SW Montana Cloud Seeding Feasibility Study

Drought Committee, Helena, MT

October17, 2024

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Photo by George Bakos - Unsplash

Montana Feasibility Study

Study Goals:

- Goal #1: Assess the potential for cloud seeding to augment snowpack and subsequent streamflow in select target mountain ranges in southwestern Montana. Early analysis favored the Big Hole watershed.

- Goal #2: Complete a preliminary cost/benefit analysis and preliminary program design based upon weather/climate analysis.

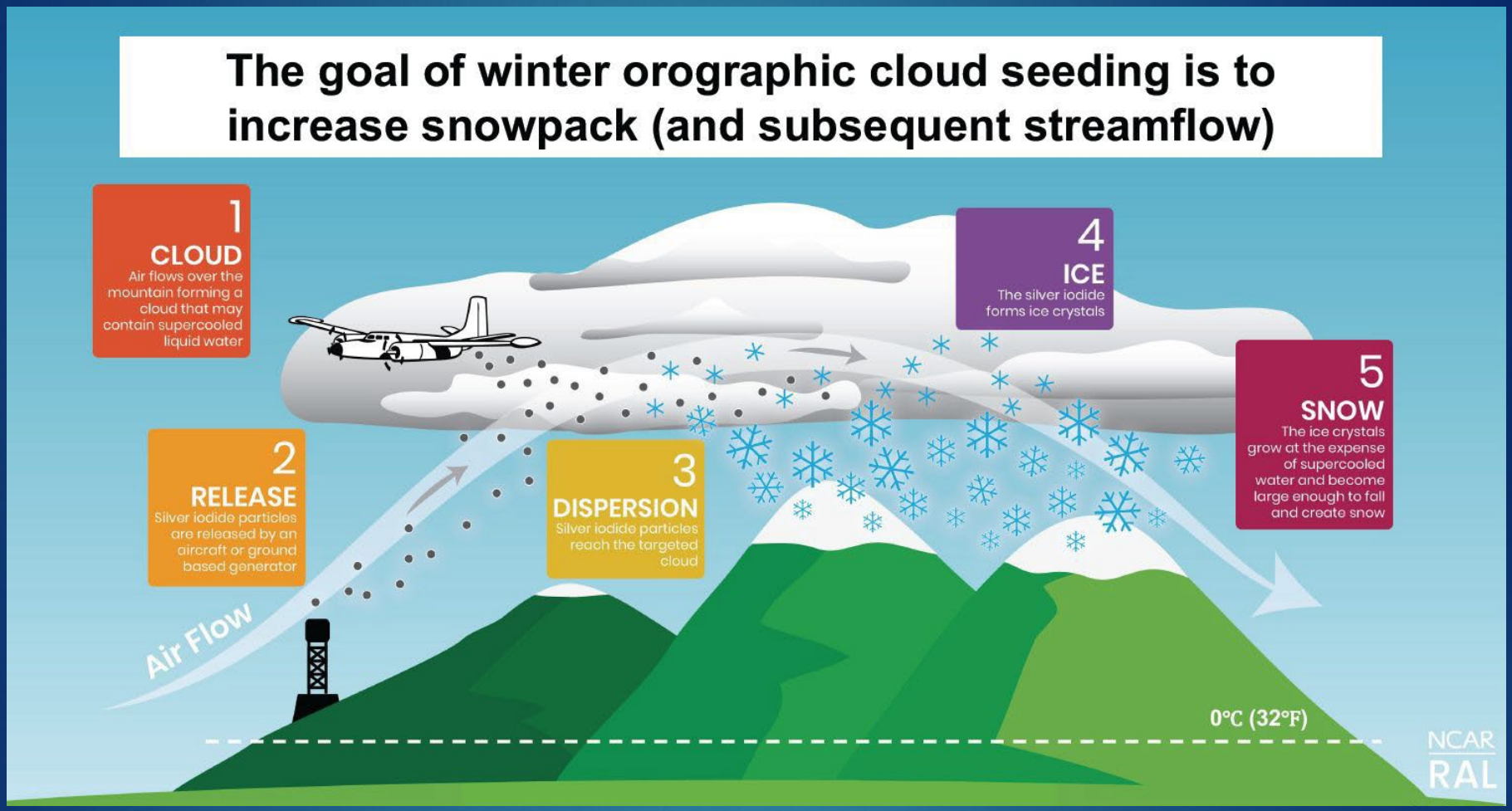
- Goal #3: Support development of public engagement and education activities and materials related to cloud seeding.

December 2023 – DNRC contract with the NSF - National Center Atmospheric Research

What is cloud seeding?

- Clouds are made up of tiny water droplets or ice crystals that form when water vapor in the atmosphere cools and condenses around a tiny dust or salt particle floating in the atmosphere.
- Without these particles, raindrops or snowflakes cannot form and precipitation will not occur.
- Cloud seeding is a process of adding tiny ice nuclei into to clouds that **contain super-cooled liquid water but lack the impurities (dust, ice, salt) necessary for precipitation**. These nuclei provide a base for snowflakes to form.

The goal of winter orographic cloud seeding is to increase snowpack (and subsequent streamflow)



This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.

Aircraft Seeding

Demonstration of flare ignition, actual dispersion occurs in cloud

- Burn-in-Place (BIP) flares are released in cloud
  - Plane flies through cloud when conditions are sustainable for the aircraft
- Ejectable (EJ) flares are released above cloud
  - Plane flies above cloud when conditions in cloud present hazardous to the aircraft and crew

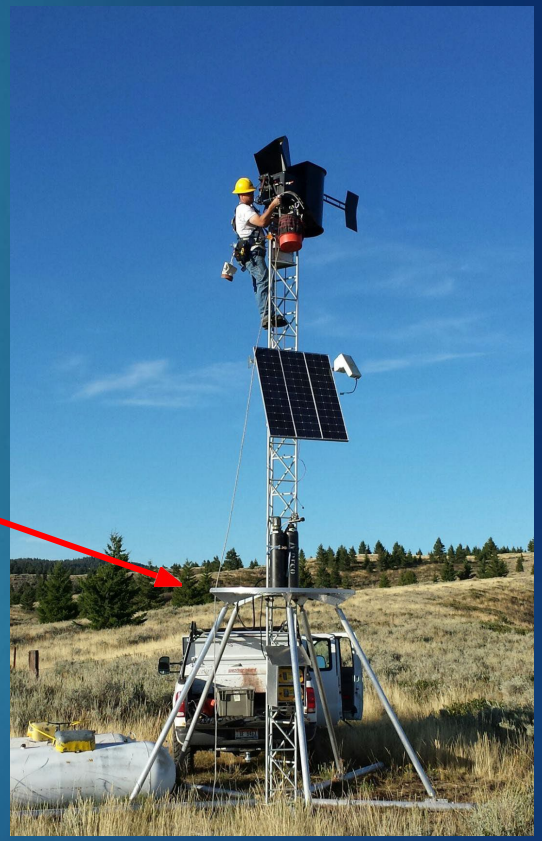
Wing mounted "Burn-in-Place" (BIP) flares

Belly Mounted Ejectable (EJ) flares

Images Courtesy of Idaho Power Company and Ice Crystal Engineering

Remote Ground Generators

Base Platform ~9 feet from ground



Images Courtesy of Idaho Power Company

How much water are we talking about?

Clouds form when invisible water vapor in the air condenses into visible water droplets or ice crystals (Example - contrails – combination of hot exhaust, water vapor and pariculates condense to form a vapor trail).

Nature will condense roughly 20% of the total available water vapor as moist air rises over a mountain barrier

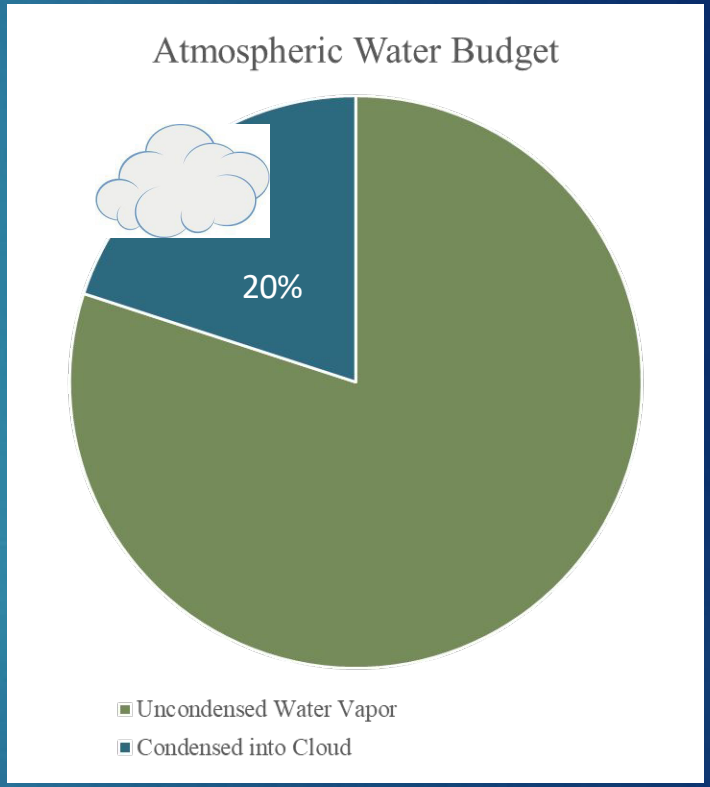


Figure Courtesy of Idaho Power Company

How much water are we talking about?

Winter storms are typically about 30% efficient.

So only about 30% of the condensed water contained in a cloud will fall to the ground as precipitation.

That's equal to roughly 6% of the total water content in the atmospheric water budget

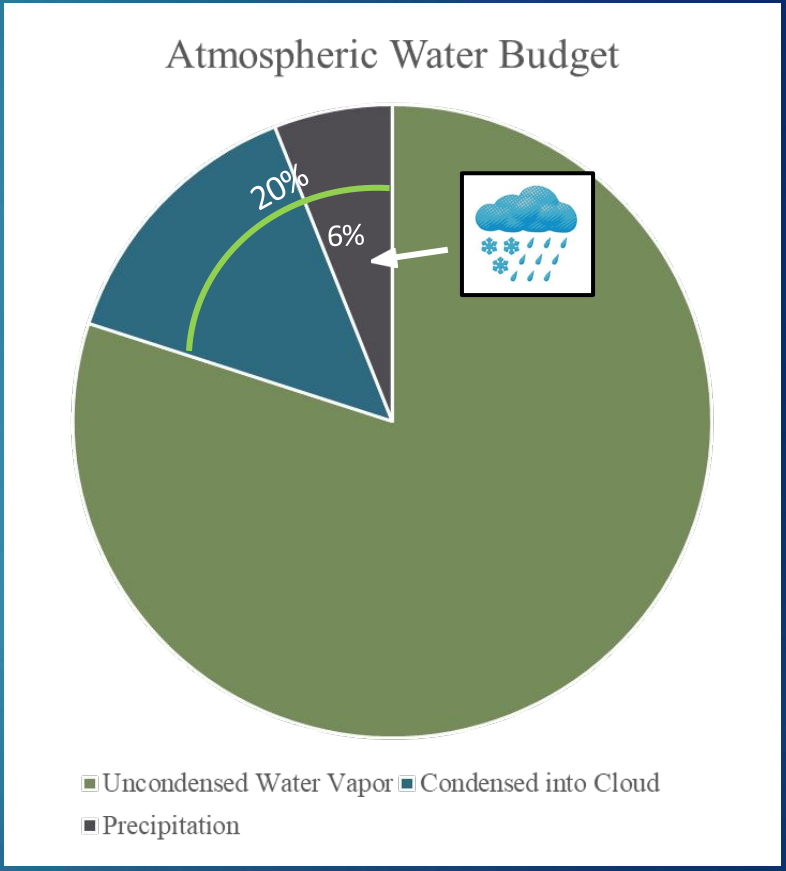


Figure Courtesy of Idaho Power Company

How much water are we talking about?

Cloud seeding enhances the storm's efficiency by an average of 10% to 15%.

That amount is equal to <1% of the total amount available in the atmospheric water budget.

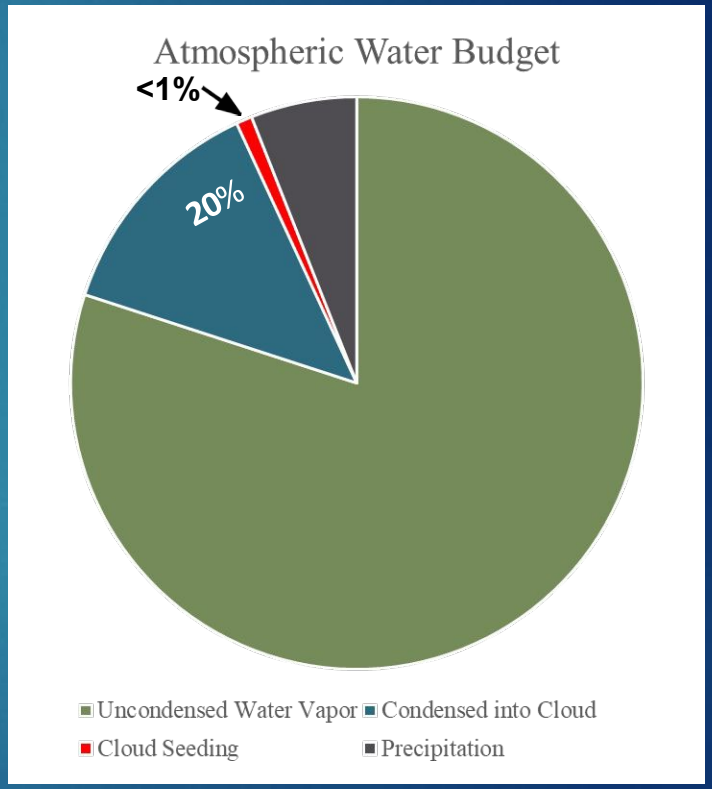


Figure Courtesy of Idaho Power Company

Silver Iodide in the Environment

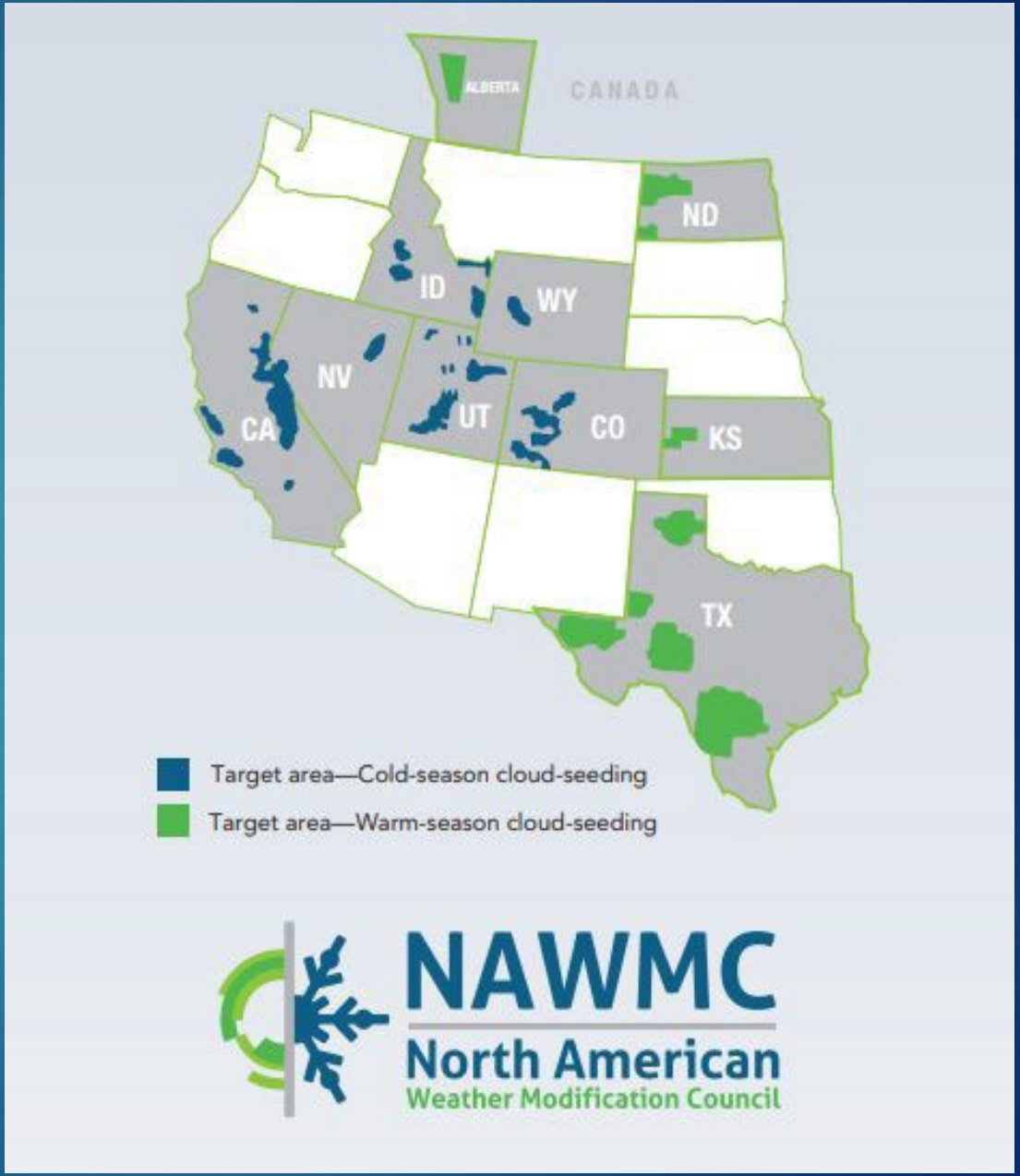
- Silver (AgI) is a toxic pollutant. World Health Organization, EPA and most state government water quality standards is 100 ppb total silver (AgI).

- Silver Iodide (Ag^+) is an insoluble salt that does not breakdown in water.

- Silver iodide primarily accumulates in soils or streambed sediments and is typically found at parts per trillion (30 -50 ppt) background levels. Ag^+ concentrations in snow vary between 1-20 ppt after seeding events.

- Environmental sampling of cloud seeding operations have found no detectible increase in total AgI concentrations above background levels in soil, streams or aquatic species in seeded areas.

CLOUD SEEDING IN NORTH AMERICA



Utah Collaborative Cloud Seeding Program

Launched in the early 1950's. Continuous operation since 1973

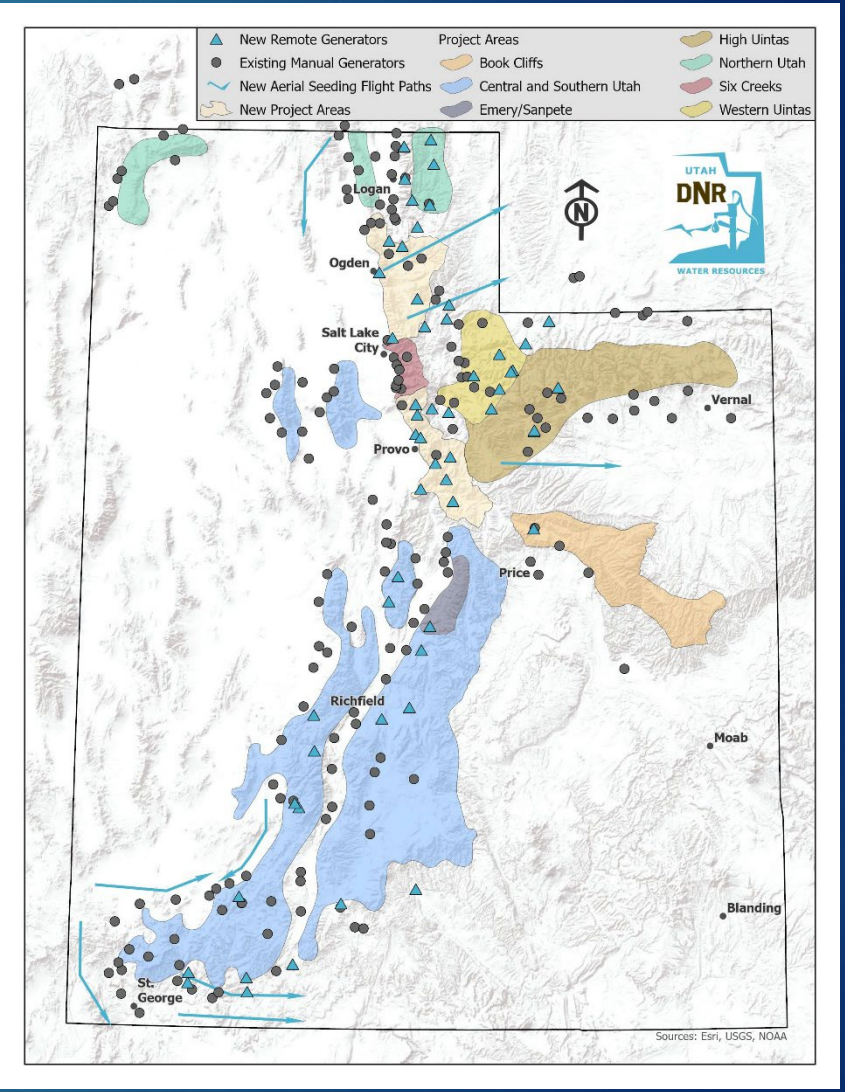
One time only funding 12M in 2023
Annual state contribution increased to 5M

Historically, $250K state funding, $250K local, $200K lower basin states

Program relies upon network of remote, manual and airborne operations.

Manually operated ground generators cost ≈ $3,000 each vs ≈$50,000 each for remote generators.

Water generated from cloud seeding costs Between $2 and $15 per acre foot.



IDAHO COLLABORATIVE CLOUD SEEDING PROGRAM

West Central Mountains Project

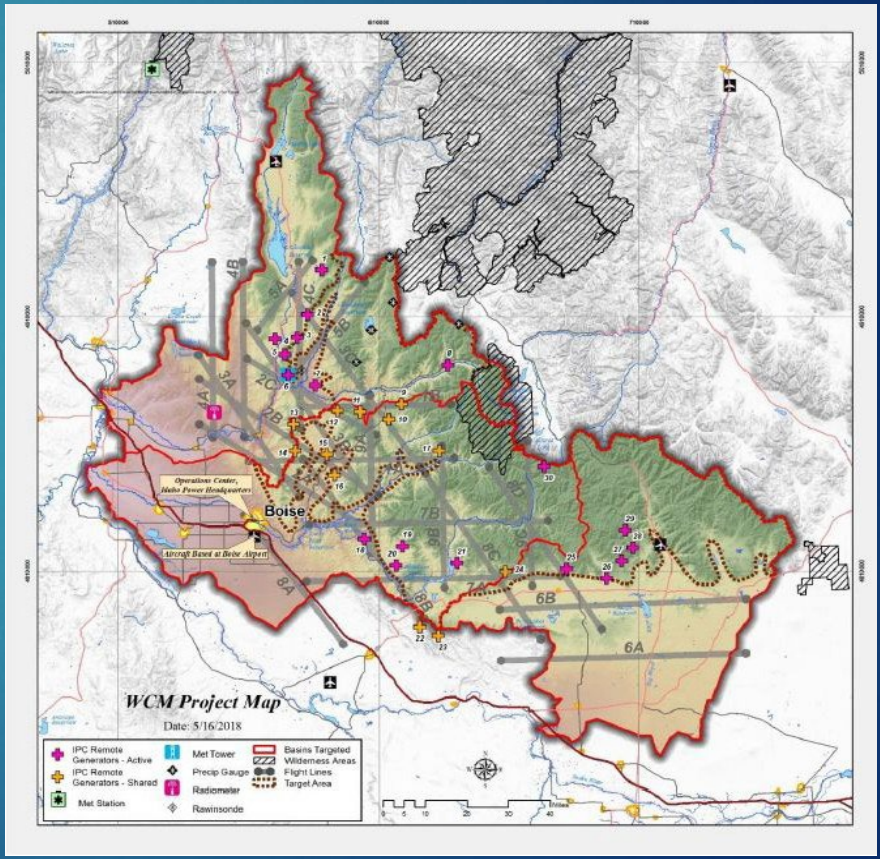
Estimated Average Additional Runoff (Unregulated) & Current Project Costs (Annually)

Boise River Basin– 273 KAF | $910K

Wood River Basin – 112 KAF | $670K

Payette River Basin* – 223 KAF | $870K

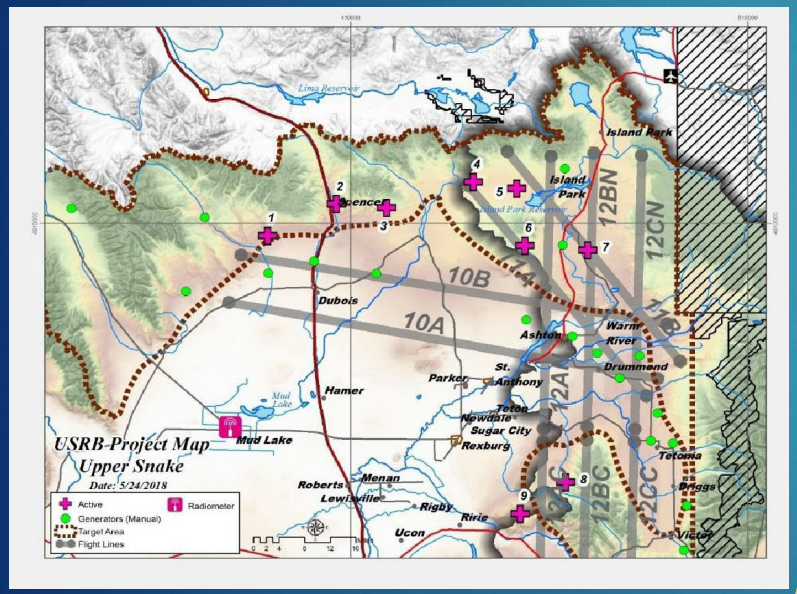
WCM Total: 608 KAF |$2.45M



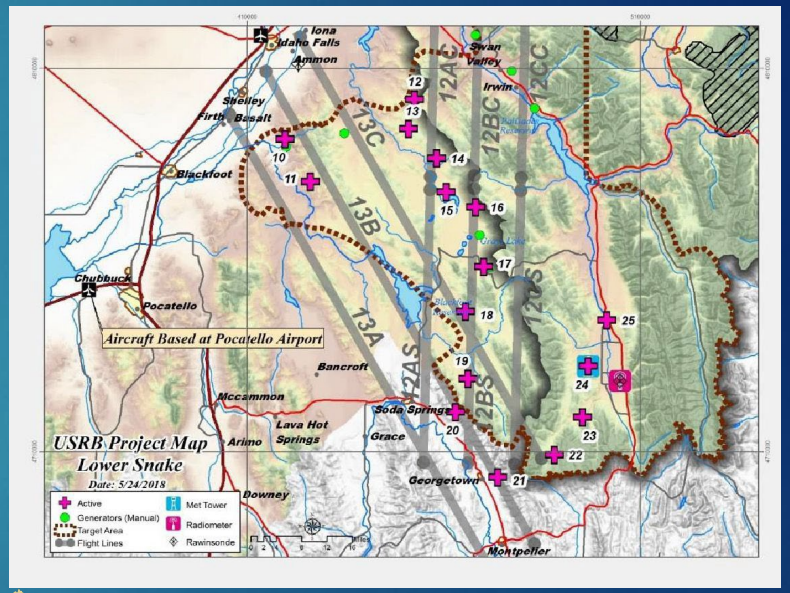
*Independent project operated by Idaho Power Co in coordination with the Collaborative. 100% Funded by IPC.

Idaho Collaborative Cloud Seeding Program

Upper Snake River Basin Projects



Northern Upper Snake
168 KAF



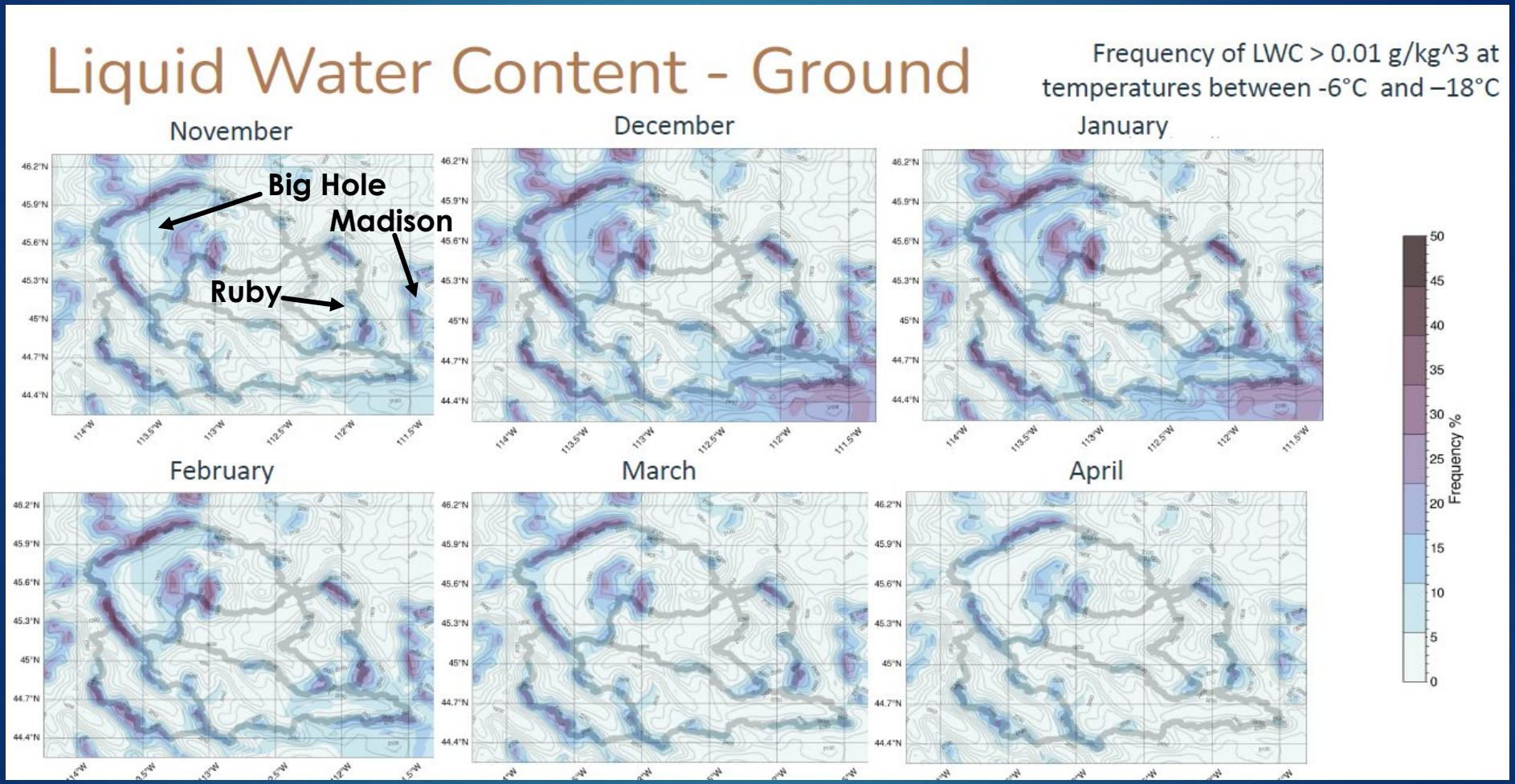
Southern Upper Snake
464 KAF

Upper Snake River Basin – 632 KAF | $1.54M

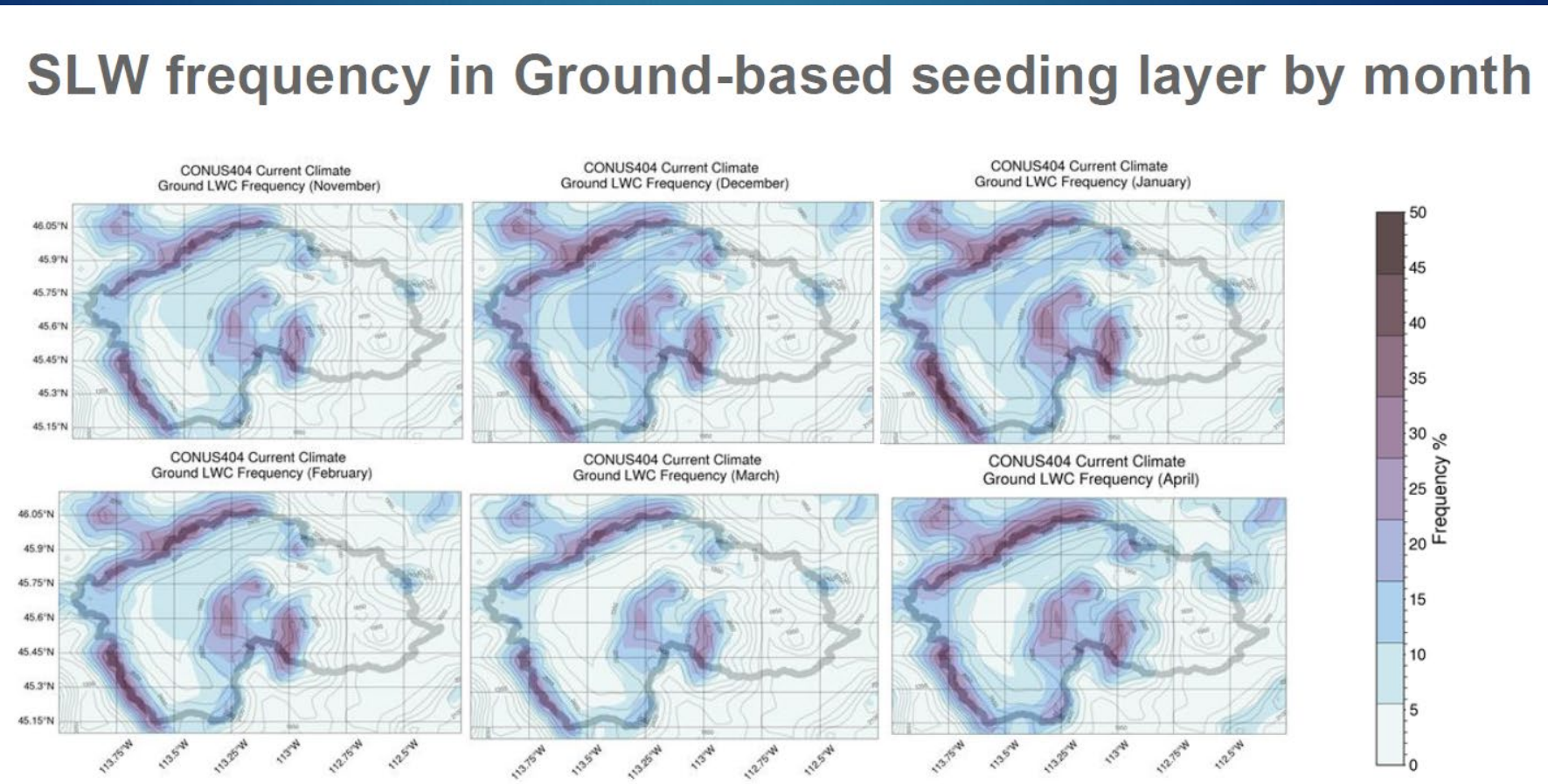
Wyoming Collaborative Cloud Seeding Program

- 2004 to 2016 – Feasibility Studies – Wind River, Medicine Bow, Sierra Madre, Salt and Wyoming mountain ranges
- 2015 to 2017 – Siting and design Studies Medicine Bow, Sierra Madre, Laramie, Big Horn mountain ranges
- 2014 to present – Ground based operations Wind River Range
- 2018 to Present – Aerial operations in Sierra Madre, Medicine Bow
- 2018 to Present – Aerial operation Never Summer Range (funding from state of Colorado)
- Funding – $2 million in state funding appropriated for 2024 – 2026
- Cost Share ≈ 37% state, ≈ 63% other partners

SLW frequency in SW Montana by Month



SLW frequency in the Big Hole Watershed by Month



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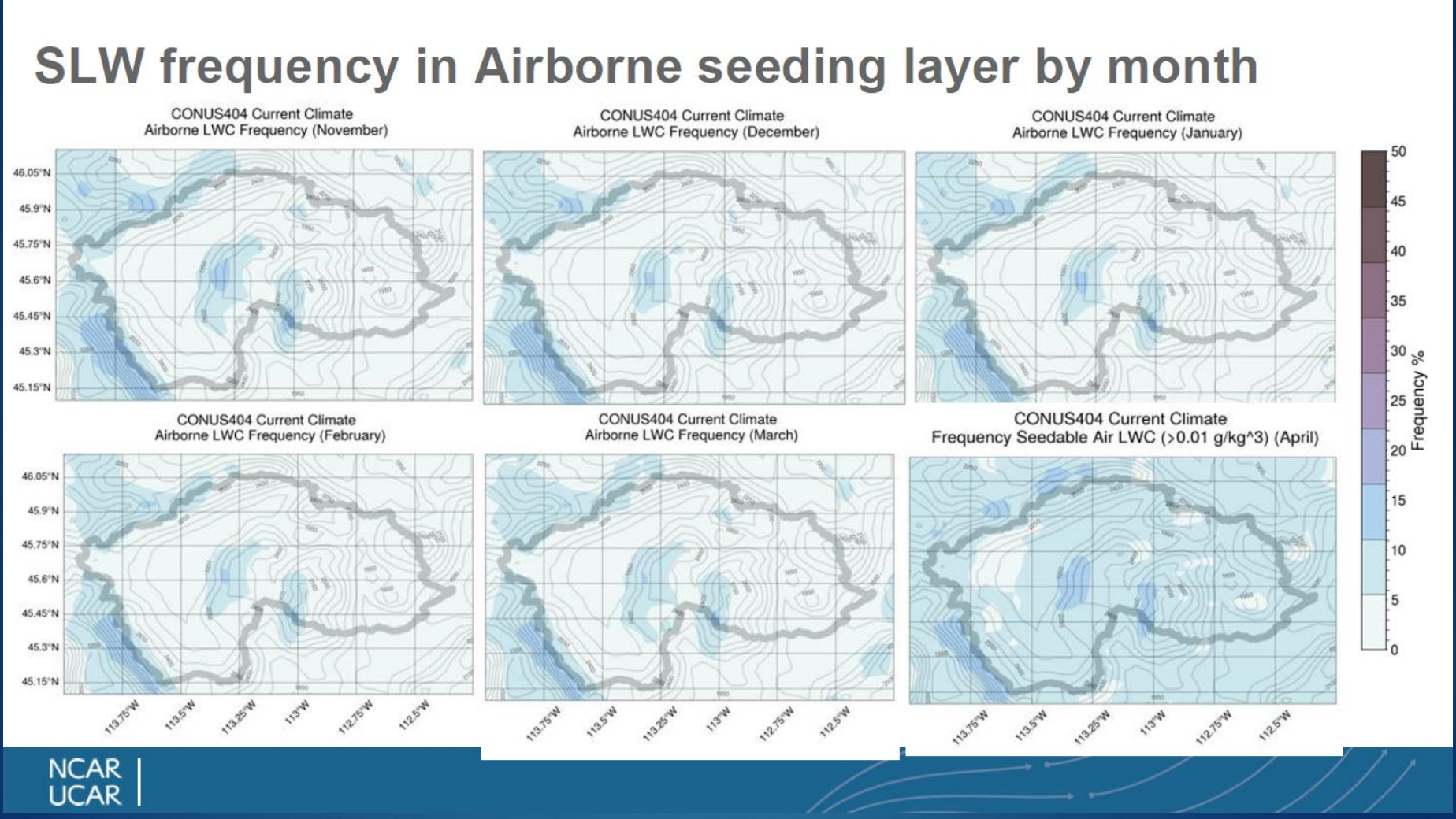
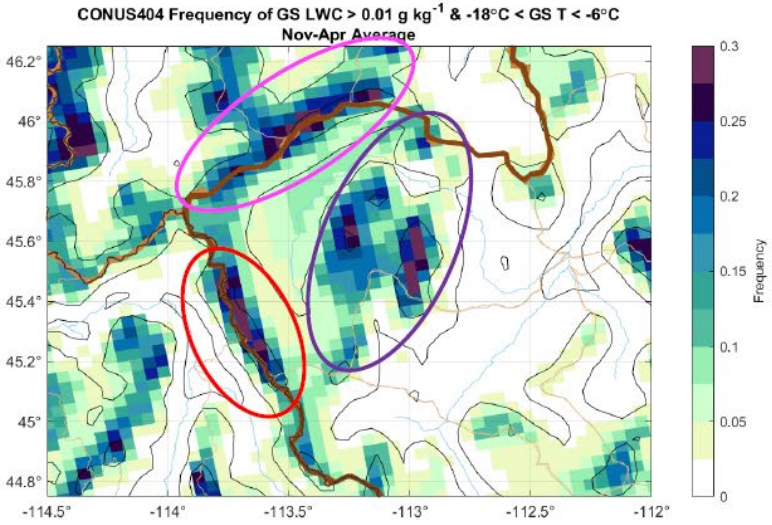


NCAR
UCAR

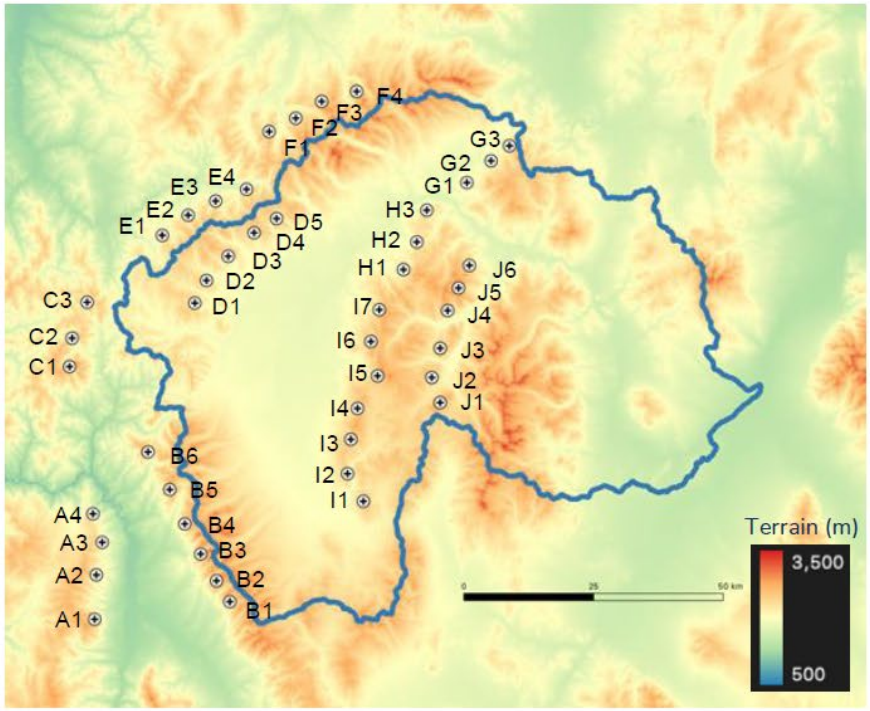
Ground-based Seeding Preliminary Design Options

Nov-Apr Average Frequency for Ground-based Seeding



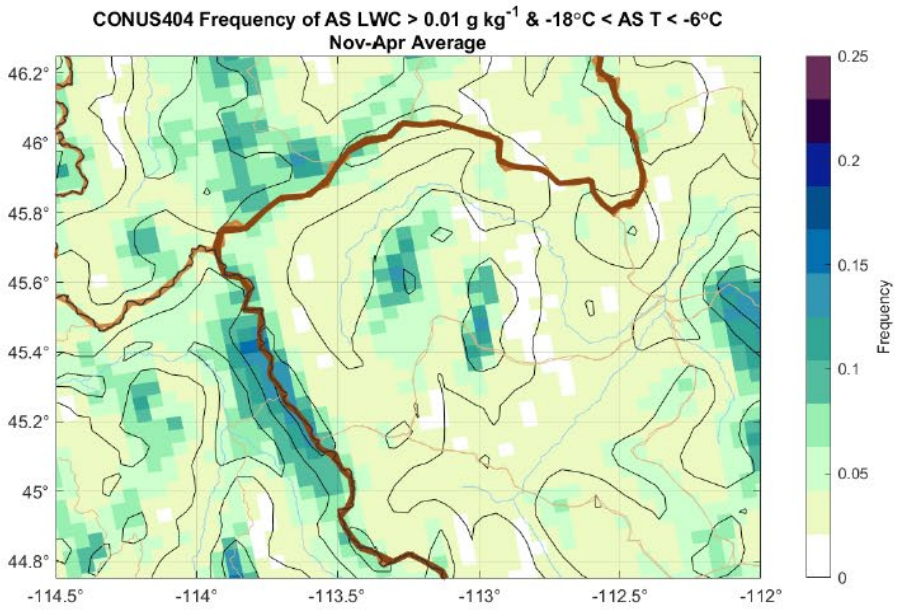
A & B Groups
C, D, E, F Groups
G, H, I, J Groups

Hypothetical Ground-based Seeding Generator Sites

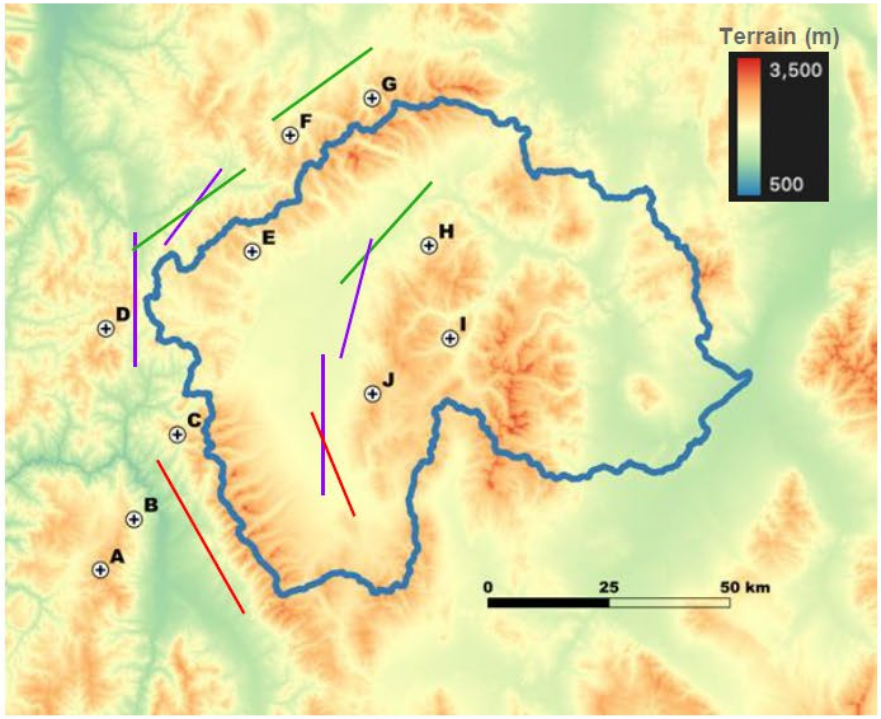


Airborne Seeding Preliminary Design Options

Nov-Apr Average Frequency for Airborne Seeding



Hypothetical Airborne Seeding Flight Tracks



Montana Feasibility Study

Study Deliverables:

- Preliminary report including results of the feasibility analysis for current and future climate scenarios and a summary of design options that will be tested with model simulations. (October 2024).

- Final report including modeling results and identification of cloud-seeding program design(s) with associated cost-benefit analysis. (February 2025).

- Program design guidance for a 3-5 year cloud seeding pilot project, including estimated costs (February 2025).

Free Online Training Module:

Produced by the COMET Program
https://www.meted.ucar.edu/USBR/cloud_seeding/

You will be asked to create an account to access this training module and any others in the catalog

Questions/Comments?

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Photo by Simon Fitall on Unsplash