THE UNIVERSITY OF ALABAMA® | Alabama Water Institute

NEWSLETTER

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FORMULATING A BETTER PARTNERSHIP FOR WATER QUALITY

Water is one of the most important resources on the planet, and researchers at The University of Alabama are calculating ways to improve its quality and management. Part of this equation is the collaboration between various disciplines through the Alabama Water Institute. Affiliated faculty members in the Department of Mathematics are offering their expertise in modeling to find solutions to water issues.

By Brock Parker

"We want to talk to people from other departments," said Dang Nguyen, assistant professor in applied and computational math. "Maybe they have many interesting problems from their own experiences and need some tools from mathematics, so we can help and work together."

UA's math department recently made several strategic searches to hire mathematicians whose strong interdisciplinary research will support the work of the research institutes on campus, such as AWI.

"This is a win for all involved," said David Cruz-Uribe, professor and mathematics department chair. "It helps our department build stronger ties with the other sciences, and it provides researchers with the mathematical expertise they need to develop better solutions to their problems."

Water touches every aspect of life, and Nguyen focuses on problems that arise from ecology, how organisms interact with their physical surroundings. While working with ecologists from the University of California, Davis, he's been able to create theoretical models that show potential for cleaner water.

"I have been working on some models in wastewater treatment using microorganisms," he said. "I use tools from optimal contour to manage the treatment of the wastewater, but I hope when I meet more people from other departments, I can benefit from practical projects."

Along with Nguyen, fellow assistant math professors Mojdeh Rasoulzadeh and Chuntian Wang want to take their expertise from the classroom to the field.

Pictured left to right: Dang Nguyen, Chuntian Wang and Mojdeh Rasoulzadeh.

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- David Cruz-Uribe, professor and mathematics department chair

"Research in water-related areas provides our students with valuable training opportunities in applied mathematics," said Rasoulzadeh. "They gain a solid foundation in advanced mathematical modeling, computational mathematics and extensive interdisciplinary collaboration experience with other disciplines such as physics, chemistry, geology and engineering."
According to Rasoulzadeh, fluid flow in complex subsurface systems is governed by several mechanisms that operate at different spatial and temporal scales. In these systems, a principal issue is the lack of a sophisticated modeling tool that takes into account the impact of nanoscale and microscale processes on the overall behavior of the macroscale and, at the same time, is representative at the reservoir scale.

"My research aim is to address the unresolved issues in multiscale multiphysics subsurface flow modeling in highly heterogeneous reservoirs, which require revisiting the modeling approach via application of advanced mathematical tools," she said.

The use of mathematical models to better understand the interaction between the different phenomena involved and to accurately estimate

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UNDER THE ICE

UA-built radar helps researchers understand rising sea levels

By Adam Jones

Using the word summer to refer to Greenland is an insult to the idea of summer.

Nevertheless, it was "summer" when a team of researchers from The University of Alabama dragged a radar across the Arctic ice in hopes of seeing underneath.

"In the middle, when you're there, it's just all white. You look around 360 degrees, and it's just flat and white," said Christopher Simpson, a doctoral student in aerospace engineering, of the experience of working on an ice sheet where temperatures never rose above freezing in August. "One day we had white out conditions where it was overcast. You couldn't tell the difference between the sky and ground."

Despite the extreme conditions, the researchers used a one-of-a-kind radar – developed and built by UA professors and students in less than six months – to help scientists unveil ancient climate history and to provide perspectives on improving climate models. The team included Simpson, along with graduate student Joshua Nunn and Dr. Stephen J. Yan, who specializes in ultra-wideband radar and antenna research.

It was the first time a radar, using high frequencies between 600 and 900 MHz, imaged the bottom 10 percent of the ice sheet, which is about 1.7 miles deep, Yan said. These results will contribute to developing satellite missions to completely map Greenland and Antarctic ice.

"People have used radars for a long time, but we are innovating to do something that has never been done with this technology," said Dr. Prasad Gogineni, lead UA engineering researcher on the project and an internationally recognized expert in the field of remote sensing. "We took measurements that could not be done otherwise."

It is uncertain how much glaciers and ice sheets will influence rising seas because scientists are not quite sure how they behave, contributing to wide predictions of future sea levels. To provide clarification, an international team of researchers is studying the North East Greenland Ice Stream, led by Professor Dorthe Dahl-Jensen at the University of Copenhagen. Engineering researchers at UA developed a radar to provide an accurate image of what occurs at the base of the ice. The radar is the first of its kind, advancing the use of a type of radar known as ultra-wideband surface-based radar for scanning the interior of ice.

"If you believe in climate change or not, coastal protections are a major issue in the future," Gogineni said. "This work contributes to a better projection of what the sea level will be and how we can protect the coasts."

Like a slow moving river, the North East Greenland Ice Stream carries water into the ocean by dumping icebergs and from melting on its edges. Its speed is increasing, but changes in the ice stream are not well understood, making it difficult to predict through modeling.

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The ice stream has been studied heavily through drilling ice core samples and radar surveys, and Gogineni has been involved in several such projects at his previous position at the University of Kansas.

However, this project aims to understand how the structure of the ice crystals and the interaction within the ice, particularly at the bottom, has influenced flow over time. To help with that, researchers need a detailed image of the ice stream from the radar built by the UA engineers.

The radar is being used to expand knowledge from a site where an ice core sample will be removed. The ultra-wideband radar operates in the Very High Frequency and Ultra High Frequency bands to penetrate deep into ice, as opposed to commercial radios or satellites that use microwave frequencies with large antennas to transmit over longer distances.

The radar is 1,000 times more sensitive than the current state-of-the-art radar used to image glaciers, operating at a higher power with a bigger, yet lighter, antenna than similar radars for ice sounding, said Yan.

"The larger the antenna, the more sensitive the system," he said.

While Yan and his students designed and developed the radar, Dr. Charles O'Neill, aerospace engineering researcher at UA, and his students built the radar antenna. Shaped like a plus sign 17.5 yards wide by 19.6 yards long and made up of 16 connected antenna panels, it was pulled over the ice surface at about 4 mph, moving much slower than existing airborne radars and thus allowing more sensitive measurements. The team in Greenland covered about 60 miles during two weeks on the ice.

The system sent signals deep into the ice, giving a vertical scan of the internal structure of the ice at a resolution of less than two feet. This helped scientists better understand how it formed over time. Collecting nearly 20 terabytes of data in the field, the UA team will generate fine images of the bottom of the ice stream.

The plan is to return to Greenland later this year for radar testing before going to Antarctica to support core drilling.

MARCO BONIZZONI BUILDING STUDENT SUCCESS THROUGH CHEMISTRY AND COLLABORATION

Marco Bonizzoni is an associate professor and director of graduate recruiting in The University of Alabama's Department of Chemistry and Biochemistry. He is also an Arts & Sciences Distinguished Teaching Fellow.

By Brock Parker

Bonizzoni leads a group of graduate students that focuses on the design and characterization of supramolecular systems, which are complex chemical systems that extend beyond a single molecule. Specifically, the group is interested in systems held together by non-covalent interactions in water-based solutions, for analytical, environmental and biomedical applications.

Dr. Marco Bonizzoni (far right) with students in his lab.

"Intermolecular interactions are the basis of life. Proteins, DNA and our very living cells are held together through careful use of such interactions," Bonizzoni said. "Their use in man-made systems is nowhere near as sophisticated as in living organisms, but it has the same potential. These techniques also sometimes naturally lend themselves to applications relevant to human well-being and development, which make them interesting and worthwhile and have the potential for significant impact on everyday applications."

Bonizzoni's group is working with five higher education institutions within the Alabama-Mississippi area. They are collaborating on a project funded by the National Science Foundation to develop polymer-based chemical sensors to detect environmental pollutants in the Gulf of Mexico and its tributaries. Research such as this brings a molecular perspective to the Alabama Water Institute, connecting macroscopic geological and geochemical events and their effects at the nanoscale level.

"These collaborative projects fit well within the framework of the Innovations at the Nexus of Food, Energy and Water thrust at the NSF," said Bonizzoni. "We are particularly tasked with using pattern-based recognition methods to recognize and measure classes of pollutants in water. Think of them as the 'fingerprinting' of chemicals."

Bonizzoni said there is still a substantial divide between chemical sensing methods proven in lab conditions and their deployment as rugged devices in challenging environments, such as unattended remote sampling work. His students intend to bridge that gap, but he believes their primary goal should be the advancement of fundamental knowledge in their field to break new ground for other researchers and engineers down the line.

"Students in my group lead their own projects and work with our collaborators at others institutions to drive their project forward," said Bonizzoni. "Depending on their progress through the program, students are made more and more completely responsible for the day-to-day design of experiments and data interpretation."

Students in the group start presenting their results very early in their career, primarily at conferences and meetings, as often as possible. He said the process of preparing materials for external presentation is a great catalyst for reflection and a driver for new directions in their experimental work.

"In addition to a group of excellent graduate students, I am also fortunate to have attracted talented and determined undergraduate researchers to my group," Bonizzoni said. "Working with us can be demanding for them because soon after a short training period, they are held to standards of work similar to the graduate students. Nevertheless, we have been lucky to attract excellent students, among those two recent recipients of the Randall Outstanding Undergraduate Research Award, UA's premier campus-wide recognition for undergraduate research."

Looking toward the future, Bonizzoni has a long-standing scientific interest in the detection of heavy metal ions. "I intend to expand our current detection techniques to these targets because of their relevance as environmental pollutants and as micronutrients to humans, as well as in aquatic environments," he said.

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the potential of complex subsurface systems is very promising. “In years past, I was focused on flow and rock dissolution in highly fractured vuggy carbonate reservoirs with the applications to flow in karst aquifers and sinkhole formation and evolution,” said Rasoulzadeh.

For Wang, her research direction is more theoretical. She is currently working on stochastic-statistical agent-based models of residential crime, which in application would significantly help law enforcement to understand the feedback between treatment and hotspots of crimes localized in time and space. The models are still being implemented.

“It shows how we can help predict where the crime may occur, and we can prevent it before it happens, allowing for more efficient strategies,” said Wang.

Wang wants to show mathematical models can help solve problems in which they may have not been considered. She said these methods, such as her example of the crime models, can prove beneficial in water research.

“I am very interested in working more with fluid dynamics and how water is transported. I think there is great potential in using theoretical math, pure math, to tackle some of the very practical problems about water,” she said. “There has to be people to build this bridge, and I hope it’s us and our colleagues on campus.”

All three researchers want to protect and enhance water quality across Alabama and the world, and they are excited about teaming up with other researchers on campus to accomplish that.

“We can let math be applied and somehow use math to solve real-world problems, to be hand-in-hand with all the other departments,” said Wang. “We have models, and we can make predictions to make better models. We can take these out into the field to help the community, the state and society. That is our eventual goal.”

Researchers interested in collaborations can contact the applied and computational math faculty members through their website: https://math.ua.edu/specialty/applied-and-computational.

A full list of AWI-affiliated members can also be found on its website: http://awi.ua.edu/awi-affiliated-members.

HOW TO GET AFFILIATED WITH THE ALABAMA WATER INSTITUTE

If you have expertise that could contribute to addressing complex water issues, please register yourself on our website. All registered members are considered affiliated with AWI and have access to all AWI resources. To register, visit the AWI website: ***awi.ua.edu.***

Affiliated Member Information:

http://ovpred.ua.edu/alabama-water-institute/awi-affiliated-members/

Eligibility Criteria:

- A faculty/staff/student appointment at the University of Alabama.
- Research expertise in a water-related field.
- Completion of registration form.

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