Completeness of Southwest Pacific Earthquake Catalog to M4.5:

A Scoping Study

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The rerun of the USGS/NSHMP American Samoa PSHA in late July 2012 assumed that the earthquake shallow-source catalogs that were available to us to compute the activity grids were complete to M5 after 1963 and to M4.5 after 1994. We had grouped all hypocenters having depth < 50 km into the shallow-source catalog. Here we perform a preliminary analysis to study the validity of the second completeness assumption. In the analysis of M4.5 completeness, we grouped shallow seismicity into 2˚ by 2˚ cells over the entire study area, which includes New Hebrides and Tonga trench regions and various islands. In each cell, we counted the rate of M>=4.5 sources after 1995 and M>=5 sources after 1963 and before 2011 from a "cleaned" catalog with dependent events omitted. The time spans for these two subsets of the data were 16 years and 47 years, respectively. If we assume that the expected number of M5 and greater earthquakes after 1963 is E[A], then the expected number of M4.5 and greater after 1994 is

$$E[B] = E[A]\cdot 16/47\cdot 10^{[-b(4.5-5.0)]}. \qquad (1)$$

This estimate assumes a Gutenberg-Richter (magnitude,frequency) distribution; more robust (distribution-free) methods have been proposed by Schorlemmer et al. (2006). If *b*=1, the ratio E[B]/E[A] is 1.08; if *b*=0.8, then E[B] /E[A] is 0.855. For simplicity assume *b*=1 everywhere in the study area (a few subregions may have slightly different b estimates). In the next two figures we plot the observed rate of M4.5, B, divided by the expected rate, based on the above estimate, E[B]. For this analysis we assume A=E[A]. The ratio R(*i*)=B(*i*)/E[B(*i*)] is plotted as a circle with radius proportional to R(*i*), where *i* is a cell-location index. A unit circle means the observed and expected rates are the same. A unit circle is labeled on these figures (this labeled point is a datum as well, not just a legend). An upper circle-size limit was also imposed.

Figure 1 shows the set of circles, one per cell, with no circle if no M4.5+ sources are observed in cell *I* during the period 1995 to 2010. For example, cells that are considerably east of the Tonga-Kermedec trench and considerably south of American Samoa tend to be devoid of M4.5+ sources, due undoubtedly to a lack of seismic stations in the vicinity as well as the brief time span. Figure 1 also shows our final model of agrid (M0 activity rate in 0.1 by 0.1˚ cells) for the general background source zone. Note in fig.1 that the region around American Samoa exhibits circles with radius>1, indicating that the observed rate of M4.5 or greater is larger than that which would be predicted by the rate of M5 or greater after 1963 in those cells. One could interpret this apparent surfeit in several ways (temporal fluctuations, other random effects), but the main conclusion is that we are observing "enough" M4.5 or greater to justify using this branch with considerable, even full, weight in the logic tree branches associated with background sources in the vicinity of American Samoa.

Figure 2 is similar to fig. 1, except that the colored agrid corresponds to the M0 activity rate in the greater Fiji zone. The same circles are shown as in fig. 1. Again, in most or all of the cells in the vicinity of Fiji, the rate of M4.5 and greater appears to at least equal the rate predicted by considering M5 and above. That is, most of the circles near Fiji have unity radius or greater. Again, we are observing "enough" M4.5 or greater in the vicinity of this island chain to justify using this activity-rate branch with considerable, even full, weight in the logic tree for Fiji shallow-source hazard. We had previously concluded that for more important parts of the study area, the observed rate of M5 and greater after 1964 was complete. However, in some sub-regions, the observed rate could be lower than the true rate, violating the assumption of completeness of this portion of the catalog. The NEIC does not claim an M5 threshold in the South Pacific Ocean region for the 1964 to 2010 period (Paul Earle, NEIC, oral commun.).

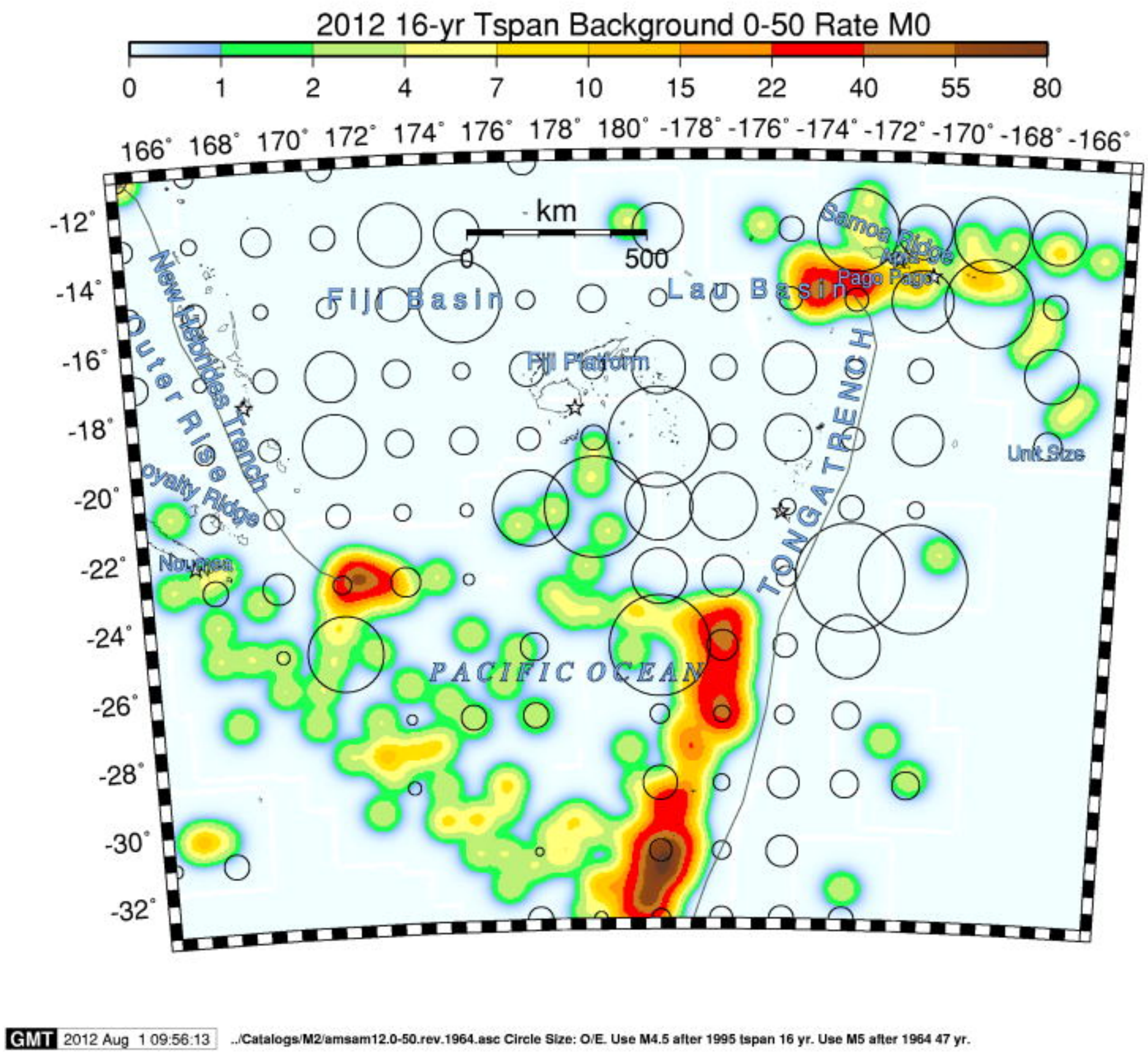

Figure 1. Indicator map for completeness of M4.5 catalog. Circles represent observed/expected rate of M4.5 or greater for the period 1995 to 2010. The radius is proportional to the ratio. Background agrid is also plotted. Expected rates are defined in the text.

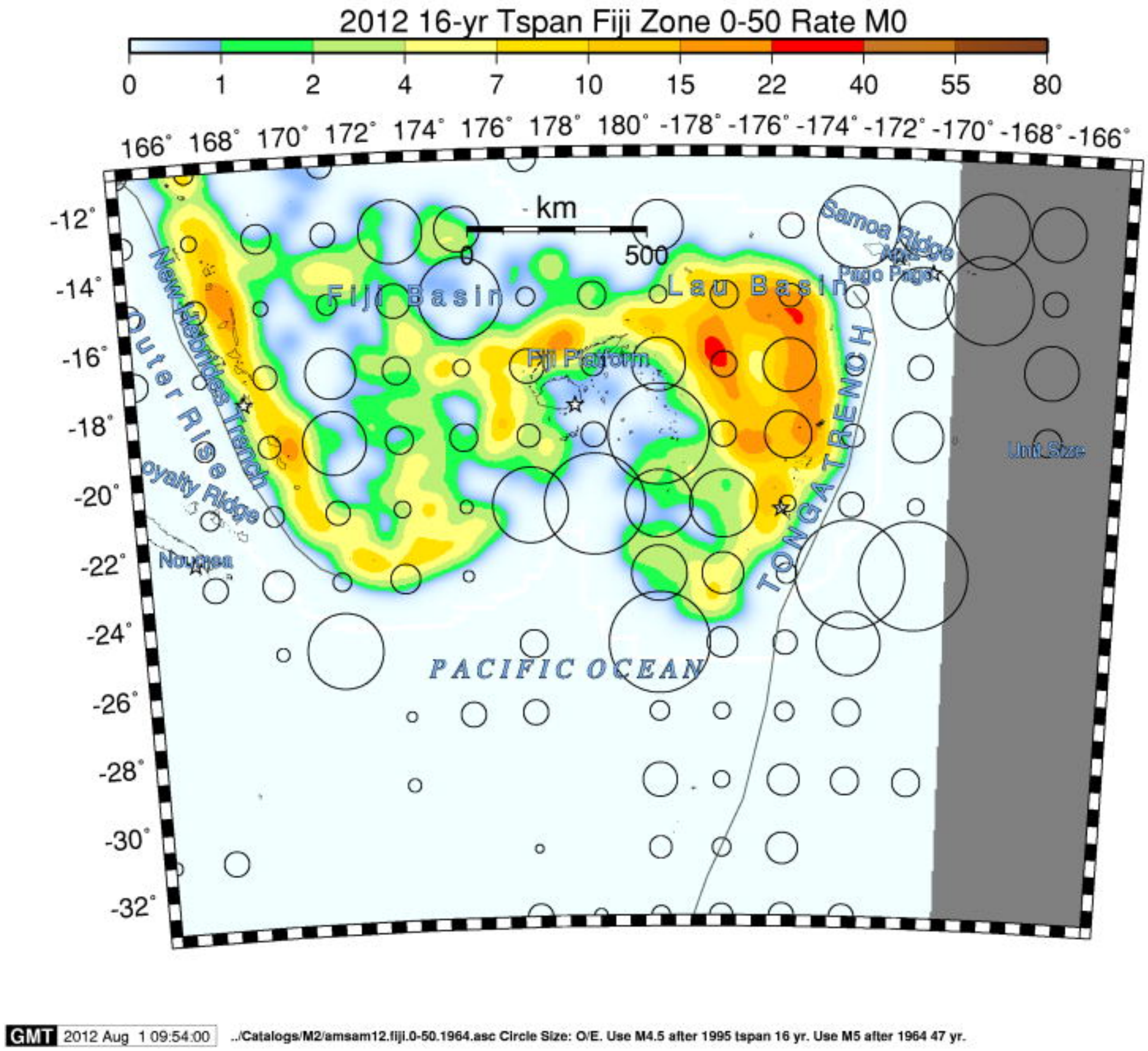

Figure 2. Indicator map for completeness of M4.5 catalog. Circles represent observed/expected rate of M4.5 or greater for the period 1995 to 2010. The radius is proportional to the ratio. The Fiji-zone agrid is shown as color contours.

Based on the above preliminary analysis, it might be helpful to supplement the M5+ sources with M4.5+ sources after 1994 when computing agrids for both the general background and the Fiji zones. For the total study area illustrated in figs. 1 and 2, the number of M5 and greater earthquakes since 1963 is 1284 and the number of M4.5 and greater eqs. since 1994 is 1187, whereas the expected number E[B] from the above reasoning is 1382. Thus, some parts of the broad study area exhibit an apparent deficit of M4.5 to M5 sources and the use of agrids which assume completeness may bias ground motions low in those sub-regions. Although further study would be needed to characterize catalog completeness as a function of time in most parts of the study area, our main focus was on more densely inhabited islands where M4.5 rates appear to be reasonably complete according to our metric. A major caveat is that the completeness period 16 years is too short to comprise a full seismic cycle for the various cells, and that 47 years is also too short. We only claim relative improvement associated with the inclusion of M4.5+ sources when determining activity rates, and that near many densely inhabited islands.

Other caveats include rounding and magnitude bias discussed by K. Felzer in a California OFR and a broad disclaimer about location accuracy for small events in the greater SW Pacific region. Regarding magnitude bias, there is a possibility that the size of M4 to M4.5 earthquakes may tend to be overestimated , putting several of them in the M4.5 to M5 bin. This is seen in screenshots of NEIC preliminary determination of epicenters (PDE), global seismicity, fig. 3.

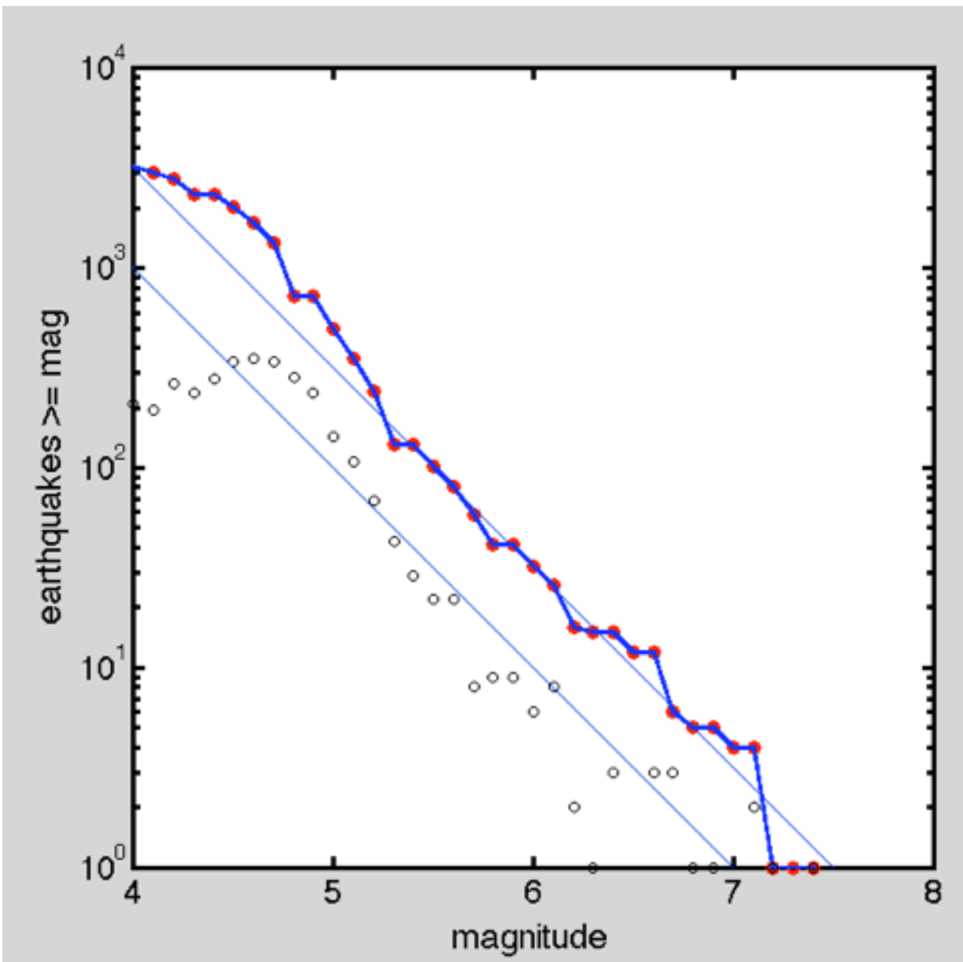

Figure 3. A sample of 3 months of NEIC PDE data, used with permission. The surfeit (relative to GR cumulative line) between M4.5 and M5 is believed to be due at least in part to magnitude bias (Jim Dewey, written commun.).

Regarding hypocenter errors, the International Seismological Centre supplied hypocenters for events near American Samoa that do not have corroborating locations from the NEIC. The ISC hypocenters are in many cases supplied by the IDC, an organization that uses only continental stations and arrays in its location work. We note that the M4.5 to M5 events near American Samoa all have phases from stations in Australia, but none from the nearby station AFI. Location uncertainty is on the order of 800 km (semi-major axis). Epicenter error ellipses for four such earthquakes with epicenters near the island of Tutuila are shown in Figure 4. These events occurred in 2001 through 2008, and all have epicenters supplied by the International Data Center. The nearest recording station is in Australia, and the error ellipse semi-major axes point towards Australia.

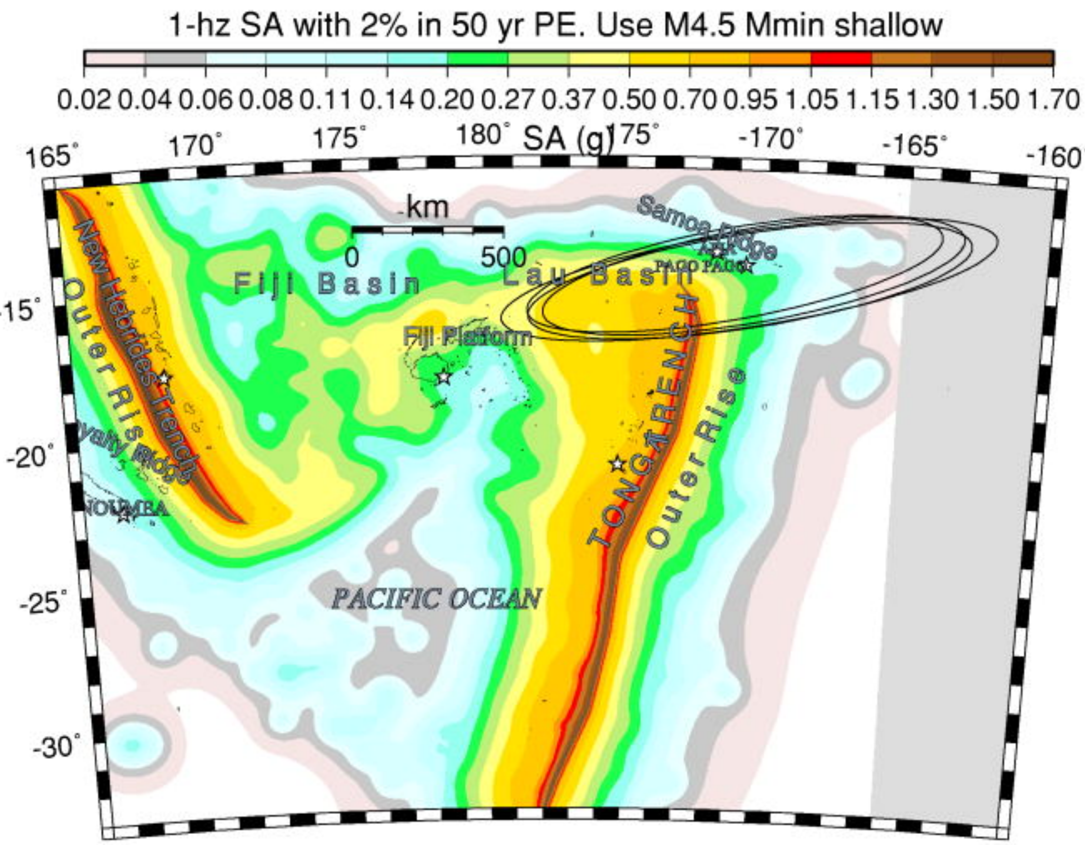

Figure 4. Preliminary seismic hazard map which bases local hazard at American Samoa on activity for M4.5 and greater earthquakes. The four ellipses are 95% confidence regions for epicenter locations for four M4.5 to M5 earthquakes near American Samoa from the International Seismological Centre On-Line Bulletin.

We were advised to either omit these events or to seek further support from the nearby stations, say S-P times if available, rather than using the ISC hypocenters uncritically, when computing gridded activity matrices, or agrids. Further study of seismograms from the station AFI on Samoa indicated that body-wave first arrivals were too emergent to scale, probably indicating that these events are much further from Samoa than the epicenters suggest (Dan McNamara, USGS, written commun. 2012). Because of the low level of precision on these small event locations, we reluctantly concluded that we could not use them to build a seismic hazard model for American Samoa.

Reference

International Seismological Centre, *On-line Bulletin*, http://www.isc.ac.uk, Internatl. Seis. Cent., Thatcham, United Kingdom, 2010.

Schorlemmer, D., J. Woessner, and C. Bachmann (2006). Probabilistic estimates of monitoring completeness of seismic networks. *Seis. Res. Lett. 77*, 233.