Follow the water to understand drought

October 25 2011, By Miles O'Brien and Ann Kellan

Water is a precious resource many take for granted until there is too little or too much. Scientists and engineers have positioned instruments at the Susquehanna Shale Hills Observatory at Pennsylvania State University to learn much more about the water cycle there. It is one of six Critical Zone Observatories in the United States.

"What we're trying to do is build experimental test beds across the United States and we're also working with several European Critical Zone Observatory test beds, to understand the cycle of water in detail," says Chris Duffy, a professor of civil and environmental engineering at Penn State.

With support from the National Science Foundation (NSF), Duffy and his team are documenting the flow of water at the forested Shale Hills watershed from rain and snow through plants, soil and rock--from "bedrock to boundary layer."

"We have very sophisticated sensors at Shale Hills," explains Duffy. "We use things like laser precipitation monitors. They're infrared lasers that measure droplets; in fact, [they] tell us the type and amount of rainfall, whether it's rain or snow or sleet, and allow us to get accurate numbers on the incoming rainfall."

Little water can escape unnoticed. Instruments poised atop a tall tower at Shale Hills measure water as it evaporates. "Water vapor that's leaving the watershed and going into the atmosphere is captured by those

sensors," says Ken Davis, a professor of meteorology at Penn State.

Davis points to two of the many instruments attached to the tall structure. "One measures the wind and temperature, and the other measures water vapor and carbon dioxide concentration in the atmosphere. We actually measure all the individual updrafts and downdrafts of air as they leave the surface and then come down from the upper atmosphere. Understanding how the earth processes water is important for drought and flood forecasting," explains Davis.

The team is also perfecting a way to fingerprint the water from individual storm events by using natural tracers to identify the pathways of storm water through the watershed. This has helped the researchers determine that in an average year, most of the annual water supply in streams actually comes from winter snow rather than summer rainfall.

"What we're using is oxygen-18 and deuterium, two isotopes of water. Both are components of water molecules," says Duffy. "By taking samples to the laboratory and making these measurements, we are able to trace this signature from rainfall to vegetation to soil water to stream flow and determine how long the water spent in the watershed."

Another device called a sap flow sensor, attached to trees, measures the rate water moves through the wood of the tree and up to the leaves. It's no surprise that plants are huge water guzzlers.

"Usually, it's the largest fraction of water that leaves this watershed," says David Eissenstat, professor of woody plant physiology at Penn State. "When you're working with trees, it's hard to measure all the water being transpired from water vapor in the air."

That is why researchers like Katie Gaines will climb trees to collect leaves and branches to sleuth out sources of water trees use.

"We climb up and we get these branch samples. We put them into vials and seal them up so that we can take them back to the lab, take the water out of them to get an idea where the water in the tree actually came from," explains Gaines. The researchers do this to measure how deep roots of plants and trees go to meet their water demands.

Geology plays a big part. The type of soil and rock under the observatory determines how much of the water will flow into streams and how much will seep into an underground basin.

"We measure the moisture content that's stored in the soil at different depths and at different times of the year so we'll know how the soil will respond to the rainfall," says soil scientist and hydrologist Henry Lin. "We want to know how much water is retained in the soil to support plant growth and groundwater and how much might run down the hill to the stream."

The scientists also have instruments within the soil to measure how the water changes throughout its journey. Hydrogeologist Kamini Singha says they want to answer a number of questions as they follow the flow of water through soil and rock. "How long does it take for water to migrate through the system? Does it have a chance to clean itself as it moves? Is it picking up material as it goes? So, some understanding of what water does in the subsurface is important to all of us," she says.

Duffy says a key goal is to understand the water cycle well enough to help planners better predict the impact of floods, droughts and reliability of water supplies because "global change and global warming is accelerating climate effects, increasing rainfall in some areas and increasing drought impacts in other areas."

Provided by National Science Foundation