Squaw Peak

The search for supercooled water in Sierra Nevada clouds was becoming a major effort in the Sierra Cooperative Pilot Project (SCPP) by 1980. It had been assumed before SCPP started and for the first few years afterward that Sierra Nevada clouds were juicy, that is, they had plenty of liquid water in them. After all, the airflow over the Sierra Nevada had its source over the Pacific Ocean not far away.

The mountain barrier extended from almost sea level to over 10,000 feet in many places and the cloud bases were low and warm. Surely the amount of condensate being squeezed out of these clouds would produce large quantities of supercooled water upwind of the barrier. In addition, the amount of precipitation which fell in the Sierra Nevada was incredible. The average annual precipitation along the crest was over 100 inches of water equivalent, mostly in the form of snow. The snow would stack up to over 20 feet deep during some winters. Snow flakes and ice crystals falling from Sierra Nevada clouds were often heavily rimed, indicating there had to be supercooled liquid water somewhere in the clouds.

However, during the first three years of the SCPP only small quantities of liquid water were measured by the instrumentation on the King Air 200 cloud physics aircraft flown by the University of Wyoming. The only large water content and aircraft icing conditions observed were in convective cells, typically seen in postfrontal convection. No aircraft icing was observed in prefrontal clouds and only occasionally during frontal passage. On the other hand, concentrations of ice crystals were almost always high, normally running between 10 and 100 crystals per liter. Crystal concentrations were unusually high in the lower, warmer part of the clouds, peaking between 15 and 20 degrees. This was later attributed to ice crystal multiplication. It turned out that Sierra Nevada clouds have all the right conditions for ice crystals to be multiplied by freezing and splintering of large cloud droplets.

Unfortunately, low supercooled water contents and high ice crystal concentrations are not the conditions hoped for in which to conduct cloud seeding operations. Tom Henderson, President of Atmospherics Incorporated and one of the contractors on the SCPP, began to get concerned about what we were finding. He had conducted commercial cloud seeding operations for years in the Sierra Nevada and around the world based on the presence of supercooled liquid water. These results could impact the assumed basis of cloud seeding operations and the viability of his company. Tom expressed his concerns that the instrumentation on the University of Wyoming cloud physics aircraft may be faulty or the flight patterns and timing of the flights may be missing the juicier parts of the clouds. For example, some of the most seedable parts of the cloud should be above the freezing level but close to the terrain where the King Air could not fly. Maybe we just weren't getting to it.

Tom suggested that he and I attempt to directly observe the liquid water content and ice crystal concentration in the cloud by positioning ourselves on the top of the Sierra Nevada during a storm with some simple equipment. We should be able to observe lots of liquid water directly on the ridgeline where the air is being lifted the fastest. If the freezing level was below the top of the mountain, we should be in an ideal location to find out what is going on inside the clouds. After a storm is over it is not uncommon to see lone trees on the ridgeline which have collected supercooled liquid water as rime on their upwind side. This was evidence that at least during part of the time some storms contain supercooled liquid water.

The perfect place to take these observations was on the top of Squaw Peak, a mountain on the ridgeline of the Sierra Nevada west of Lake Tahoe and about 15 miles south of Donner Pass, the infamous location of the Donner Party. Squaw Peak is almost 9,000 feet high and the Squaw Peak Vortac is located atop this mountain. This Vortac which the FAA provides for aircraft to navigate by was extremely useful to our aircraft operations. It was not only in the center of our target area but was also elevated, sometimes even above our flight patterns over lower elevations to the west. The main lift for the Squaw Valley ski area, used in the 1968 winter Olympics, terminated directly on top of Squaw Peak.

Tom arranged with the Squaw Valley officials for him and me to ride the lift to the top and use the Ski Patrol warming hut during the next storm. We would drive to the ski area early in the morning, work during the day, and return home that evening. When the next storm approached we headed to Squaw Peak with our instrumentation and high expectations. Tom parked his Volvo in the parking lot and we rode to the top with no difficulty. The ride up the lift was a little bumpy due to the gusty wind, but otherwise pleasant enough. When we arrived at the warming hut, the wind was blowing from the west at about 50 miles per hour and gusting to 65 or so. An occasional snowflake blew by, but it hadn't really started to snow yet.

We placed our equipment in the snow outside the hut to keep it cold and went in to have lunch. The warming hut was about ten feet long and five feet wide. It had two long benches along each wall and large windows along the north wall. An electric heater kept the hut at about 100 degrees Fahrenheit. We never could find the thermostat to turn the temperature down.

After lunch we set up our equipment to measure the dry and ice bulb temperatures and collect rime samples and ice crystals. Tom had brought a cylindrical stake on which to collect rime and I had brought glass slides and a Formvar solution to replicate ice crystals. Late in the afternoon it began to snow, and we started taking data. We had planned to work until about six p.m. and then head back down the lift. However, since we didn't get started taking data until so late, we weren't too disappointed when the operator called to tell us he had decided to shut down the lift. We would have to spend the night! That was okay with us. We had brought plenty of food and water and the hut was nice and warm.

Tom and I took turns during the night walking outside to take measurements. We had to use a flashlight to see our instruments and needed to be careful not to fall off the mountain. Not more than ten feet in any direction from the door of the hut, the mountain sloped downward. To the west it dropped off several hundred feet. The wind also picked up and we were sometimes walking into a gale of over 100 miles per hour. In such winds the visibility becomes almost zero and we had to navigate using a rope strung along the ridge to take care of personal business. One could easily see why scientists in the Arctic and Antarctica became disoriented and lost when walking between buildings. The wind moaned and gusted all night, making it hard to sleep. Between the noise and the need to take measurements every 30 minutes or so, neither Tom nor I got much rest.

As the day broke the next morning, little changed except the visibility went from blackout to whiteout conditions. The wind continued to blow at about 100 miles per hour and the snow flew by horizontally. All day long we checked the stake for rime, but none appeared. Late in the day the wind became even more gusty and had a more northerly direction. The temperature began to drop. This probably meant that the front had gone by, but we still didn't notice any rime.

We were beginning to get weary and had hoped we wouldn't have to spend another night in the warming hut atop Squaw Peak. However, about six that evening the operator called again and told us the wind was still too strong for us to come down. We would have to spend another night on the mountain.

Tom and I ate the last of our food and finished off the water. We weren't too worried about running out of water. All we had to do was scoop up some snow and let it melt in the hut. It was so warm in the hut that it only took about 30 minutes to melt a glass full of snow. We repeated the regimen from the previous night, but at less frequent intervals. We were beginning to lose interest in this little exercise. We had yet to see any rime. Apparently, for this storm at least, we weren't going to observe any supercooled water. This seemed to be a good confirmation that the aircraft observations were legitimate.

The next morning, we awoke to a major reduction in the wind speed. All was quiet! The snow had stopped, and the temperature had cooled by at least twenty degrees. By eight a.m. we were on the ski lift descending toward a hardy breakfast in the snack shop below. However, when we arrived at the base of the ski lift, the world had changed. We had parked Tom's car two days before on an empty parking lot decorated with a few piles of dirty snow here and there. Now the lot was covered with about four feet of fresh, clean snow with a few rounded hills covering the buried cars. It was a beautiful, white, winter wonderland. But, where was Tom's car? After poking into a dozen or so mounds, we finally located his Volvo and began trying to retrieve it. It would probably have taken us until noon to get his car out of the lot shoveling by hand. But, the manager of the resort sent a snow plow to assist us and we were on our way in less than an hour.

This had been an interesting experiment. On top of the mountain, we had not observed any evidence of supercooled liquid water. But, we had seen plenty of snowflakes and ice crystals and plenty of wind. At the bottom of the mountain plenty of snow had fallen out of the clouds. Apparently, Sierra Nevada clouds are very efficient in turning the condensate from the air lifted over the mountain into snow without the need to artificially introduce more ice crystals. These clouds appeared to be truly "Clouds without Water!"