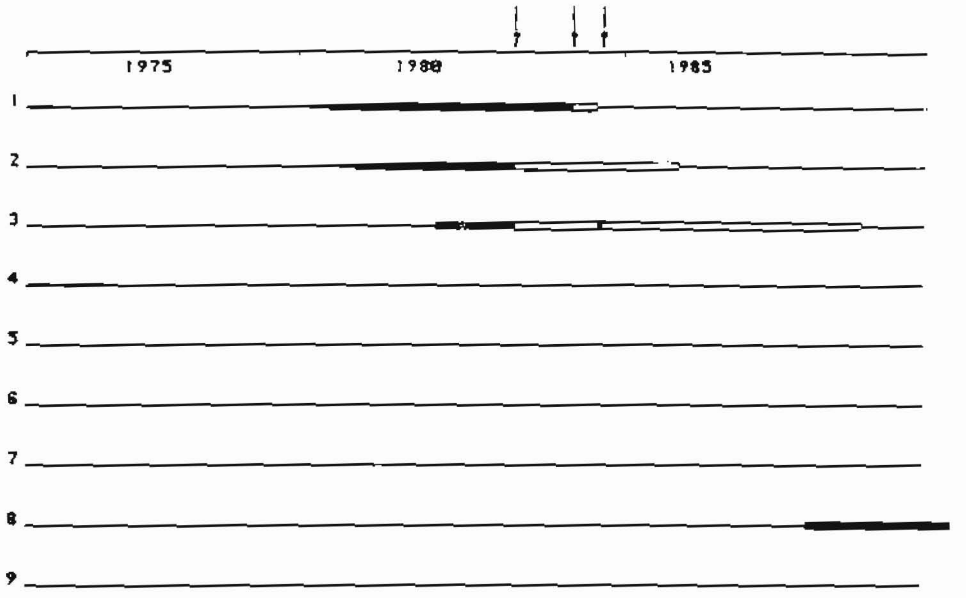

Fig. 4. *Application of the algoritm M8: the TIPs diagnosed for M≥7.* **(Latoussakis and Kossobokov, 1990).**

After that an attempt was made (Latoussakis and Stavrakakis, 1991) to explore the applicability of the M8 algorithm for smaller earthquakes. This application is considered to be of practical importance for the area of Greece due to their frequent occurrence.

The results show that 10 out of 11 events with M_L≥5.5 which took place in Greece from January 1977 till the end of 1990 occurred within TIP's diagnosed by the algorithm M8 (Fig. 5). Only the Thessaloniki earthquake (June 1978) did not occur within a TIP. This application forecasts a TIP of occurrence of a strong earthquake in the southwestern part of the Hellenic arc. It should be also emphasized that the same TIP has been diagnosed by Latoussakis and Kossobokov (1990) by considering a threshold surface magnitude equal to 7.0.

These results indicate that the algoritm M8 can be used to

DISCUSSION

Earthquake prediction is not a discipline in which one can make rapid progress. Predictions made by serious scientists are still few as large earthquakes happen infrequently in unexpected places. The problem in indentifing seismicity anomalies as precusors to mainshocks is a multiple one. The detected seismicity anomaly has to connect with the preparation process for an impeding earthquake, which is not very easy.

A convincing way is the verification that the anomalous seismicity area has different physical parameters than the background area.

Attention must be also paid to magnitude changes which can cause apparent changes in seismicity rates that easily can be mistaken for precursors.

The present review of the studies related to the seismicity patterns have shown that the most common features are either relative quiescence, clustering of events in space and time or a combination of them. Between them, quiescence is a basic tool for an earthquake prediction.

The Seismological Institute of the National Observatory of Athens will continue the research on earthquake prediction by using these methods among others. In our intention is the help of complementary methods for the areas which are considered as canditates for the occurrence of large shocks in the comming years as well as their continous seismicity check in real time.

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