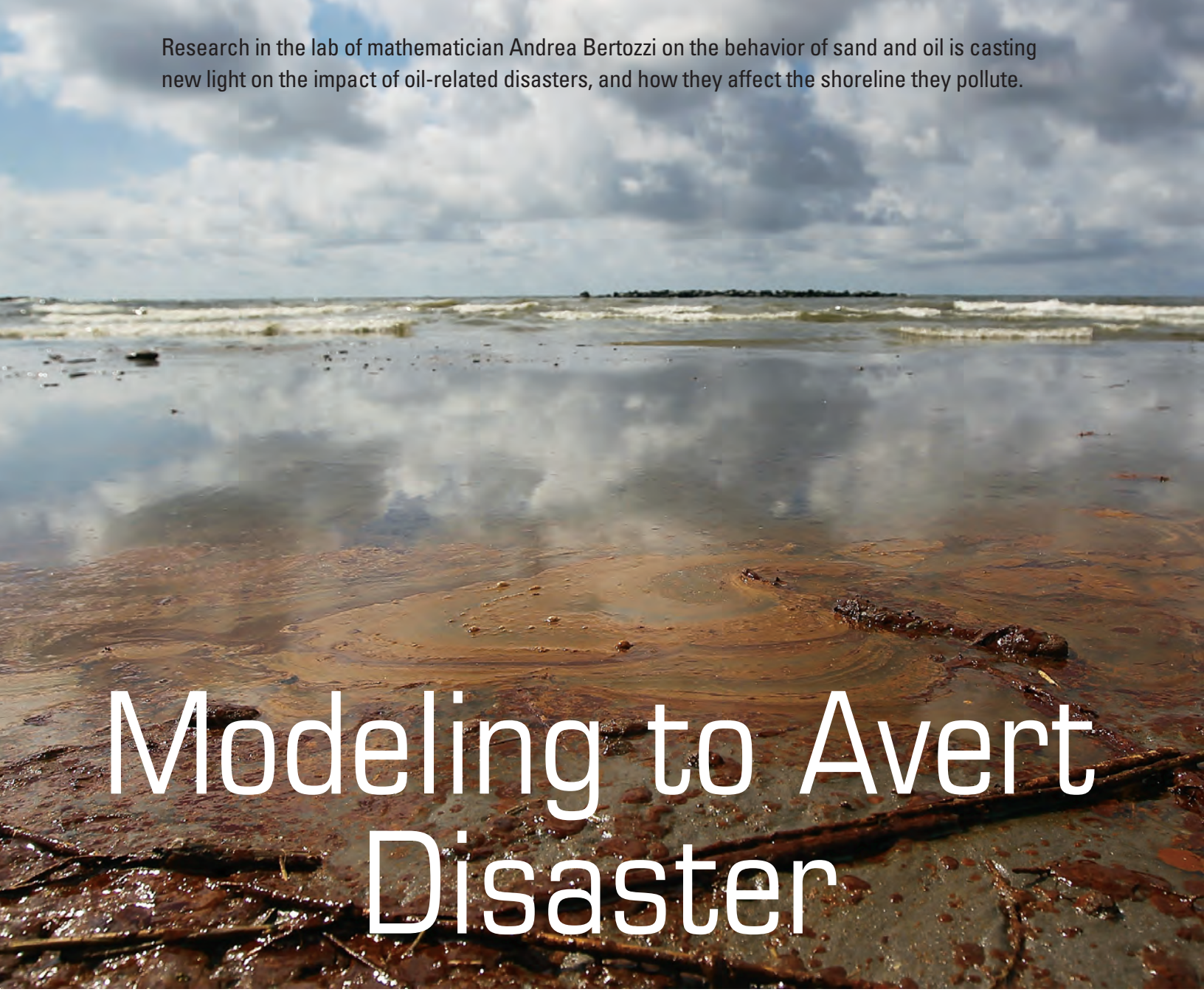


Research in the lab of mathematician Andrea Bertozzi on the behavior of sand and oil is casting new light on the impact of oil-related disasters, and how they affect the shoreline they pollute.

Modeling to Avert Disaster

By Cynthia Lee

For five years Professor Andrea Bertozzi, director of UCLA's applied mathematics program, has been working with her students and postdoctoral researchers on experiments in a Math Sciences lab to understand the physics of what happens when sand and oil mix together and flow down a slope.

While the experiments are simple enough for beginning researchers to do, the challenge of developing a mathematical model to predict how this sludgy mixture will behave, based on the size of the grain of sand, the viscosity of the oil, and the angle of the slope, makes the problem a lot more complex and intriguing to young scientists.

With modest funding over the years from the Office of Naval Research, the National Science Foundation, and the UC Lab Fees Research Program, the experiments gave undergraduates a chance to dive into basic science research. Bertozzi's applied math lab is the first at UCLA to give students an opportunity to do hands-on experiments that are primarily driven by mathematics. The papers it produced addressed some basic science questions of relevance to the food industry, coal recovery, and mudslides.

"I always felt that this project was something we did on the side," said Bertozzi.

Then something happened to give their research nationwide relevance: on April 20, the Deepwater Horizon oil rig blew up in the Gulf of Mexico.

When crude oil began to wash up on the beaches of Louisiana, Bertozzi immediately saw a connection between the theoretical work she and her students had been doing since 2005 and the tragic outcome of what has been called the worst environmental disaster in the history of the country.

"I thought we might start thinking about problems that were more directed at the oil spill," the mathematics professor said.

A call for "rapid response" proposals related to the Gulf of

Mexico oil spill by the National Science Foundation clinched it. Winning a year's worth of funding, Bertozzi and her students have now found themselves working at the leading edge of oil spill-related research.

"We're one of the few organizations funded in the wake of the oil spill that is doing basic research in the laboratory rather than field work," said Bertozzi. "One of the things we've tried to do with the lab is create a platform in which young students can get involved."

The lab's research addresses fundamental questions that relate to the monumental cleanup problem, ideally producing theories about the dynamics of oil and sand. For example, is there a critical angle of incline for beach sand dunes that would result in oil collecting in the dune itself instead of flowing to the bottom of the dune?

Scientists on the oil-contaminated beaches are finding not only globs of oil sitting on the sand, but layers of crude that have been deposited 6 to 10 inches beneath the sandy surface.

"Springboarding off our study, what we see happening depends on the angle of the incline, the viscosity of the oil and the amount of oil there in comparison to sand," Bertozzi said. "We might be able to predict how the oil is going to separate from the beach sand."

To duplicate the basic physical forces that are involved in this study of fluid dynamics and sedimentation, where particles suspended in a fluid exert forces on other particles in complex ways, Bertozzi and her group use non-toxic oil of various viscosities and glass beads (like sand, but engineered to be identical in size), to make sludge. They then examine how it behaves as it flows down an inclined trough. Does the sludge stay well-mixed? Or does sand flow faster to the front edge to form a ridge?

In some cases, some of the oil separates to flow in "fingers" ahead of the sand. Using a laser to help them see the profile of the flow, they can create a 3-D computerized mathematical profile of the flow to help them in their analysis.

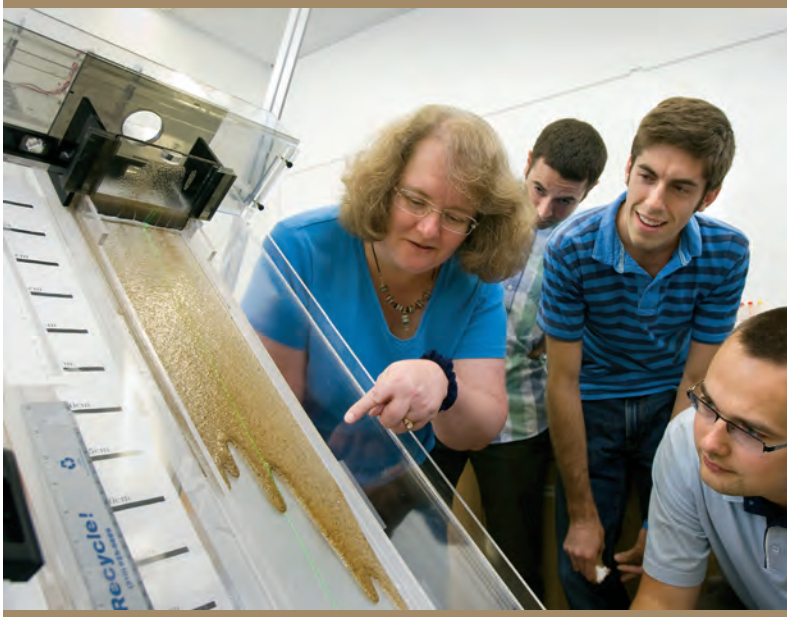
In a recent paper, Bertozzi's team successfully compared detailed experiments with a new theory for how sand separates from oil. As principal investigator of the study, Bertozzi is currently designing experiments that will directly focus on some of the issues related to the cleanup of beaches.

"We've met online with geologists doing fieldwork all over the gulf," said Bertozzi. "We're learning more about the problems as we do the research.

"There could be a lot more science to understand about basic physical problems in this type of disaster," she said. "For example, why does oil sometimes wind up in tar balls on the beach and sometimes percolate down under the sand?

"And, if we know oil is coming ashore, there may be ways to prep the beach ahead of time."

Andrea Bertozzi and her students study the flow of non-toxic liquids combined with glass beads to simulate the dynamics of the movement of oil that has saturated beach sand.



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