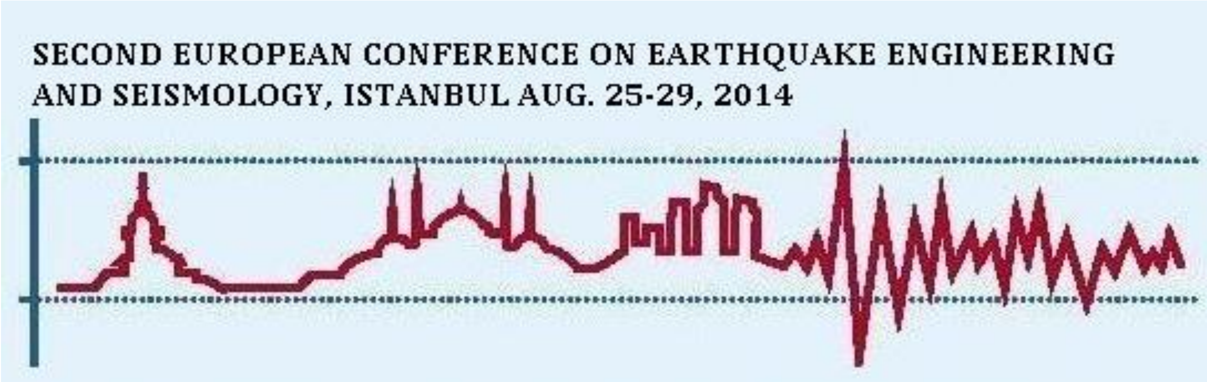

DETERMINISTIC PRECURSOR TOOLS FOR EARTHQUAKE LOCATION

Anthony C Boucouvalas, Athanasios Keskempes, and Nikos Tselikas

ABSTRACT

We report on the development of new and online set of tools for use within Google Maps, for earthquake research. We demonstrate a server based and online platform with new tools using a database system with earthquake data. The platform allows us to analyze, display data on maps and plot seismicity graphs. The tool box is now extended to draw on the map line segments, multiple straight lines horizontally and vertically as well as multiple circles, including geodesic lines. The application is demonstrated using localized seismic data from the geographic region of Greece as well as global earthquake data. The application further offers regional segmentation which allows the studying earthquake clustering, and earthquake cluster shift within the segments in space and time. The plotting facility allows cumulative earthquake magnitude plots and time plots of earthquake magnitude histograms. Using the newly developed line and circle tools we have studied the spatial distribution of earthquakes and we here show for the first time the link between Fibonacci Numbers and spatial location of earthquakes. The new tools are valuable for examining trends in earthquake research.

INTRODUCTION

With the advent of the internet and popular map facilities such a Google Earth and Google map combined with location data from coordinates or GPS, has given a tremendous growth in geographic mapping of data using local national or global maps depending on the source of data. The easy access of data using databases and the client server model of communication has also allowed online access and display of data never thought possible before. In accordance to this trend earthquake data given by magnitude in Richter scale and coordinate of the epicenter in latitude and longitude have benefited with visualization by online location mapping and display of the earthquake epicenter for information and access via the internet. Apart from the live information access after the event, there is interest in identifying seismic active areas within countries based on precursor earthquake activity. Anomalous seismic patterns (Keskebes et al., 2011) and areas exhibiting seismic quiescence (Keskebes et al 2011) have recently been studied based on standalone software such as ZMAP, Chouliaras (2009), based on Matlab. This approach has the advantage that powerful signal analysis can be carried out using Matlab and ZMAP user interface but the local database must be imported and updated regularly Weimer (2009). Online systems especially those which can be fed with real time data from the European Mediterranean Seismological Centre (EMSC) and a national source such as the Geodynamic Institute of Athens with some data processing and plotting facility have not been demonstrated. Online systems ideally allow access from anywhere and can be viewed by any browser.. However the data are not displayed on the map of the region of interest, and furthermore no data plotting facility exists. Apart from plotting facilities it is often important to have a set of spatial tools to be used with the maps for research in identifying location trends. Basic map tools such as drawing a line segment, a horizontal or vertical line and circles are very useful and can be used in identifying earthquake trends. The ease of accessibility of the tools we describe here allowed us to identify some important global and national earthquake trends. We demonstrate some interesting links between location of earthquakes and

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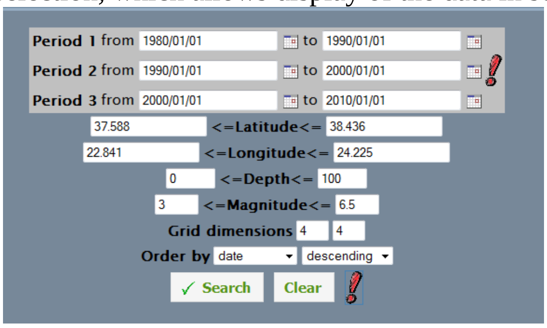
Fibonacci lines. We show for the first time with examples that there is a high probability for an earthquake to take place if there is a confluence of a number of Fibonacci lines converging on a location on the earth.

DESCRIPTION OF THE SYSTEM

We have demonstrated (Keskebes et al 2011) that with the use of PHP, Javascript, MySQL, with Google Maps is useful for the development of online seismicity map applications. This online system application is enhanced with a number of tools the use of which we demonstrate here to earthquake research. Using MySQL and earthquake data from the publically available source of the European Mediterranean Seismological Centre (EMSC), each event characterized by the latitude, longitude (location) of the earthquake epicenter, the magnitude of the earthquake, the depth, and the time stamp of the event has been used.
Google Maps pins give a location to the earthquake and the zoom allows us to home in and view on any part of the country and examine its seismicity. A user defined rectangular map region can be drawn by clicking at its diagonal corners, defining the perimeter of the region to be studied. The data selection and display part of the interface is shown in Figure 1. The date period of interest for database search can be selected from a calendar style entry system. The system allows for three time periods to select from, and can be compared as shown in Figure 1. The depth limits of the epicenter may also be selected followed by the magnitude range. The selected geographical region can be subdivided into NxN sub regions which is useful for when looking for earthquake cluster location shifts. Within each grid sub region we can use all the available plotting facilities. The database filters allow the display on the map not only of the activity over the selected period but also the selected magnitude range of the earthquakes. This selection matrix is shown in Figure 2. In Figure 2 we also show the polyline selection, which allows display of the data in sequence as they occurred in time and joined by a line.



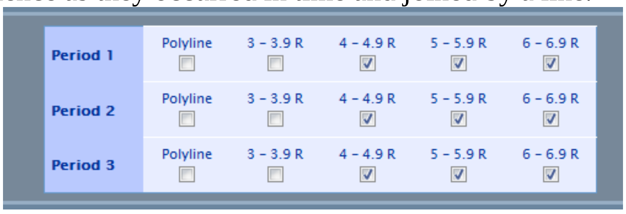


Figure 2: *The data display filter selection*

Figure 1: *Search Interface of the application*.

The results of the database search are displayed in colour dots on the chosen Google Map, Figure 3.

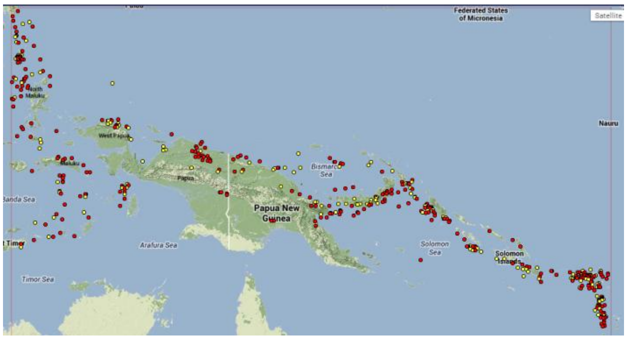


Figure 3: *Display of 3+R earthquake locations in the region of Papua New Guinea within the red box area from July. 2007-Nov. 2013.*

The displayed data can be colored using a magnitude range corresponding to different colors if needed.
Figure 4 shows a selected 4x4 regional segmentation of a region of the Aegean Sea in Greece. Each of the 4x4 cells can be studied individually by the charting routines and plots can be created. For each cell we display the data contained within by coordinates, magnitude, depth and date as shown in Figure 5. Figure 5 shows the data for three cells 1, 2, and 3, each of which if it contains enough data can be used to plot a selection of three charts, (Graphs 1, 2 and 3 buttons shown in Figure 5).

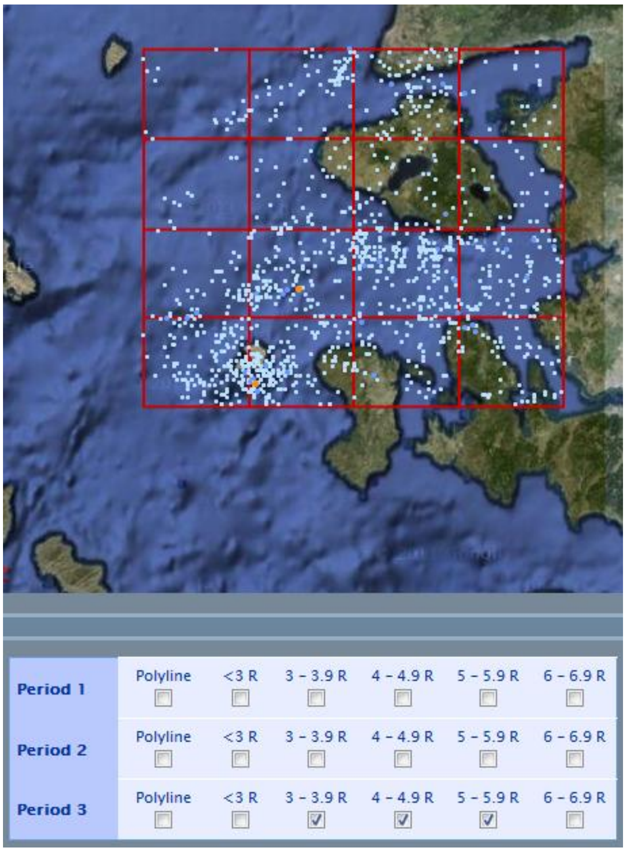
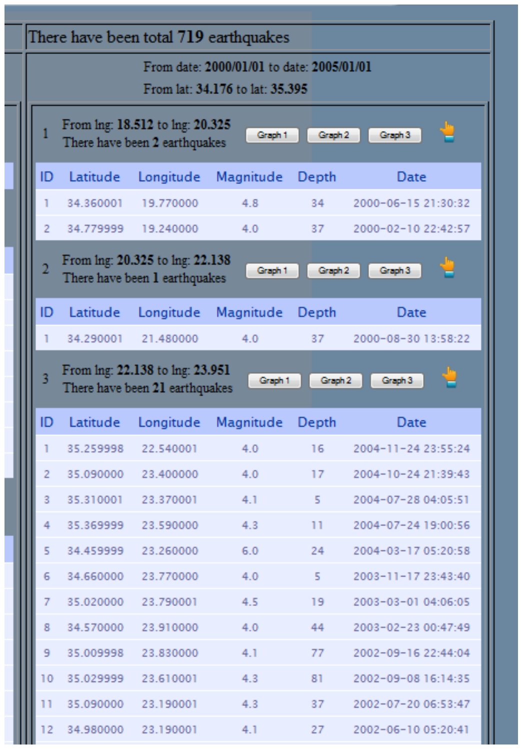


Figure 4: *3R+all since 2000-2005, Lesvos Island Greece*



There have been total **719** earthquakes

From date: **2000/01/01** to date: **2005/01/01**
From lat: **34.176** to lat: **35.395**

1 From lng: **18.512** to lng: **20.325**
There have been **2** earthquakes
Graph 1 Graph 2 Graph 3

ID	Latitude	Longitude	Magnitude	Depth	Date
1	34.360001	19.770000	4.8	34	2000-06-15 21:30:32
2	34.779999	19.240000	4.0	37	2000-02-10 22:42:57

2 From lng: **20.325** to lng: **22.138**
There have been **1** earthquakes
Graph 1 Graph 2 Graph 3

ID	Latitude	Longitude	Magnitude	Depth	Date
1	34.290001	21.480000	4.0	37	2000-08-30 13:58:22

3 From lng: **22.138** to lng: **23.951**
There have been **21** earthquakes
Graph 1 Graph 2 Graph 3

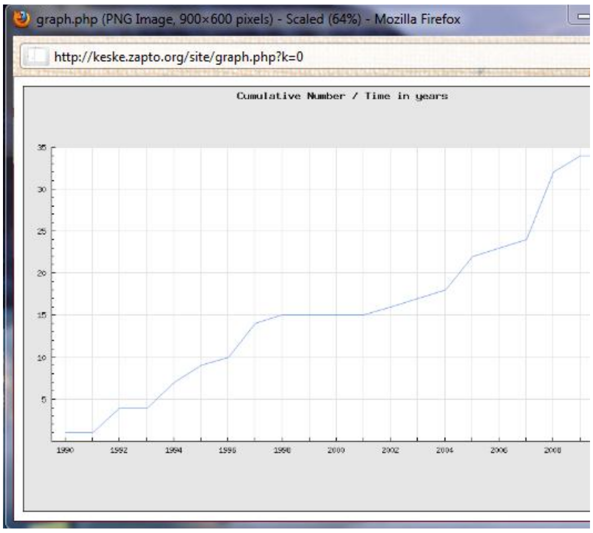
ID	Latitude	Longitude	Magnitude	Depth	Date
1	35.259998	22.540001	4.0	16	2004-11-24 23:55:24
2	35.090000	23.400000	4.0	17	2004-10-24 21:39:43
3	35.310001	23.370001	4.1	5	2004-07-28 04:05:51
4	35.369999	23.590000	4.3	11	2004-07-24 19:00:56
5	34.459999	23.260000	6.0	24	2004-03-17 05:20:58
6	34.660000	23.770000	4.0	5	2003-11-17 23:43:40
7	35.020000	23.790001	4.5	19	2003-03-01 04:06:05
8	34.570000	23.910000	4.0	44	2003-02-23 00:47:49
9	35.009998	23.830000	4.1	77	2002-09-16 22:44:04
10	35.029999	23.610001	4.3	81	2002-09-08 16:14:35
11	35.090000	23.190001	4.3	37	2002-07-20 06:53:47
12	34.980000	23.190001	4.1	27	2002-06-10 05:20:41

Figure 5: *Typical list of searched data of a specific cell.*

Three graphs are possible to be selected and displayed for every regional cell:

1) Cumulative graph of all earthquakes of any magnitude for a certain period of interest, Figure 6. This is indicative of the time seismic activity of the region. Quiet periods (quiesence periods) can be spotted as well as rapid acceleration periods.

2) The second graph offered is the magnitude spectra within a cell region, as shown in Figure 7. Here the number of earthquakes as a histogram is displayed with their strength in thr Richter scale.



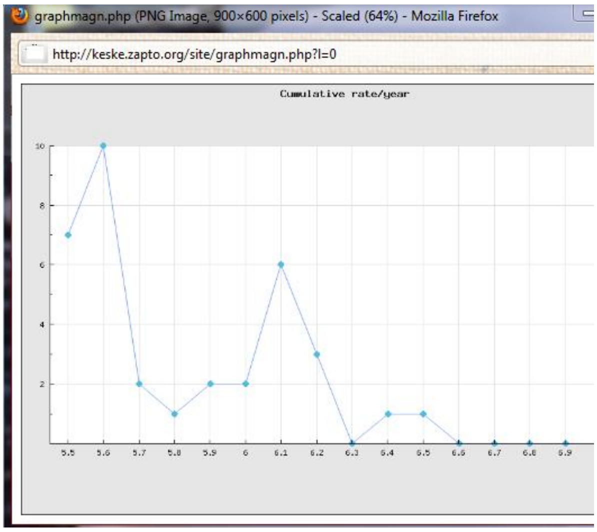


Figure 6: *Cumulative number of Earthquakes against time.*

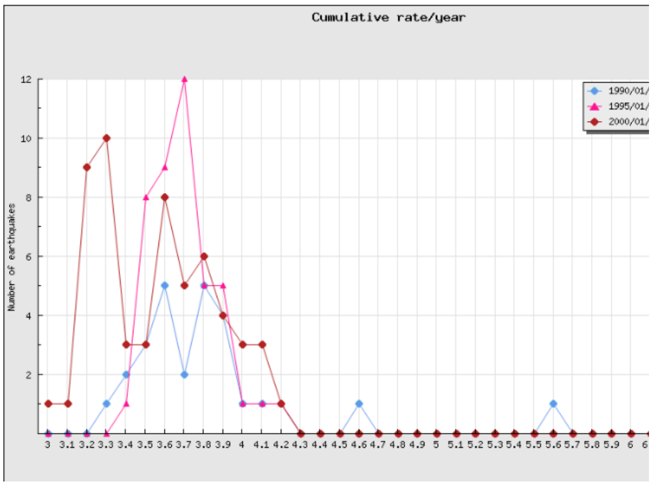
Figure 7: *Number of earthquakes against magnitude for the time duration selected*.

3) The second graph offered is the magnitude spectra within a cell region, as shown in Figure 7. Here the number of earthquakes as a histogram is displayed with their strength in thr Richter scale.

In this graph one can see the number of earthquakes for certain magnitude occurred within the period of interest and region. of the each magnitude earthquake.

4) The last graph oprion (Figure 8) offered is a 3-curve comparative plot of number of earthquakes for each magnidude of earthquakes occurred in a cell for three time periods of interest. This is extremely useful as it shows clearly the increase or decrease of activity in the regional cell of interest.

5) Other facilities such as statistical tools as appearred in (Sobolev et al. 1991), (Spassov et al. 2002), (Baskoutas et al 2011) and (Papadimitriou 2008), are possible to impliment.



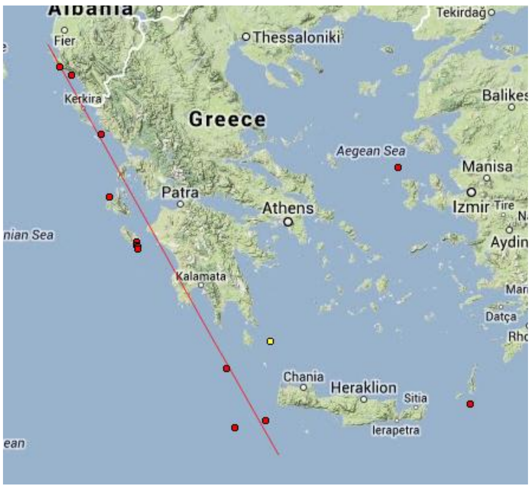


Figure 8: Comparative earthquake magnitude spectra for periods 1990-95 1995-2000, 2000-2005 for the eastern part of the island of Crete.

Figure 9: *5R+ Earthquakes between Nov-2005-Nov2007.*

Figure 9 shows the use of the straight line tool applied to the earthquakes 5R+ for the Greek Region between Nov 2005-Nov 2007. We can clearly see the activity during this period concentrated on the West of Greece. Changes of activity is illustrated by Figure 10. During the time period Nov. 2000-Nov. 2011 the acivity now has shifted very clearly along the axis Istanbul-Patras and the axis Kalamata-Rhodes, mainly Southern Greece.

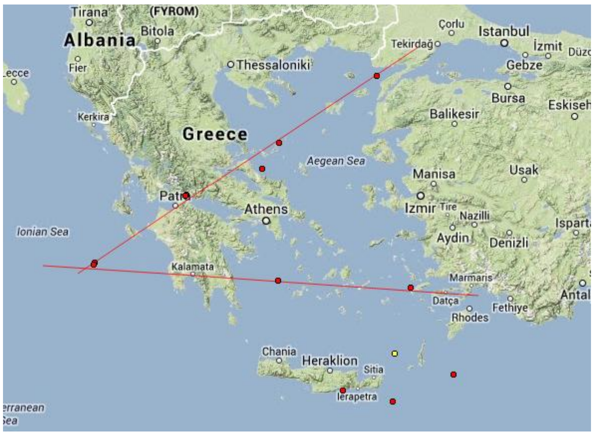


Figure 10: *5R+ Earthquakes between Nov-2009-Nov2011.*

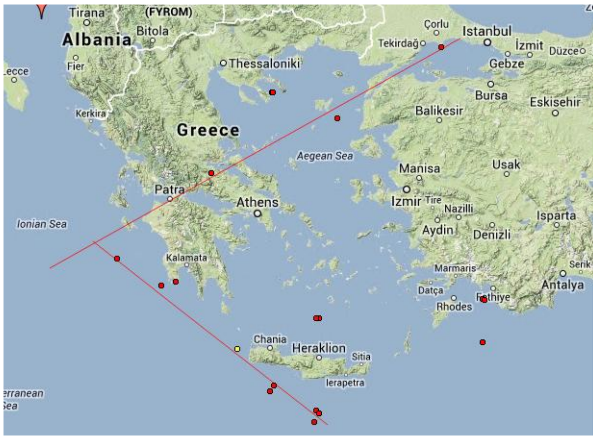


Figure 11: *5R+ Earthquakes between Nov-2011-Nov-2013.*

During the period Nov. 2011-Nov 2013 this last axis has moved again and the activity axes has moved to activate the line Southern Crete South-West Peloponnese as shown in the Figure 11.

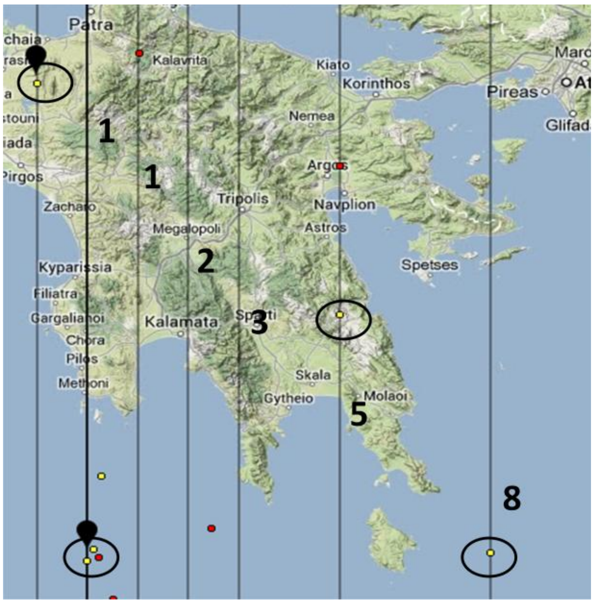


Figure 12: *5.5R+ during Nov 2005-Nov 2008*

Figure 13: *5R+all since 2003*

Another tool which we developed is the multiple vertical line tool. Using this tool we can draw at any desired longitude vertical lines. As shown in Figure 12, on localized scale within the region of Peloponnese we have drawn the lines via some selected 5.5R earthquakes which occurred during Nov. 2005-Nov. 2008. The leftmost two lines are the 0,1 Fibonacci lines and determine a seed distance and the other numbered lines are some higher order Fibonacci lines at the corresponding multiples of the seed distance.. The earthquakes here have occurred inversely sequentially in time, i.e. first the location

8, then 5 etc. We can clearly see how lines 5 and 8 locate the longitude of the encircled earthquakes confirming the theory that there exists a Fibonacci relationship between the location of some significant earthquakes.

The new tools developed include the generation of concentric circles. The circle radii can be set by the user. A typical set up is shown in Figure 13 where a map of Greece with all 5+ Richter earthquake locations since 2003 are being displayed, with a two sets of circles. The circles have radii according to the Fibonacci number sequence. What is interesting is that all the earthquakes are located on the Fibonacci circles. This indicated that the mechanism of location of earthquakes has embedded the Fibonacci sequences.

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Figure 14: *6.0R+ earthquakes 2002-2008*

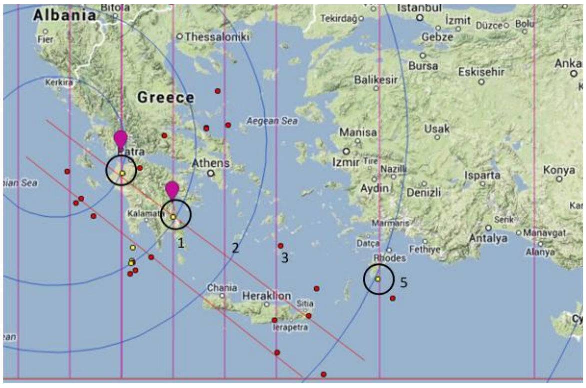

Figure 15: *5.0R+ during Nov 2007-Non-2009*

In a similar manner a horizontal line tool was developed. Figure 14 is an example using the horizontal and vertical lines tools combined.

In the same map we can also see two straight line segments in red and two Fibonacci vertical and horizontal line sets. The chart displays all 6R+ earthquakes since 2002 in the region of Greece, predicting the occurrence of earthquake number 5.

We can combine circles and lines as shown in Figure 15, where the Fibonacci vertical lines are shown in combination with Fibonacci Circles. From Figure 15 we can see that the earthquake circled near Rhodes Island is the Fibonacci extension of the earthquakes in Peloponnese encircled. The amazing observation is that the three encircled earthquakes are on the intersection of the Fibonacci Circles and Fibonacci Lines.

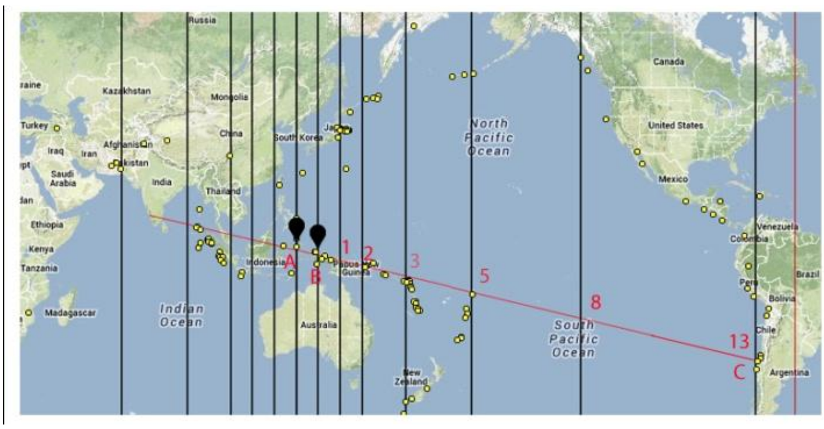

Figure 16: *7R+ earthquakes since 2004, and the intersection of vertical Fibonacci lines and a line segment.*

We have extended the application to include earthquakes on global scale as in Figure 16, which includes the Asian – Pacific Region with the 7R+ earthquakes since 2004. It clearly shows that many earthquake locations are at Fibonacci extensions of some selected seed distances. The figure shows the intersection of a straight line section and vertical Fibonacci lines. Using the distance between two selected (black pins) as seed, the Fibonacci extensions numbered 1,2,3,5,8,13 as shown, extend to earthquakes occurred all the way to the shores of South America! The 'gaps' such as Fibonacci line 8, could be a future earthquake locations.

Figure 17: *7R+ earthquakes since 2004 Fibonacci Series*

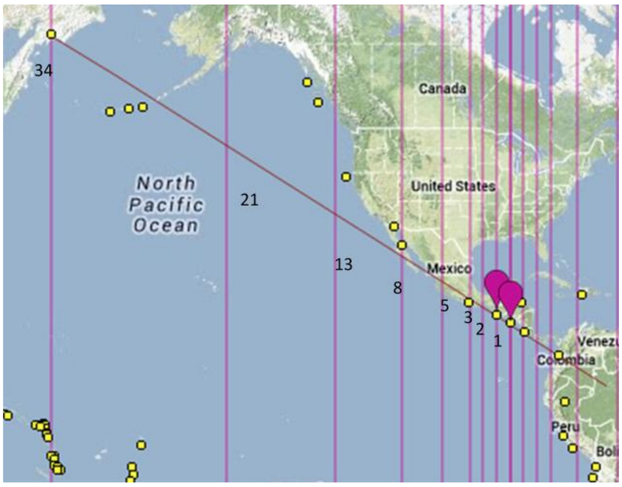

Figure 18: *7R+ earthquakes since 2004 in the Pacific Region.*

Similarly in Figure 17 we display another extreme Fibonacci series extension of an earthquake pair as shown by the pins. The extensions, lines up to 21 are also shown in the figure. The intersection with the chosen straight line section locates other significant level earthquakes. This shows the global scale of this observation, that Fibonacci lines are hidden within the earthquake mechanism not only on a local scale but on a global scale of thousands km. This example spans distances from Alaska to Mozambique.

Using the vertical line tool in a Fibonacci sequence we are examining in Figure 18 another set of 7R+ earthquakes along the coast of Americas . From Columbia, Mexico to Alaska we draw a line as shown and displayed together with a vertical set of Fibonacci Lines with seed as shown with pins in Mexico. We draw the Fibonacci lines to 34 and we see the location of earthquakes and the 'gaps' where we claim it is future earthquake locations.

Figure 19: 6.*5R+ earthquakes since 2004. Geodesic line option*

It is well known that geodesic arc on a map is the shortest path on the earth's surface. The tools developed allow us to have the option of the straight line segments to be geodesics. We can see in

Figure 19, a circle or the shortest path from Greece to South America is displayed as a geodesic curve. Together with the vertical Fibonacci lines shown it is very interesting how many earthquake active regions are located on the intersection of those curves.

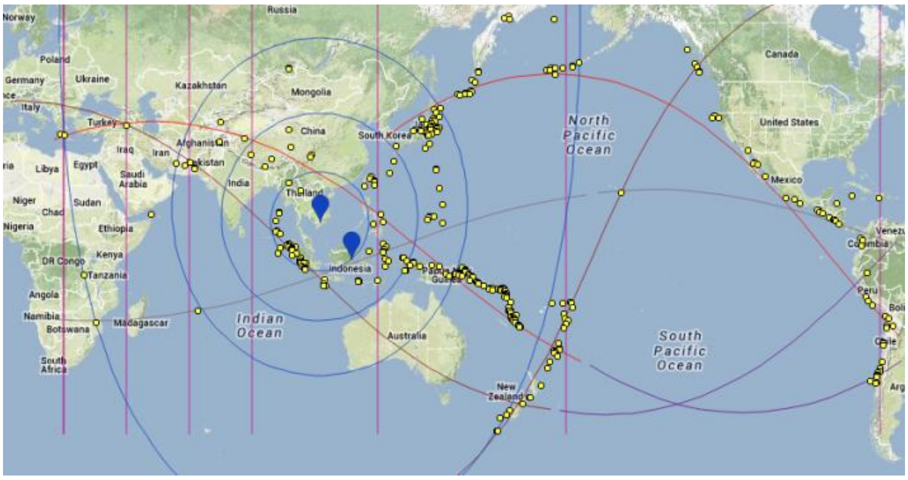

Figure 20: 6*.5R+ earthquakes since 2004. Geodesic lines and circles.*

Figure 20 shows a series of Fibonacci vertical lines and concentric circles projected as geodesic curves as well as straight lines (geodesics) on the plane 2D map. We observe a long series of earthquakes on parts of those curves and the Fibonacci lines.

Fibonacci line clustering as a means of locating future earthquake locations.

The last example of the use of our developed tools is by showing how Fibonacci clustering tends to locate future earthquake spots. We are not trying to explain this phenomenon, but it is well known in other parts of nature, such as the stock market, where price and time Fibonacci line clustering is well known to be a magnet and of high probability of occurrence. In a similar manner we use here the latitude and longitude coordinates of horizontal and vertical lines to create clusters in the 2D space of the map.

In Figure 21 for example we show the Southern Greek space with horizontal and vertical sets of Fibonacci lines.

We will locate the two encircled earthquakes A and B >6R each by the clustering formed by a group of seed earthquakes between Rhodes and Crete as shown in Fig. 21, for the earthquake period of 2002-2008. We draw three vertical Fibonacci sets from the earthquake pins in pink, blue and the other in green, around Karpathos. The selected seeds predict precisely the longitude of A and B. The set of horizontal lines created by the earthquakes via the pins yellow and brown pinpoint the latitude lines of A and B, as can be seen in the figure.

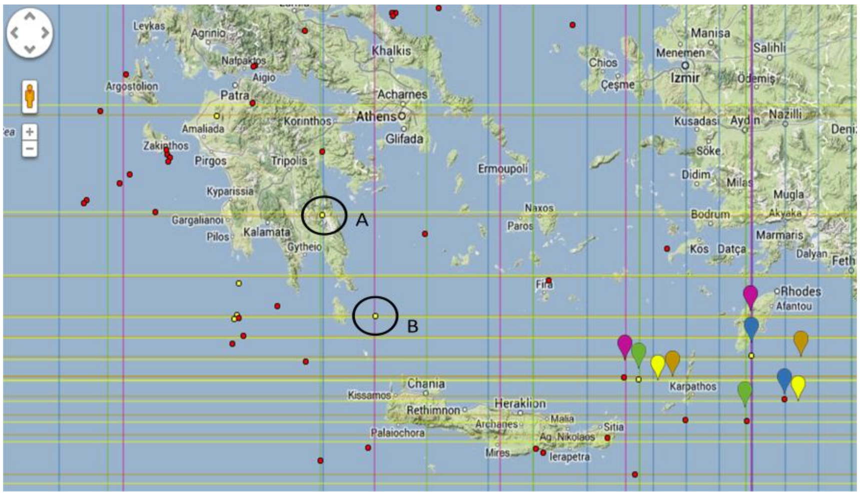

Figure 21: *6.1R and 6.4R location predicted by a horizontal and vertical set of Fibonacci lines forming a cluster on A and B*

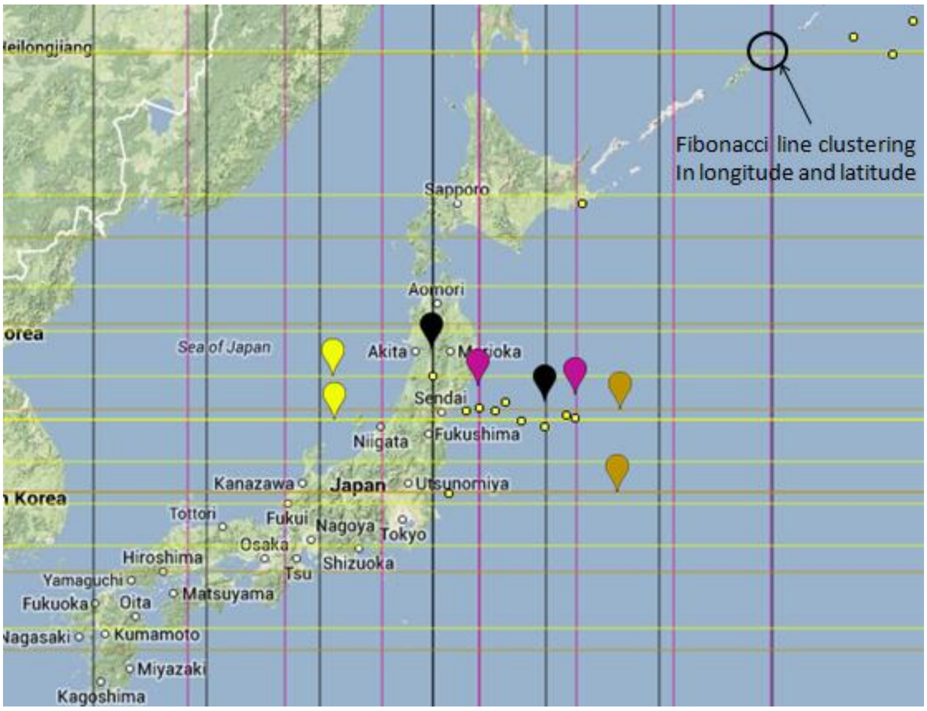

Figure 22: *Region of Japan (2004-2013, 7.0R+) clustering example using Fibonacci horizontal and vertical lines.*

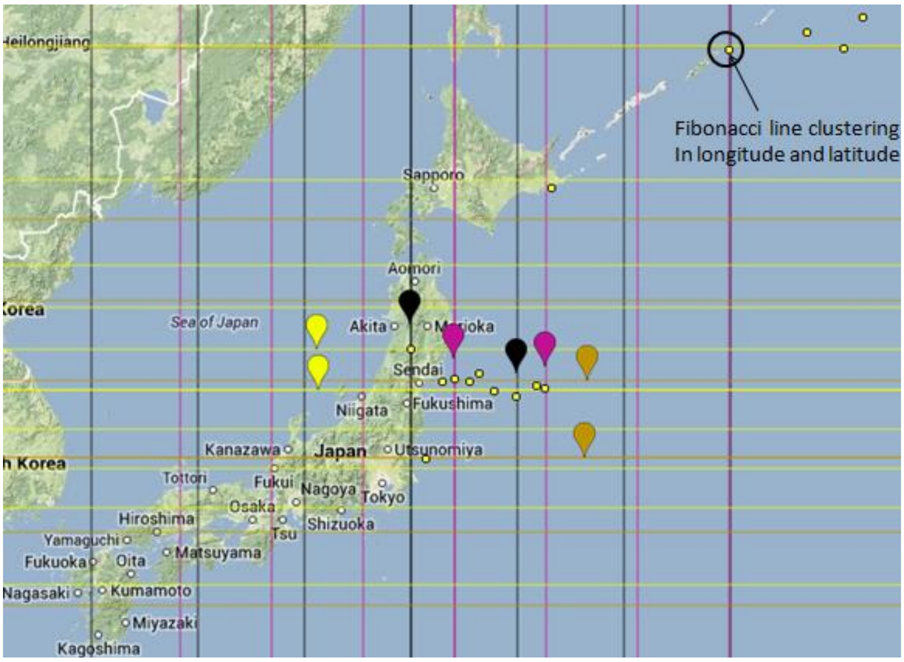

Figure 23: *Region of Japan. 2004-2013, 7.0R+) Fibonacci lines clustering example using Fibonacci horizontal and vertical lines.*

A final example is shown in Figure 22 and 23 of Fibonacci line clustering. We select the region of Japan because of the high earthquake activity of this region and select 7.0R+ earthquakes for our maps. Similarly to the previous examples a set of horizontal and vertical Fibonacci lines are drawn via the selected earthquakes (pins) producing a set of horizontal and vertical line clustering spot as shown at the top right corner of Figure 22, shown encircled. In Figure 23 we show the later occurrence of a cluster predicted earthquake in this particular regional location spot, thus confirming our theory that there is a high probability of occurrence of earthquakes in the future when such clusters occur.

CONCLUSION

We have developed an application using Google Map which displays earthquake data locations and offers graphing of data. It uses PHP and Javascript with a database MySQL and queries in PHP. The result of the queries are displayed in many useful ways on Google Map. A novelties of the application is the use of selective displaying, the use of polylines, and map region segmentation. The results can also be plotted in three different methods, one is cumulatively against time, the other is a histogram of the magnitude of the earthquakes and finally a comparative time periods plot of the magnitude spectrum. New tools are being developed which draw single and multiple lines, horizontal and vertical, as well as single and multiple circles. The programmable distance between the lines allowed us to use Fibonacci distance sequences based on seed distances between earthquake locations. For the first time we have demonstrated the link between spatial location of earthquakes and Fibonacci numbers. We have also shown for the first time, that such Fibonacci line clustering from different seeds indicate possible future earthquake location. The potential of such platform and such tools are clearly demonstrated for earthquake research.

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REFERENCES

Keskebes A, Roussos A, Tselikas N, and Boucouvalas A (2011)
"Seismicity online grid map for regional earthquake activity studies", *Proceedings 15th PCI 2011*, 30 Sep-2 Oct 2011, Kastoria, Greece, pp.321-329.

Keskebes A, Roussos A, Tselikas N and Boucouvalas A. (2011)
"Online seismicity grid map of Greece with subregion multiple seismicity plots" *Proceedings Eureka 2011,* 30 Sep-2 Oct 2011, Kastoria, Greece, (2011)

Sobolev G A, Chelidze T L, Zavyalov A D, Slavina L B and Nicoladze V E (1991)
"Maps of expected earthquakes, based on combination of parameters", *in Tectonophysics,* 193, pp255-265, 1991.

Spassov E, Sinadinovski C and McCue K. (2002)
"Spatial and temporal variation of seismic activity across Australia", *Journal of the Balkan Geophysical Society*, Vol.5, No.4, Nov. 2002, pp.115-122.

Baskoutas I, Papadopoulos G, P., Chingtham G P. (2011),
"Temporal variation of seismic parameters in the western part of the India-Eurasia plate collision zone", *in Research in Geophysics* 2011, vol. 1:e3

Papadopoulos G. Baskoutas I. (2009)
"New tool for the spatio-temporal variation analysis of seismic parameters"'.
Natural Hazards and Earth System Sciences 9,859-864, 2009.

Papadimitriou P (2008)
"Identification of seismic precursors before large earthquakes. Decelerating and accelerating seismic patterns" P. *J. Geophys. Research*, 113, B040306, 2008.

Chouliaras G. (2009)
"Seismicity anomalies prior to 8th June 2008, M=6.4 earthquake in Western Greece", *Natural Hazards and Earth System Sciences* 9,327-335,2009

Wiemer S. (2001)
"A software package to analyse seismicity: ZMAP", *Siesmological Research Letters*, Vol 72, Number 2, March/April 2001, pp.374-383

European Mediterranean Seismological Centre, (EMSC) http://www.emsc-csem.org/