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The Great Rivers Modeling Framework and Decision Support System

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The health of the world's freshwater ecosystems is fundamental to the health of people, plants and animals around the world. The sustainable use of the world's freshwater resources is recognized as one of the most urgent challenges facing society today. An estimated 1.3 billion people currently lack access to safe drinking water, an issue the United Nations specifically includes in its recently published Millennium Development Goals (http://www.un.org/millenniumgoals/). To address the scale and urgency of this challenge, IBM is collaborating with The Nature Conservancy and the Center for Sustainability and the Environment (SAGE) at the University of Wisconsin, Madison to develop an innovative decision support tool and modeling framework for improved management of water resources worldwide.

The Great Rivers Modeling Framework and Decision Support System (DSS) is designed to help policy makers and a variety of stakeholders (farmers, fish & wildlife managers, hydropower operators, et al.) to assess, come to consensus, and act on land use decisions representing effective compromises between human use and ecosystem preservation/restoration. Initially focused on Brazil's Paraguay-Paraná, China's Yangtze, and the Mississippi Basin in the US, the DSS will integrate data and models from a wide variety of sectors, including water balance, water quality, carbon balance, crop production, hydropower, biodiversity, and economic valuation of ecosystem services. Our aim in this project is to build a community framework that supports the sharing and coupling of component models by modelers and other stakeholders worldwide.

The challenges of coupling component models in a framework are many and various. Common data and metadata representations are needed to represent interfaces between component models. Rules must be developed that express constraints on how and if component models may be coupled into a simulation, and which components are swappable. Once defined, simulations must be calibrated and validated; since autocalibration is arguably not yet well developed enough for unsupervised use, this step typically involves much manual intervention. The uncertainty of simulations built out of coupled models must be estimated and conveyed to the user. Data sets in diverse formats with disparate semantics and a variety of associated software must be integrated. Data must be interrogated at different temporal and spatial resolutions.

A key question in designing a community modeling framework is: on which level should the component models be defined? Two choices that readily come to mind are: 1) on the model level, resulting in components that are large multi-function programs like SWAT (Soil and Water Assessment Tool, Texas A&M University: www.brc.tamus.edu/swat/avswat.html); and 2) on the sector level, with components such as water balance, water quality, crop production, carbon storage. But critical requirements for the framework are: defining interfaces between component models; expressing model semantics and assumptions in metadata; and developing rules that enforce constraints on how component models may be composed together into a simulation. These requirements are much more readily met if the model components are atomic, i.e., if each one has one and only one function. This is not true of large multi-function models, nor even of sector-level components like water balance. Following this reasoning, we are investigating defining model components at a lower level. For example, model components that deal with water balance include: Net radiation, Precipitation, Canopy loss, Transpiration, Soil evaporation/sublimation, Soil moisture, Runoff, Percolation, and Ground Water Recharge.

Our community modeling framework supports six basic tasks: 1) register and calibrate new component models and datasets; 2) define simulation workflows as compositions or couplings of model components; 3) run the simulations; 4) view the results of the simulations; 5) run searches over the database of simulation inputs, metadata, and results; and 6) tag, annotate, and interactively chat about models and simulations. Three levels of user are defined. Expert users may perform all 6 tasks; non-expert users perform tasks 4-6 only; and administrative users handle security, access control and system maintenance and operations. Sample searches over simulations include:

- "Show me all the grid cells from any simulation's output where fertilizer < x and crop yield > y and water quality > z", where x, y and z are user-defined threshold values.
- "In all streams that are order >4, within ½ mile buffer, what percentage of land is in crop and fertilized?"