

Flying High

Lew Grant, my major professor at Colorado State University, gained his reputation as one of the world's leading researchers in weather modification by successfully conducting a series of cloud seeding experiments in the mountains along the continental divide near Climax, Colorado, not far from Leadville. These experiments were called Climax I and Climax II. They were five-year long statistical experiments in which half of the winter storms crossing the central Colorado mountains meeting proscribed conditions were seeded with silver iodide from ground generators and half were left unseeded.

Climax I was a five-year exploratory experiment—one for which the detailed results were not explicitly stated beforehand, other than that seeded clouds were expected to produce more snow than unseeded clouds. At the end of the Climax I field experiment the storms were partitioned by cloud-top temperature and it was found that seeding increased the precipitation for clouds warmer than about -24°C but caused little change in precipitation for colder clouds. It was argued that colder cloud tops nucleate more ice crystals that fall into the lower part of the cloud and precipitate a greater amount of the moisture. For every 4°C colder the cloud top was, approximately ten times as many ice crystals were nucleated.

The Climax I orographic cloud seeding project was one of the first experiments to clearly demonstrate that precipitation could be induced from clouds with warm tops. Unfortunately, the statistical results computed as a function of cloud-top temperature were not considered to be statistically significant because the cloud-top partitions had not been specified before the experiment began. Because of the strong statistical results of Climax I and the theoretical relationship between cloud-top temperature and seeding efficiency, Climax I became the basis for many other experiments.

Climax II, a five-year confirmatory experiment using the same procedures and field location as Climax I, did not reproduce the same results. In Climax II the cloud-top temperature cutoff was specified before the experiment was started and an *a priori* statistical test applied. Although the same general trends were observed, the significance level was less than desired.

After twenty years of trying to export seeding criteria and technology from the Climax experimental area to other mountain barriers in the western U.S., it became clear that the Climax, Colorado clouds and terrain were unique. The terrain works to funnel and mix the seeding material from the ground seeding generators to the proper position in the clouds. Clouds near Climax, Colorado seemed to more frequently fall into categories of warm clouds and cold clouds. And, finally, Climax clouds seemed to have less complex ice crystal multiplication mechanisms in them. Ice multiplication mechanisms naturally increase the concentration of ice crystals in clouds and make artificial cloud seeding unnecessary. These unique cloud characteristics may be partially due to the long distance the Rockies are from the ocean and their high elevation. At any rate, after many years of effort and millions of dollars spent on research in other locations, funding of winter orographic research was suspended in the early 1990s. It was determined that cloud seeding could increase precipitation in limited situations, but these situations are so infrequent and short-lived in most locations that operational cloud seeding is difficult and experimental verification almost impossible.

During the height of cloud seeding activity in the '70s and '80s considerable funding was directed toward improving new and sophisticated airborne platforms for measuring variables like liquid water content and ice crystal concentration. Remote sensing equipment from the ground and from satellites was also developed. Several of these systems helped to define the conditions in clouds directly, which ultimately helped determine their "seedability". However, in the early field studies most measurements were taken from the ground. Cloud-top temperatures were inferred from radiosonde measurements—balloon borne

temperature and humidity sensors used by the U.S. Weather Service. Large, helium-filled balloons are released twice each day from about 100 upper-air locations across the US.

During the Climax experiments it became evident that cloud-top temperature was an important variable for seedability. Lew Grant decided he needed measurements of temperature and humidity in the clouds directly over Climax, Colorado. He had been estimating cloud-top temperature by averaging soundings from four upper-air weather stations surrounding the central Colorado region – Denver, Colorado; Lander, Wyoming; Grand Junction, Colorado; and Albuquerque, New Mexico. These twelve-hour soundings were not only distant from Climax, but not frequent enough to give good time and space resolution. He began supplementing these soundings with ones released from the top of 12,000-foot Chalk Mountain about one mile west of Climax.

Although the supplemental radiosonde releases from Chalk Mountains were helpful, the effort and danger involved in manning the site and releasing the balloons was extreme. Getting crews atop Chalk Mountain in the winter was very difficult. Snowmobiles were required to reach the remote site, sometimes during snowstorms and high winds. One crew got lost while trying to reach the top and drove over the edge of a cliff killing one person and injuring another.

The winds on top of Chalk Mountain can sometimes reach over 100 miles per hour, creating whiteout conditions and great danger of frostbite. Launching radiosonde balloons in these conditions was extremely challenging. Special shelters had to be built to protect the balloon and instrument package until the final release. Even then, many of the balloons burst and the instrument package was lost. The supplemental balloon launches only added occasional data to the project.

Conditions atop Chalk Mountain were very primitive. A permanent building was installed on the top of the mountain and water and fuel were delivered in the

summer. But, food and other supplies had to be ferried up with the crews by snowmobile throughout the winter. Louisiana State University also maintained a nuclear research laboratory on top of Chalk Mountain about a half mile away from the Colorado State Cloud Physics Observatory. However, during the whiteout conditions of a storm it might as well have been on the moon.

I visited Chalk Mountain several times during the Climax II experiment. Because the temperatures atop Chalk Mountain remain far below freezing during the six months of winter, some of the facilities would fail. For example, the plumbing for a standard toilet would freeze and a propane toilet system was found to be more reliable. Such a toilet is not commonplace, and I was not informed how the ignition system worked when directed to the toilet. I was only told to stand up quickly when I was finished. I soon found out the reason for these rather strange instructions. Upon standing, I heard a loud whoosh, a pop, and a sudden cloud of flame and heat, which incinerated the waste. If I had dallied or changed my mind, I'm convinced I would have had blisters for several days. The noise and activity behind me frightened me so that I almost crashed through the toilet door with my pants around my ankles.

Lew Grant wanted better data for estimating cloud-top temperature. He came up with an idea that would provide continuous measurements of temperature and humidity directly over Climax. He asked, why not fly an instrumented kite from the top of Chalk Mountain? Of course, the kite would have to be specially built to withstand winds of up to 200 miles per hour and, possible heavy icing conditions. The kite would have to be constructed of metal and thick plastic. It would need to be tethered with a steel cable wound in and out by an electric winch. The drum would need to hold at least 20,000 feet of cable. Similar kites had been built before and flown in storms, but they had never been flown into the Jetstream from the top of a mountain!

After much discussion and many design revisions, an odd-looking kite was constructed and carried to the top of Chalk Mountain. The wind across the mountain was blowing at about fifty miles per hour with gusts to sixty-five when it was first launched. This wind was more than sufficient to lift the kite from the surface, but, would it be stable and lift gently, or begin weaving back and forth in the flow? The kite was slowly reeled out and remained almost level with the mountain initially, since the air was flowing up the west side of the mountain and down the east side near the release point. It behaved well as the drum slowly turned releasing more and more wire.

After about 200 feet of wire had been uncoiled the kite disappeared into the cloud and the line was inclined to a higher angle. The tension on the cable slowly increased as the kite rose higher into the storm where the wind speed was stronger. When the angle became about 45° , a thumping sound could be heard. The kite was apparently being buffeted by the turbulence in the storm. The plan was to let the kite rise to 20,000 feet above sea level and then reel it back in, taking measurements along the way, up and back. This would be continued during the lifetime of the storm, acquiring temperature and humidity throughout its depth.

When the drum had been unwound so that about 10,000 feet of cable was released and the angle of the wire was about 60° , a sudden gust of wind caused the cable to begin making high-pitched musical sounds like a piano. The drum vibrated and the brakes on the electric winch began to smoke. The winch stopped, and the electric motor reversed, but it was too late. Another violent gust lifted the drum partially off its concrete foundation and then the cable snapped! Everything was suddenly quiet except for the wind. The kite was gone! One of the crew members exclaimed, "Well, I guess that's that!"

There wasn't anything more the crew could do that night. It would be safer to wait until morning when the storm was over to travel down the mountain and look for the kite. Who knew how far it would drift before landing in the forest below. It

would probably take quite a while to locate it and then reclaim almost two miles of cable. Everyone headed indoors to wait until morning.

That probably would have been *that*, except shortly after the crew removed their coats, the lights suddenly went out. “What in the world? Now what? You don’t suppose the kite shut down the power, do you? What would happen if that steel cable fell across the high-voltage power lines along the highway below? Oh boy! We could really be in trouble!”

Sure enough, next morning when the crew reached the bottom of the mountain they found the entire valley surrounding Climax, Colorado without power. This not only included Chalk Mountain, but many private homes and the entire Climax molybdenum mine across the valley. By the time Lew and his crew arrived at the bottom of the mountain, several dozen mining officials were milling around talking about a wire that was dangling across the power line feeding the mine. It had shorted out the power line and shut down their entire operation. Worst of all, several miles of conveyor belts filled with ore had stopped and could not be restarted, even if the power were to come back on right away. All the conveyors would have to be shoveled off by hand before the electric motors could be reengaged!

Needless, to say, Lew Grant was called to the Climax Mine office to meet with the mining officials. He was informed that it would take over a week to get the mine back into operation. What in the world did he think he was doing flying a kite with a steel wire from the top of Chalk Mountain? Who was going to pay for the lost time and expense of clearing the conveyors?

Eventually the mining officials calmed down. They chose not to make Lew Grant or Colorado State University pay for the cost of the shutdown. But, Lew decided not to try flying a kite from the top of Chalk Mountain again. Data

averaged from the four upper-air sites supplemented with a few additional balloon releases from Chalk Mountain would have to do.