SIMULATION OF HEAT WAVES IN CLIMATE MODELS USING LARGE DEVIATION ALGORITHMS

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One of the goals of climate science is to characterize the statistics of extreme, potentially dangerous events (e.g. exceptionally intense precipitations, wind gusts, heat waves) in the present and future climate. The study of extremes is however hindered by both a lack of past observational data for events with a return time larger than decades or centuries, and by the large computational cost required to perform a proper sampling of extreme statistics with state of the art climate models. The study of the dynamics leading to extreme events is especially difficult as it requires hundreds or thousands of realizations of the dynamical paths leading to similar extremes.

We will discuss here a new numerical algorithm, based on large deviation theory, that allows to efficiently sample very rare events in complex climate models. A large ensemble of realizations are run in parallel, and selection and cloning procedures are applied in order to oversample the trajectories leading to the extremes of interest. The statistics and characteristic dynamics of the extremes can then be computed on a much larger sample of events. This kind of importance sampling method belongs to a class of genetic algorithms that have been successfully applied in other scientific fields (statistical mechanics, complex biomolecular dynamics), allowing to decrease by orders of magnitude the numerical cost required to sample extremes with respect to standard direct numerical sampling.

We study the applicability of this method to the computation of the statistics of European surface temperatures with the Planet Simulator (Plasim), an intermediate complexity general circulation model of the atmosphere. We demonstrate the efficiency of the method by comparing its performances against standard approaches. Dynamical paths leading to heat waves are studied, enlightening the relation of Plasim heat waves with blocking events, and the dynamics leading to these events. We then discuss the feasibility of this method for applications with state of the art climate models, and we explain why this new approach could represent a change of paradigm for the study of extreme events, allowing to study their dynamics extensively at a reasonable computational cost.