OAK RIDGE NATIONAL LABORATORY FACT SHEET
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

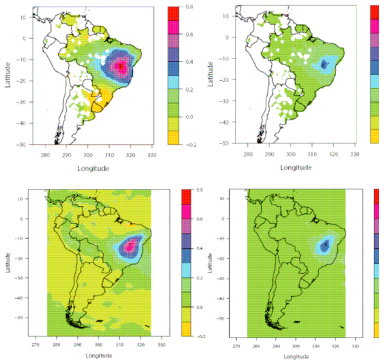
Geographic Information Science and Technology

Systematic Evaluation of Complex Simulation Systems with Uncertainty Quantification

Complex simulation systems, ranging from the suite of global climate models used by the Intergovernmental Panel on Climate Change (IPCC) for informing policy-makers to the agent-based models of social processes which may be used for informing military commanders and strategic planners, typically cannot be evaluated using standard techniques in mathematics and computer science. Uncertainties in these systems arise from intrinsic characteristics which include complex interactions, feedback, nonlinearity, thresholds, long-range dependence and space-time variability, as well as our lack of understanding of the underlying processes compounded by the complicated noise and dependence structures in observed or simulated data. The complicated dependence structures, interactions and feedback rule out the use of mathematical or statistical methods on individual differential equations or state transition rules. The direct application of computational data science approaches like spatial of spatio-temporal data mining is limited by the nonlinear interactions and complex dependence structures. The complexity of the systems precludes multiple model runs to comprehensively explore the space of input data, random model parameters, or key component processes. The importance of extreme values and space-time variability, as well as the ability to produce surprising or emergent behavior and retain predictive ability, further complicates the systematic evaluation and uncertainty quantification. The area of verification and validation within modeling and simulation is not yet equipped to handle these challenges. We have developed a set of tools, which range from pragmatic applications of the state-of-the-art to new adaptations of recent methodologies and all the way to novel approaches, for a wide variety of complex systems. These include systematic evaluation of social processes and agent-based simulations for an activity funded by DARPA/ DOD, multi-scale uncertainty characterization and reduction for simulations from the IPCC suite of global climate models towards research funded by ORNL / DOE and DOD, as well as high-resolution population modeling funded by multiple agencies. The set of tools and methodologies, which represents an interdisciplinary blend of mathematics, statistics, signal processing, nonlinear dynamics, computer science, and operations research, has demonstrated wide applicability over multidisciplinary simulation systems.

Primary Applications and Sponsors

- IPCC suite of climate models (ORNL/DOE, DOD)
- Complex adaptive social systems (DARPA/DOD)
- High-resolution population mapping (Multiple agencies)



A climate model was evaluated based on complex dependence

Selected References

- Ganguly, A.R., Et Al. (2009): Higher trends but larger uncertainty and geographic variability in 21st century temperature and heat waves. PNAS, 106(37): 15555-9.
- Ganguly, A.R., Et Al. (2008): Towards characterization and systematic evaluation framework for theories and models of human, societal, behavioral, and cultural processes. ORNL/TM-2008/062.
- Sabesan, A., Et Al. (2007): Metrics for the comparative analysis of geospatial datasets with applications to high resolution grid-based population data, GeoJournal, 30, 2401-2423.

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