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Increasing the sample size for climate extremes in catastrophe models, by several orders of magnitude, at a fixed numerical cost

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For planing purposes, government bodies or insurance and reinsurance companies need trustworthy return time curves in order to properly estimate hazard. Moreover the hazard module of catastrophe models (CAT models) requires a large sample of possible patterns for each type of climate extreme. For those events that have not been observed yet, those statistics and patterns are built from model outputs and statistical models. However, for the rarest events, which are the most important, it is extremely difficult, not to say impossible, to build a good statistics with the best climate models, because of the limitations related to computational costs.

In order to tackle this issue, we propose a genetic algorithm that should be used on top of climate models. Using this algorithm, we have demonstrated that the probability and the patterns of extreme heat waves can be estimated in a comprehensive General Circulation Model (GCM) extremely efficiently. At a fixed numerical cost, several hundreds more heat waves are observed than in a control run, and the return times of events much longer than the ones observed in the control run can be estimated. This new tool opens perspectives, out of reach so far, for the study of climate extremes, and their representation in CAT models.

The algorithm is a rare event algorithm. It uses ensemble simulations where the ensemble is modified in order to favor the extreme events and in order to avoid the useless computation of typical climatic situations. The rule of the algorithm gives a precise mathematical relation between the algorithm ensemble return times and the model ones. This approach is based on large deviation theory, a key mathematical tool in statistical physics.

F. Ragone, J. Wouters, and F. Bouchet, Computation of extreme heat waves in climate models using a large deviation algorithm, PNAS 2018 115 (1) 24-29, doi:10.1073/pnas.1712645115