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Chaos serving order : budget diagnostics of internal variability in regional climate simulations

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It is well known that, in chaotic systems, repeated predictions launched with even minute differences in initial conditions will eventually diverge from one another. Hence deterministic predictions have finite validity time horizons. The predictability time limit is not unique, but depends on the relevant process and scale of interest ; in Earth System prediction, it can range from a few minutes for cloud processes to a few years for planetary-scale patterns induced by ocean circulation and land-moisture anomalies.

External forcings and boundary conditions exert some control on the trajectory in phase space : hence forced components of the Earth System do not suffer from predictability time limitation. This is what permits climate-change projections under altered conditions, such as increased greenhouse gases resulting from the combustion of fossil fuel. While chaos limits weather forecasts, it is in fact exploited in climate projections. Ensemble simulations from several models, and several runs of each model launched from slightly different initial conditions, are pooled together. Averaging over members of a model and over the different models remove the unpredictable and unreliable components, respectively. The spread between members and models provides an estimate of the sampling (members) and structural (models) uncertainties. Due to the ergodicity property of Global Earth System simulations, the statistical robustness of the climate-change signals and accurate determination of rare events can be improved either with longer simulations or with more numerous shorter simulations. This is only possible due to the chaotic nature of the Earth System. Hence chaos contributes to order !

The situation is quite different in nested regional climate models (RCM) simulations because lateral boundary conditions applied around the limited-area computational domain exert some (but not total) control over RCM simulations. Internal Variability (IV) is generally smaller than Time Variability (TV) in RCM simulations, and hence RCM simulations do not satisfy the ergodicity property as do GCM simulations. A detailed diagnostic budget study of IV will reveal the physical processes responsible for the maintenance and time variations of IV in RCM simulations. The results confirm that IV arises in RCM simulations from the chaotic nature of the governing field equations. Hence ensemble of RCM simulations can be exploited to improve the statistical robustness of climate extremes and climate-change signal at regional scale.

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