Realistic predictions: are they worthwhile?

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It is certainly possible to define the reliable prediction of individual earthquakes so narrowly that success is impossible. For instance, in Main's level 4 he refers to predictions with such precision and accuracy that a planned evacuation can take place. None of the contributors have yet to suggest that this is a possibility and I agree with Wyss that using this straw man as the standard will not lead to a useful debate. However, Main's levels 2 and 3 may lead to socially useful tools regardless of whether we call them predictions or probabilistic forecasts.

As Main's extremely accurate short-term predictions are impossible, the public should neither expect to be saved from calamity by such predictions nor support research based on this expectation. However, further research into earthquake prediction may well bring real social benefits even if they are less spectacular than the vision of huge populations in mass exodus.

As discussed by Richard Andrews[1], head of the California Office of Emergency Services, earthquakes are the one natural disaster that currently allows for no advance warning. Storms approach, fires grow, floods migrate after large rainfalls, but earthquakes can turn a perfectly normal day into a disaster in seconds. So, if we can make low probability forecasts, short term (such as those currently based on foreshock and aftershock models) what can society do with them?

Raising awareness

There are a number of low cost actions that can have large payoffs if a damaging earthquake occurs. Often earthquake preparedness plans are not maintained as real world pressures focus attention onto other problems. Low probability warnings can serve as reminders, like fire-drills, to update plans and review the state of preparedness. For instance, childcare facilities might check their first aid supplies and review the parents' emergency contact numbers. Companies might service their emergency generators.

Such actions can be very valuable, even if the predicted event comes later than expected[2]. Many hospitals now store medical supplies offsite in order to make more efficient use of their main buildings. However, this can create problems if an earthquake simultaneously causes casualties and cuts off transportation to the storage areas. Under a low probability warning, additional supplies can be moved to the hospital at little cost. Some unusual industrial processes, such as handling nuclear fuel rods, may be more difficult during an earthquake and can be put off until a time of lower risk.

Low probability warnings also have an advantage over the high probability, deterministic, predictions that Main gave as one end result. One frequent concern about earthquake prediction is the cost of false alarms. Extreme actions like evacuations and shutting down businesses have great economic and social costs and thus false alarms are very troubling. In contrast, low probability forecasts temporarily focus public attention on reasonable preparedness activities and have not caused problems when carefully carried out in California. The warnings issued by the California state government include recommendations for specific actions, giving the public a method of dealing with the advisories without causing problems.

A need to know

Improvements in these low probability predictions might come from a continued search for precursors. Geller[3] suggests that this search has been vigorous but, at least in the US, the large networks of diverse instrumentation dreamed of during the optimism of the 1960s[4] was never realized. The result is that we have few records of the strain and electromagnetic fields very close to earthquake ruptures. Current strain records suggest that strain records can not observe the earthquake source preparation process from outside the rupture zone[5] but without data from within the rupture zone it is difficult to say that no precursors will be found.

Even knowing that earthquake prediction is impossible would be useful. Amateur scientists will continue to predict earthquakes and without swift, knowledgeable response from the scientific community these predictions will do more harm than good[6].

Proving that earthquakes are truly unpredictable will help us deal with the problems posed by less scientific approaches. However, our current understanding of earthquake physics can not prove this point. For instance, the majority of contributions to this debate have discussed self-organizing criticality models but there is no agreement on what they imply for earthquake prediction or if they are a good explanation for earthquakes (see contributions from Per Bak, David Bowman & Charles Sammis, and Chris Scholz).

Testing studies

As highlighted by Geller and Wyss an important concern is the quality of earthquake prediction research. As Geller points out, we must be more careful to separate hypothesis development from hypothesis testing. Earthquake prediction research is dominated by case studies which are good for hypothesis development, but we often lack the global studies that are necessary for hypothesis tests. As also noted by Geller, Wyss cites that some earthquakes are preceded by increased seismicity, some by quiesence, and some by neither. Viewed as case studies this has lead to the development of both activiation and quiesence precursors. But, viewed as a global hypothesis test, this assortment of differing observations suggests completely random behaviour[7].

Unless we can separate out when to expect each behaviour *a priori*, such precursors are useless. A similar problem currently exists with those proposing that earthquakes can be predicted with 'time to failure analysis', a version of the activation hypothesis with its roots in material science. While many case studies have been presented, these are all hypothesis development. We now need a good hypothesis test but such studies are unfortunately rare. Thus we need some way to encourage more researchers to undertake these critical tests.

Certainly, earthquake prediction is extremely difficult, but it is possible that we will be able to improve our ability to make low-probability, short-term forecasts and these may be much better for society than the high probability ones that are most likely impossible. The trick will be to improve the quality of both the data collected, particularly in the near-source region, and the work done with it.

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