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Seismic catalog condensation with applications to multifractal analysis of South Californian seismicity

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Latest advances in the instrumentation field have increased the station coverage and lowered event detection thresholds. This has resulted in a vast increase in the number of located events with each year. The abundance of data comes as a double edged sword: while it facilitates more robust statistics and provides better confidence intervals, it also paralyzes computations whose execution times grow exponentially with the number of data points. In this study, we present a novel method that assesses the relative importance of each data point, reduces the size of datasets while preserving the information content.

For a given seismic catalog, the goal is to express the same spatial probability density distribution with fewer data points. To achieve this, we exploit the fact that seismic catalogs are not optimally encoded. This coding deficiency is the result of the sequential data entry where new events are added without taking into account previous ones. For instance, if there are several events with identical parameters occurring at the same location, these could be grouped together rather than occupying the same memory space as if they were distinct events. Following this reasoning, the proposed condensation methodology is implemented by grouping all event according to their overall variance, starting from the group with the highest variance (worst location uncertainty), each event is sampled by a number of sample points, these points are then used to calculate which better located events are able to express these probable locations with a higher likelihood. Based on these likelihood comparisons, weights from poorly located events are successively transferred to better located ones. As a result of the process, a large portion of the events ($\sim$30%) ends up with zero weights (thus being fully represented by events increasing their weights), while the information content (i.e the sum of all weights) remains preserved.

The resulting condensed catalog not only provides more optimally encoding but is also regularized with respect to the local information quality. By investigating the locations of mass enrichment and depletion at different scales, we observe that the areas of increased mass are in good agreement with reported surface fault traces. We also conduct multifractal spatial analysis on condensed catalogs and investigate different spatial scaling regimes made clearer by reducing the effect of location uncertainty.