Multiple-rupture earthquakes and hazard assessment – the case of Lisbon 1755
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The significant number of M>8.5 earthquakes since the start of the current century provided unprecedented insight into the rupture process of the largest events. In particular, the M8.6 intraplate Indian Ocean earthquake of 2012 (left) was an eye-opener, revealing a complex and disjoint pattern of nearly-simultaneous ruptures with a spatial footprint of ~500km. A close inspection of the coeval accounts of the 1755 earthquake suggests that the two events may have similarities in their rupture processes. They also share the triggering of unusual levels of seismic activity at very large distances (see Pollitz et al., 2012 and Figure on the right).

HOW BIG WAS THE EARTHQUAKE?

While early estimates based on (exaggerated) perceptibility areas led to values of 8 % (Gutenberg and Richter, 1958) or 9 (Machado, 1966), the commonly adopted magnitudes range from M8.5 to M8.7, and have been estimated from isoseismal areas for different intensities (Johnston, 1998; Martinez and Mezcua, 2004). The inherent averaging process has ignored a strong correlation between the chosen intensity and resulting magnitude (figure on the left). “Calibration” corrections of 0.32 and 0.47 were summed to the average by Johnston (1998) and Martinez-Solares and Mezcua (2004).

HOW OFTEN CAN IT RECUR?

While the proposed process of fault rupture is clearly non-Poissonian, the seismic catalog suggests that these faults can, in other occasions, rupture individually. For example, the M7.9 1969 Gorringe Bank Earthquake is a likely recurrence of the leading 1755 rupture, and the M7.8 1999 Haicheng Earthquake is another example from a 1755-like scenario. We posit that the damage distribution, as well as the scatter in tsunami traveltime modeling results, can be better accounted for by multiple rupture of independent faults. This would also explain the abnormal shaking duration: ~8 min with two intervals, according to several coeval accounts (Vilanova et al., 2003). Re-computing the magnitude following Martinez-Solares and Mezcua (2004) but using intensities IV to VI only (and the 0.32 correction of Johnston, 1998), we obtain a moment magnitude of 8.1+0.4 (Fonseca, 2017). We propose that this was the magnitude of the largest sub-event. The task (still ahead) of identifying capable sources whose combined rupture explains the data becomes less challenging (figure in the left).

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