CORSSA: Community Online Resource for Statistical Seismicity Analysis

Jeremy Douglas Zechar\textsuperscript{a}

with J. Hardebeck\textsuperscript{b}, A. Michael\textsuperscript{b}, M. Naylor\textsuperscript{c},
S. Steacy\textsuperscript{d}, S. Wiemer\textsuperscript{a}, and J. Zhuang\textsuperscript{e}, and
the CORSSA Community

\textsuperscript{a) ETH Zurich, SWITZERLAND}
\textsuperscript{b) USGS Menlo Park, USA}
\textsuperscript{c) University of Edinburgh, SCOTLAND}
\textsuperscript{d) University of Ulster, NORTHERN IRELAND}
\textsuperscript{e) Institute of Statistical Mathematics, JAPAN}
Results from the Regional Earthquake Likelihood Models experiment

Jeremy Douglas Zechar\textsuperscript{a}

with Danijel Schorlemmer\textsuperscript{b}, Max Werner\textsuperscript{c}, Matt Gerstenberger\textsuperscript{d}, David Rhoades\textsuperscript{d}, and many others

\textsuperscript{a) ETH Zurich, Zurich, Switzerland}
\textsuperscript{b) GFZ, Potsdam, Germany}
\textsuperscript{c) Princeton University, Princeton, NJ, USA}
\textsuperscript{d) GNS Science, Lower Hutt, New Zealand}
Regional Earthquake Likelihood Models (RELM) experiment in California

- Objective: forecast rate of $M_{\text{ANSS}} \geq 4.95$ eqks in California for the following five years
- Seventeen 5-year forecasts
  - 12 mainshock forecasts
  - 5 mainshock+aftershock forecasts
- Forecasts are specified as number of expected eqks in lat/lon/mag bins (0.1° x 0.1° x 0.1).
- Forecasts evaluated for consistency with observations using likelihood tests.

Schorlemmer & Gerstenberger, 2007
(For details, see 2007 special issue of Seismological Research Letters)

MAINSHOCK MODELS
Ebel

- Decluster 1932-2004 catalog
- Determine average 5 yr rate of M5+ events in 0.3°x0.3° cells
- Use Gutenberg-Richter relation to extrapolate
- Power-law smoothing of M2+ events
  - Bandwidth is density-dependent and optimized

- Account for spatially-varying $M_c$
Holliday

- Search for recent changes in seismicity of each cell relative to long-term behavior
  - Activation and quiescence

- One variant of the **Pattern Informatics** method
• Smooths large events in southern California since 1800

• Includes spatial anisotropy, extending the event along the presumed fault
Shen

- Uses **GPS data**
- Assumes seismicity rate is proportional to horizontal maximum shear strain rate
- Uses tapered Gutenberg-Richter relation for extrapolation
Ward’s geodetic forecast

- Uses **larger GPS dataset**
- Slight variation on mapping strain rate to seismicity rate
- Assumes maximum magnitude $M_{\text{max}} = 8.1$
Ward’s geodetic forecast

- Same as previous, except assuming $M_{\text{max}} = 8.5$
Ward’s geologic model

- Uses **geologic data**

- Maps slip rates to smoothed moment rate density, then to seismicity rate
Ward’s seismic forecast

- **Smoothed** large events since 1850
Ward’s simulation forecast

- Derived from “physics-based” simulations of velocity-weakening friction on a prescribed fault network

- One variant of the **ALLCAL eqk simulator**
Ward’s combination

- **Average** of Ward’s forecasts
Estimates Gutenberg-Richter $a$- and $b$-values in every cell

Variations in these parameters are assumed to indicate presence of asperities
A Prospective Earthquake Forecast Experiment In The Western Pacific

David Eberhard, J. Douglas Zechar and Stefan Wiemer

SED ETH Zurich
Test Region: NW & SW Pacific

- Global CMT catalog, 2009
- One year period
- Centroid Location & Mw
- Mw>5.8 & Depth<70km
- „Undeclustered“ catalog
- Two study regions
  - NW: 32 Eq for 2009
  - SW: 63 Eq for 2009
Method: Error Estimation

- Location uncertainty: $\sigma_x = \sigma_y = 30\text{km}$ (M. Nettles personal communication)
- Moment uncertainty: $\sigma_{M0} = 0.2 \times M_0$ (M. Nettles personal communication)
- 1000 perturbed catalogs were used
## Consistency results

<table>
<thead>
<tr>
<th>Model</th>
<th>N-test</th>
<th>L-test</th>
<th>S-test</th>
<th>M-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ebel</td>
<td>✔</td>
<td>✗</td>
<td>✗</td>
<td>✔</td>
</tr>
<tr>
<td>Helmstetter</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Holliday</td>
<td>✗ (high)</td>
<td>✔</td>
<td>✗</td>
<td>✔</td>
</tr>
<tr>
<td>Kagan</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Shen</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Ward Combo</td>
<td>✗ (high)</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Ward Geodetic 8.1</td>
<td>✗ (high)</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Ward Geodetic 8.5</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Ward Geologic</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Ward Seismic</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Ward Simulation</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Wiemer</td>
<td>✔</td>
<td>✔</td>
<td>✗</td>
<td>✔</td>
</tr>
</tbody>
</table>

95% confidence
## Comparison results

<table>
<thead>
<tr>
<th></th>
<th>jee</th>
<th>hkj</th>
<th>jrh</th>
<th>yyk</th>
<th>she</th>
<th>com</th>
<th>d81</th>
<th>d85</th>
<th>geo</th>
<th>sei</th>
<th>sim</th>
<th>alm</th>
</tr>
</thead>
<tbody>
<tr>
<td>jee</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>hkj</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>jrh</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>yyk</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>she</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>com</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>d81</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>d85</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>geo</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>sei</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>sim</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>alm</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Arrow points to the “winner,” colored arrows indicate statistical significance (95% confidence)
Conclusions & Outlook

- Most forecasts are consistent with observations, but some forecasts are better than others. Helmstetter et al. smoothed seismicity seems to be the best.

- We are conducting a comprehensive analysis of these results, with an emphasis on stability and uncertainties.