THE UNIVERSITY OF CHICAGO | THE COMMITTEE ON COMPUTATIONAL AND APPLIED MATHEMATICS

COLLOQUIUM

JUSTIN FINKEL

Department of Geophysical Sciences and the Data Science Institute
University of Chicago

Try Early, Emulate: on Timescale Considerations for Sampling Extreme Weather Events

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Jones 303, 5747 S. Ellis Ave. Chicago, IL 60637

ABSTRACT

A critical challenge for modern climate science is to characterize extreme weather events. From heat waves to hurricanes to cold snaps, extreme events share the common feature of being uncommon, occupying some tail of the climatic probability distribution and thus presenting only scant historical data for analysis. Such sporadically occurring events catch societies and ecosystems off-guard when they do occur, and better estimating risks can help greatly to mitigate the impacts. There are several competing approaches to this challenge, each with their own tradeoffs: classical statistical methods such as extreme value theory are "universal", but limiting in their asymptotic assumptions; physical simulations can generate additional realistic data, but are expensive to run at high resolution; and machine-learned model simulations are fast but dubiously reliable, especially on extremes where training data is limited. This talk will present some Monte Carlo strategies to bring out the best in all three approaches, in particular rare event sampling (RES): a "generic" set of protocols for selectively pruning, cloning, and perturbing simulations in an ensemble to over-sample the tails while down-weighting to correct for the bias introduced. But it remains unclear how to perturb an atmospheric simulation to favor extremes that are sudden and transient---such as heavy precipitation events carried by extratropical cyclones. Such events are in a sense too predictable, resulting in under-dispersion of ensemble members. I will demonstrate this failure mode, and a simple remedy, on a hierarchy of systems from an idealized "aquaplanet" climate model to a two-dimensional channel flow to a one-dimensional chaotic system. The solution is to "try early", at a particular lead time set by the dynamics' predictability timescale, and with the right choice we achieve ~10x speedup in sampling of local, transient extremes. Crucially, the optimal timescale is not a universal quantity like the leading Lyapunov exponents, but rather must be customized for the event of interest. More generally, I argue that extreme event research should employ less random sampling and more deterministic optimization. This incidentally invites synergistic coordination between traditional physics-based codes and differentiable-by-construction machine-learned emulators. Early results on that front will also be presented. Overall, the diversity of definitions of “extreme events" and the computer models that simulate them demand commensurate flexibility in sampling methods. Rising to this challenge will be a long-term collaborative research agenda.

Organizers:
Guillaume Bal, Department of Statistics (CCAM), guillaumebal@uchicago.edu & Nisha Chandramoorthy, Department of Statistics (CCAM), nishac@uchicago.edu, Daniel Sanz-Alonso, Department of Statistics (CCAM), sanzalonso@uchicago.edu

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