by Marta Nelson, Derek Blestrud and David Patton

THE COOL FACTOR

Microwave radiometers hold key to identifying supercooled liquid water

Idaho Power Company's comprehensive weather modification program delivers water for hydroelectric power generation

Wintertime orographic cloud seeding plays an increasingly important role in meeting the demands for fresh water in the western USA. Idaho Power Company (IPC), headquartered in Boise, Idaho, runs one of the largest, most sophisticated and successful weather modification programs in North America. A key component of IPC's program is the use of microwave radiometers to accurately identify supercooled liquid water, essential to cloud seeding effectiveness, in winter storms.

In the rugged mountains of northwest Wyoming, snowfall in Yellowstone National Park and the Teton Mountain Range gives birth to the headwaters of the Snake River. The Snake River curves south, growing as snow-fed streams and the snowpack-influenced Central Idaho Aquifer discharge into the river. In western Idaho, the Snake loops northward, through Hells Canyon, gathering waters from numerous tributaries, including the Owyhee, Salmon, Boise, Payette and Clearwater rivers. The Snake River is central to the history of Idaho, from the Lewis and Clarke expedition to the Oregon Trail, to its current role as a major water source for irrigation, residential supply, recreation and hydroelectric power generation.

Harnessing the power of the Snake River for electricity generation is the role of Idaho Power Company. Founded in 1916, IPC's service area spans approximately 24,000 square miles (62,000km^2), much of that in the rugged and remote terrain of southern Idaho and eastern Oregon. Within this vast area, IPC provides power to a population of approximately one million. IPC's 17 hydroelectric generation plants along the Snake River and its major tributaries are the utility's largest source of electricity production. Depending on snowpack, these plants provide between 30% and 50% of IPC's total electrical power.

Between 2010 and 2014, the population of Idaho increased by 4.3% (higher than the national average of 3.3%). During that same time period, much of the state experienced severe-to-extreme drought conditions. To ensure plentiful water – the fuel for hydroelectric generation – IPC conducts a wintertime orographic cloud-seeding program in the Payette, Boise and Wood River basins of Idaho's Central Mountains, as well as the Upper Snake River region of eastern Idaho and western Wyoming.

Figure 1: The Radiometrics MP-3000A microwave radiometer, installed in wintertime cloud seeding program (photo: Marta Nelson, Radiometrics staff meteorologist)

IPC's weather modification program

A team of three full-time meteorologists oversees IPC's weather modification program. They forecast winter storms, determine when and where to activate ground-based and aircraft seeding assets, and monitor snowpack. This team is charged with maximizing the effectiveness of the IPC weather modification activities, and ensuring compliance with all relevant local, state, and federal environmental and land-use guidelines.

A recent report published by the National Center for Atmospheric Research (NCAR) concluded that cloud seeding can increase snowpack by 5-15% in the winter storms that meet the criteria for seeding. Only about 30% of winter storms meet seeding criteria, and superfluous seeding is both costly and ineffective. For seeding to produce good results, silver iodide (the benign seeding agent) must be released into a saturated environment rich in liquid water at temperatures below freezing, at the proper place and time during the storm.

Identifying the right storms to seed, and determining the optimum location and time for seeding, is a complex task. To address this challenge, IPC meteorologists use all publicly available data sources, augmented with four rawinsonde launching facilities; real-time atmospheric profiles from its four MP-3000A radiometers; a network of 11 high-resolution precipitation gauge sites; two meteorological towers; and numerous anemometer and thermometer locations. As shown in figure 2, meteorological sensors and generators are often located in remote areas.

This past winter, IPC's weather modification program in Idaho's Central Mountains included 23 remote-controlled, ground-based generators, two seeding airplanes, and one Radiometrics MP-3000A microwave radiometer (see Figure 1). The program in the Upper Snake River Basin included 21 remote-controlled, ground-based generators; 25 manual ground generators owned and operated by the High Country Resource Conservation and Development; and two MP-3000A microwave radiometers.

Passive atmospheric remote sensor

The MP-3000A microwave radiometer is a passive atmospheric remote sensor that provides continuous, real-time profiles of

Figure 2: Ground-based seeding generator and meteorological tower (photo: Idaho Power Company)

water vapor, temperature, liquid and relative humidity up to 10km above ground level. Its ability to detect supercooled liquid water, the atmospheric ingredient most necessary for effective wintertime cloud seeding, makes the instrument a vital tool in IPC's weather modification program.

IPC installed its first MP-3000A microwave radiometer in Boise, ID, in the autumn of 2008. The radiometer was later moved to a mountaintop site north of Emmett, ID, upwind of the target seeding area, to allow better visibility of incoming supercooled water.

IPC has since purchased three additional radiometers. The second radiometer was placed in Afton, Wyoming, to assess suitability of the Salt and Wyoming ranges of the upper Snake River Basin for seeding, and it remains in Afton in an operational mode. NCAR uses the radiometer data collected since the initial study to support the State of Wyoming's cloud seeding research program.

Large areas of the upper Snake River Basin are void of meteorological instruments, so a third MP-3000A located near Mud Lake, Idaho, is used to fill the gap in boundary layer data in this area. This unit provides weather data for cloud seeding operations as well as model verifications.

A fourth unit will be deployed in late summer 2015 to support cloud seeding operations in the Boise and Wood River basins of central Idaho.

The MP-3000A radiometers produce real-time observations of liquid water needed to direct aircraft flight paths during seeding operations. The radiometer data also provides insight into the amount of liquid water transported into the target area, and information on whether the atmospheric conditions are warming, cooling, or changing. The radiometers also provide accurate integrated liquid water measurements that are used as ground verification of model data. An example of supercooled liquid water detected by the MP-3000A as displayed by Radiometrics' VizMet-B software, is shown in Figure 3. In this example, the height of the liquid water between approximately 12:30 and 13:30 GMT corresponds to an atmospheric temperature near the activation range for silver iodide nucleation, indicating ideal cloud seeding conditions.

As described by Derek Blestrud, a meteorologist at IPC, "Seeding the wrong storms, or seeding too late or too early, is expensive and unproductive. Forecasting the optimum seeding conditions, and monitoring those conditions in real time during seeding operations, is critical for an effective weather modification program." He continues, "Aircraft seeding, while expensive, is highly effective in large, warmer storms. Determining the best times and locations to fly a cloud seeding aircraft is critical. Without the radiometer, we wouldn't have the ability to continually monitor the atmosphere for supercooled liquid water. The resolution of launching rawinsondes can only give us a data source every hour or two, whereas the radiometer continuously monitors the changing conditions."

Radiometer data is also valuable for improving the ability of weather models to predict supercooled liquid during winter storms. Blestrud explains, "As we continue to push weather modeling, 'ground truthing' the model is essential. Models sometimes have a tough time determining the amount of liquid water that is available in the atmosphere. If the models aren't handling the water correctly, precipitation forecasts are inaccurate. By placing radiometers in our model domain, we are able to understand how the model handles liquid water in a wide range of storms, and we use this insight to make the models better."

As a result of its weather modification program, IPC's analysis indicates the average annual snowpack in the Payette River Basin has increased by nearly 13% since 2003. This additional precipitation provides nearly 200,000 additional acre-feet of water for the Hells Canyon Complex each year, equal to approximately 100,000MWh, or enough to power roughly 7,900 homes. Similar results, although not independently verified, are realized in the upper Snake River Basin. ∎

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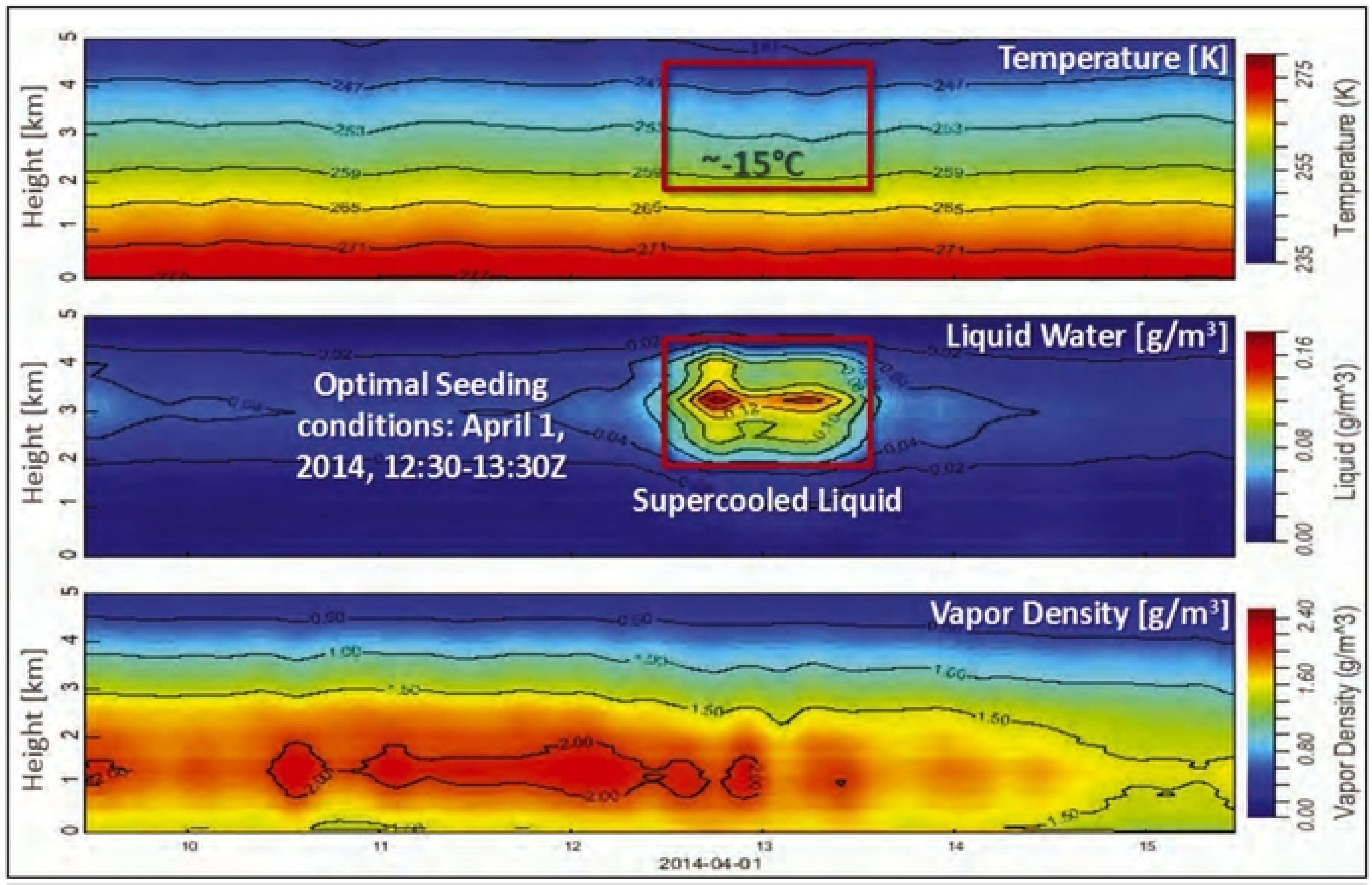

Figure 3: Radiometric data visualization showing time-height cross sections of temperature, liquid water and vapor density during a winter storm near Mancos Colorado (VizMet-B software)