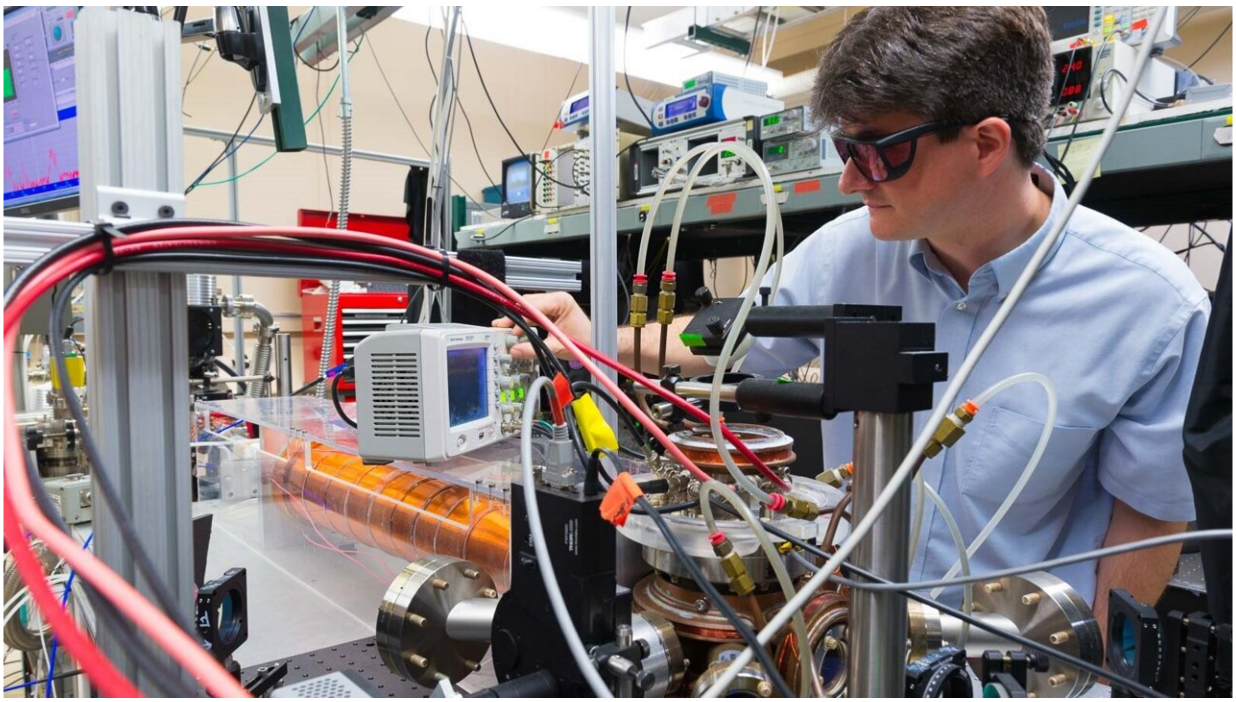
Scientists use nuclear physics to probe Floridan Aquifer threatened by climate change

September 30 2021, by Savannah Mitchem



Argonne scientist Peter Mueller at the TRACER Center. The facility has advanced the science of krypton dating for young and ancient groundwater and glacial ice. Credit: Argonne National Laboratory

As rising sea levels threaten coastal areas, scientists are using an emerging nuclear dating technique to track the ins and outs of water flow.

Florida is known for water. Between its beaches, swamps, storms and humidity, the state is soaked. And below its entire surface lies the largest freshwater aquifer in the nation.

The Floridan Aquifer produces 1.2 trillion gallons of water each year—that's almost 2 million Olympic-sized swimming pools. It serves as a primary source of drinking water for over 10 million people and supports the irrigation of over 2 million acres. It also supplies thousands of lakes, springs and wetlands, and the environments they nurture.

"The data from just a few samples is rich with opportunity, and this study demonstrates the great potential of krypton-81 in multiple fields of geochemistry," says Argonne National Laboratory scientist Peter Mueller.

But as glaciers melt due to global warming, rising sea levels threaten this water source—and other coastal aquifers—with the intrusion of saltwater. It's more crucial than ever to study the history and behavior of water in these aquifers, and Florida's dynamic water systems make it a prime testbed.

In a study led by the University of Chicago, scientists applied a dating technique developed by nuclear physicists at the U.S. Department of Energy's (DOE) Argonne National Laboratory that uses a radioactive version of the element krypton to study the origin and flow of freshwater and saltwater in the Floridan Aquifer. Their findings demonstrate the promise of this novel technique to help understand and forecast the effects of climate change on coastal aquifers, to inform water resource management and to reveal insight into other geological processes.

Counting krypton

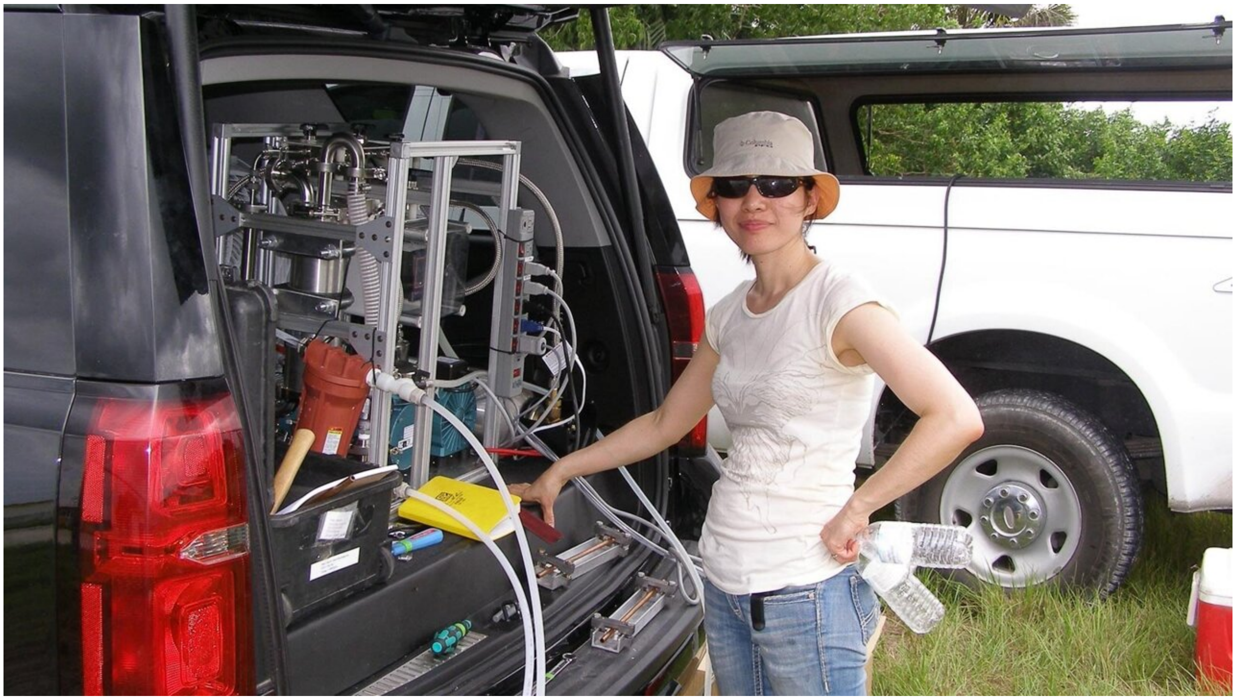
To study the flow of water in the aquifer, the scientists used the TRACER Center at Argonne to perform radiokrypton dating. This technique works by the same principles as carbon dating, where the age of something is determined based on the amount of a certain element remaining in the sample. But instead of carbon, it uses the radioactive isotope krypton-81.

A small amount of krypton-81 is naturally produced in the atmosphere and can dissolve into the water droplets in clouds and bodies of water. Once the water goes underground, it stops absorbing krypton-81 from the atmosphere, and what remains slowly changes into other elements overtime.

If scientists can figure out the ratio between the krypton-81 in the water and in the atmosphere, they can calculate how long it has been underground.

"This is extremely challenging," said Peter Mueller of Argonne's Physics division. "Since krypton-81 is so rare, you need very sensitive measurement tools to detect the tiny amount within a sample."

Only one in a million atoms in the atmosphere is krypton. What's more, only one in a trillion krypton atoms is krypton-81 specifically. This leaves so few atoms to detect in a sample that scientists count them one by one using a technique called Atom Trap Trace Analysis, developed at Argonne.



Scientist Reika Yokochi collecting water samples from the Floridan Aquifer. The team collected samples from eight wells and extracted the gas dissolved in the water, including the krypton-81, to analyze at Argonne's TRACER Center. Credit: Argonne National Laboratory

The team collected samples from eight wells tapping the aquifer and extracted the gas dissolved in the water, including the krypton-81. At the TRACER Center, they sent the gas down a beamline where six laser beams come together to create a trap unique to the isotope of interest (in this case, krypton-81). The trapped atoms show up on a camera, and scientists can count them down to the individual atom.

This study is the first application of radiokrypton dating on the Floridan Aquifer.

There's good news and bad news

Some of the samples contained 40,000-year-old saltwater from just before the last glacial maximum at around 25,000 years ago, when much of the water that is now in the ocean was captured in huge glaciers. During this period, the sea level was over 100 meters lower than it is now.

"Because of global warming, the sea level is rising, causing seawater to spoil freshwater sources," said Reika Yokochi, research professor at the University of Chicago and lead scientist on the study. "The presence of the moderately old water means saltwater persists in the aquifer once it gets in. This is bad news. We have to minimize the rate of this pollution."

While the salty samples are concerning, there is good news, too. The scientists confirmed that the water in the southern part of the Floridan Aquifer was recharged with freshwater during the last glacial period (sometime between 12,000 to 115,000 years ago), bolstering the current understanding of freshwater dynamics.

"We also found a sample with relatively young freshwater, which is good news for Florida because it means that the water is actively flowing and renewable near central Florida," said Yokochi.

New technique with great potential

Radiokrypton dating is a relatively new technique, and the scientists are just getting started. This tool has incredible potential to drive discovery in physics, geology and beyond.

For example, scientists armed with radiokrypton dating can use the water in coastal aquifers as potential messengers of changes in water cycles and the composition of ancient seawater. The technique can also provide insight about the movement of elements across land-ocean boundaries, which impacts carbon dioxide (CO_2) levels in the atmosphere.

"As water flows on the surface or underground, it reacts with surrounding rock and picks up signatures that tell a story," said Yokochi. "This information can help to improve and validate our models of Earth's systems and the cycle of the elements, which are tightly linked with global climate."

Radiokrypton dating also serves as a complement to carbon dating when performed on the same samples. Scientists can use results from radiokrypton dating to calibrate carbon dating analysis. Once corrected, the carbon data can provide additional insight, especially on rates of water-carbonate reactions.

"When you have a new tool like this and apply it for the first time, even in an aquifer that has been studied a lot, suddenly you get a new perspective and new insight," said Mueller. "The data from just a few samples is rich with opportunity, and this study demonstrates the great potential of krypton-81 in multiple fields of geochemistry."

More information: Reika Yokochi et al, Origin of water masses in Floridan Aquifer System revealed by 81Kr, *Earth and Planetary Science Letters* (2021). DOI: 10.1016/j.epsl.2021.117060

Provided by Argonne National Laboratory