CSEP participation, including the Canterbury experiment, testing of non-Poisson models, and effects of catalogue deficiencies

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Investigators: David Rhoades, Matt Gerstenberger, Annemarie Christophersen and David Harte (GNS Science, New Zealand)

SCEC Science Priorities: 2b
SCEC Groups: Collaboratory for the Study of Earthquake Predictability (CSEP)
Earthquake Forecasting and Predictability (EFP)

Abstract

The award was for travel to the SCEC annual meeting only. Our associated activities included four main objectives (1) To collaborate with the CSEP team in conducting and analyzing an experiment to retrospectively test forecasting models based on Coulomb stress calculations using data from the Canterbury earthquake sequence in the New Zealand CSEP testing center, and to subsequently test the models prospectively on future New Zealand earthquakes. (2) To implement a pilot experiment for non-Poisson testing of one-day models in the New Zealand Earthquake Forecast Testing Centre. At the request of the CSEP working group, we agreed to shift this experiment to the California testing center and provided a non-Poisson ETAS model as a test case. (3) To undertake a retrospective experiment in the New Zealand testing center to evaluate the effect of deficient catalogs on forecasting models. (4) To participate in international CSEP activities, including the design of future experiments, promotion of hybrid modeling capability within CSEP, and preparation of new models for testing in the CSEP framework. Matt Gerstenberger, David Rhoades and Annemarie Christophersen attended the 2016 SCEC Annual Meeting. David Rhoades visited Masha Liukis at USC for two days after the meeting to collaborate on installation of non-Poisson testing software in the CSEP system.

Research Highlight

The Poisson assumption underlying the standard CSEP tests of consistency is inconsistent with short-term clustering models and with catalog data. We used data from the Canterbury earthquake sequence to trial non-Poisson tests of model consistency, which can be applied when the model generates its own simulated catalogs. The Canterbury earthquake sequence has provided a series of near real time earthquake catalogs that show the deficiency of real-time data. We are interested in the effect of the deficient real-time data on earthquake forecasts. We calculated forecasts from short-term clustering models using the preliminary and final catalog data with durations varying from 1 –365 days. We applied a number of non-Poisson consistency tests to evaluate the effect of the changing input data on the model forecasts. The tests include: An NSIM (Number) test based on simulated catalogs, the TERD (Target Earthquake Rate Distribution) test and the TERF (Target Earthquake Rate Family of K-S statistics) test. The TERD test compares the distribution of spatial cell rates for target earthquakes with the combined empirical distribution based on all simulated catalogs. A variation of this test, which can be applied to a standard CSEP-type grid forecast, compares the distribution for target earthquakes with the theoretical distribution based on the cell rates. Statistical significance is assessed using the Kolmogorov-Smirnov (K-S) test for the maximum distance between two cumulative probability distribution functions. The TERF test compares the K-S statistic of the TERD test with the family of K-S statistics derived from the cell rate distributions of each simulated catalog compared with the combined distribution based on all simulated catalogs. Statistical significance is measured by a one-sided test based on variation of the family of simulated K-S statistics. Analogous tests were also applied to the distributions of inter-event times and inter-event distances of successive earthquakes in the catalogs. These tests use only synthetic and real earthquake catalogs and do not require a standard grid forecast. The TERD test is being implemented in the CSEP system software.

The tests show that the M6.3 Christchurch earthquake and its subsequent aftershocks of 22/2/2011 were not consistent with the forecasts of short-term forecasting models calculated just before the Christchurch earthquake. However, the subsequent aftershock activity following the Christchurch earthquake was mostly consistent with the models. These conclusions are unaffected by deficiencies in the preliminary catalogue.

Exemplary Figure

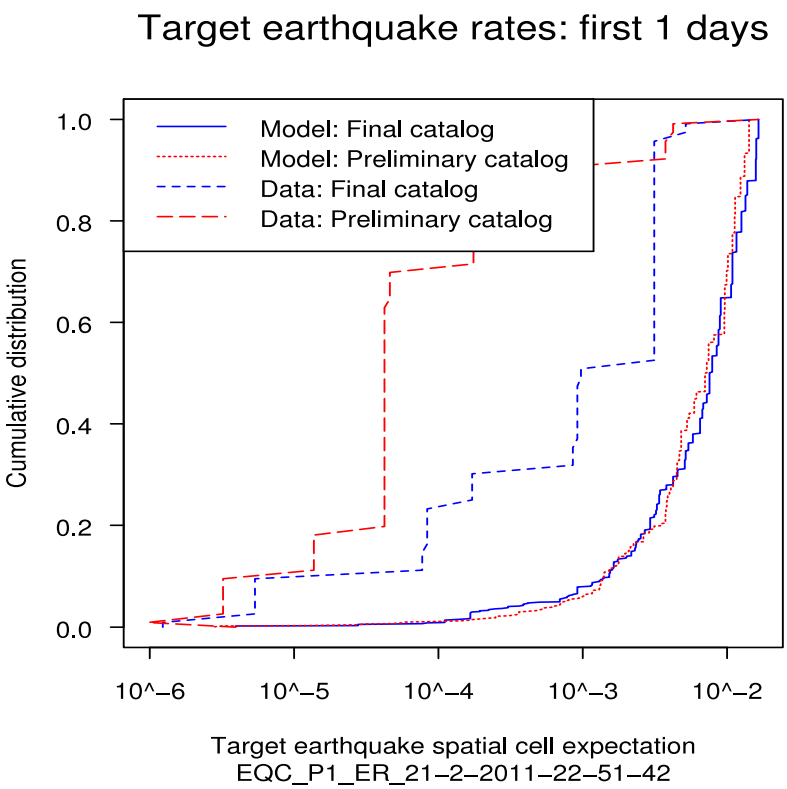

Figure 1. Example of a non-Poisson test of CSEP-style grid forecasts with accompanying simulated catalogs. TERD (Target earthquake rate distribution) test for 24-hour ETAS model forecasts beginning one hour before the Christchurch M6.3 earthquake of 22 Feb 2016. The test is calculated using a preliminary catalog and the final catalog. A Kolmogorov-Smirnov (KS) test compares the distribution of cell rates for target earthquakes expected by the model (calculated from the combination of 5000 simulated catalogs) with the distribution calculated from the actual catalog data. There were 33 target earthquakes in the preliminary catalog and 52 in the final catalog. Preliminary catalog data: KS = 0.87, $p=10^{-7}$; final catalog data: KS = 0.74, $p=2\times10^{-6}$. The low p-values indicate that the model is inconsistent with both the preliminary and final catalogs. The similarity of the distributions calculated from the simulated catalogs shows that the forecast for this 24-hour period was not much affected by catalog deficiencies.

Intellectual Merit

The activities in this project are directly relevant to the SCEC objectives for earthquake forecasting and predictability and development of the CSEP project, including the development of improved forecasting models and testing methods, and the use of hybrid methods to improve forecasting. Our activities are not solely focused on New Zealand, but rather on the general problems of earthquake forecasting and the common international CSEP methodology. Therefore, there are substantial benefits for California resulting from our work.

Broader Impacts

The collaborative CSEP project is making major advances to the development and testing of earthquake forecasting models on all time scales. Our contributions are a significant component of the overall international collaboration, from which all parties derive mutual benefits. The Canterbury earthquakes have provided a useful data set on which to retrospectively test a range of models, which can subsequently be applied more generally in California and other regional testing centers.

Presentations and Publications

The following presentations were made at the SCEC 2016 annual meeting.

M. Gerstenberger, D. Rhoades, G. McVerry, D. Harte, A. Christophersen. *Blurring the boundary between earthquake forecasting and seismic hazard*. *Talk 9/13 14:30*, EFP.

M. Liukis, M. Werner, D. Schorlemmer, J. Yu, P. Maechling, D. Jackson, D. Rhoades, J. Zechar, W. Marzocchi, T. Jordan, the CSEP Working Group. *Recent Achievements of the Collaboratory for the Study of Earthquake Predictability* Poster 315, CSEP.

A. Christophersen, D. Rhoades, D. Harte, M. Gerstenberger. *Testing the effect of deficient real-time earthquake catalogs on non-Poissonian earthquake likelihood models: Examples from the Canterbury earthquake sequence* Poster 308, EFP.

D. Rhoades, A. Christophersen, M. Gerstenberger. *Earthquake likelihood models for New Zealand combining information on strain rates, earthquakes and faults*. Poster 304, EFP.

M. Werner, M. Liukis, W. Marzocchi, D. Rhoades, M. Taroni, J. Zechar, T. Jordan. *CSEP Evaluations of 24-Hour Earthquake Forecasting Models for California: New Results and Ensemble Models*. Poster 314, CSEP.

C. Holden, C. Williams, D. Rhoades *Dynamic stress triggering in the 2010-2011 Canterbury earthquake sequence*. Poster 195, Seismology.