Testing the Precursory Seismic Quiescence Hypothesis

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Abstract: Precursory seismic quiescence (PSQ) has been investigated in numerous studies in the past; nevertheless it is not widely accepted in the seismological community. We believe that in order to make progress we need to move from retrospective testing to prospective testing, using well defined and community accepted testing approaches. As a first step, we are currently re-investigating selected cases studies of PSQ (e.g., Landers, Big Bear, Adak, Utah, and Nisqually), using an improved quiescence mapping approach as well as re-located earthquake catalogs when available. From these case studies we will derive a model to forecast seismicity for the next 24 hours for selected regions, to be implemented as a prospective test in the upcoming collaboratory for the study of predictability activities.

1. Introduction

Earthquake rates and earthquake size distribution are sensitive to stress and strain build-up in the Earth’s crust. The occurrence patterns of micro-earthquakes, therefore, might contain information on upcoming large events. One of the patterns that have been consistently reported as precursors is seismic quiescence in the months to years before a mainshock.

Precursory seismic quiescence (PSQ) is generally defined as a significant decrease in the rate of micro earthquakes in the months to years preceding a mainshock. PSQ has been investigated in more than 70 publications in the past 25 years; nevertheless it is not widely accepted in the seismological community. Many case studies has been carried out using data analysis in a retrospective sense by different methods as calculating the z-values, using the AS(t) function (Habermann 1983), AS(t) function (Habermann 1987), AS(t) function (Habermann 1991), LTA(t) function (Habermann 1988; Habermann 1991), β-values (Reasenberg and Matthews 1988), or the RTL-algorithm (Sobolev 2003). Two examples of PSQ are shown in Figure 1.

Figure 1 Two example of precursory seismic quiescence observed prior to a M5.3 mainshock in Utah (Arabasz and Wyss 1996) (left) and the 1986 M8.0 Adak (Alaska) mainshock (Kisslinger 1986; Kisslinger and Kindel 1994; Wyss and Wiemer 1999). Plotted is the cumulative number of small earthquakes as a function of time near the hypocenter area.

Increased computational power allows the application of processor expensive methods such as Monte Carlo simulations to scan the six-dimensional parameter space (x, y, z, window length, time, sample size) and determine the probability of the solution. This and the fact data quality and availability have dramatically improved and so have the analysis techniques for data mining makes us believe that we can make significant progress in the systematic evaluation of the PSQ hypothesis. Within our anticipated test areas (Japan, California, Utah, Alaska, and Switzerland) more than 300'000 micro earthquakes are
reported annually.

2. Case study: Systematic investigation of the parameter space

To improve our understanding of the dependency of the rate change value as a function of the six-dimensional parameter space (x, y, z, time, duration, and sampling area), we first conduct a case study for the anomalies preceding the 2001 Feb. 28, M6.8 Nisqually earthquake in the subducting slab of the Pacific Plate. We have calculated the rate changes with different definitions of the z-value (AS-, LTA-, Rubberband-Method and percent change) and β-values as a function of window length and sampling area and have translated them to probability with respect to uniform distribution. While the choice of the way we calculate the z-value is not a critical issue, the choice of the window length and the size of sampling area was much more critical.

One of the critical issues dealing with seismic rate changes is declustering. Declustering – or the modeling of clustered seismicity - is generally needed in some form or another in order to be able to deal with the fact that a large fraction of seismicity stems from dependent events. This process, however, is non-unique, since no unique definition of an aftershocks or clustered seismicity in general exists. We strive to incorporate this uncertainty by applying a Monte Carlo simulation that covers a realistic parameter space as input of declustering using the method of Reasenberg (Reasenberg 1985).

3. Parameter Search and Testing

We will test the forecasting ability of PSQ that is based on a fully prospective sense. In our test, PSQ, we will map out the occurrence of quiescence in a six-dimensional parameter space volume (x, y, z, time, duration, sampling area), following the approaches outlined by (Wiemer and Wyss 1994), (Dieterich and Okubo 1996), (Joswig 2001), (Ogata 2001), and (Wyss, Hasegawa et al. 1999)). The significance of each rate decay is estimated using a Monte Carlo type simulation over the parameter space Figure 2. An illustration of our method for the Landers/Big Bear is shown in Figure 3, 4, and 5.

Once we have re-evaluated several case studies of PSQ using our new mapping approach in multi-dimensional space, we plan to derive a quantitative forecast model, a
time-dependent model that forecasts the seismicity rates for the next 24 hours based on the recent seismicity. This model will be build on top of the STEP model (Gerstenberger, Wiemer et al. 2005) where the clustered seismicity forecast of STEP is modulated based on the observation of PSQ. We will thus also be able to systematically test for precursory quiescence before larger aftershocks (REFS).

To test the performance of our model, we will integrate our model into the RELM (Regional Earthquake Likelihood Model) testing initiative (Schorlemmer, Gerstenberger et al. 2005) of SCEC and the future collaboratory on the study of earthquake predictability, CSEP. Forecast models will be created for several regions with good network coverage and an established history of PSQ: Alaska, California, Japan, Utah, Greece, and Switzerland.

4. Outlook

Our goal is to complete within a time frame of 2 years a re-evaluation of the PSQ hypothesis and the implementation of prospective test for selected regions. We believe that within about 5 years we would thus be able to report first result of the prospective testing.

6. References


