Idaho Power Company’s Cloud Seeding Program

Shaun Parkinson, PhD, PE

Presentation Overview

- What is cloud seeding?
- How we know cloud seeding works…
- Perceptions…
- IPC’s cloud seeding program…
  - Payette
  - Upper Snake
- Benefits
  - Increased Runoff…
  - Increased Generation…
What is cloud seeding?

- The term cloud seeding has been used to describe:
  - Fog suppression (airports)
  - Hail suppression (reduce crop and property damage)
  - Rainfall enhancement (water supply augmentation)
  - Snowpack enhancement (snowpack augmentation)
- Our focus is **snowpack** enhancement
- In particular – IPC does winter orographic cloud seeding

Winter Orographic Cloud Seeding

- As air is forced up and over mountains, it cools.
- If moist enough, it condenses to form a cloud of tiny water droplets.
- Cloud droplets do not freeze at 0°C (32°F). Instead, they supercool, remaining liquid at much colder temperatures.
- Eventually, ice gets introduced into these supercooled clouds, usually at temperatures colder than about -12°C (+10°F). Ice formation is induced by tiny particles called **ice nuclei**.
Winter Orographic Cloud Seeding

• Once ice forms, the particles grow quickly, forming flakes that become large enough to fall out as snow.

• Ice crystals continue to grow and may become large enough to fall as snow as they travel beyond the peak.

• As air continues over a mountain it may descend and warm. Crystals that haven’t fallen as snow may be too small to fall, or they may melt and evaporate.

Winter Orographic Cloud Seeding

• *Cloud seeding* provides additional ice nuclei that function at warmer temperatures, allowing ice formation to begin sooner.

• This occurs at temperatures as warm as -5°C (+23°F), though more effectively at -8°C (+17°F) or colder. (The majority of natural ice nuclei become effective between -15°C to -20°C (+5 to -4°F).)
Winter Orographic Cloud Seeding

- Snowfall is thus increased incrementally because more ice crystals have a better opportunity to grow and fall as snow while over the mountain.

- Cloud seeding enhances the efficiency of converting supercooled cloud water into snow, increasing precipitation (snowfall) efficiency. Otherwise, this cloud water would likely pass over the mountain and evaporate.

Cloud Seeding Summary

- Cloud seeding provides mother nature with ice nuclei
- But, it is only effective when ice nuclei are limiting and nature is performing the other required precipitation processes
  - cloud seeding doesn’t create clouds to seed – it will not cure a drought!
- Effectiveness depends on:
  - temperatures,
  - available water in the atmosphere,
  - ice nuclei properties,
  - cloud droplet and natural ice distributions
- Several agents can be used as ice nuclei, with silver iodide (AgI) being the most common used in commercial cloud seeding.
### Cloud Seeding Programs - WMA

- **Silver Iodide Distribution**

  - In commercial programs, silver iodide is burned to release silver iodide particles (ice nuclei) of an appropriate size to the atmosphere.
  - **Ground generators** - Acetone – silver iodide solution is burned in a propane flame.
  - **Aircraft** - silver iodide is incorporated into a flare, or solution is burned.
Presentation Overview

- What is cloud seeding?
- How we know cloud seeding works…
- Perceptions…
- IPC’s cloud seeding program…
  - Payette
  - Upper Snake
- Benefits
  - Increased Runoff…
  - Increased Generation…
  - Water Temperature Benefits…

Cloud Seeding

- Lots of evidence that it works in laboratory and controlled conditions.
- The big question – how do we know it puts snow on the ground?
- Plume tracing – UT pulsed seeding experiment
- Trace chemistry (IPC’s dual tracer)
- Aircraft data collection
UT Pulsed Seeding Experiment

Before Seeding  Seeding  After Seeding

- NCAR Counter
- Target T = -10.7 °C
- 2D-C Probe

MST on 15 December 1994
IPC’s Dual Tracer Assessment

Approach
• IPC needed to demonstrate that project can effectively put snow in target area, and that seeding increases snowpack as expected.
• Independent contractors performed assessment
• Co-located seeding and tracer generators – ground and aircraft
  – Release seeding and tracer aerosols at same rate
• Nucleating particles (silver iodide) incorporated into snowpack through either ice nucleating (seeding) process or scavenging
• Non-nucleating particles (inert tracers) incorporated in snowpack through scavenging process only.

Co-located Generators
IPC’s Dual Tracer Assessment

Approach (cont.)

- Following seeding, analyze snowpack for evaluation of trace levels of silver, indium, and cesium as well as snowpack density.
- Ratio of silver to tracer (ex. Indium) in the snow pack gives an indication of how much silver deposited by ice nucleating vs. scavenging processes.

Sampling Snow Pack

- Snow samples collected using ultra-trace ‘metal clean’ techniques and acid cleaned equipment.
Analytical Methods

- Samples acidified with ultra-pure nitric acid in class 100 clean room.
- Analysis by High Resolution Inductively Coupled Plasma Mass Spectrometry.
- Detection limits of ~ 300 parts per quadrillion for silver
  - \(\frac{300}{1,000,000,000,000,000} \times 10^{15}\)
- Think of it as a single drop of water in a cube 368m on a side or in a sports arena like the Idaho Center (Nampa, ID), or 5 minutes out of 31.7 million years.

Targeting from Chemistry Data

- Targeting of the seeding operations was assessed by integrating the silver found in the snow over a given storm period to estimate the total amount of silver deposited during the storm.

Example Targeting Maps for the March 2004 and December 2004 storm periods
Targeting Results

- The amount of silver deposited downwind of active ground generators was much greater than that found at the control sites.
- Silver distributions show that targeting was effective.
- Indium concentrations were generally very low
  - Silver not from scavenging
- Evidence for targeting by aircraft was found in the target area
- The project layout and operations can effectively hit the target area with both ground generators and aircraft.

Trace Chemistry Summary

- Snowpack conditions during assessment were 74% and 65% of normal (lack of storms limited seeding opportunities).
- During 2004-2005, DRI concluded cloud seeding revealed an overall average increase of 7%. Individual storm events ranged between 7% and 35% increases.
- Under favorable conditions, greater increases may be obtained through longer and more frequent seeding periods.
- Moving to flares significantly increases seeding potential from the aircraft.
Presentation Overview

- What is cloud seeding?
- How we know cloud seeding works...
- Perceptions...
- IPC’s cloud seeding program...
  - Payette
  - Upper Snake
- Benefits
  - Increased Runoff...
  - Increased Generation...
  - Water Temperature Benefits...

Downwind Effects

- Research on the subject has shown there are neutral or positive effects (more precipitation) from a well run program
- A poorly run program has the potential to reduce precipitation
- To put quantities into context...
  - Nature will condense about 20% of the water vapor as moist air rises over a mountain barrier (the remaining 80% remains uncondensed).
  - Winter storms are typically about 30% efficient, meaning 30% of the 20%, or 6% of the total, reaches the ground.
  - If cloud seeding increases precipitation 15%, that amounts to 15% of the 6%, or 0.9% of the total water vapor is the additional amount cloud seeding pulls from the atmosphere.
Silver Toxicity

- The WMA has issued a statement on toxicity of silver originating from cloud seeding…
  http://weathermodification.org/AGI_toxicity.pdf
- In summary, “The published scientific literature clearly shows no environmentally harmful effects arising from cloud seeding with silver iodide aerosols have been observed; nor would they be expected to occur. Based on this work, the WMA finds that silver iodide is environmentally safe as it is currently being dispensed during cloud seeding programs.”

IDEQ Review

- IDEQ reviewed cloud seeding w.r.t. water and air quality.
- Water quality - it is unlikely that cloud seeding will cause a detectable increase in silver concentrations in target area or pose a chronic effect to sensitive aquatic organisms.
- Air quality permit not needed based on screening thresholds.

Presentation Overview

• What is cloud seeding?
• How we know cloud seeding works…
• Perceptions…
• IPC’s cloud seeding program…
  • Payette
  • Upper Snake
• Benefits
  • Increased Runoff…
  • Increased Generation…
  • Water Temperature Benefits…

Idaho Power’s History with Cloud Seeding

• At the request of shareholders – began investigating cloud seeding in 1993
• Literature review 1993 and 1994
• Climatology study 1994-95
• Contracted operational program in 1996-97
• Planned to perform internal program in 1997-98
  – canceled due to no mechanism to recover project expenses and share benefits
• Reinstated in Feb 2003.
• Operational including assessment in fall of 2003
• Completed second year of assessment and third year of operations in May 2005.
• In 2008 worked with HCRC&D and E Idaho Counties to enhance their program
  – In 2008 installed 3 remote generators, provided meteorological data and operations guidance
  – In 2009 installed 6 additional remote generators (total of 9)
  – In 2010 installing 7 additional generators for HCRC&D program (total of 16)
  – Purchasing data collection equipment and working with NCAR for a Phase II feasibility study
    for a project in Salt and Wyoming ranges.
Effective Program Includes

- Knowledge of:
  - Storm timing – prepare for operations
  - Water content – is the storm conducive to seed?
  - Temperature profile
  - Wind speed and direction
    - The wrong combination of temperature and water content can easily lead to reduced precipitation.
    - Winds effect targeting

- Operating Criteria
- Flexibility – ability to seed a range of conditions
- Aircraft safety
  - Flying a plane in storm conditions – pilot needs guidance regarding severe ice, lightning, etc.
- Suspension Criteria

Idaho Power’s Cloud Seeding Projects

Payette

Upper Snake
In cooperation with E. Idaho - HCRC&D

Salt and Wyoming Ranges
Rawinsonde

Radiometrics M3000A
Microwave Radiometer

- Radiometers measure the power radiated by the atmosphere at different wave lengths. They are passive, receive-only instruments, meaning they emit no radiation themselves.
- The wave length of the radiation identifies the source of the emission resulting in an atmospheric profile:
  - Temperature
  - Relative Humidity
  - Liquid Water
Radiometer Data

- Real time atmospheric profiling by elevation:
  - Temperature
  - Relative Humidity
  - Liquid Water
  - Vapor Density

Generator Types

- Burn Head
- Ignition Coil
- Solar Panel
- Nitrogen
- Propane
- Temperature Probe
- Valve Box
- Satellite Communication
- Tower
- Computer Box
- Solution Tanks
- Platform
- Batteries

Image courtesy of Radiometrics
Aircraft Seeding

Presentation Overview

• What is cloud seeding?
• How we know cloud seeding works…
• Perceptions…
• IPC’s cloud seeding program…
  • Payette
  • Upper Snake
• Benefits
Operations Summary
Payette

<table>
<thead>
<tr>
<th>Water Year</th>
<th>(April-July) % Normal*</th>
<th>% TC** Benefit</th>
<th>Silver Iodide (grams)</th>
<th>Hours</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total</td>
<td>Air</td>
<td>Ground</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>93%</td>
<td>16%</td>
<td>33558</td>
<td>23270</td>
<td>10288</td>
</tr>
<tr>
<td>2004</td>
<td>74%</td>
<td>5%</td>
<td>21485</td>
<td>2803</td>
<td>18682</td>
</tr>
<tr>
<td>2005</td>
<td>65%</td>
<td>25% / 7%</td>
<td>27301</td>
<td>11122</td>
<td>16179</td>
</tr>
<tr>
<td>2006</td>
<td>136%</td>
<td>15%</td>
<td>113173</td>
<td>97710</td>
<td>15463</td>
</tr>
<tr>
<td>2007</td>
<td>56%</td>
<td>10%</td>
<td>100862</td>
<td>76980</td>
<td>29102</td>
</tr>
<tr>
<td>2008</td>
<td>105%</td>
<td>16%</td>
<td>61147</td>
<td>38740</td>
<td>22407</td>
</tr>
<tr>
<td>2009</td>
<td>91%</td>
<td>15%</td>
<td>50274</td>
<td>20130</td>
<td>24164</td>
</tr>
<tr>
<td>2010</td>
<td>89%</td>
<td>25%</td>
<td>49823</td>
<td>30090</td>
<td>19733</td>
</tr>
</tbody>
</table>

* Unregulated Payette Apr-Jul volume at Horseshoe Bend ’71-’00 (USBR)
** TC = Target Control
*** DRI Trace chemistry average benefit

Seeding Summary All Years_10.xlsx
Benefit Estimation
Payette

- IPC has used 3 approaches to assess benefits since DRI’s assessment:
  1. USBR Run-off regression equations
  2. Streamflow comparison
  3. Watershed modeling using IPCRFS forecasting model

USBR Regression

- USBR Equations use precipitation and SWE as input to predict runoff at specific locations.
- Target control analysis indicates precipitation increases ranging from 5% to 16% (average over 6 years of 13%*).
- Assuming a precipitation increase of 10% from cloud seeding results in an average of approximately 120 KAF of additional April – July runoff at Horseshoe Bend.

*dropped highs from dry years. Retaining all years is a 16%.
Run-off Comparison

- After running the program for a number of years, a comparison of streamflows was possible.
- By comparing streamflows, no analysis or assumptions regarding precipitation increases are necessary.
- Relative to the NF Payette, streamflows in the SF Payette have increased an average of 130 KAF per year.
- Average precipitation increase of 9%.

PRELIMINARY
Streamflow Modeling
IPC River Forecast System

- Additional runoff estimated using IPC’s NWS river forecast model.
- Model uses mean aerial temperature and precipitation (MAT & MAP) by elevation
- Two scenarios…with and without cloud seeding
- Without seeding – adjusted MAP down by amounts indicated by target-control analysis (observed data includes seeding)
- With seeding – used MAP based on observed data
- Streamflow increase nearly 200 KAF / year

Cost: $4.25 - $7.00/AF

Upper Snake Potential

Using the IPCRFS:
- Assumes 10% winter precipitation increase (Oct – Mar)
- Local unregulated flows
- Average increase in runoff over period ‘49 to ’09
- DRAFT Results
Upper Snake Opportunities

- IPC will have 16 remote generators in upper Snake this winter.
- Conduct Phase II feasibility study in Salt and Grays drainages.
  - Data collection – weather balloons, radiometer, weather station
  - Modeling evaluation with NCAR

Example Modeling Results

WRF-RTFDDA Trajectory/Cloud Water Map (2 April 2010)
Questions?