SN MONTHLY
June 1999

NCAR archivist Diane Rabson sheds light on our institutional history in this bimonthly series.

NCAR's assault on the hail problem: The National Hail Research Experiment

The 1999 NHRE reunion gang: (front row, left to right) Jim Fankhauser, David Atlas, Chuck Wade; (back row) John merrill, Chuck Frush, William Bradley, John Firor, Don Ferraro. (Photo by Carlye Calvin.)

Humans have long dreamed of being able to control weather. After World War II, weather modification projects multiplied around the world. In 1971, amid amazing claims of success in the suppression of hail by Soviet scientists in the Caucasus Mountains, the National Hail Research Experiment (NHRE) was inaugurated at NCAR to test hail suppression techniques as well as try to better understand the physics of summer storms in "Hail Alley"--northeast Colorado, northwest Kansas, southeast Wyoming, and southwest Nebraska.

NHRE became the largest weather modification project in the world. The multidisciplinary project was based at NCAR and scheduled to last for five years. Plans called for a major field

NHRE Basics

What: The National Hail Research Experiment, a multiyear examination of the usefulness of cloud seeding in reducing damaging hailfall. A variety of related studies addressed the microphysics and dynamics of hail formation, the

program in hail suppression each year for several months. As part of a double-blind study, thunderstorms were seeded with silver iodide in an attempt to create smaller, less damaging hailstones or even rain. Results were equivocal at best; for one thing, the decade of the 1970s was the second driest decade on record, and in one summer, 1973, only six "hail days" were declared, compared to 22 hail days in 1972. By 1975, the seeding program was suspended, two years short of the original goal.

Earlier this spring, on 20 April, the NCAR Archives invited several veterans of NHRE to discuss their memories of the project in a tape-recorded session at Foothills Lab. Coincidentally, Dave Atlas, former director of ATD and the second director of NHRE, was visiting NCAR that day, and we invited him to join our group reminiscence. Also in attendance were John Firor (director emeritus of ASP and NCAR), Toni Biter (MMM), William Bradley (ACD), Jim Dye (MMM), Jim Fankhauser (retired, MMM), Don Ferraro (ATD), Chuck Frush (ATD), Charlie Knight (MMM), John Merrill (SCD), and Chuck Wade (RAP). Note: Some of the excerpts that follow appear in a different sequence than in the original interview, and some of the participants augmented their comments for this article.

forecasting value of numerical models, and the societal impacts of hailfall and cloud seeding.

Where: The plains of northeast Colorado, with a home base near the town of Grover

Who: A host of universities and laboratories and several private contractors, led by NCAR and funded by NSF

When: Randomized seeding experiments in the summers of 1972-74; data analysis in 1975; additional field phase in 1976; incorporation into NCAR's research program thereafter.

How: About half of all days showing promise for hail were randomly selected for flights that seeded all storms in the vicinity. Results of the seeding were assessed through ground-based hailfall measurements; other research goals were addressed through radar, aircraft, and surface data.

Rabson: Can you describe the birth of NHRE?

Firor: NSF asked NCAR to plan a coordinated national hail suppression experiment to begin in fiscal year 1972 and involving the cooperation of all relevant groups. This was during my tenure as director, so I assembled a committee of all the interested people. There were territorial arguments among the committee members. All of them saw that NSF was warming up to ask NCAR to conduct the project, and some of the other groups wished to do it themselves. So there was a certain amount of pushing and tugging. But they were able to endorse having a coordinated program and to recommend that NCAR develop the detailed plan.

This committee had insisted that the project not be called a national program, since they feared that such a name would cut off their NSF funding for individual university field efforts. The original name chosen for the program was Northeast Colorado Hail Experiment--NECHE. But someone on the NCAR staff, when I was out of town, changed the name to National Hail Research Experiment, or NHRE. The staff just began using the new name, and since no one chose to object, that became the name.

Fankhauser: The first director, Bill Swinbank, very wisely broke the objectives of the program into two very clearly defined goals. One was the statistical part of hail suppression, and the other was better understanding of convection itself. A lot of us wouldn't have gotten involved if it hadn't been for this dichotomy.

Atlas: I was certainly a skeptic. The Russian claims for hail suppression were incredible. Weather modification in those days was partly a religion. There were very few academics in those days who remained in the field for very long. The scientific foundations for weather modification were very weak.

But I was young enough at that time to think I could solve any problem.

Knight: The Soviets claimed almost 100 percent mitigation of hail. That was a big motivation [for NHRE] at the start.

Dye: The Russian model was based on an accumulation zone of large supercooled drops at midcloud levels. But the research we did in NHRE did not show the existence of this accumulation zone and in fact showed that the dominant mechanism of precipitation formation was through the ice process.

Aerial view of the NHRE site near Grover, Colorado. (Photo by Ginger Hein.)

How did people in northeastern Colorado feel about this program of hail suppression?

Firor: We had worried about public opposition to cloud seeding because during hail suppression in Maryland and Virginia some farmers feared that seeding would reduce their rainfall. Shots were fired at aircraft believed to be doing the seeding. We had noticed that earlier weather modification projects that experienced public opposition had attempted to avoid criticism by being very secretive. We decided to take the opposite tack. We organized a consulting group, an NHRE Citizens' Council, in northeast Colorado--bankers, county agents, and farmers--and met with them regularly. We issued daily bulletins on local radio stations on what we had done the day before and what our plans were for the current day.

This canceled the double-blind nature of the experiment, but we thought that was a small sacrifice to achieve credibility in the community. And by and large, it worked. We never got any organized opposition. Meanwhile, in the San Luis Valley, somebody dynamited a radar trailer belonging to a private weather modification group.

Merrill: For the local people out there, there was a lot of skepticism, a lot of curiosity, and maybe a bit of fear about what these people were doing with these instruments. These people had never seen the big

CP-2 radar dish. And there was real worry amongst the locals about what we were doing; were we going to affect something? When we were flying around, they couldn't see the seeding, of course, but they could see the planes up there.

Bradley: In their view, we were "punching holes in the clouds and letting the water out early."

Weren't there Minuteman missiles buried underground in that part of the state?

Firor: I got a call from Air Force authorities in Cheyenne about the big radar we were setting up. They worried that if they launched a missile toward the Soviet Union, and as it came out of the silo it was hit with a sufficiently powerful radar beam, it might blow up right there. That would be a show-stopper, indeed. We told them that with the smallest angle above the horizon we used, the missile would be about 1,000 feet [300 meters] above the ground when it was struck by the radar beam. The Air Force said that seemed safe enough, so we went ahead. No nuclear wars were begun during the time NHRE was under way, so we don't know if the Air Force calculations were correct.

View inside the CP-2 radome near Fort Morgain. (Photo by Ginger Hein.)

What was the technique for the randomized cloud seeding program?

Firor: The delivery of seeding agents into the cloud was a considerable problem. We thought we'd copy the Russians, who fired artillery shells loaded with seeding agents into what they considered to be the correct position in the cloud. We had no artillery, but we assumed that small rockets could do the job. But then the idea of launching 3.75-inch [9.5-cm] rockets into the clouds over northeast Colorado and having them come down in the main street of Fort Morgan didn't

Cloud seeding, 1999 style

Although NHRE cast doubt on any dramatic benefits to be

appeal to us. We investigated much smaller rockets that went straight up from the side of a seeding aircraft.

Wade: We actually did the seeding in two different ways. In 1972 and 1973, it was all cloud-based seeding; 1974 was the first year we seeded the clouds by firing rockets vertically from the seeding aircraft. The aircraft were positioned so that the flares would ignite when they reached the -5°C [23°F] temperature level as determined from nearby soundings. This was our closest attempt to match the Russian technique of firing rockets from the ground. That was the last year that we did any of this type of seeding.

What finally undid the suppression part of the project?

Atlas: The problems were largely political. RANN [Research Applied to National Needs], the group that was managing NHRE within NSF, had to make sure that the programs that they were sponsoring were productive and they were going to result in great contributions to the economy of the nation. They didn't want to hear negative results.

I remember reporting once that we had something like 34 cases of hailstorms; they were roughly half seeded and half unseeded, in order to test the statistics. In the seeded column, there happened to be less hail than in the unseeded column. However, I pointed out that if one storm in the seeded column had been put in the other column, it would turn the whole result upside down. So there was no statistical evidence whatsoever that seeding was efficacious.

Firor: When I became a member of a congressional weather modification advisory committee a couple of years later, it dawned on me that there's a fundamental flaw in all these projects. If you set up a five-year program, and you pick the time when you're going to seed and not seed, do the statistics, do it well, and at the end if you find no statistical evidence that the seeding worked, you're no further along than when you started because you don't know why it didn't work. If on the other hand, it does work, you're no further along because you don't know how to improve it, how to sharpen it. So to achieve a useful weather modification result, it is necessary to have done the basic science before the randomizing experiment--measuring what goes on in a cloud without worrying about statistics. A randomized experiment without a high degree of understanding is likely to be of very little value.

Atlas: Brant Foote and Keith Browning did a wonderful paper on a supercell storm studied during the project, and they concluded that there was such a vast supply of moisture for

gained from cloud seeding for hail-damage reduction, seeding by public and private outfits has continued apace, particularly outside the United States. Hail "cannons" operated by private entities are hurling sound waves into showers and thunderstorms in northeast Colorado. Hail cannons are also being used in France, where a major hailstorm in late April damaged crops in the wine-producing region of Perpignan.

Closer to home, a different type of cloud seeding is being tested by NCAR for its potential value in rainfall enhancement. RAP is preparing to embark on its fourth and final summer of seeding above the drought-prone Mexican state of Coahuila, just south of Texas. While NHRE was spurred by hail-suppression claims from the Soviet Union, this project was inspired by encouraging results from South Africa. The technique relies on releasing hygroscopic (moisture-attracting) particles, produced by burning flares attached to an aircraft, into the updraft at the base of a cloud. As droplets form on these particles, the range of droplet sizes inside the cloud is expanded, which helps to stimulate rainfall.

Dan Breed (RAP/MMM) has spent much of the past three summers on site in Coahuila. "The preliminary results are promising," says Dan, "consistent with the results in South Africa at this point. Ideally, we should have enough cases after this summer to present results with statistical

hail growth that you could not possibly suppress it. Rather, you would probably enhance the hail. You'd need a fleet of 747s to seed it with enough material to make the hailstones small by competing with one another for the available moisture supply. That's the whole process of suppressing any precipitation or hail, to increase the competition. This was presented at the NHRE symposium in 1975 up in Estes Park; experts from all over the country were invited. We had some wonderful discussion when Browning and Foote reported their findings. That really convinced me that we didn't know enough of the science and that we should stop the hail suppression program, do some more research, and analyze the data.

significance." RAP scientist Roelof Bruintjes is the project's principal investigator. A report on the first year of seeding (1996) can be found on the Web . ***•Bob Henson***

Merrill: The problem was an experiment that you can't duplicate. You can't take the same storm and seed it or not seed it. Every storm has got its own little personality. It's not something that you produce in the lab. Your lab is the wide open spaces. If you could both seed and not seed the same storm, then you would have something. But how can you do that?

Dye: And NHRE found that only 20 percent of the storms produce 80 percent of the hailfall--i.e., the distribution is very skewed. So as Dave Atlas said earlier, if one of the big storms happened to be seeded rather than not seeded (or vice versa) the statistical results could be reversed.

Chuck Wade (foreground) and Brant Foote in the operations trailer at Grover. (Photo by Ginger Hein.)

On the research side, what were some of the successes associated with NHRE?

Frush: This was one of the first instances where we were able to take small, manageable computers and put them together in an environment that provided real-time processing. This allowed us to do more with the data from radars, for example, than we would have otherwise been able to. We got a lot out of a relatively small amount of hardware by today's standards. We also got our first Doppler radar displays that allowed us to see velocity information in weather. And I think there were quite a few remote sensing instrumentation successes.

Wade: ATD developed the PAM [portable automated mesonet] system during that time period; it was deployed for the first time in 1976. It was helpful for us to be able to see the mesonet data collected and available to us in real time. It was sure better than going out and having all these people going up and down roads changing all these charts on these antiquated thermometers and hygrothermographs and barographs.

Fankhauser: One technical advancement I would like to emphasize is the early use of aircraft as platforms for air motion measurements. Although in its infancy, the systems were being developed to measure turbulence, but our objective was to measure a mean air flow and it turned out to be more difficult because you had to account for error sources in the aircraft measurement systems. Aircraft intercomparison programs designed by Cleon Biter were useful in resolving some of these problems.

Firor: From an NCAR point of view the program led to the creation of a division having to do with NHRE, which we now call MMM. It went through several perturbations. And I think NSF was not averse to transferring funding from RANN back to the research budget. The project also had a big

impact on this organization, giving us a concentration on smaller-scale events.

Of equal importance was the creation of an impacts group to parallel the hailstorm field work, to tell us, in case we learned how to suppress damaging hail, whether it was a good idea to do so. We looked into the effect of the seeding agent on the ground, but most exciting was a statistical study showing that if, while suppressing 15 percent of the hail we also suppressed 3 percent of the total precipitation, the program would have no net value. Much of the hail-prone area is in pasture or hay crops that are not very sensitive to hail but, in the high plains, very sensitive to any lack of water. This finding helped us make the decision to terminate the project ahead of time. It also showed us the importance of studying the larger context of our atmospheric science work so that the impacts group evolved to the current, world-famous Environmental and Social Impacts Group--ESIG. •

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