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Interactive comment on "The ISC-GEM Earthquake Catalogue (1904–2014): status after the Extension Project" *by* Domenico Di Giacomo et al.

Anonymous Referee #1

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General Comments

The extended ISC-GEM catalogue of earthquakes and associated commentary on its development are both critical resources to the earth science community. As the authors note, a list of earthquakes with the longest possible temporal duration and most consistent possible physical criteria is requisite for a range of research endeavors, including identification of temporal and spatial patterns, testing of various hypotheses related to formation of such patterns, and development of potential actuarial or theoretical tools for earthquake forecasting. The longer the duration of such a catalog, the more effective are statistical approaches. The more consistent the catalog and realistic the uncertainties, the more effective are hypothesis tests.

As the authors note, previous attempts to create long earthquake catalogs, including

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the most common: PAGERCAT, the Centennial Catalog, and the USGS/NEIC, rely on the compilation of event information from multiple sources. As a result, these previously developed catalogs are very likely to be internally inconsistent with respect to magnitude estimates and uncertainty thereof, as well as with respect to depth and epicentral location (to a lesser extent). Such biases and uncertainties alias into all efforts to answer key questions about global earthquakes, such as whether moment release rate varies in time and space, the extent to which quakes can directly trigger one another, and which forcings may be coupled to earthquake cycles. For example, several recent publications using different earthquake catalogs and different statistical methods differ on whether the largest quakes are clustered in time or not (e.g. Abe and Suzuki, 2004; Ben-Naim et al., 2013; Beroza, 2012; Bragato and Sugan, 2014; Daub et al., 2015; Michael, 2011; Sammis and Smith, 2013; Shearer and Stark, 2012) and whether it may be possible or not to forecast large events with time-dependent probabilities based either on past earthquake occurrence or other potential physical forcing (e.g. Barbot et al., 2012; Bendick and Bilham, 2017; Dieterich and Richards-Dinger, 2010; Zahn and Shearer, 2015). All such work is critically sensitive to catalog quality. Consequently, future related and novel efforts will benefit from the initial development of the ISC-GEM catalog and its recent extensions.

The most notable updates to the catalog consist of relatively large numbers of added events in the early 20th century. This is the part of previous catalogs that is most inconsistent, so such careful additions have the greatest impact. Many of the events are derived from paper records, journals, and other obscure sources which are not readily available and do not have consistent or well-known quality, so they especially benefit from the careful re-analysis required for inclusion in ISC-GEM. The extension also includes the most recent events. Although the latter are accessible from many different sources, their treatment consistent with the body of the catalog enforces the standardization practice that ensures minimum bias.

In general, the ongoing development and improvement of a standardized earthquake

catalog with clearly reported methods and uncertainties is an incredibly valuable scientific contribution. Widespread uptake of such a catalog, even if it has some flaws and missing records, will mean that a wide range of investigations of seismicity patterns can be compared and integrated into a broader understanding of earthquakes, whether their fundamental physical dynamics or applied statistics.

Technical Comments

There are two big considerations embedded within the extended ISC-GEM catalog. They both likely arise from the requisite consistent treatment of observational data over time. First, strictly using the latest extended ISC-GEM catalog would imply that earthquake productivity has systematically increased through the 20th century (Figure 1). This is certainly due to the strict criteria for inclusion used by the ISC-GEM group, which results in the rejection of many more events prior to the 1940s than later, and is noted and acknowledged in the methodological description. An alternative approach, apparently taken by the PAGERCAT group, is to relax the selection criteria in the early century when the observational data are poor. With this strategy, the global seismic productivity does not have a strong secular trend (or it is at least not statistically significant). The difference in selection strategy appears in the figures below as a decreasing difference between the two catalogs, which pretty much goes away between 1950 and 1960 (Figure 2).

Second, the reported uncertainties on ISC-GEM events are very large in the early 20th century, making it difficult to assess the catalog completeness at any specific magnitude threshold (Figure 3).

Both of these effects arise from enforcing a consistent treatment of event observations for the entire catalog duration, and it is not clear that there is any better way to handle the differences in data quality over time. However, these effects also make it rather difficult to use the full catalog, as they have the potential to hide real signals under selection limits and magnitude uncertainties. It might be useful for the commentary to

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point out that, in addition to the acknowledged likelihood of missing events early in the century, these missing events alias into an unlikely-to-be-real trend in number of large events and therefore seismic productivity. Alternatively, the commentary could include a short additional section that specifically outlines the implications of the event counts (as, for example, clearly shown in figure 1) to hypotheses about temporal patterns. Some note of how the ISC-GEM compares to other commonly used catalogs should be included in the same section. Such a commentary would help ensure that researchers using the catalog are sufficiently aware of its inevitable biases. As long as studies using the ISC-GEM catalog either acknowledge the resulting systematic bias or use additional events from other catalogs to "fill-in", the impacts can be addressed, if not mitigated. However, any studies using the whole catalog without consideration of the selection bias may produce spurious results.

Figure 1: Counts of annual earthquakes above indicated magnitude thresholds in Mw=0.2 increments for the ISC-GEM catalog (5-year averaging). For comparison purposes, the dashed line represents the annual Mw$\geq$7 seismicity rate from Pagercat (average 15.1$\pm$2.9/yr, reducing by 2.9 earthquakes per century).The ISC-GEM Mw$\geq$7 count (11.1$\pm$2.9/yr) increases by 4.9 earthquakes per century.

Figure 2: The difference (solid green) between Pagercat (red) and ISCGEM (black) Mw$\geq$7earthquakes (and the smaller difference between the raw ISC/GEM catalog and the mean of 20 ISCGEM synthetic catalogs (dashed green line).

Figure 3: Example showing the rate of Mw$\geq$6.6 earthquake productivity if Mw uncertainties are included. The blue line is the raw ISCGEM catalog and red line the smoothed 5 year running mean of 20 synthetic ISCGEM catalogs (grey). Green dots indicate $\pm$ ISCGEM uncertainties for individual earthquakes (right hand scale in Mw). The orange line is a 5 year gaussian smoothing estimate.

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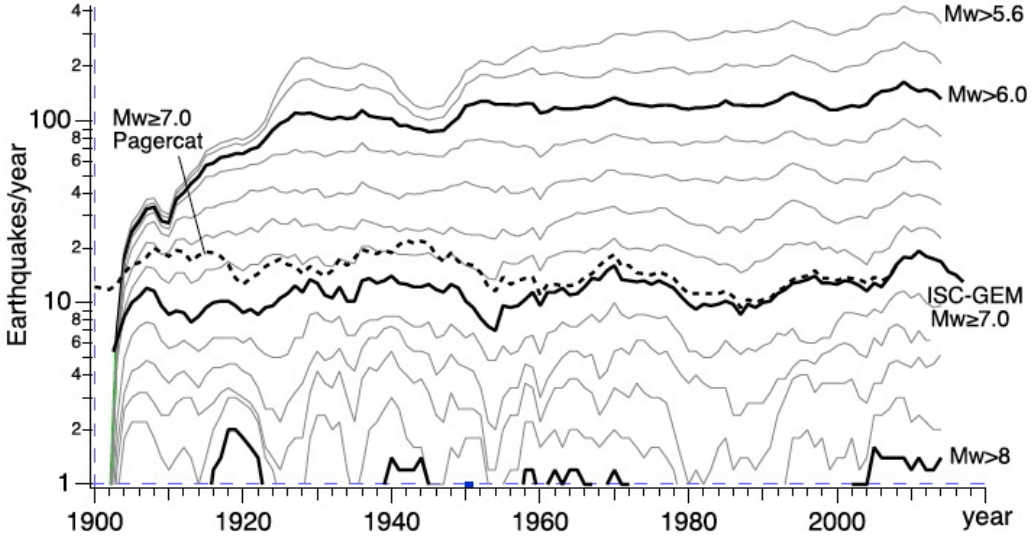

Fig. 1. Quake counts (see text for full caption)

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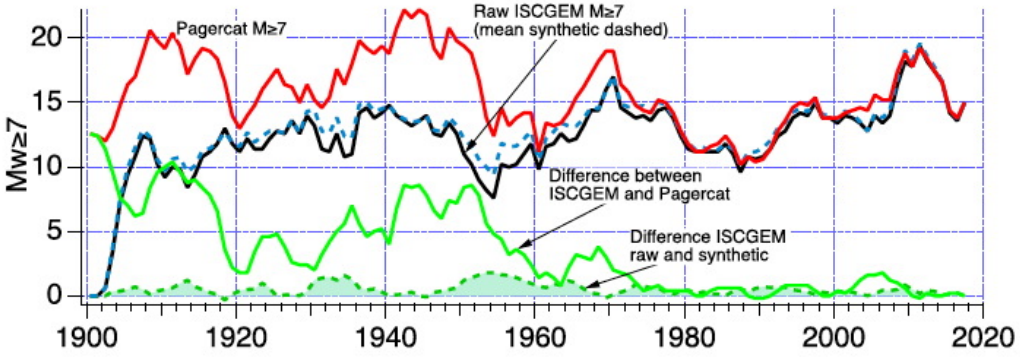

Fig. 2. Comparison with PAGERCAT (see text for full caption)

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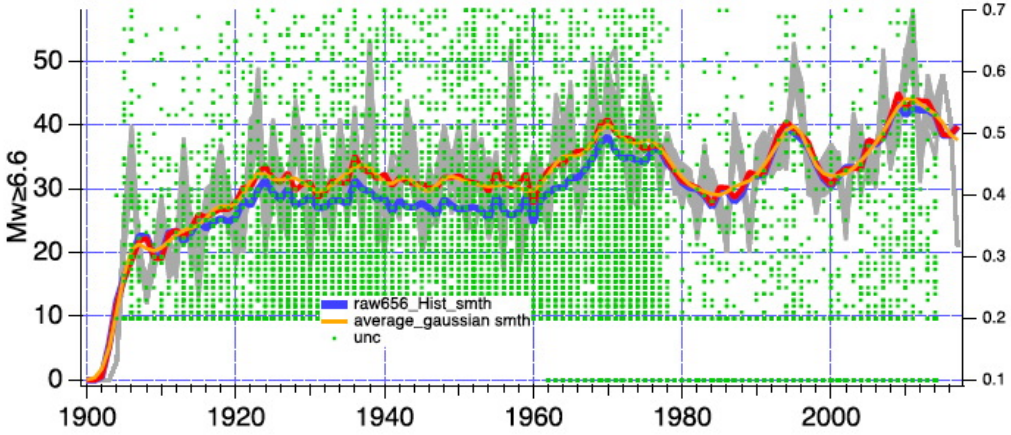

Fig. 3. Magnitude uncertainty (see text for full caption)

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