Conf-9208149--1

PNL-SA--20951

DE92 041339

MODELING THE UNCERTAIN IMPACTS OF CLIMATE CHANGE

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August 1992

Presented at the Conference
on Environmetrics and 3rd
International Environmetrics Society
August 17-21, 1992
Espoo, Finland

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

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ABSTRACT

Human and earth systems are extremely complex processes. The modeling of these systems to assess the effects of climate change is an activity fraught with uncertainty. System models typically involve the linking of a series of computer codes, each of which is a detailed model of some physical or social process in its own right (see [5] for examples). In such system models, the output from one process model is the input to another. Traditional methods for dealing with uncertainty are inadequate because of the sheer complexity of the modeling effort: Monte Carlo methods and the exhaustive evaluation of "what if?" scenarios to estimate sensitivities fail because of the heavy computational burden. More efficient methods are required for learning about system models that are constructed from a collection of computer codes.

A two-tiered modeling approach is being developed to estimate the distribution of outcomes from a series of nested models. The basic strategy is to develop a simplified executive, or simplified system code (SSC), that is analogous to the more complex underlying code. An essential feature of the SSC is that it uses information abstracted from the detailed underlying process codes in a manner that preserves their essential features and interactions among them. Of course, to be useful, the SSC must be much faster to run than its complex counterpart. The success of the SSC modeling strategy depends on the methods used to extract essential features of the complex underlying codes.

The basic idea is to develop a computationally simple approximation to the response surface of the underlying code (i.e., to develop a SSC), using a judiciously selected set of model runs, that retains essential model features. The success of this strategy depends upon both the sampling design, i.e., the method of choosing the (input points for) selected model runs, and the method of approximation. Efficient sampling methods exist. One of the most widely-used is Latin hypercube sampling (LHS), which, when used to derive suitable response-surface approximations, has proved very effective for sensitivity and uncertainty analysis; see [6] or [4]. By contrast, there are few sampling methods that take advantage of available output information to select additional runs. Multivariate adaptive regression spline methods (see [1], [2], [3]) of approximation are attractive because output data are exploited to define a "good" set of input regions. A suitable class of low-order (first- or second-degree) piecewise polynomials generally provides quite adequate approximations.

Once derived, the response surface approximations are linked to create the SSC. Because the approximating functions involve piecewise polynomial

* Work supported by the U. S. Department of Energy under Contract DE-AC06-76RLO 1830.

functions, linking is comparatively easy. The resulting SSC can now be used to perform analyses that would be prohibitive with the underlying code. In particular, well-known and widely-used sampling strategies can be employed with the SSC to estimate parameter sensitivities and model uncertainty.

Two examples are given to illustrate the proposed methods. Both involve analyzing the regional-scale consequences of climate change. In the first, the problem is to estimate the effects of climate change on an agriculture-based regional economy. In the second, the task is to estimate the effects on regional climate and its biosystems caused by global climate changes. In this example, the regional climate is driven from boundary conditions obtained from a global general circulation model. In both cases, sources of uncertainty in the outcome can be thought of as hierarchy of several layers or levels. Moreover, each layer can give rise to (i.e., be the source of) several distinct types of uncertainty; see [5] for amplification.

References

[1] Friedman, J.H. 1991. "Multivariate Adaptive Regression Splines" (with discussion). Annals of Statistics **19(1)**, 1-141.

[2] Friedman, J.H. 1991. "Adaptive Spline Networks." Technical Report No. 107, Laboratory for Computational Statistics, Department of Statistics, Stanford University, Stanford, California.

[3] Friedman, J.H., and B.W. Silverman. 1989. "Flexible Parsimonious Smoothing and Additivity Modeling" (with discussion). Technometrics **31(1)**, 3-39.

[4] Iman, R.L., and W.J. Conover. 1980. "Small Sample Sensitivity Analysis Techniques for Computer Models, with an Application to Risk Assessment." Communications is Statistics--Theory and Methods **A9(17)**, 1749-1842.

[5] Liebetrau, A.M., and M.J. Scott. 1991. "Strategies for Modeling the Uncertain Impacts of Climate Change." Journal of Policy Modeling 13(2), 185-204.

[6] McKay, M.D., R.J. Beckman and W.J. Conover. 1979. "A Comparison of Three Methods for Selecting Values of Input Variables in the Analysis of Output from a Computer Code." Technometrics **21(2)**, 239-245.

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DATE FILMED

12/10/92