An integrated computer modeling system for water resource management

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Goodall mentored middle school students to find solutions related to storm water and sustainability. Credit: Jonathan Goodall, University of South Carolina

(Phys.org) —Water resource management involves numerous and often distinct areas, such as hydrology, engineering, economics, public policy, chemistry, ecology and agriculture, among others. It is a multi-disciplinary field, each with its own set of challenges and, in turn, its own set of computer models.

Jonathan Goodall's mission is "to take all these models from different groups and somehow glue them together," he says.

The National Science Foundation (NSF)-funded scientist and associate professor of civil and environmental engineering at the University of Virginia, is working to design an integrated computer modeling system that will seamlessly connect all the different models, enabling everyone involved in the water resources field to see the big picture.

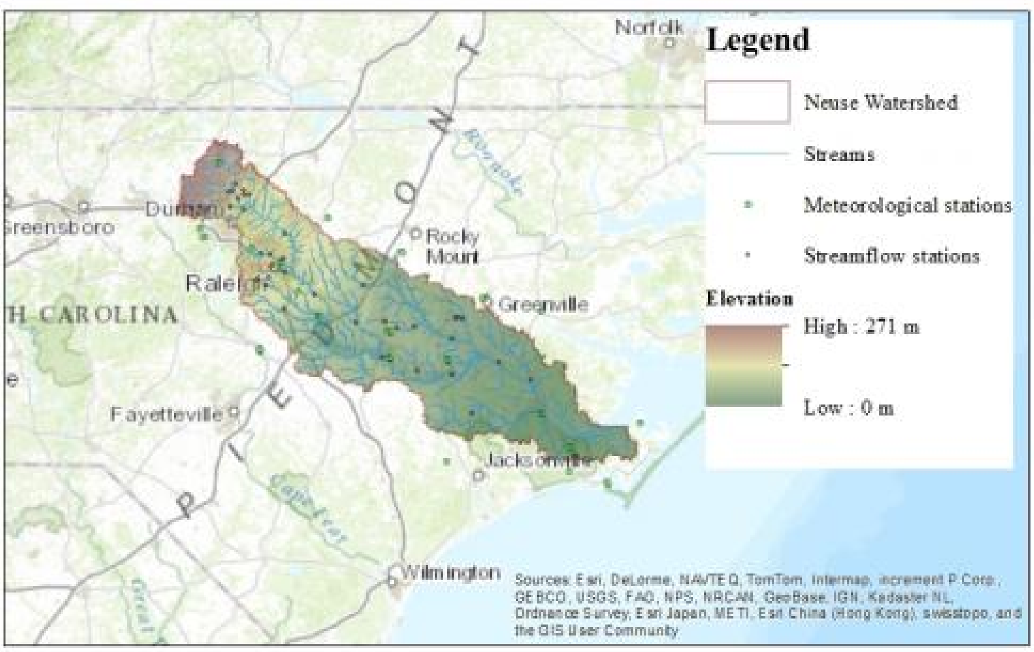
"We are trying to computationally design models as components within a larger modeling framework so that we can integrate them," he says. "We want to be able to look at connections across the systems. For example, if you grow corn for ethanol for fuel, there are economic, water quality and agricultural aspects. How do you look at the issues and problems holistically? How do you look at all the components of the system and their interactions? We need to have this perspective if we want to understand all the consequences that happen to water, so we can manage it properly."

In doing so, "it will make the models we use to address water resources challenges more accurate and more robust," he says. "There are a lot of current water challenges that require sophisticated computational models."

He lists, among others, the Chesapeake Bay and the Gulf of Mexico, where fertilizer runoff has created dead zones; Southern California, which faces water shortages resulting from an over allocation of the Colorado River, and depleted groundwater resources; and floods along rivers in the Midwest, which prompted difficult decisions about releasing water through levies, and flooding lands, to avoid significant downstream flooding of cities, such as New Orleans.

"Models are used by water resource engineers every day to make predictions, such as when will a river crest following a heavy rain storm, or how long until a city's water supply runs dry during a period of drought," he adds. "One of the problems with our current models is that they often consider only isolated parts of the water cycle. Our work argues that when you look at all the pieces together, you will come up with a more comprehensive picture that will result in more accurate predictions."

His work was motivated and builds off an initiative funded by the European Union called Open Modeling Interface, known as OpenMI, originally conceived to facilitate the simulation of interacting processes, particularly environmental ones, by enabling independent computer models to exchange data as they ran.



The Neuse River Basin in North Carolina, the study watershed for the modeling to understand nitrogen transport at watershed-scales using integrated modeling approaches. Credit: Jonathan Goodall, University of South Carolina

Later, it became a generic solution to the problem of data exchange among any models, not just environmental, and soon after, not just models but software components, thereby connecting any combination of models, databases and analytical and visualization tools.

"We are trying to advance the software that bridges all the models," Goodall says. "One of the ways we are trying to strengthen the software is by trying to understand which kinds of problems it can handle."

For example, one challenge with bridging models of different systems is that one system might be more dynamic than another. In water resources, water movement in the atmosphere is more dynamic than water movement in deep aquifers.

"When the models are bridged, you need to allow for the flexibility that allows for these differences, otherwise you may run into significant computationally efficiencies," Goodall says.

"Also, you can quickly get into semantics problems, where different models have different vocabularies in their internal systems," he adds. "You may need to have a variable passed between two different models, but each model might have its own semantics for naming the variable. Computers do not handle this well without very specific runs, such as unified, controlled vocabulary, or clear rules for how to translate terminology between the two models."

These semantic differences can be complex, since variables in models may have slight differences in units or dimensions that, if not properly handled, can cause major problems when linking the models together, he says.

While this work applies generally across water resource modeling challenges, Goodall and his team are applying the work specifically to the challenge of modeling water and nutrient transport within watersheds. They are using the Neuse River Basin in North Carolina as a case study, running widely used models alongside their new modeling framework system in order to test and verify whether the new system reaches the same answers as well-tested models.

"The modeling framework system will then be used to go beyond the capabilities of current models by including new disciplines into the watershed modeling process, and then eventually allowing specialized groups to advance components of the overall modeling system," he says.

Goodall is conducting his research under an NSF Faculty Early Career Development (CAREER) award, which he received in 2009 as part of NSF's American Recovery and Reinvestment Act. The award supports junior faculty who exemplify the role of teacher-scholars through outstanding research, excellent education, and the integration of education and research within the context of the mission of their organization. NSF is funding his work with $408,042 over five years.

Goodall is using the educational component of the grant to plan courses, as well as a workshop for graduate students across different water-related disciplines who "will come up with a water problem that is cross-disciplinary, and then construct a model using the new modeling system that can really test our approach," he says. "We will be talking about the integration we have to do so we can have an integrated system where each person contributes his or her own component."

In 2013, Goodall volunteered as a mentor at a local middle school, where he guided students through design a city of the future and "specifically think about how that city would handle its storm water," he says. "We discussed the general problems cause by storm water," which is runoff caused by heavy rain storms, "falling on impervious surfaces such as roads, roofs and parking lots.

"Because this rain does not infiltrate into the soil, it can cause problems such as flooding or erosion of river beds," he adds. "We talked about the ways engineers handle storm water so that it does not cause these problems, as well as how the philosophy for handling storm water runoff has changed over the years."

While many urban storm water systems were designed in the past simply to remove rain water from a city as quickly as possible—for example, by using large concrete channels—the focus has changed in recent years. Many cities now employ new practices, such as using pervious surfaces for roads or lots, or capturing rainfall in ponds or rain gardens distributed across the city, allowing water to slowly infiltrate into the soil.

"Storm water is something that most people spend very little time thinking about and these students were no different," he says. "But as they began to think about the problem and the challenge of not only solving the problem, but doing it in a sustainable way, they were hooked. You could see their minds go as they tried to come up with solutions to the problem, and that was fun."

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