

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

Predicting New Zealand Earthquakes
Using the 'M8' Algorithm

A Thesis presented

in partial fulfilment of the requirements

for the Degree of

Master of Applied Statistics

at Massey University

Palmerston North, New Zealand

Maaïke Jane Vreede

December 1999

Abstract

The M8 algorithm uses seven time series to issue intermediate term earthquake predictions, stipulating which areas have an increased probability of a strong earthquake in the next five years. The series measure the frequency of earthquakes, change in frequency, energy release, and numbers of aftershocks. If six out of seven series (including series 7) cross the thresholds specified a 'Time of Increased Probability' is declared. This thesis takes the series as given and examines the role of each series. It also explores using alternative ways of summarising the predictive information in the series, using linear combinations of them rather than considering the number of series which cross certain thresholds.

It was found that the maxima of the series, rather than linear combinations of them, are related to future earthquakes. It was also found that the series have no predictive power unless they are all considered. Both of these findings are consistent with M8s own treatment of its series. The models using the M8 series that were constructed here can not be generalised to data they were not constructed with, so they cannot be used as a prediction tool. However, because of the scarcity of large earthquakes, earthquakes targeted for prediction have magnitudes less than the magnitudes that M8 is intended to predict. When data is available with enough target magnitudes that the algorithm is designed to predict the algorithm may yet be proven to be a successful tool for intermediate term earthquake prediction.

Acknowledgments

My thanks go to Greg Arnold, my long-suffering supervisor. He was always ready to do battle with red tape on my behalf, and he kept my thesis from straying down the wrong track. He has always been willing to give help, above and beyond the call of duty, and he helped me to keep things in perspective. Whenever my sanity was endangered, he was always on hand for a medicinal cup of coffee.

I wish to thank David Harte for taking the time to teach me about the curious phenomenon of earthquakes. His discussions with me were always interesting. I also thank him for giving me valuable tuition with the S+ programming language.

David Vere-Jones provided me with many ideas. His enthusiasm was infectious, and I was encouraged by his perseverance with difficult problems.

Mark Bebbington started me off on earthquake research. By his making certain that I got to meet the right people, I started off on the right footing.

Contents

Title page	i
Abstract	ii
Acknowledgments	iii
Chapter 1 ~ Introduction	1
Chapter 2 ~ Measuring earthquakes	3
2.1 Introduction.....	3
2.2 Earthquake forces	3
2.3 History of earthquake prediction	9
2.4 Seismographs.....	12
2.5 Finding the geographical origin of earthquakes	13
2.6 The Earth's structure and seismic readings	14
2.7 Measures of earthquake size.....	16
2.8 Quality of seismic data	16
2.9 Conclusion.....	17
Chapter 3 ~ The M8 algorithm: development, testing and additions	18
3.1 Introduction.....	18
3.2 The beginnings of M8.....	18
3.3 The forerunner of M8	20
3.4 The emergence of the M8 algorithm	21
3.5 Case studies of M8 applied to different regions	23
3.6 The Menocino scenario algorithm.....	24
3.7 Using active zone size instead of the number of earthquakes	26
3.8 Conclusion.....	27
Chapter 4 ~ The Working of the M8 Algorithm	28
4.1 Introduction.....	28
4.2 Preparing data for the M8 algorithm	28
4.3 A Flow Chart of the Procedure Used by the Algorithm	30
4.4 The algorithm in more detail	34
4.4.1 Arguments passed to the M8 function	34
4.4.2 What the algorithm produces	37
4.4.3 The procedure used by the algorithm.....	39
4.5 Conclusion	43
Chapter 5 ~ Issues arising when applying M8 to New Zealand data	44
5.1 Introduction.....	44
5.2 Earthquake depth	44
5.2.1 The problem of predicting depth.....	44
5.2.2 Concerns regarding data dredging	45
5.2.3 Justification for using earthquakes of all depths.....	45
5.3 Analysis of New Zealand data.....	47
5.3.1 Analysis in which predictions aimed at magnitude 7 earthquakes	47

5.3.2	Predictions targeted at magnitude 6.5 earthquakes.....	55
5.3.2.1	Positioning of circles for magnitude 6.5	56
5.3.2.2	The results of setting the magnitude targeted for prediction to 6.5	58
5.3.2.3	Differences in type I error between predictions for magnitude 6.5 and magnitude 7.....	61
5.4	The stability of M8 predictions with regard to circle position	63
5.4.1	Testing the stability of M8 when the circle of investigation is moved slightly.....	63
5.4.2	Discussion of the results	66
5.5	Conclusions	70
Chapter 6	~ Exploratory analysis using principal components	71
6.1	Introduction.....	71
6.2	Three-dimensional spin plots.....	71
6.3	'Snaky lines' in seismically active circles	73
6.4	Form of the principal components	74
6.5	Conclusion	79
Chapter 7	~ Linear models using modified M8 series	80
7.1	Introduction.....	80
7.2	Data.....	81
7.2.1	Response variables and modifications to the M8 and TIP level series.....	81
7.2.2	Choice of circle size.....	82
7.2.3	Standardisation of series within circle of investigation	83
7.3	General summary of models.....	85
7.4	Canonical correlation analysis.....	87
7.4.1	Canonical correlation analysis using the seven M8 series.....	87
7.4.2	Canonical correlation analysis with the TIP level series	88
7.5	Models using series 1 to 7 of M8.....	88
7.5.1	Regression models using series 1 to 7 of M8	88
7.5.2	Logistic regression using the seven M8 series.....	96
7.6	Models with the TIP level series	99
7.6.1	A regression model with the TIP level series	99
7.6.2	A logistic model for the probability of an earthquake with the TIP level series.....	105
7.7	Conclusion	109
Chapter 8	~ Conclusion	110
References	113
Appendix	~ The M8 Algorithm	116