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Defining climate by means of an ensemble: why it is possible

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Any prediction for the weather of a time instant in the far future is uncertain due to possible model errors, the unknown forcing, and internal variability. Since the latter is inherent to the Earth system, it is more useful to consider the statistical (probabilistic) description of all possibilities permitted by the system's dynamics (in a particular model under some particular forcing), which is the basic idea behind defining climate. Regardless of how one chooses initial conditions to construct an ensemble representing an initial probability distribution, this initial choice is forgotten during time evolution, and the distribution ("spread") of the evolving ensemble members converges to a unique, so-called natural probability distribution (supported by a dynamical, so-called snapshot or pullback attractor; it may depend on time if the forcing is not stationary). Among others, this is the case for a set of initial conditions consistent with observations.

We find in an intermediate-complexity general circulation model, the Planet Simulator of the University of Hamburg, as well as in a toy model, that the rate of the convergence (equivalently, that of the loss of memory about initial conditions) is approximately exponential. Since independence of initial conditions is approximately reached within a finite time (a few decades in the Planet Simulator in the presence of a mixed-layer ocean), we propose to identify climate with the natural probability distribution.

We use the relationship between the El Niño–Southern Oscillation and the Indian monsoon in the Max Planck Institute Grand Ensemble to illustrate that evaluating a statistical quantifier, the correlation coefficient, with respect to time in a single ensemble member may provide with a very poor approximation to the same quantifier evaluated with respect to the natural probability distribution. In particular, conclusions about its time evolution can be opposite.