For water researchers, an atmosphere full of questions

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A Gulfstream turboprop sits on the McClellan Airport runway under gray, gloomy skies. Kim Prather has waited two weeks for this day.

"I can't believe there are finally clouds," she says gratefully as she and her research team check and calibrate several million dollars' worth of equipment stacked in the plane's cabin.

After the plane takes off, it slices through a 9,000-foot-thick layer of storm clouds, zigzagging up the western slope of the Sierra Nevada to probe the mysteries of California's rain and snow.

Onboard, a special instrument that Prather invented and named "Shirley" will blow apart atmospheric particles with a laser and map their chemical composition, all in real time. Other devices will count and measure millions of cloud droplets, record water content and analyze gases.

On the ground, in the Tahoe National forest, another array of equipment will simultaneously sample Sierra air masses.

Prather's team is trying to figure out why some clouds give up their moisture and others don't as they roll across the mountain ranges that provide much of California with water.

They wonder: Is urban pollution reducing precipitation in Northern California's high country? Is Gobi Desert dust blown thousands of miles across the Pacific Ocean boosting the Sierra snowfall? Will atmospheric rivers - the moisture-laden bands in the sky that drenched the state in December and March - dump even more rain with global warming?

The answers will help resolve some of the unknowns of California's future water supply.

In 2009, federal and state agencies launched a research project called CalWater. It has two aims: to gain a better understanding of the mechanics of atmospheric rivers when they slam into the state's mountain ranges and how computer models of climate change should account for the rivers, and to determine if and how precipitation is influenced by the tiny particles called aerosols that are at the center of every cloud droplet.

Prather and her project colleague Daniel Rosenfeld are studying the aerosols, which can be liquid or solid, the products of nature, such as sea salt or windblown desert dust, or the products of man, such as urban soot or nitrates from farm operations.

Five years ago, Rosenfeld, an atmospheric scientist at the Hebrew University of Jerusalem, conducted research suggesting that man-made pollution particles from the Bay Area and Central Valley hindered the formation of rain clouds over the Sierra.

By creating more surfaces on which water vapor can condense, the theory goes, certain types of pollution may promote the formation of a lot of tiny droplets that never get big enough to fall as rain.

But the idea that aerosols influence the nature and amount of precipitation is controversial.

Meteorologists believe "that if a cloud wants to rain/snow, it is going to regardless of the type/amount of aerosol seeds," said Prather, a professor of atmospheric chemistry at the University of California at San Diego who worked out of McClellan during the project's five-week field campaign this winter.

"There are so many factors that ultimately affect precipitation - meteorology, atmospheric dynamics, cloud microphysics and chemistry - and their effects are all intertwined and often change at the same time, so sorting them out is very, very difficult," she added.

The CalWater team hopes to settle the matter.

Today, while Rosenfeld and other scientists soar above her, Prather heads up the I-80 corridor to Sugar Pine Dam in the Tahoe forest. Halfway into her drive, she gets a call on her cellphone from McClellan that the plane was forced to turn back two hours into the flight because of power problems. "Shoot," she says.

It is lightly raining at Sugar Pine, where a small trailer is packed with 14 instruments - including "Laverne," Shirley's big sister - that are taking air samples. Nearby, a huge radar drum is collecting data from the same cloud layer the Gulfstream flew through.

By combining the ground and plane measurements, researchers can compile a vertical profile of the air masses that drop - or don't drop - rain and snow over the Sierra on this stormy afternoon.

Prather gets an update from the Sugar Pine staff and checks the instrument monitors. She studies a data stream that provides an instant chemical snapshot of the particles sampled by a periscope-like intake atop the trailer.

She heads back to McClellan, eager for the details of Shirley's aerial meal.

"It's really happy," Prather says as she scans Shirley's readings on a laptop computer in a second-floor conference room of the airport's corporate jet center. "It really had a lot of particles."

Prather identifies them with a practiced glance. "Organics, dust, sea salt." She notes that the samples taken outside the cloud have a different composition. "That's cows," she says, recognizing ammonium and nitrate from Central Valley dairy operations.

Prather, 48, grew up in Santa Rosa and almost flunked high school chemistry out of boredom. She never dreamed of a career in science - she wanted to be a legal secretary - until her chemistry instructor at Santa Rosa Junior College made the subject understandable and challenging. "It explains everything and it's part of everyday life," she said.

Her interest in physical processes led her to atmospheric measurements. While teaching at UC Riverside in the early 1990s, Prather wondered what she could learn if she sampled individual air particles rather than collections of them, as was commonly done. She assumed she could buy the necessary equipment. She soon found it didn't exist.

So Prather and husband Joseph Mayer, a machinist whose father constructed NASA airplane models for wind tunnel tests, designed the "Beast," Shirley's hulking forebear. Then Mayer built the mass spectrometer. A few dozen Beast descendants are in operation worldwide, used in scientific research, environmental sampling and even defense testing for signs of biological warfare.

Prather says she has turned down offers to start her own instrument company. Most of the licensing fees and royalties for the spectrometers' manufacture go to the UC system. "When I'm on my deathbed, do I want to be rich or have made a difference?" she asks.

The next morning the research group gathers in the conference room to go over the day's flight plan, get a detailed weather forecast and review data.

On the flight that afternoon, Rosenfeld is in the cockpit's jump seat snapping photos for a visual diary of the cloud conditions.

Paul DeMott, a Colorado State University research scientist, sits not far behind Shirley, monitoring an instrument that hunts for ice-making particles. It draws air samples, exposes them to cold and humidity onboard and then measures the ice nuclei they form.

He is trying to crack nature's codes for making atmospheric ice, the first stage in forming a significant amount of precipitation. In the atmosphere, small cloud droplets can remain liquid at temperatures as low as minus 38 degrees. But some particles will cause droplets to freeze at higher temperatures, promoting ice formation.

DeMott has previously shown that mineral dust transported long distances is a major global source of ice-creating particles. In 2009, measurements at Sugar Pine revealed heavy concentrations of Asian dust in rain and snow collected during a big Sierra storm. The desert particles seem to have a "magic recipe" for growing ice, Prather says.

At the end of the three-hour flight, Rosenfeld is smiling as he walks across the tarmac. The instruments detected precipitation in clean marine clouds on the flight up the Sierra, but on the way back, when the cloud layer at the same altitude was spiked with pollution particles, there was less rain.

By the end of the field season, the Gulfstream will have flown 27 times. "We measured everything we could think of," Prather said.

The results seemed to support the idea that aerosols influence precipitation. But it will take her team several years to analyze the 300 gigabytes collected and write up the findings.

"It's an amazingly rich data set," Prather said. "It's going to take a lot to tie all these pieces together."