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Sampling extreme heat waves using a large deviation algorithm

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For some aspects of climate dynamics, rare dynamical events may play a key role. A class of such problems are extreme events that have huge impacts, for instance extreme heat waves. The study of those events from numerical models is extremely difficult because of the rareness of the event and the related numerical cost. This makes detection and attribution study in this context even more difficult as factual and counterfactual studies have to be sampled through prohibitively long simulations, in order to be compared.

In the recent past, new theoretical and numerical tools have been developed in the statistical mechanics community, in order to specifically study such rare events. Those approaches are based on large deviation theory for complex dynamical systems.

We will present some of these tools and apply them to a paradigmatic example in climate dynamics: we will study the probability of extreme heat waves over Europe, in a comprehensive climate model. We will demonstrate that large deviation algorithms allow to sample extremely efficiently extreme heat waves. The number of sampled extreme heat waves is increased by a factor of a few hundreds to a thousand, for a given numerical cost, compared to direct numerical simulations. We discuss the future implications for detection and attribution studies.