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Quantifying the uncertainty of climate predictions

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Our initiative in uncertainty quantification addresses fundamental challenges in the numerical simulation of complex systems: not only attaching defensible error bars to predictions, but also assessing low-probability but high-consequence events. To achieve these goals with a large number of uncertain input parameters, both raw computational power and an intelligent, self-adapting search of the possible combinations are needed. Either a cloud-computing network or a centralized supercomputer can do this, but the second choice is more straightforward for adaptive sampling refinement. Taking the second choice, we have produced the most comprehensive set to date of climate simulations from the US Community Atmosphere Model (CAM, a.k.a. "the NCAR model"). The computations were guided by our general purpose uncertainty-quantification software pipeline. Our goal is to evolve the pipeline toward the intelligent search capability mentioned above. Most of our climate simulations to date prescribe sea-surface temperature and sea-ice as boundary conditions matching recent observations, i.e. they are AMIP simulations. We are now examining over 40 Terabytes of output from 3000 12-year AMIP simulations (36,000 simulated years in total) to make a first assessment of CAM's accuracy as a function of 28 uncertain input-parameter values involving the boundary layer and clouds. Fully searching such a 28-dimensional space is impossible, but a new ranking algorithm indicates that some input parameters have little effect on a variety of globally averaged output fields, either individually or in nonlinear combination. Further, "pass-fail grading," based on the criterion of planetary albedo, reduces the number of viable input-parameter combinations by two-thirds, though it may not tightly restrict the value of any one input parameter. Application of more sophisticated constraints employing a variety of climate observations gives similar results. Observational constraints will be important for the next phase of the project, which will address climate change due to increased atmospheric carbon dioxide. This work was performed under auspices of the US Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344, and was funded by the Uncertainty Quantification Strategic Initiative Laboratory-Directed Research and Development Project at LLNL under project tracking code 10-SI-013.