Cloud Seeding as a Water Management Tool– The Idaho Approach

Central Oregon Farm Fair | February 2, 2023

Kala Golden, IWRB Cloud Seeding Program Manager

IDAHO WATER RESOURCE BOARD

WATER IN IDAHO

Idaho Department of Water Resources

MISSION

To serve the citizens of Idaho by ensuring that water is conserved and available for the sustainability of Idaho's economy, ecosystems, and resulting quality of life.

VISION

To achieve excellence in water management through innovation, efficiency, planning, and communication.

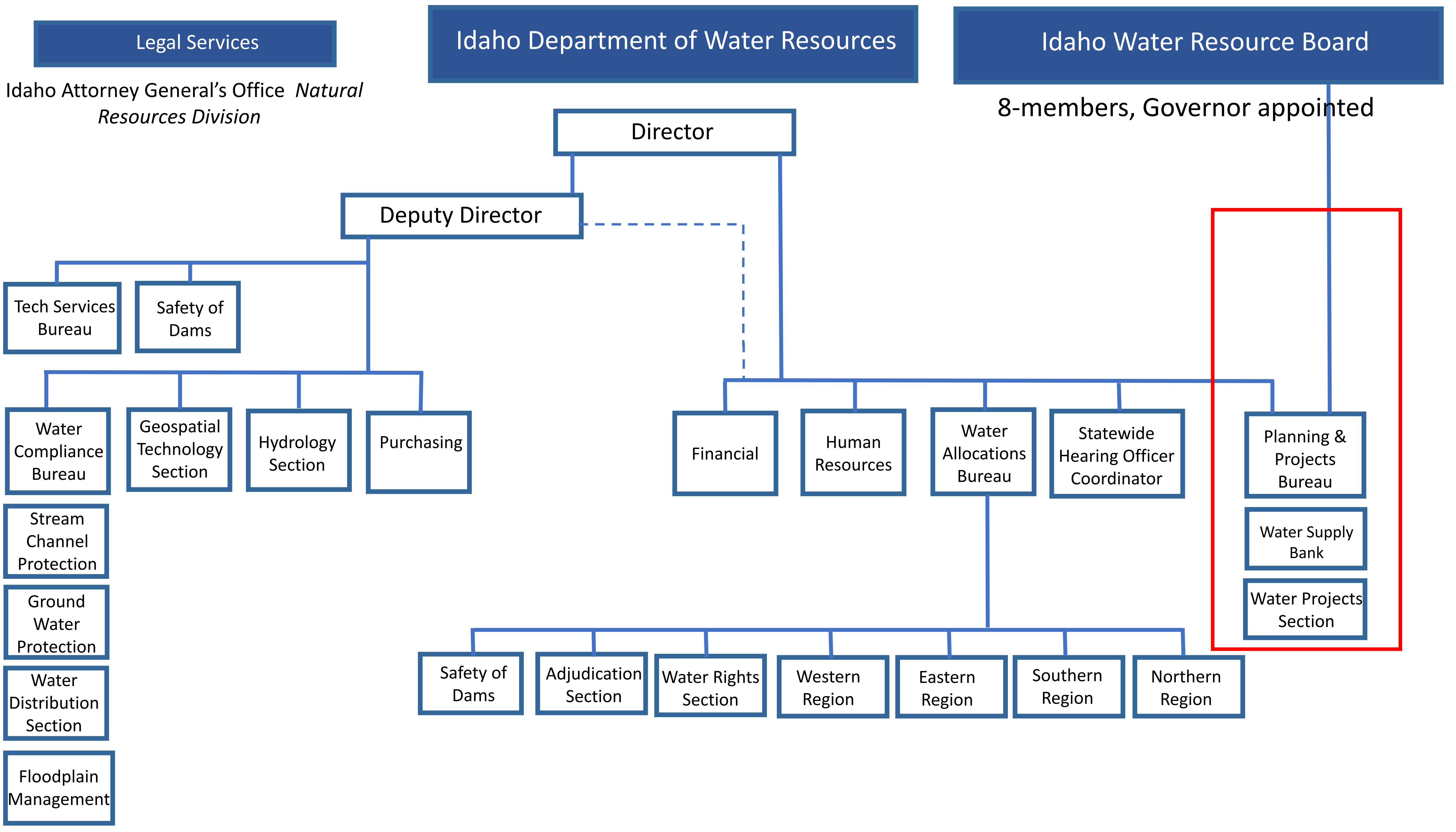
IDAHO DEPARTMENT OF WATER RESOURCES

Idaho Water Resource Board

- Formulation and implementation of the State Water Plan
- Implementation and financing of large water projects
- Operation of programs that support sustainable management of Idaho's water resources
  - Water Supply Bank
  - Managed Aquifer Recharge
  - Cloud Seeding
  - Water Transactions
  - Financial Programs

IDAHO WATER RESOURCE BOARD

WATER IN IDAHO



OVERVIEW

- Cloud Seeding 101
- History of Cloud Seeding in Idaho
- Current Projects
- Program Development

Image Courtesy of Idaho Power Company

CLOUD SEEDING 101

What is Cloud Seeding?

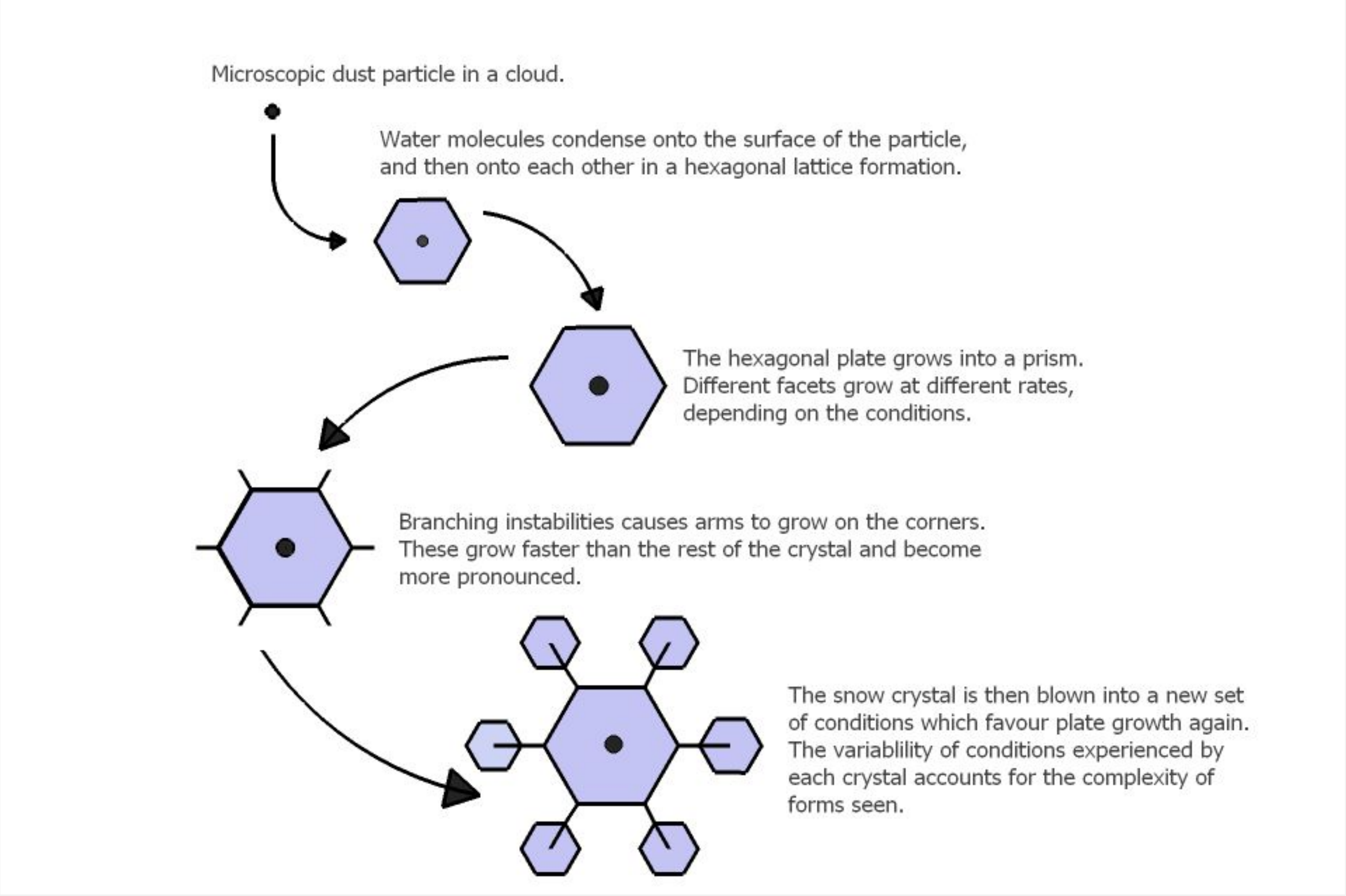
Cloud seeding is a form of weather modification that increases the efficiency of a cloud by enhancing its natural ability to produce precipitation.

Why do we seed clouds?

- Augmentation of snowpack
- Rain Enhancement
- Fog suppression
- Hail Mitigation

CLOUD SEEDING 101

How does a snowflake develop in nature?



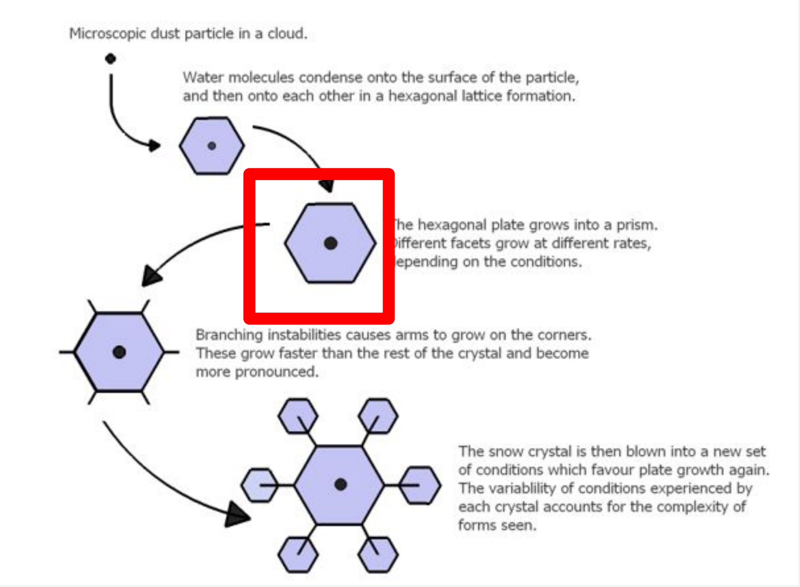
Images Courtesy of Idaho Power Company

CLOUD SEEDING 101

How do we seed clouds?

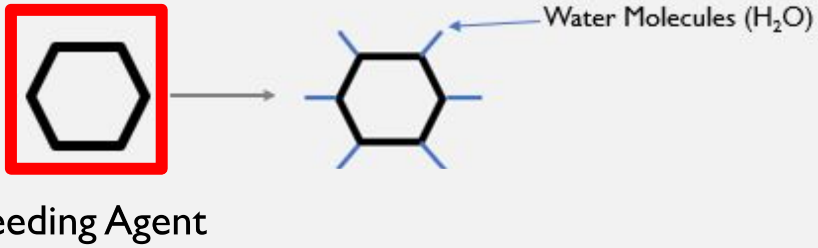
- A seeding agent is released into an ***existing*** cloud formation with "Supercooled Liquid Water" (SLW)

- Seeding agent has structure like that of naturally occurring ice (hexagonal)



- Cloud Seeding is a ***physically*** based process →

  Provides surface for water molecules to bond to each other; does not bond to water molecules to form chemical reaction



CLOUD SEEDING 101

What is Supercooled Liquid Water (SLW)?

- Water that is cold enough to freeze, but remains in the liquid state
- Water ***can*** freeze at 32°F
- Water requires a nucleation process to freeze
  - Impurities in nature such as dust
- Water in the liquid state can be present in clouds much colder than 32°F

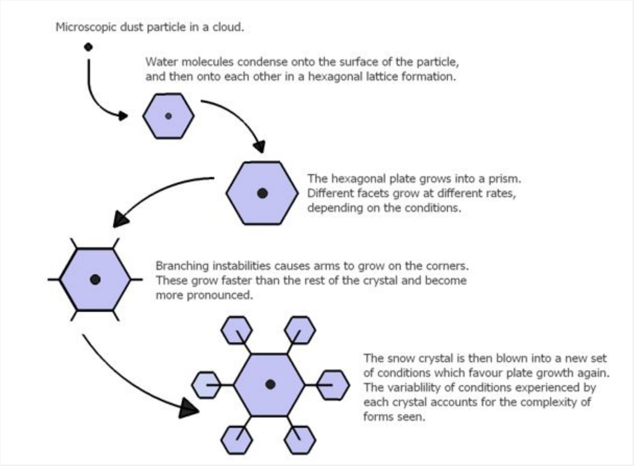


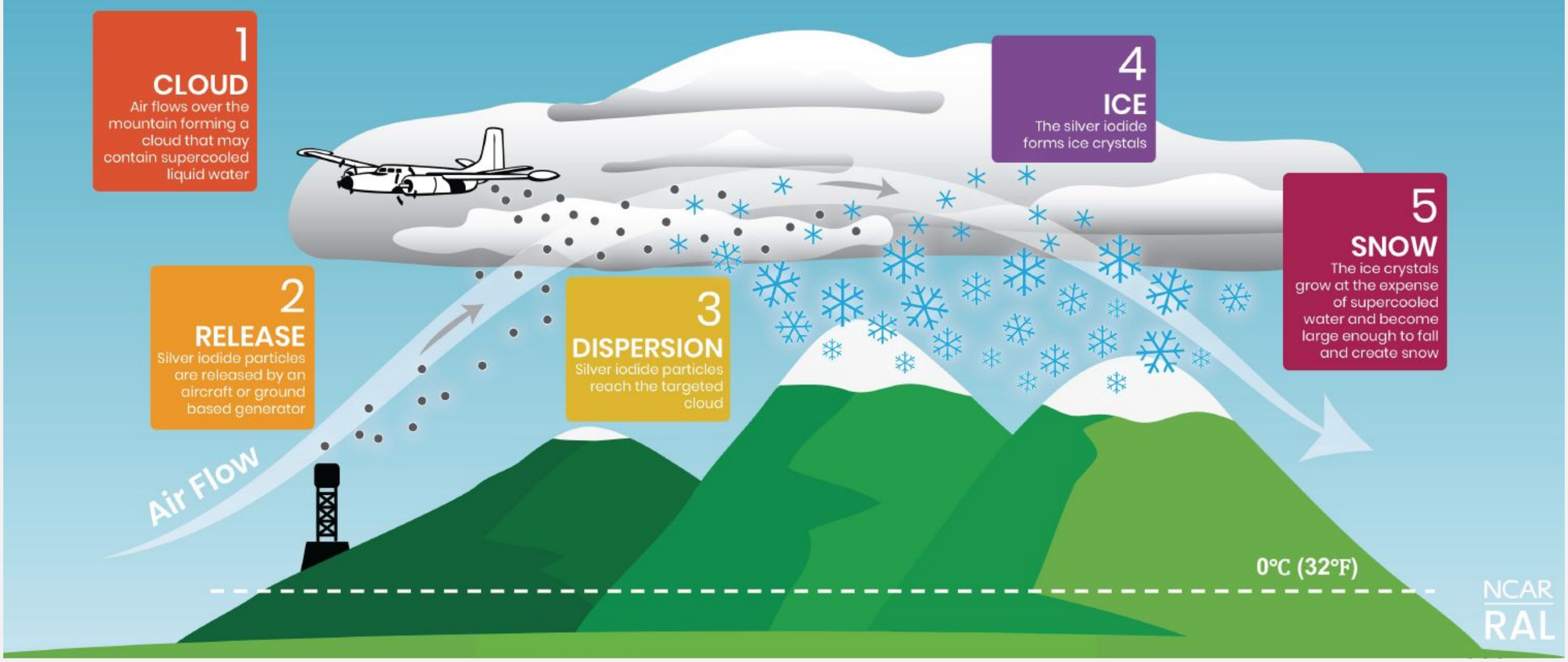
Image Courtesy of Idaho Power Company

CLOUD SEEDING 101

Methods of seeding

- Silver Iodide (AgI), most commonly used seeding agent
  - Functions at warmer temperature, allowing ice formation to begin sooner
  - Most effective at 17° F or colder
  - Natural ice nuclei become effective below 5° F
- Ground Generators: AgI Solution is burned through propane flame
- Aircraft: AgI is incorporated into a flare (or solution is burned)

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

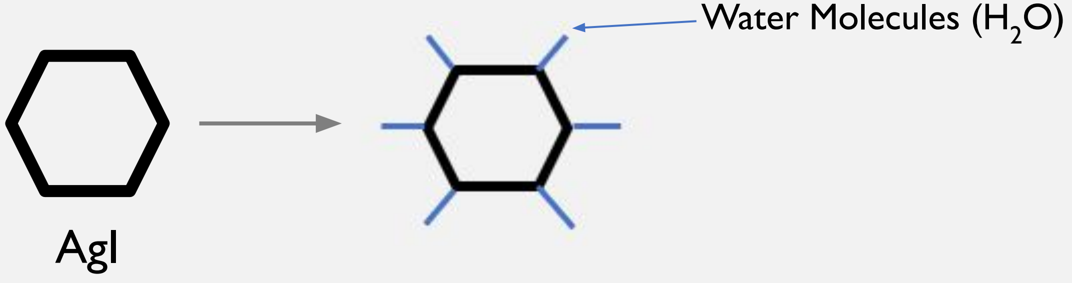


This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.

CLOUD SEEDING 101

What is Silver Iodide (AgI)?

- Inorganic compound
- Inert in the *natural* environment
  - Insoluble in water □ can't become free silve
    available to aquatic organisms
  - Solubility close to that of Quartz
- Similar hexagonal structure as naturally forming ice crystals



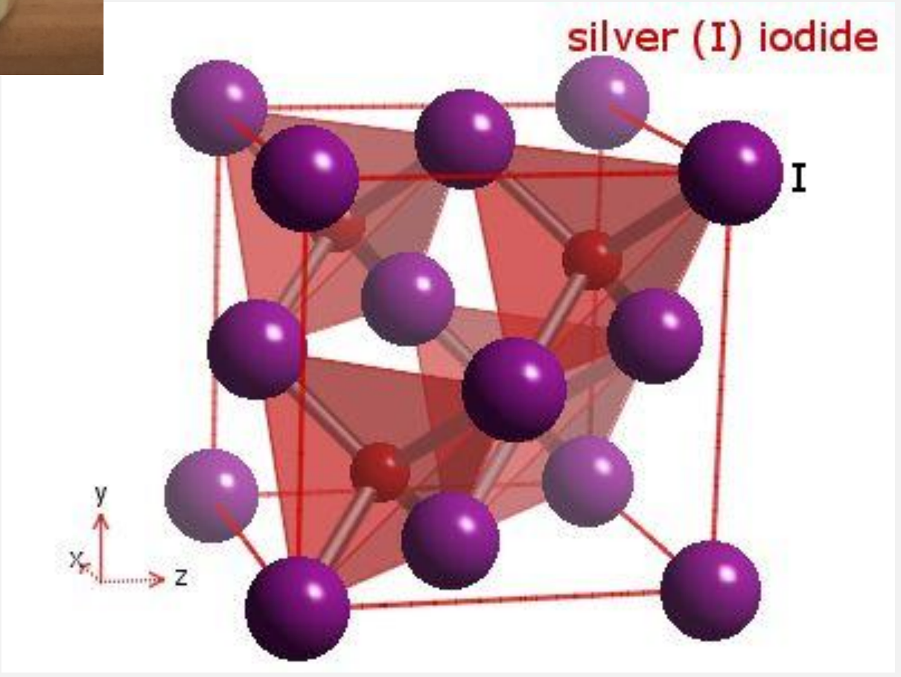
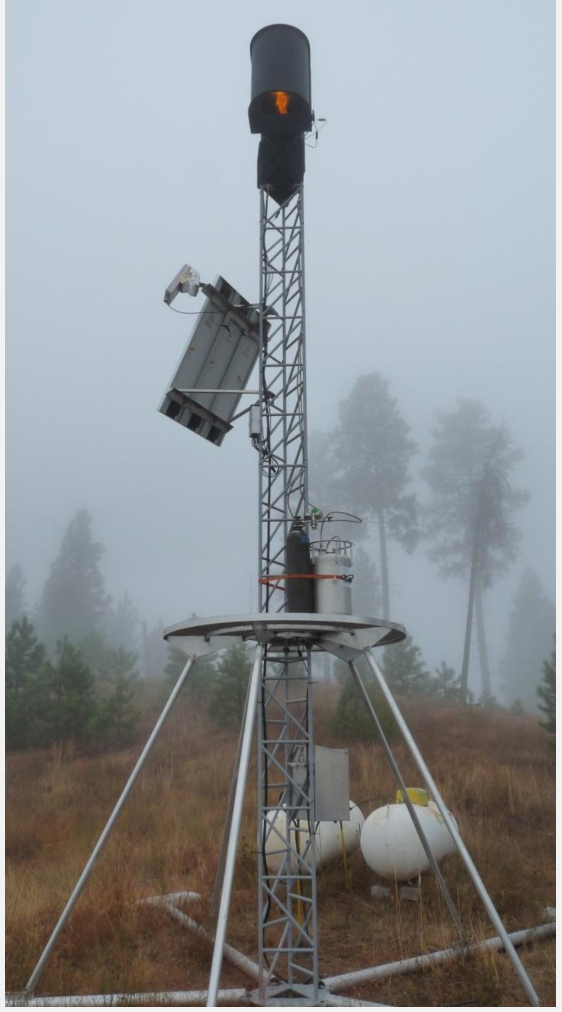


Image Courtesy of WebElements.com

CLOUD SEEDING 101

Types of Ground Generators

Manually Operated Generator
- Inexpensive to operate
- Must be located where accessible for operation mid to lower-level elevations
- Can be limited by inversions



Remote Generator
- More flexibility in placement
- Can target higher elevation snowpack (last snow to melt → extended seasonal flows)
- More costly to operate

The cost efficiency and effectiveness of using each type of generator is largely dependent upon the climatology and geography of the basin where they're being used.

Images Courtesy of Idaho Power Company

CLOUD SEEDING 101

Remote Ground Generators

Base Platform ~9 feet from ground

Images Courtesy of Idaho Power Company

CLOUD SEEDING 101

Aircraft Seeding

Demonstration of flare ignition, actual dispersion occurs in cloud*

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

- 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

Belly Mounted Ejectable (EJ) flares

Images Courtesy of Idaho Power Company and Ice Crystal Engineering

CLOUD SEEDING 101

How much water are we talking?

- Clouds form when invisible water vapor in the air condenses into visible water droplets or ice crystals

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

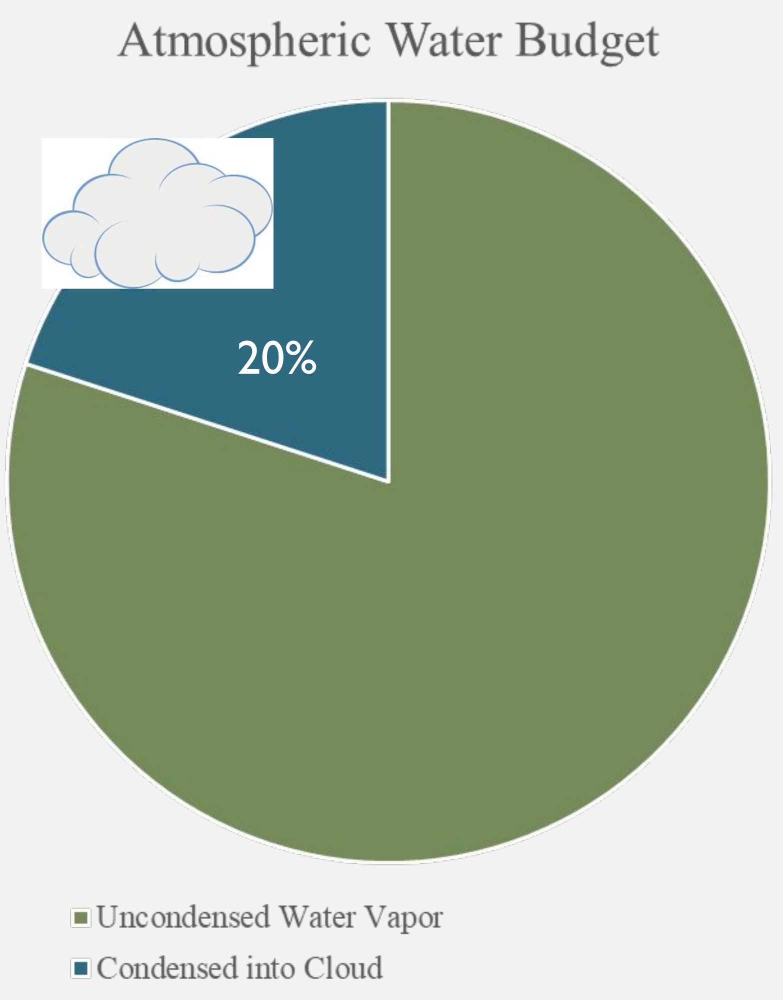


Figure Courtesy of Idaho Power Company

CLOUD SEEDING 101

How much water are we talking?

Winter storms are typically about 30% efficient

*“only **30%** <u>of</u> that total **20% condensed water vapor** will fall to the ground as precipitation, roughly equal to 6% of the total water content”*

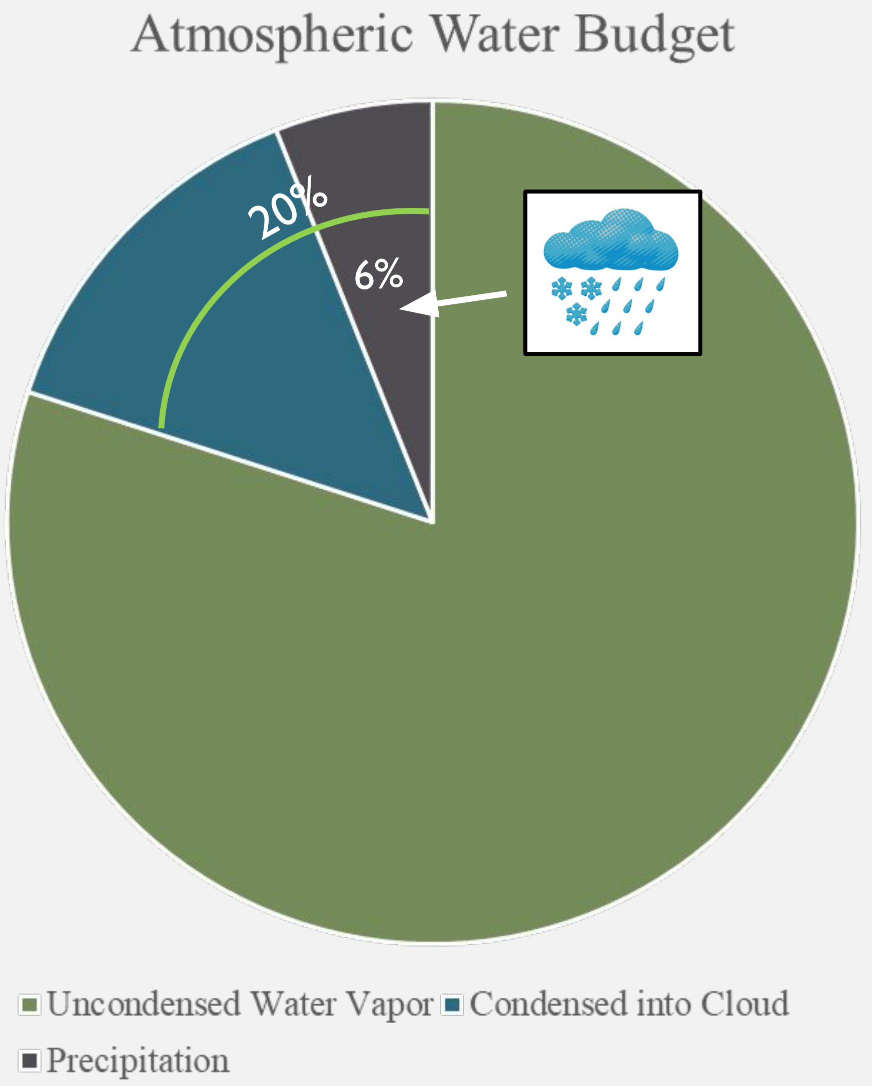


Figure Courtesy of Idaho Power Company

CLOUD SEEDING 101

How much water are we talking?

Cloud seeding enhances the storms efficiency

*"with cloud seeding there could be **~10-15% more** (on average) <u>of</u> that **20% condensed water vapor** hitting the ground as precipitation; an increase of <1% from the total water content"*

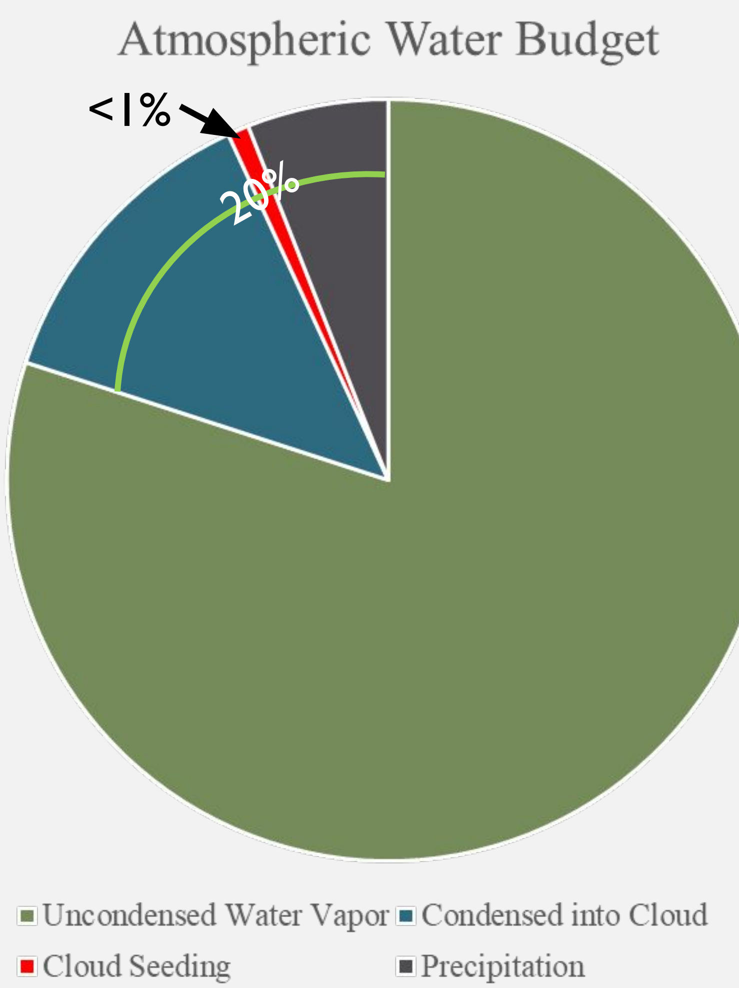


Figure Courtesy of Idaho Power Company

CLOUD SEEDING 101

Are we "Robbing Peter to Pay Paul," or taking water from downwind users?

- Consider that an atmospheric river is very dynamic, and, like a surface flowing river, also has many gains and losses as it moves across the continent

- Factoring the amount of overall water content "diverted" through seeding, and the rate of resaturation, it is unlikely to see negative impacts to downwind basins

- It is more likely that there are ***benefits*** to downwind basins, as the nucleation process in a seeded cloud can continue for a given distance downwind of the target basin → aiding downwind precipitation as a result.

- Further research is required to better address this question

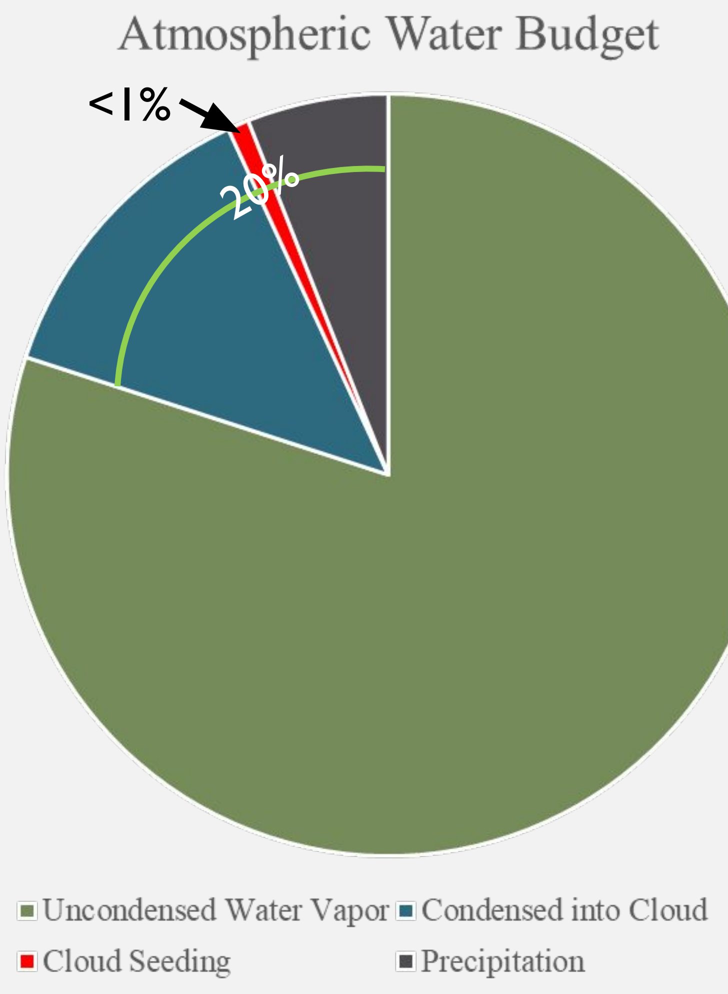


Figure Courtesy of Idaho Power Company

2017 SNOWIE RESEARCH

How do we know it works?

Seeded and Natural Orographic Wintertime clouds: the Idaho Experiment

"SNOWIE"

National Science Foundation study | $2.1M

- Field campaign winter 2017 in the Payette River Basin of Idaho
  - Over 75 research aircraft and ground-based instruments
- Objectives:
  - Further understand winter precipitation processes
  - Determine how cloud seeding effects winter precipitation

"SNOWIE provided the '… first unambiguous observations of the physical chain of events following introduction of glaciogenic cloud seeding aerosol into supercooled liquid orographic clouds."

Proceedings of the National Academy of Sciences

Collaborating Organizations:

National Center for Atmospheric Research (NCAR)

University of Wyoming

University of Colorado, Boulder

University of Illinois

Idaho Power Company

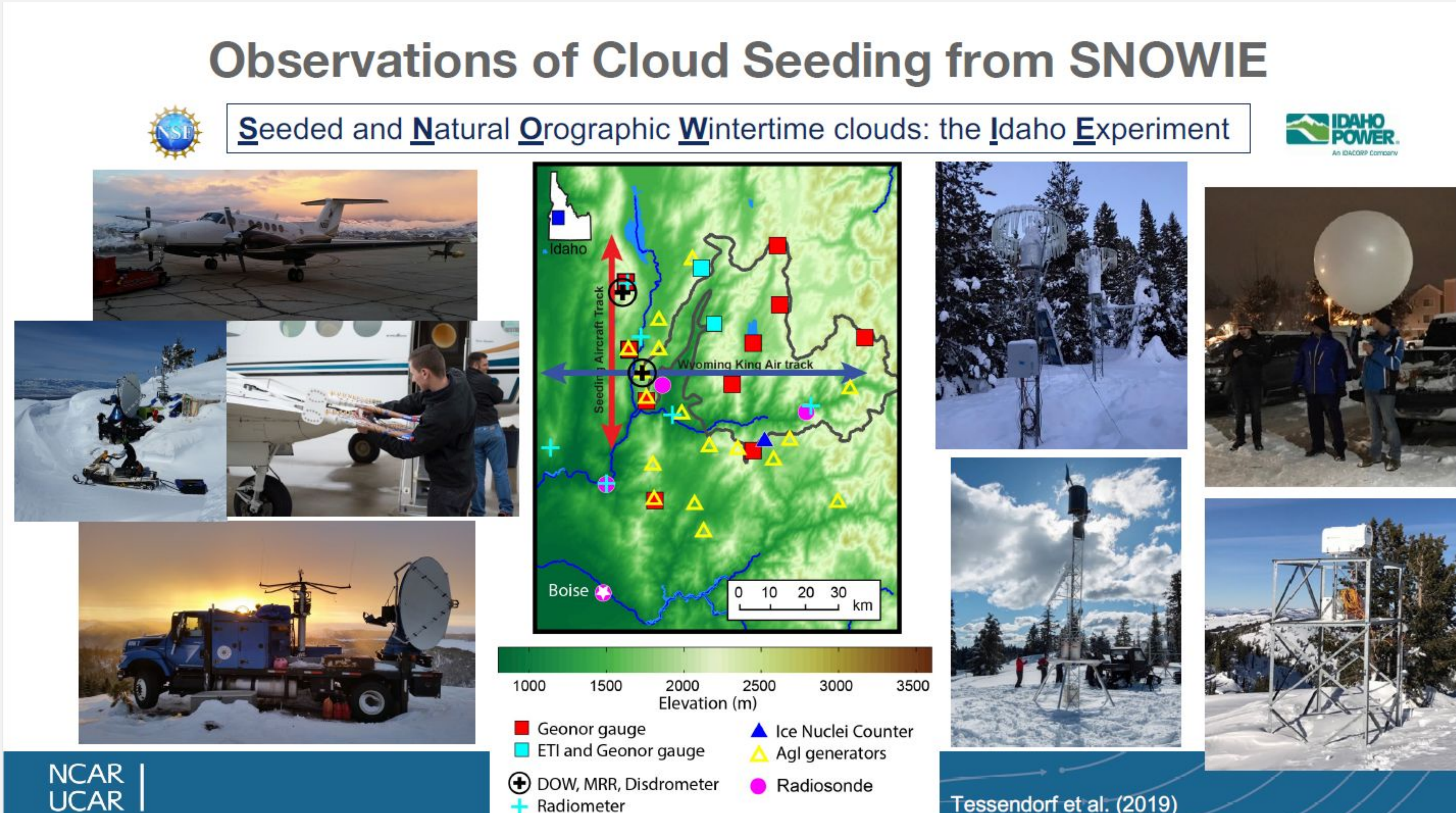
Additional Efforts

BSU – Silver sampling

WMI - Research seeding aircraft

WMI - Ice nuclei counter

2017 SNOWIE RESEARCH

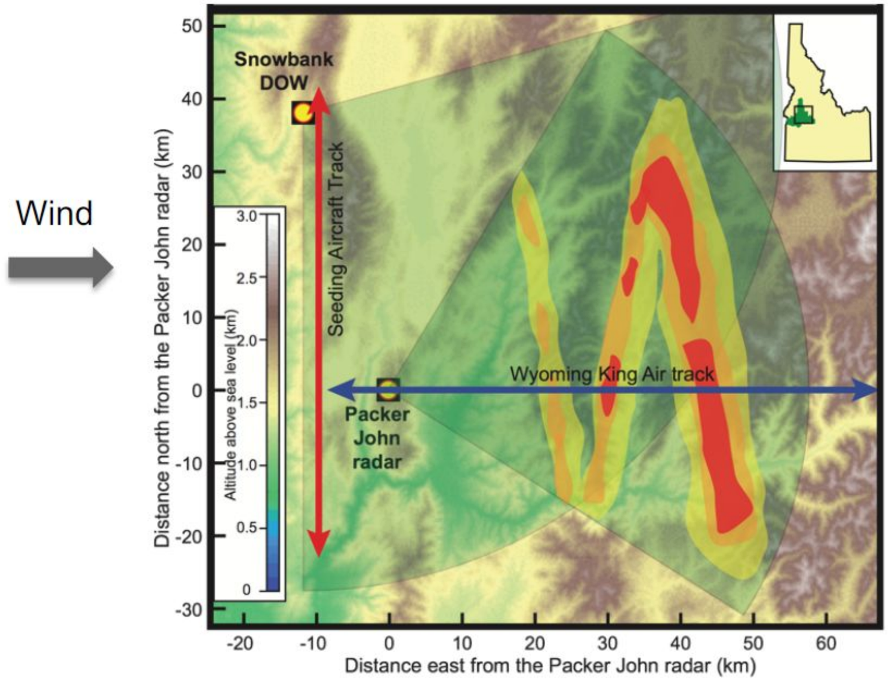


2017 SNOWIE RESEARCH

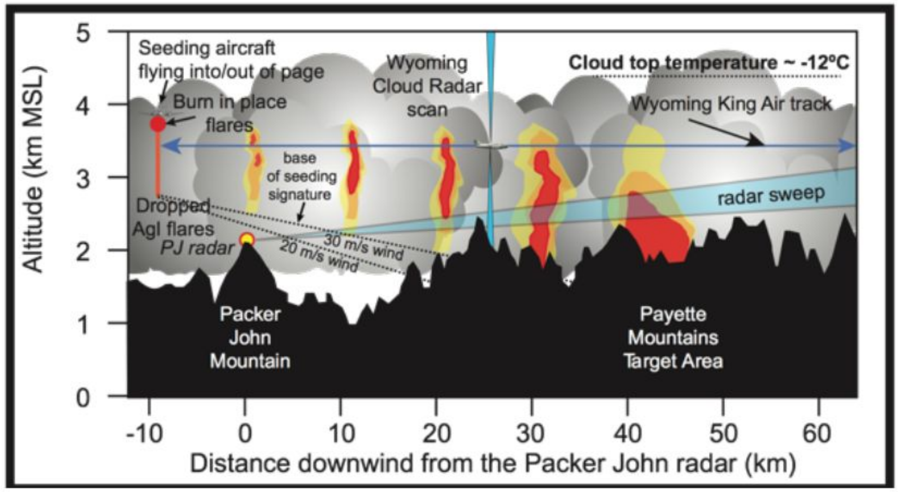
SNOWIE Experimental Design and Strategy

- Strategy was to fly the research aircraft directly in silver iodide seeding plumes to detect and measure the impacts of seeding

Hypothesized seeding plume dispersion

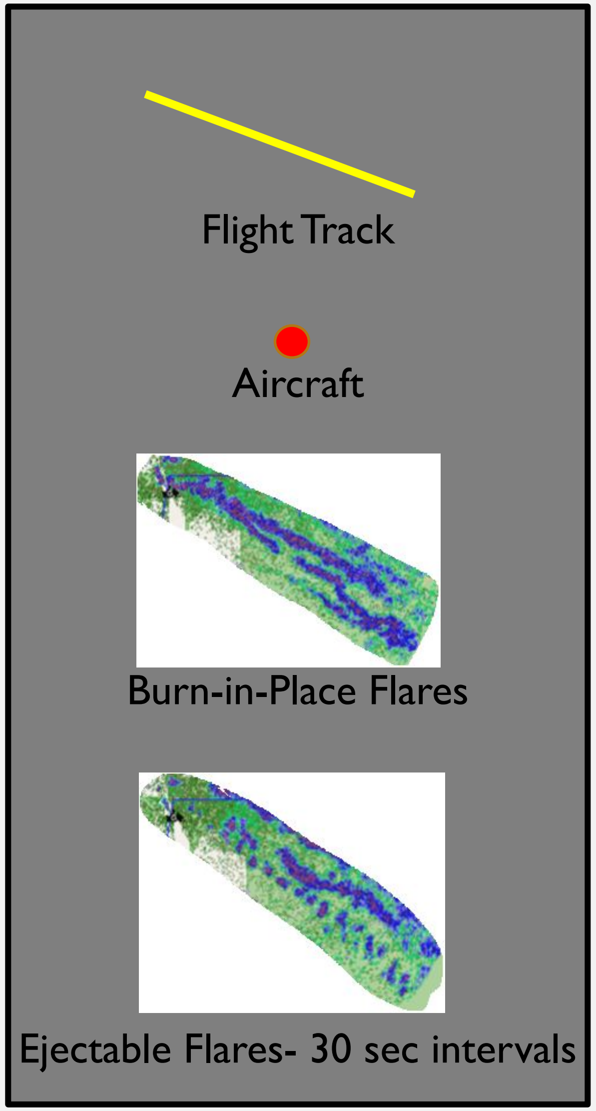


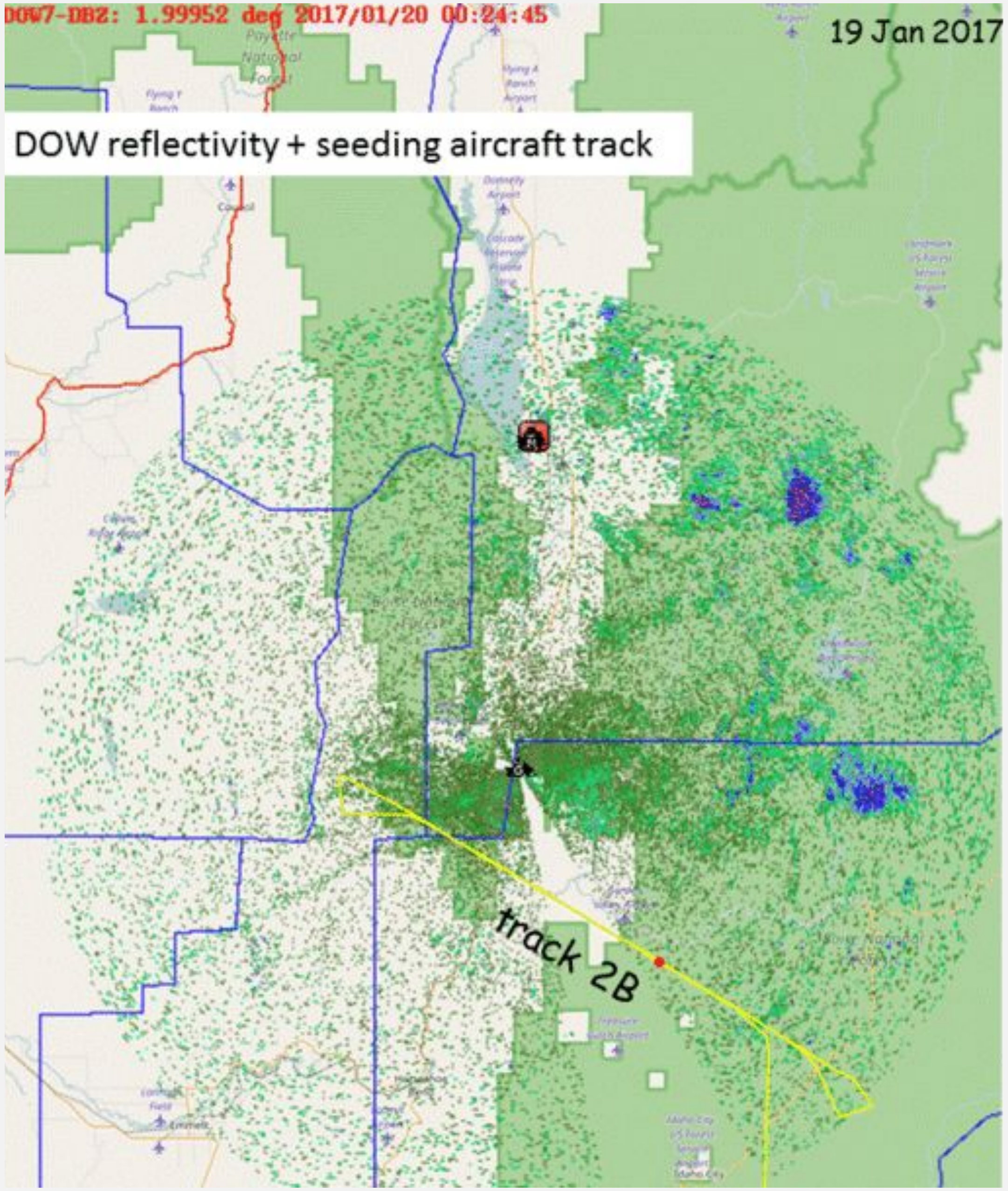
Hypothesized seeding plume dispersion along vertical cross section of UWKA path



French et al. (2018) and Tessendorf et al. (2019)

2017 SNOWIE RESEARCH

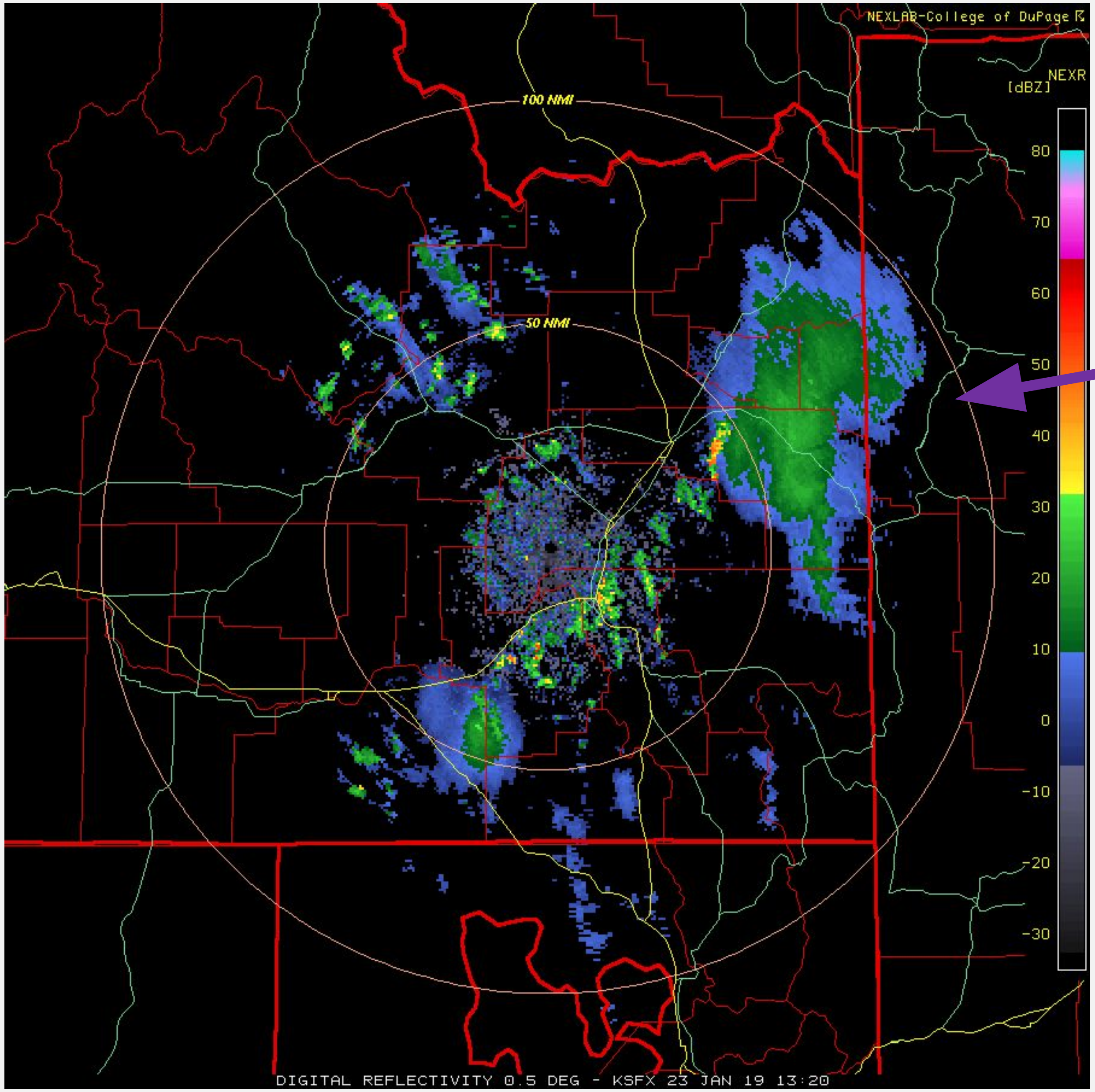




"SNOWIE has addressed many of the scientific questions, it is now transitioning to an engineering problem"

"SNOWIE provided the '… first <u>unambiguous</u> observations of the physical chain of events following introduction of glaciogenic cloud seeding aerosol into supercooled liquid orographic clouds." – *Proceedings of the National Academy of Sciences*

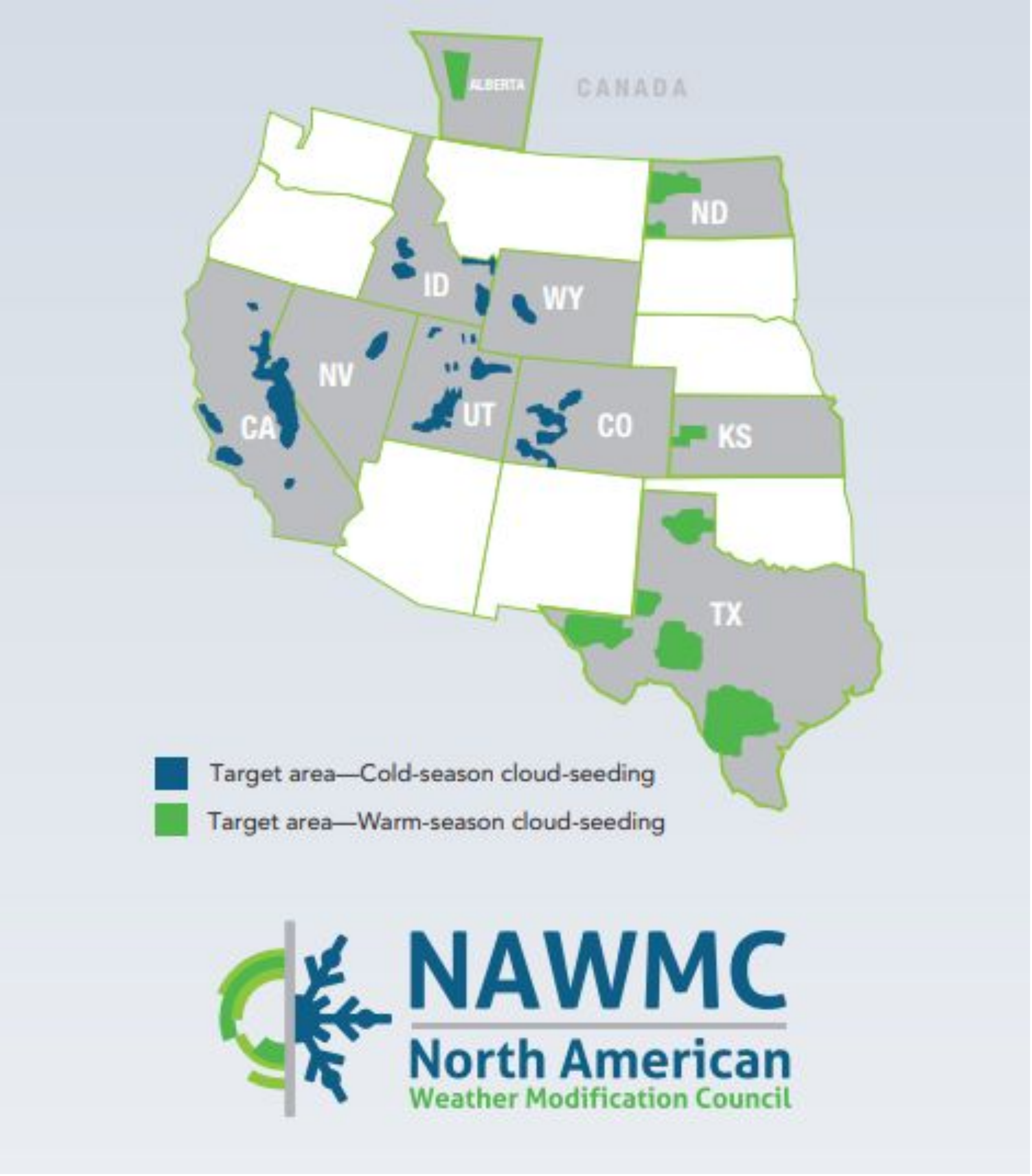
POCATELLO NWS RADAR



"Zig-zag" pattern from cloud seeding operations

January 23, 2019

CLOUD SEEDING IN NORTH AMERICA



HISTORY OF CLOUD SEEDING IN IDAHO

Water Year	Northern Idaho	Southwestern Idaho	Southern Idaho	Southeastern Idaho
1950	*	*	*	*
1951	NAWC	*	*	*
1952	*	*	*	*
1953	NAWC	*	*	*
1954	NAWC	*	NAWC	NAWC
1955	NAWC	NAWC	NAWC	NAWC
1956	NAWC	NAWC	*	NAWC
1957	NAWC	*	*	NAWC
1958	NAWC	*	*	NAWC
1959	NAWC	*	*	NAWC
1960	NAWC	NAWC	*	NAWC
1961	*	NAWC	*	NAWC
1962	*	NAWC	*	NAWC
1963	*	*	*	NAWC
1964	*	*	*	NAWC
1965	*	*	*	NAWC
1966	*	*	*	NAWC
1967	NAWC	*	*	NAWC
1968	NAWC	*	*	NAWC
1969	NAWC	*	*	NAWC
1970	NAWC	*	*	NAWC
1971	NAWC	*	*	*
1972	*	*	*	*
1973	*	*	*	*
1974	NAWC	*	*	*
1975	*	*	*	*
1976	*	*	*	*
1977	*	*	*	*
1978	*	*	*	*
1979	*	*	*	*
1980	*	*	*	NAWC
1981	*	*	*	NAWC
1982	*	*	*	NAWC
1983	*	*	*	*
1984	*	*	*	*
1985		*	*	*

Water Year	Payette	Boise	Wood	Northern Upper Snake	Southern/Eastern Upper Snake
1986	*	*	*	*	*
1987	*	*	*	*	*
1988	*	*	*	*	*
1989	*	*	*	NAWC	NAWC
1990	*	*	*	*	NAWC
1991	*	*	*	*	*
1992	*	*	*	*	NAWC
1993	*	NAWC	*	NAWC	NAWC
1994	*	NAWC	*	*	*
1995	*	NAWC	*	*	NAWC
1996	*	NAWC	*	*	*
1997	AI	*	*	LIS	*
1998	*	*	*	LIS	*
1999	*	*	*	LIS	*
2000	*	*	*	LIS	*
2001	*	*	*	LIS	*
2002	*	NAWC	*	LIS	LIS
2003	IPC	NAWC	*	*	LIS
2004	IPC	NAWC	*	LIS	LIS
2005	IPC	NAWC	*	*	LIS
2006	IPC	*	*	LIS	*
2007	IPC	*	*	LIS	*
2008	IPC	NAWC	*	LIS/IPC	LIS/IPC
2009	IPC	NAWC	*	LIS/IPC	LIS/IPC
2010	IPC	*	*	LIS/IPC	LIS/IPC
2011	IPC	NAWC	*	LIS/IPC	LIS/IPC
2012	IPC	NAWC	*	LIS/IPC	LIS/IPC
2013	IPC	*	IPC	LIS/IPC	LIS/IPC
2014	IPC	NAWC	IPC	LIS/IPC	LIS/IPC
2015	IPC	IPC	IPC	LIS/IPC	LIS/IPC
2016	IPC	IPC	IPC	LIS/IPC	LIS/IPC
2017	IPC	IPC	IPC	LIS/IPC	LIS/IPC
2018	IPC	IPC	IPC	LIS/IPC	LIS/IPC
2019	IPC	IPC	IPC	LIS/IPC	LIS/IPC
2020	IPC	IPC	IPC	LIS/IPC	LIS/IPC
2021	IPC	IPC	IPC	LIS/IPC	LIS/IPC
2022	IPC	IPC	IPC	LIS/IPC	LIS/IPC
2023	IPC	IPC	IPC	LIS/IPC	LIS/IPC

Let it Snow (LIS), North American Weather Consultants (NAWC), Atmospheric Inc (AI), Idaho Power Company (IPC), Idaho Water Resource Board (IWRB)

* No CS Operations

COLLABORATIVE CLOUD SEEDING PROGRAM

What is Idaho's Collaborative Cloud Seeding Program?

- Unique partnership between:
  - Idaho Water Resource Board (IWRB)– State of Idaho
  - Idaho Power Company (IPC)
  - Local water users in basins of operation
- IPC operates the program, the State and local water users participate in program funding
- Includes the Boise, Wood, Upper Snake River Basins of Idaho
- IPC operates independent project in the Payette River Basin, in coordination with the collaborative program.

*IPC provides forecasting support to the Upper Snake's High Country RCD program, however the HCRCD manual program is independently operated by Let it Snow

COLLABORATIVE PROGRAM DEVELOPMENT

History of the Collaborative Program

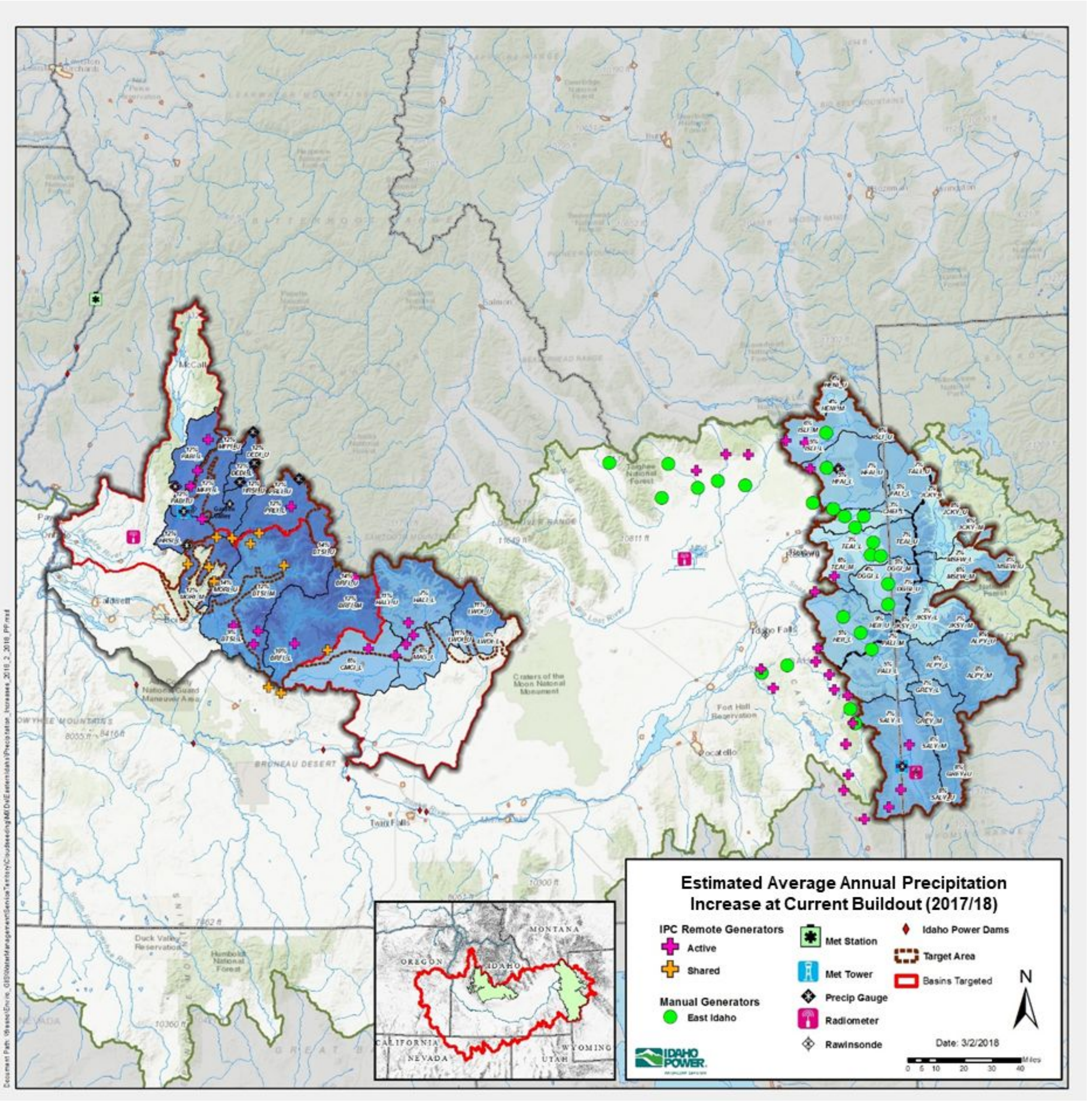
- 1990's, Idaho Power Company (IPC) began investigating cloud seeding to support hydropower
- 2003, first operational program in the Payette River Basin– IPC
- 2008, ESPA CAMP □ implementation of 5-year pilot project in the Upper Snake Basin– IPC
- Water users in the Wood and Boise River Basins partnered with IPC to begin new projects
- 2014, the IWRB began participation in program funding with capital for new infrastructure
- 2016, the IWRB began contributing towards program operations and modeling
- 2019, program reached existing build-out (3 aircraft, 57 remote generators, network of weather instrumentation)

IDAHO COLLABORATIVE CLOUD SEEDING PROGRAM

Average Additional Runoff (estimated):

1,240,000 AF *annually*

- *57 Remote Ground Generators*
- *3 Aircraft*
- *Network of Weather Instrumentation*
- *Sophisticated Modeling technologies*
- *Atmospheric Science Team*



COLLABORATIVE CLOUD SEEDING PROGRAM

Program Operations

- Guidelines for the operation of cloud seeding– American Society of Civil Engineers (ASCE)
- Operational Planning
  - When, Where, How, Communications
  - Suspension Criteria to mitigate risks for flooding/avalanche or other hazards
- Forecasting & Analysis
  - Weather Instrumentation (precipitation gages, balloons, radiometers, etc.)
  - High Resolution modeling, WRF Model
- Supported by team of atmospheric scientists, 24-7

COLLABORATIVE CLOUD SEEDING PROGRAM

West Central Mountains Projects

Estimated Average Additional Runoff (unregulated) &

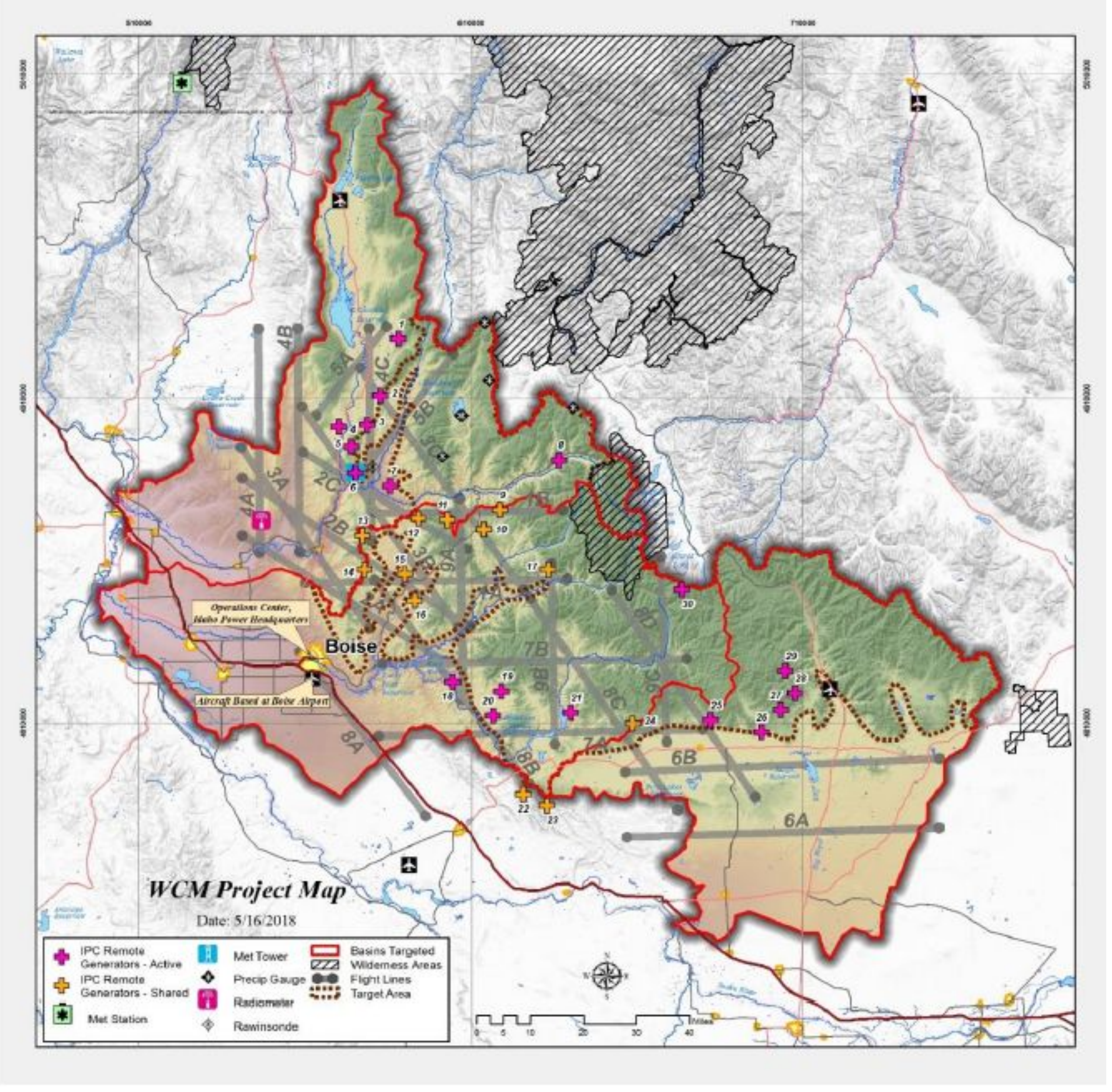
Current Project Costs (Annually)

Boise River Basin– 273 KAF | $910K

Wood River Basin – 112 KAF | $670K

Payette River Basin* – 223 KAF | $870K

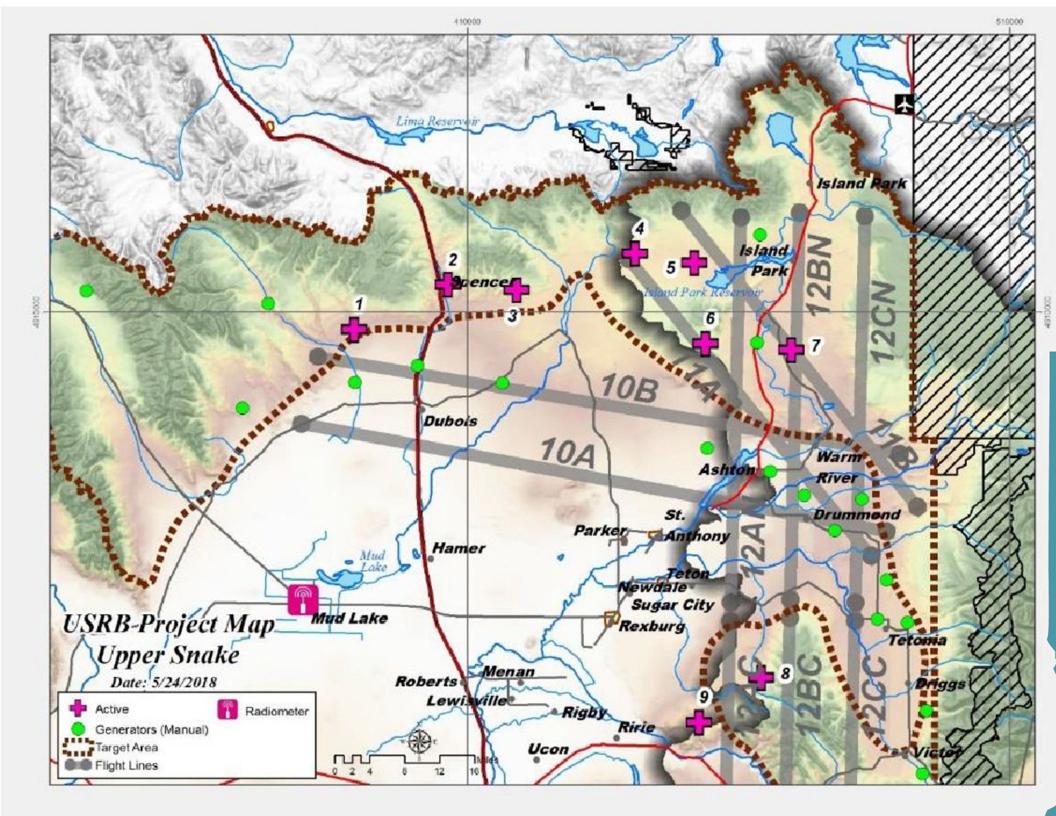
WCM Total: 608KAF |$2.45M



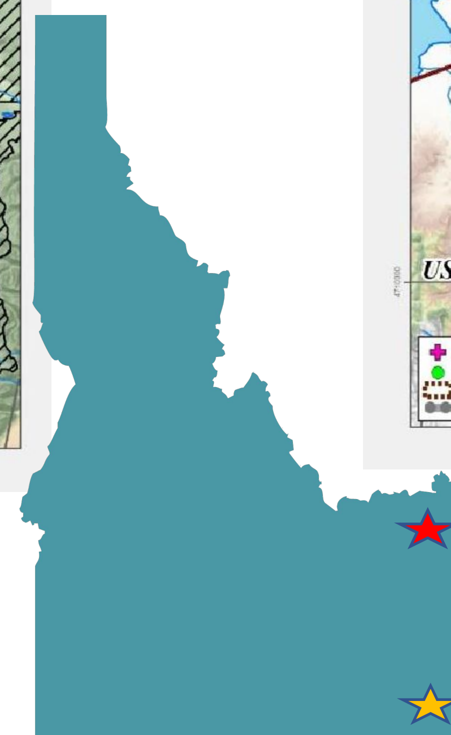
**Independent project operated by Idaho Power Company in coordination with the Collaborative. 100% Funded by IPC.*

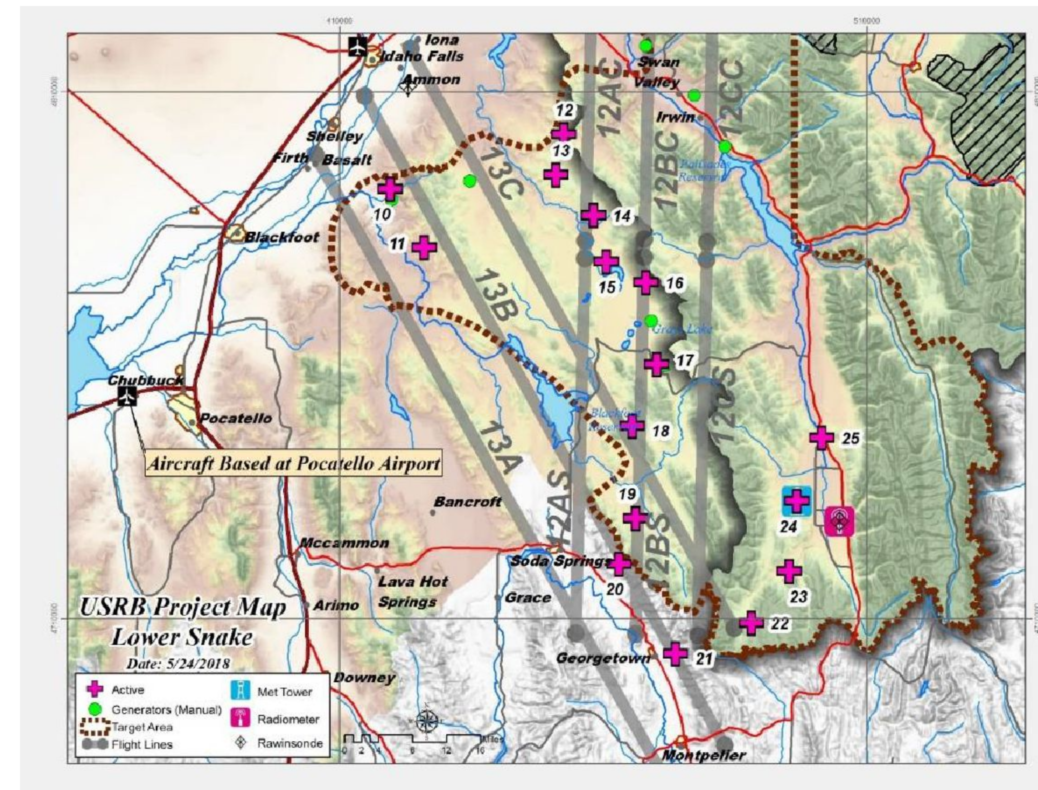
COLLABORATIVE CLOUD SEEDING PROGRAM

Upper Snake Basin Projects



Northern Upper Snake
168 KAF





Southern Upper Snake
464 KAF

Upper Snake River Basin– 632 KAF | $1.54M

COLLABORATIVE PROGRAM SUMMARY

Current Annual Operations Cost:	$3,995,000
Average Annual Runoff Generated:	1,240,000 AF
Estimated Cost Per Acre Foot:	$3.22/AF

Current Goals:

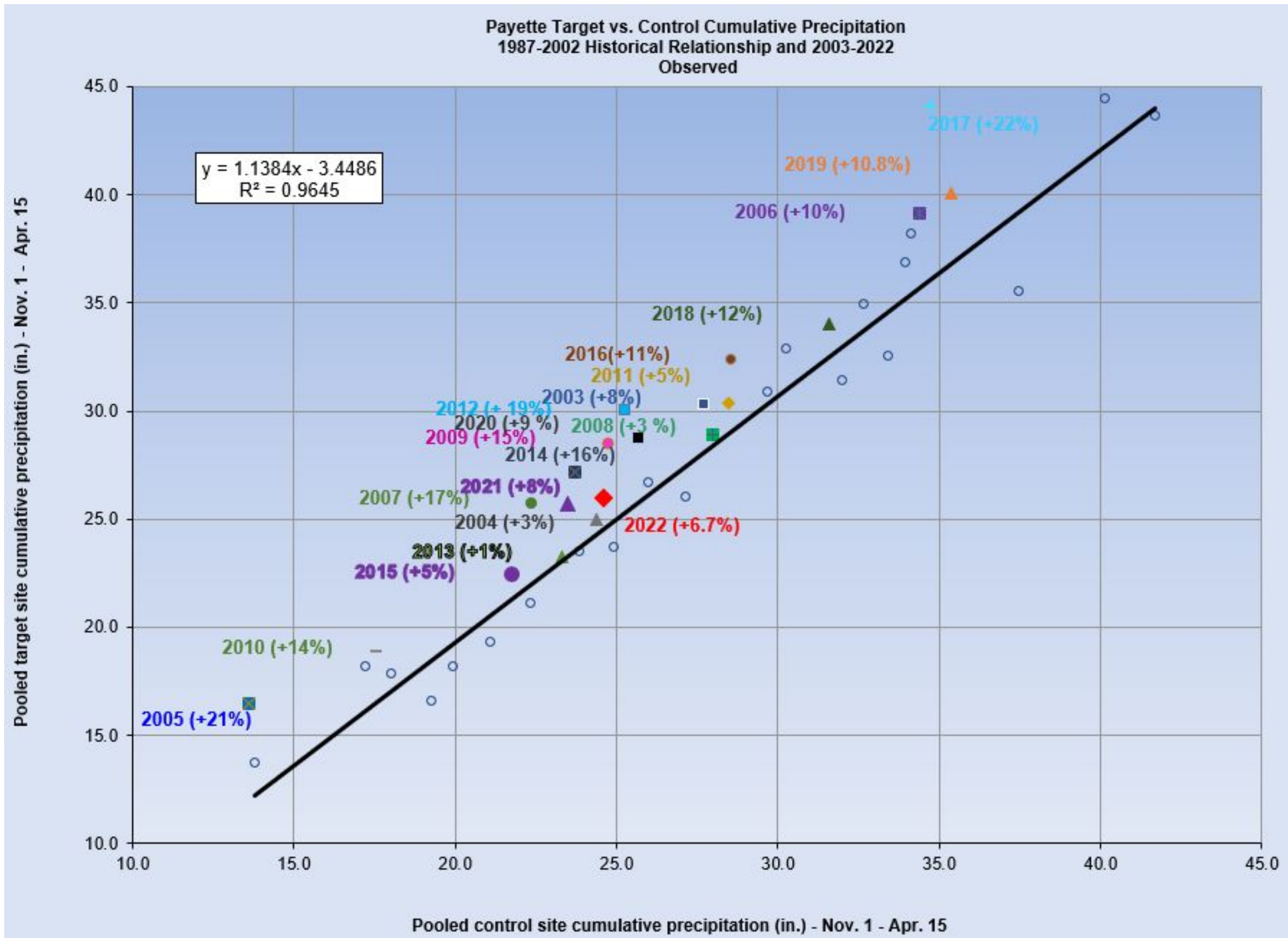
- Determine equitable distribution of program funding
- Secure long term collaborative agreements
- Assess opportunities for program expansion or enhancement
- Ongoing monitoring and analysis

TARGET/CONTROL ANALYSIS

How do we know the amount of precipitation that was increased?

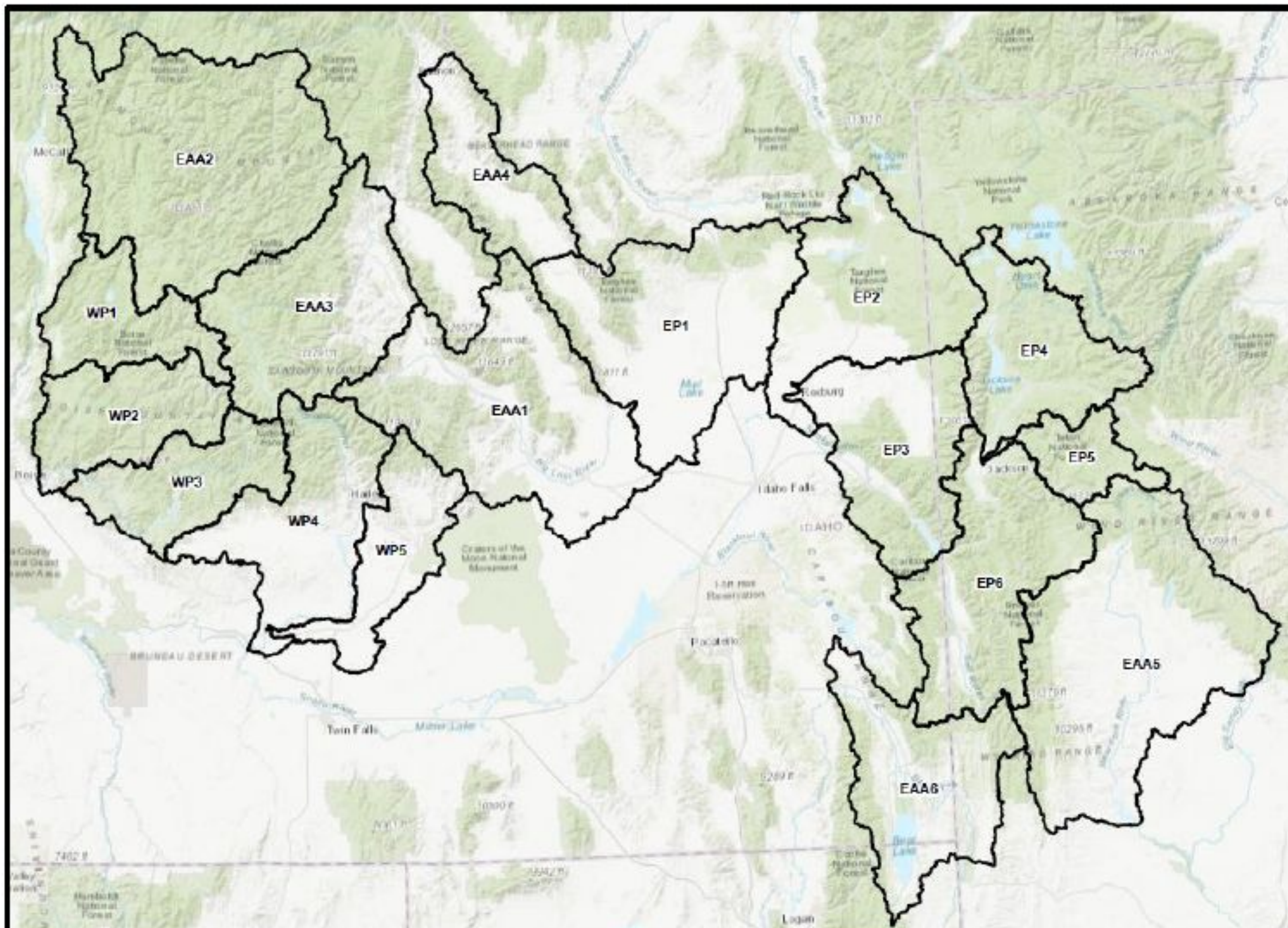
- Target/Control analysis compares historical data between 2 areas with similar climatology
  - TARGET area: Seeded area; location where seeding impacts are intended to occur
  - CONTROL area: non-seeded area; location just outside target area, with historically similar climatology
- A statistical relationship is developed between the 2 areas used to compare % change in the target area

COLLABORATIVE CLOUD SEEDING PROGRAM

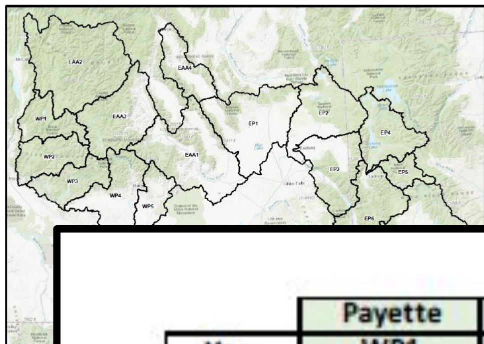


COLLABORATIVE CLOUD SEEDING PROGRAM

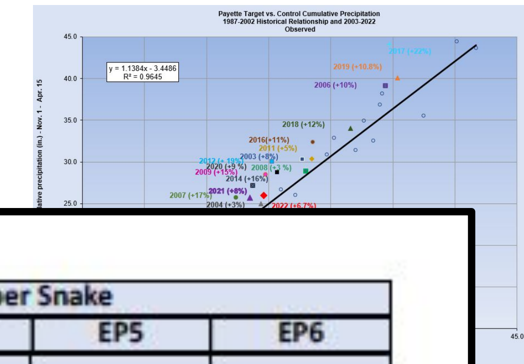
Target/Control Zones



COLLABORATIVE CLOUD SEEDING PROGRAM



Average % Increase in Snowpack



	Payette	Boise		Wood		Henrys Fork		Upper Snake			
Year	WP1	WP2	WP3	WP4	WP5	EP1	EP2	EP3	EP4	EP5	EP6
2003	8%										
2004	3%										
2005	19%										
2006	12%										
2007	14%										
2008	4%					2%	3%	3%	3%	3%	3%
2009	16%					6%	8%	12%	10%	11%	9%
2010	16%					3%	4%	13%	13%	13%	9%
2011	7%					6%	7%	9%	8%	8%	8%
2012	18%					3%	4%	14%	14%	14%	9%
2013	1%	4%	3%	10%	9%	2%	3%	8%	7%	8%	5%
2014	15%	24%	22%	11%	10%	3%	5%	11%	10%	11%	8%
2015	5%	15%	14%	13%	12%	3%	4%	12%	10%	11%	7%
2016	14%	8%	7%	8%	8%	4%	6%	5%	5%	5%	6%
2017	21%	21%	19%	16%	15%	9%	11%	12%	10%	11%	11%
2018	15%	12%	11%	9%	8%	6%	9%	8%	7%	8%	8%
2019	15%	10%	9%	11%	10%	6%	8%	17%	14%	15%	11%
2020	6%	7%	7%	7%	6%	5%	8%	10%	9%	9%	8%
2021	8%	10%	9%	9%	7%	4%	5%	9%	8%	9%	7%
2022	6.6%	6.5%	5.7%	6.1%	7.1%	5.1%	4.0%	5.8%	5.9%	6.4%	5.4%
Average	11.2%	11.7%	10.8%	10.0%	9.3%	4.5%	5.9%	9.9%	8.9%	9.4%	7.6%

Based on Target Control Analysis

Idaho Cloud Seeding Program Costs

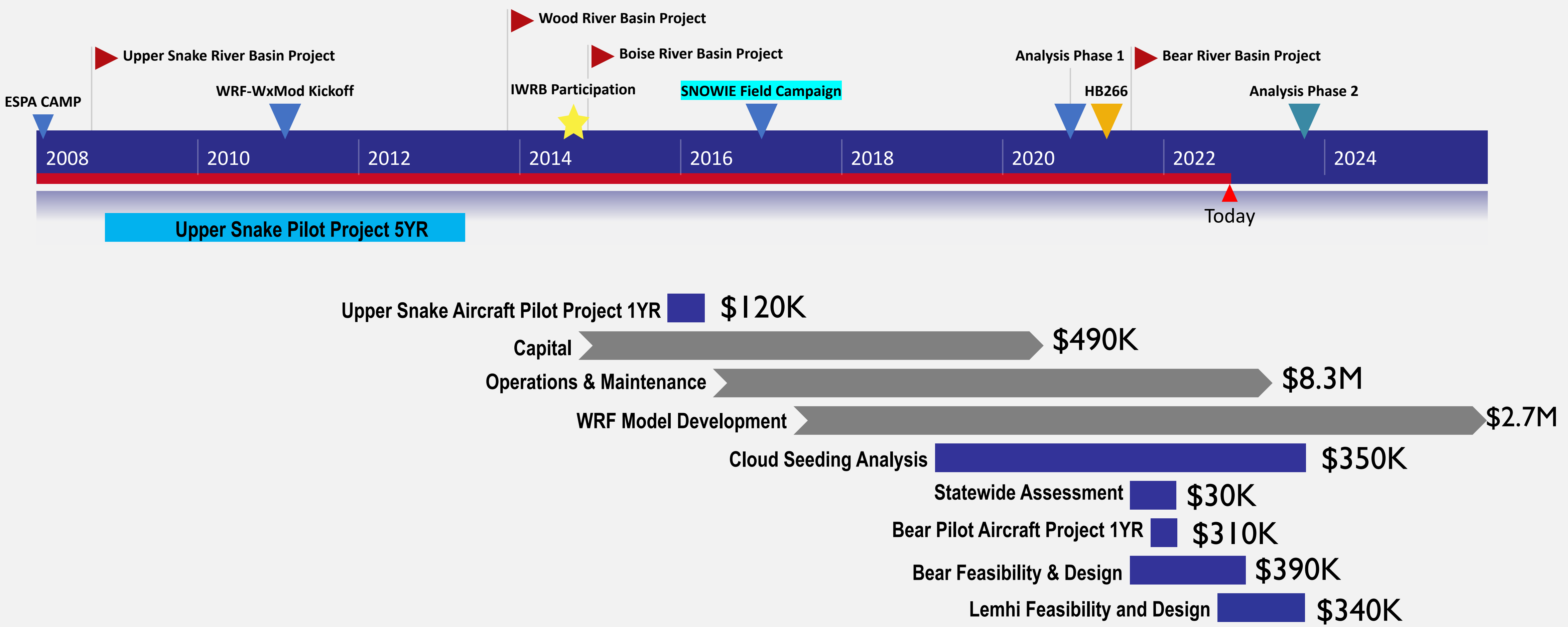
Project Basin	Payette	Boise	Wood	Upper Snake	Bear	Lemhi	TOTAL
Annual Operations	$870,000	$910,000	$670,000	$1,545,000	TBD	TBD	**$3,995,000**
# Dedicated (# shared)							
Ground Generators	8 (9)	5 (12)	7(3)	25	TBD	-	57
Aircraft	(2)	(2)	(1)	1	TBD	-	3
Estimated Avg Annual Increase (Unregulated Runoff) AF	**223**	**273**	**112**	**632**	TBD	TBD	**1,240,000**

$ 3.22 $/AF

- IPC Independent Projects
- Collaborative Program Projects
- State Projects

Shared infrastructure between adjoining basins allows for shared costs and provides for increased operational efficiency

IWRB PROGRAM DEVELOPMENT



Total State Funding: ~ $14,050,000

Costs reflect State funding contributions only

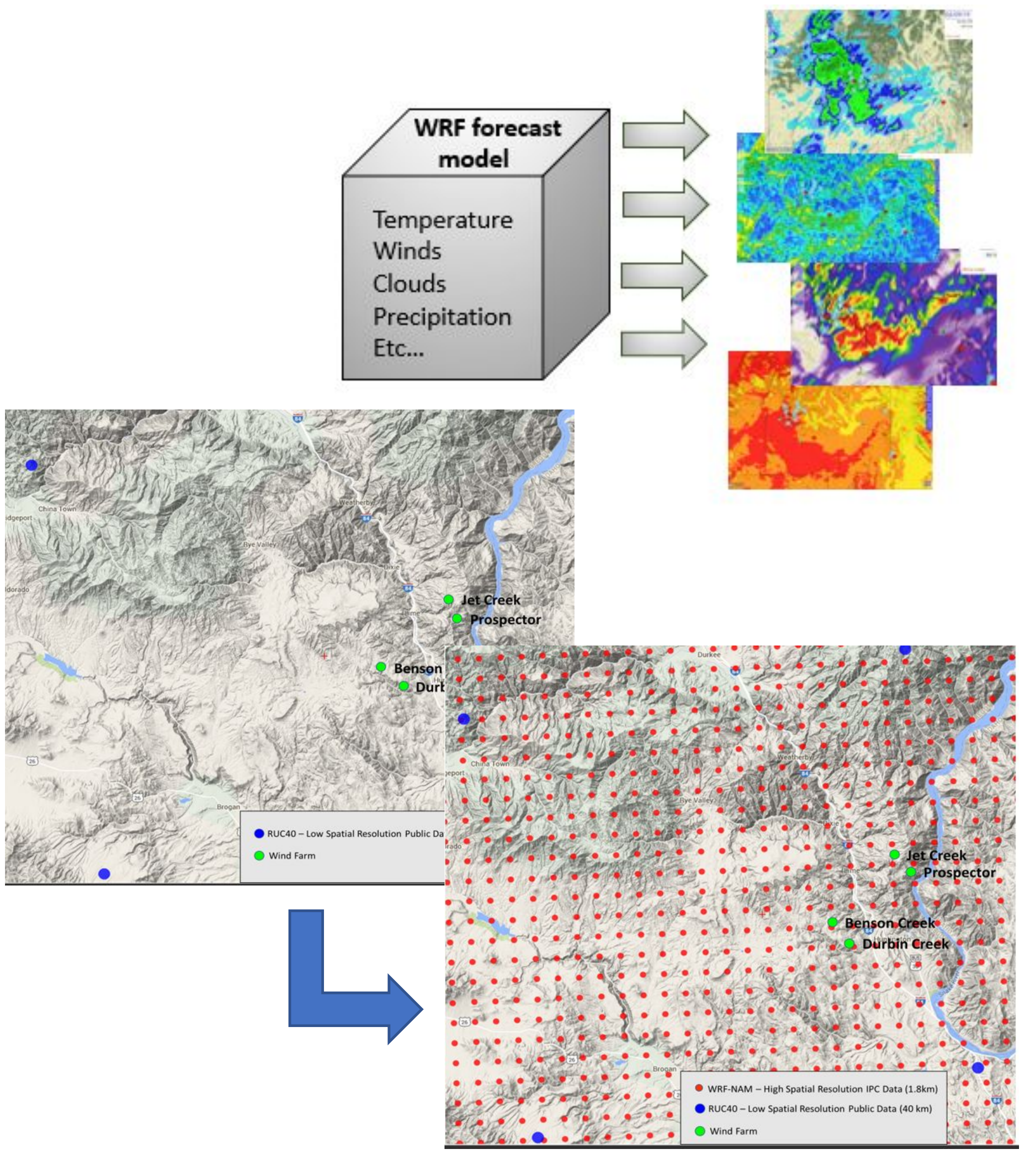
MODELING

Sophisticated modeling technologies are necessary for:

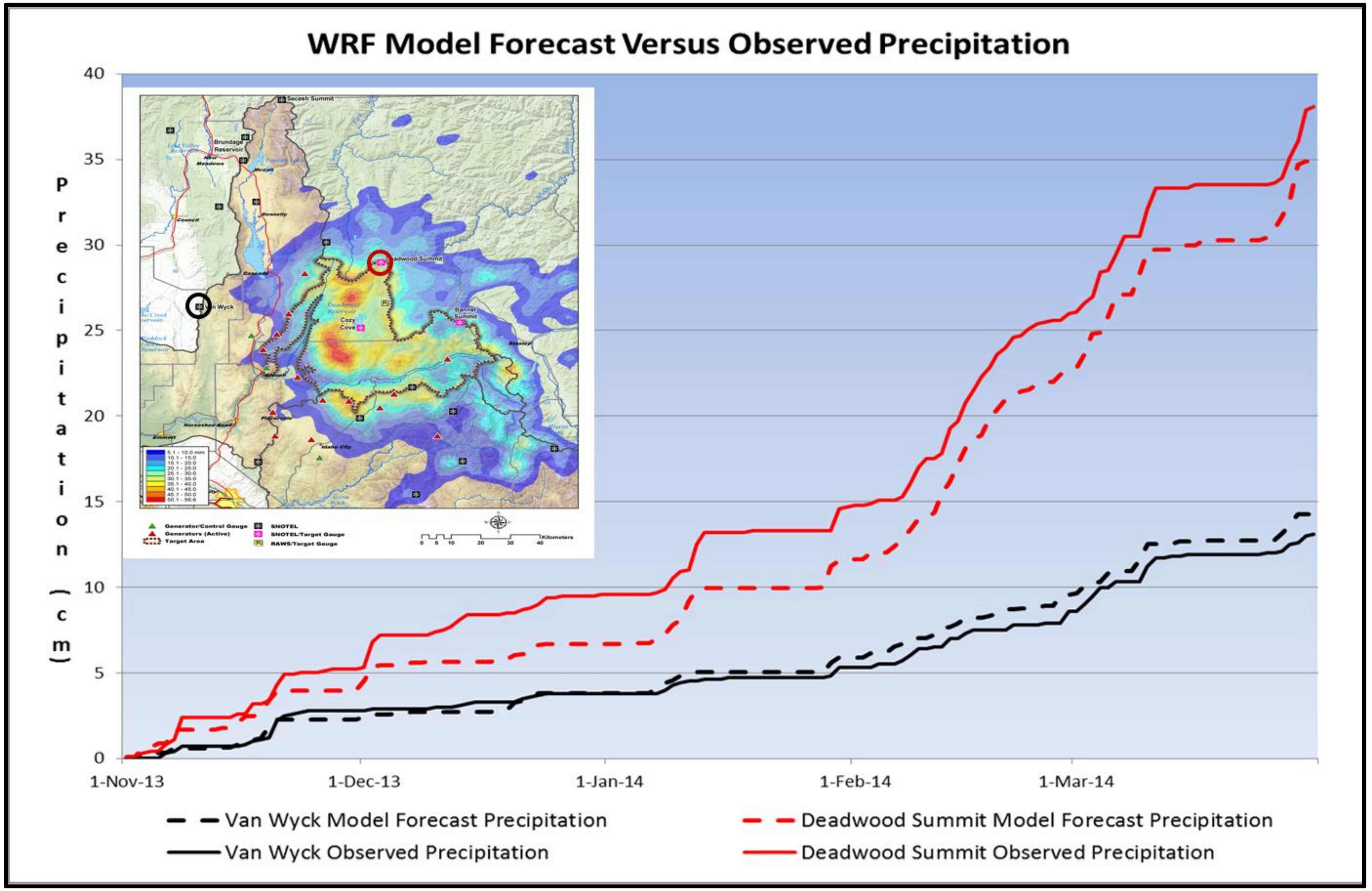
- Planning & Development of new projects
- Forecasting & Guiding Operations
- Analysis

Weather Research & Forecasting (WRF) Model

- Designed for atmospheric research and operational forecasting
- National WRF model struggles to resolve mountainous terrain, need for development of region-specific model
  - ~40km grid size □ 1.8km
- IPC & IWRB partnered with NCAR to develop model for Idaho
- Continued model development using data from SNOWIE
- The IWRB and IPC share costs for model development



MODELING



WRF Model Forecast Versus Observed Precipitation
Precipitation (cm)
0
5
10
15
20
25
30
35
40
1-Nov-13
1-Dec-13
1-Jan-14
1-Feb-14
1-Mar-14
Secesh Summit
Brundage Reservoir
New Meadows
Mccall
Donnelly
Council
Cascade
Deadwood Summit
Van Wyck
Cozy Cove
Banner Summit
Stanley
Placerville
Horseshoe Bend
Emmett
Idaho City
5.1 - 10.0 mm
10.1 - 15.0
15.1 - 20.0
20.1 - 25.0
25.1 - 30.0
30.1 - 35.0
35.1 - 40.0
40.1 - 45.0
45.1 - 50.0
50.1 - 56.6
Generator/Control Gauge
Generators (Active)
Target Area
SNOTEL
SNOTEL/Target Gauge
RAWS/Target Gauge
0 5 10 20 30 40 Kilometers
Van Wyck Model Forecast Precipitation
Van Wyck Observed Precipitation
Deadwood Summit Model Forecast Precipitation
Deadwood Summit Observed Precipitation

CLOUD SEEDING 101

Water Supply Benefits

Augmentation of winter snowpack results in the enhancement of runoff, increasing the availability of water for a variety of uses and providing a range of other resulting benefits

- Reservoir storage
- Extended seasonal flows due to increase of high elevation snowpack*
    - Fill of natural flow water rights
    - Reduced dependence on storage water
    - Increased reservoir carryover
- Flow Augmentation
- Recreation
- Water quality
- Aquatic habitat

*When using *remote* ground generators and aircraft

CLOUD SEEDING ANALYSIS

Objective: *Determine the impact of cloud seeding operations in the Payette, Boise, Wood, Upper Snake River Basins*

Phase 1 completed November 2020

- preliminary estimates
- several assumptions used

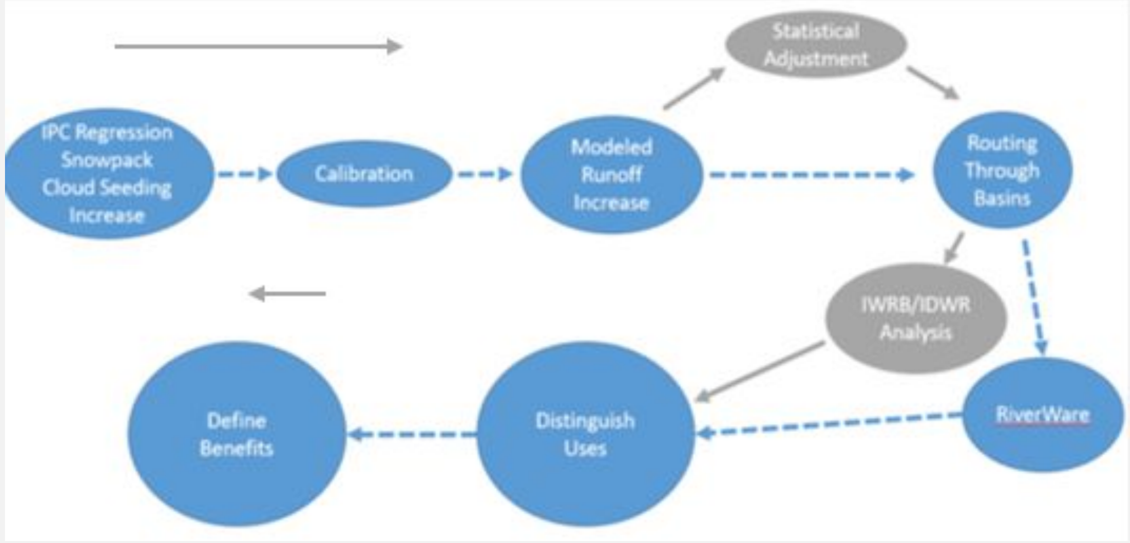
Phase 1 Preliminary Estimates

	In-Basin Use	Hydropower	Spill Out of State	IWRB Recharge	Captured by Reservoirs
Snake	32%	13%	33%	12%	10%
Boise	17%	45%	30%	-	7%
Wood	29%	20%	28%	1%	22%

Total Project Cost: $350K

Phase 2 estimated late 2023

- refine results using sophisticated modeling tools
- development of new tools



1. WRF-Hydro model (NCAR), *How much water was generated?*
2. RiverWare planning model (IDWR), *Where does the increase in supply go to?*
3. Route WRF-Hydro results through RiverWare model Determine impacts

RECENT LEGISLATION

Idaho House Bill 266 (*HB266, 2021*)

Directed the IWRB to:

1. Continue analysis of existing cloud seeding projects
2. Complete an assessment of opportunities for cloud seeding in other basins
3. Authorize cloud seeding programs in Idaho

Provides the IWRB authority to:

- Sponsor or develop local or statewide cloud seeding programs

  State funds may only be used in basins where the IWRB finds that existing water supplies are insufficient to support existing water rights, water quality, recreation, or fish and wildlife

CLOUD SEEDING PROGRAM DEVELOPMENT

Statewide Assessment

- July 2021– Contracted with the National Center for Atmospheric Research (NCAR) to look at opportunities for cloud seeding across the State of Idaho
- Provides initial look, more detailed feasibility required for basins of interest
- Looks for ground and airborne seeding opportunities (AgI)
- Opportunities for seeding with propane

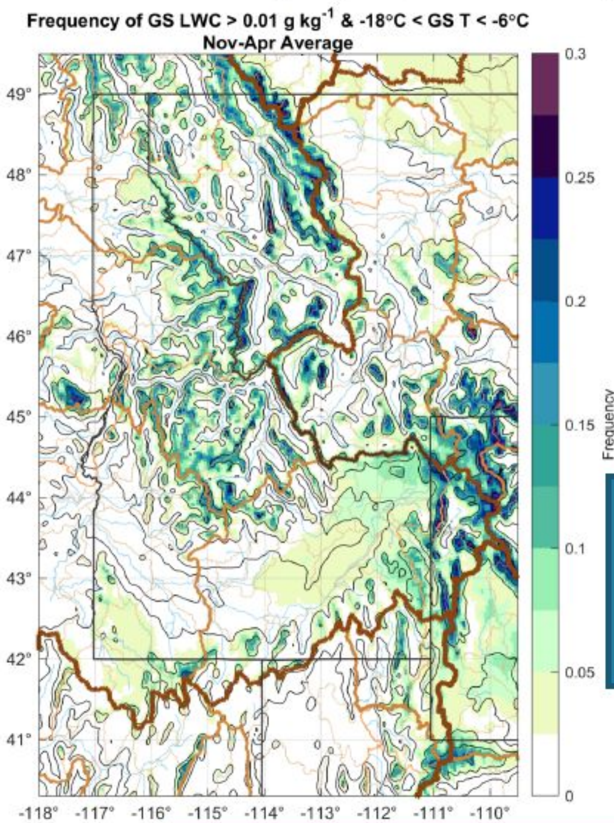
Total Project Cost: $30K

CLOUD SEEDING PROGRAM DEVELOPMENT

Statewide Assessment

Frequency of Cloud Seeding Opportunities

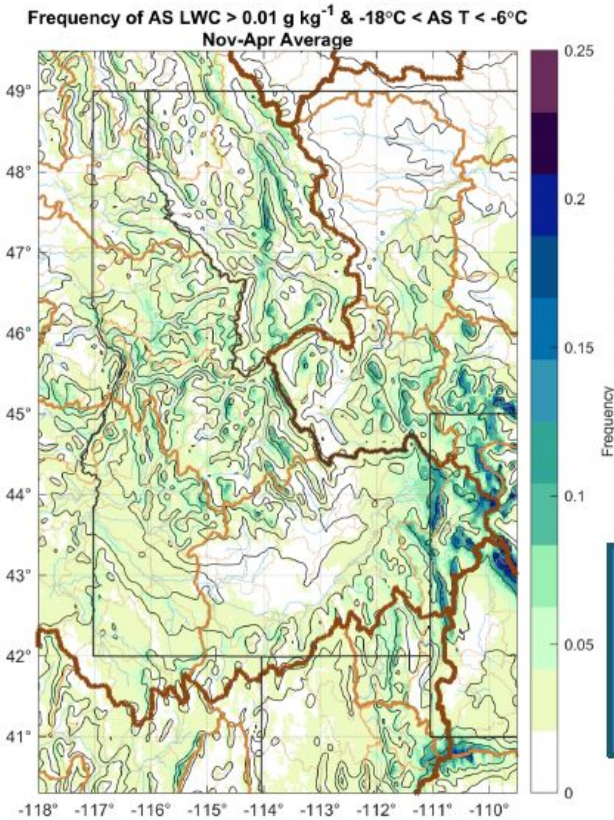
Ground seeding layer (0-1 km AGL)



This maps shows the frequency that temperature and SLW conditions are met, but not the additional dispersion criteria that are specific to each mountain barrier.

More detailed analysis by basin or mountain barrier is needed

Airborne seeding layer (3.5-4.5 km MSL)



This layer was determined based upon minimum safe flight altitudes over most of the state. Regions with lower altitude mountains may have more potential than shown here since SLW decreases with altitude.

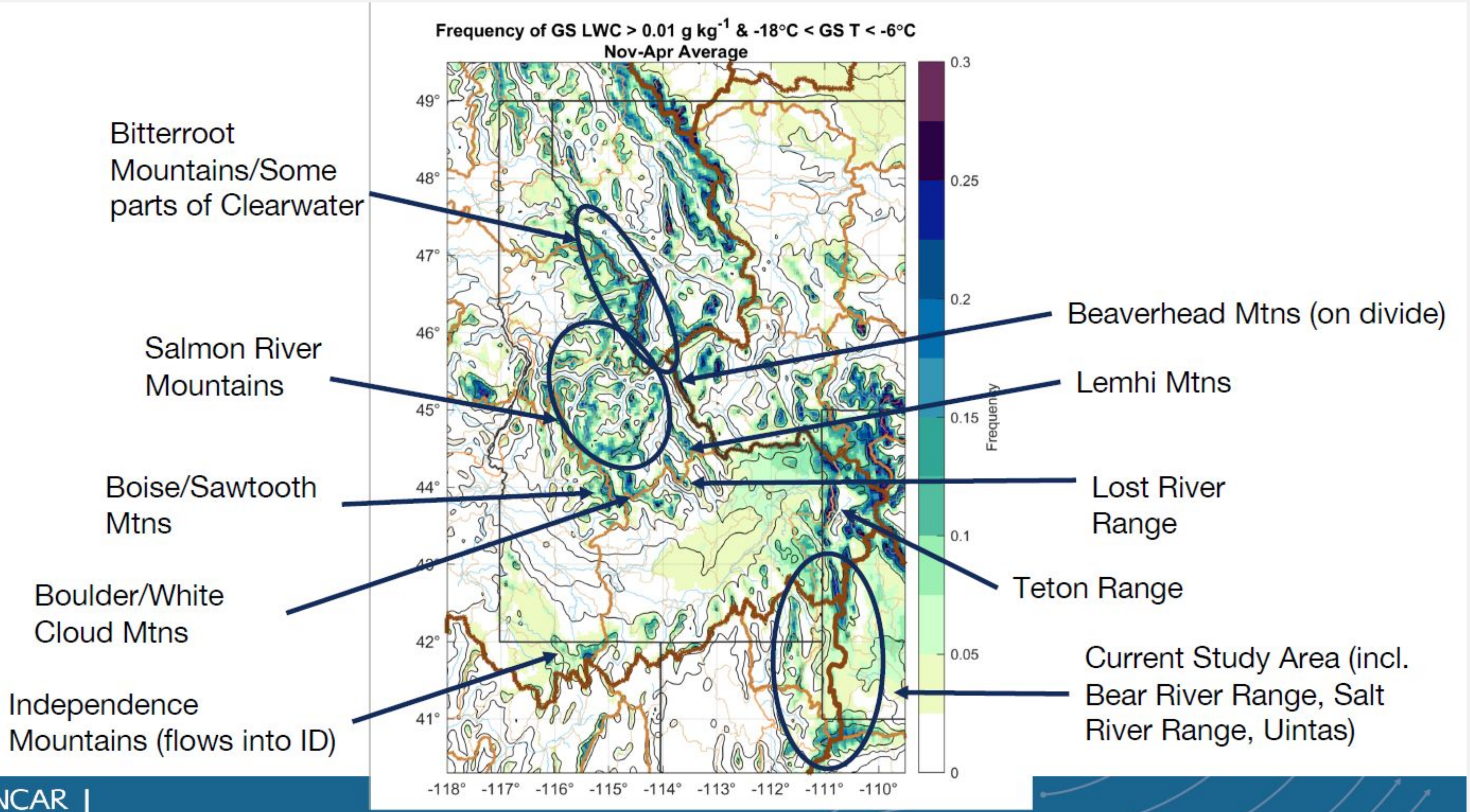
More detailed analysis by basin or mountain barrier is needed

NCAR | UCAR

We recommend focusing on basins with some ground-seeding potential to investigate both ground and airborne seeding potential with a more detailed analysis approach

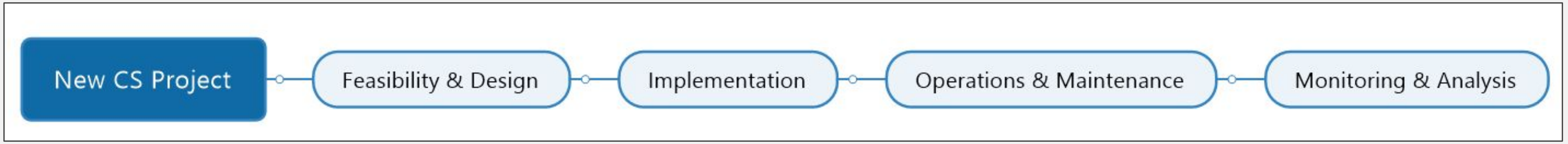
CLOUD SEEDING PROGRAM DEVELOPMENT

Statewide Assessment



CLOUD SEEDING PROGRAM DEVELOPMENT

- Prioritizing new projects
  - Develop criteria for IWRB (State) participation
  - Funding requirements
- Significant stakeholder interest in new projects

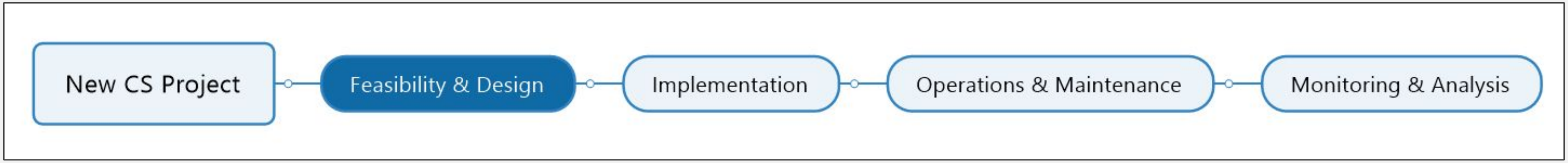


CLOUD SEEDING PROGRAM DEVELOPMENT

Feasibility & Design Studies

- Bear River Basin, Completed Dec 2022 | $390K
  - Includes investigation of opportunities for shared infrastructure with the Upper Snake River Basin

- Lemhi River Basin, est Sep 2023 | $340K



CLOUD SEEDING PROGRAM DEVELOPMENT

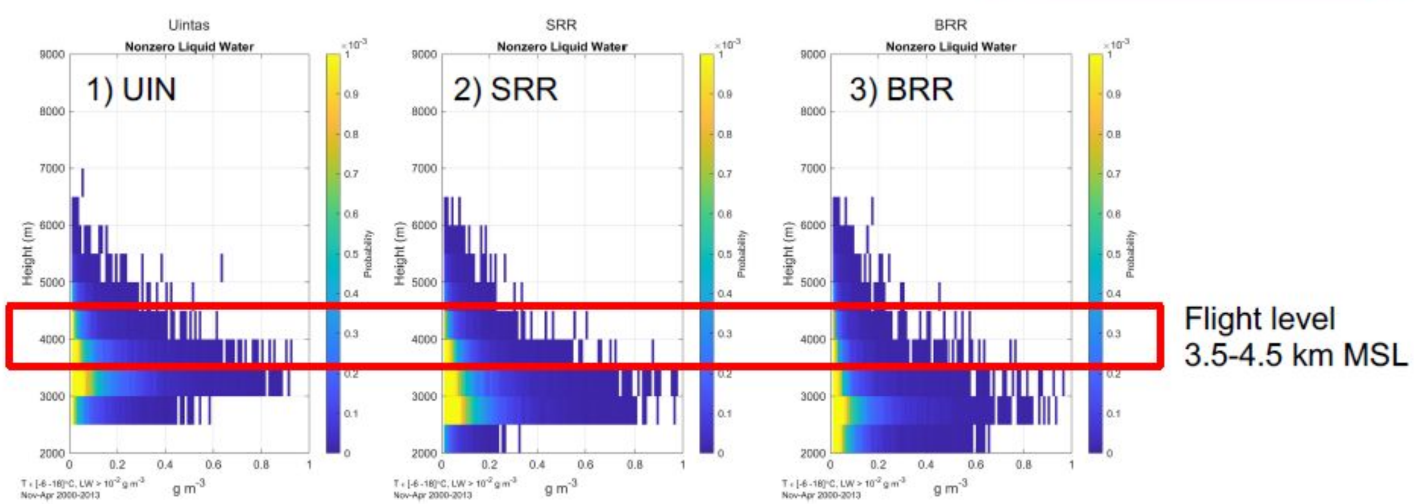
Feasibility & Design Studies

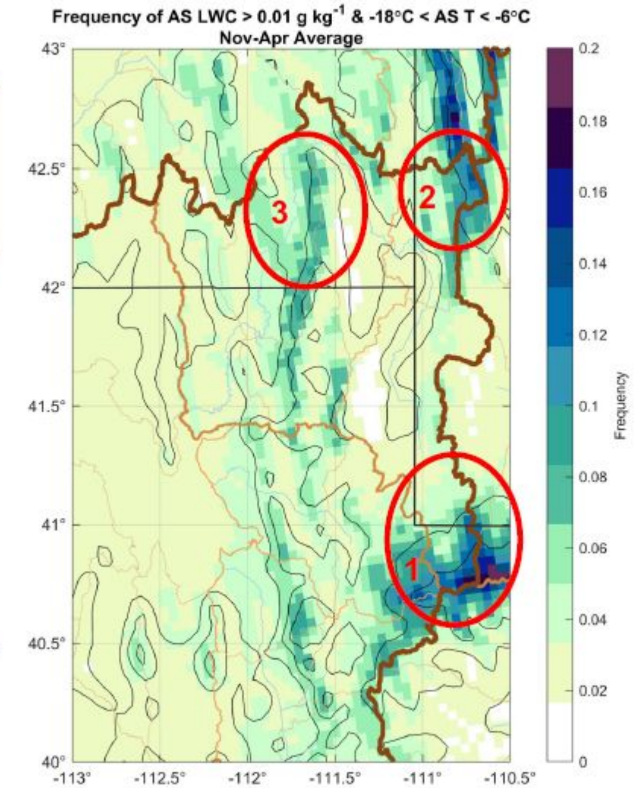
Cloud-seeding Feasibility and Design Study: Bear River Basin of Idaho

Three regions feed the Bear River Basin:

1. Uintas (UIN)--Bear River headwaters
2. Salt River Range (SRR)
3. Bear River Range (BRR)

Airborne seeding opportunities between Nov-Apr, peak in late winter





Research sponsored by the Idaho Water Resource Board

NCAR | UCAR

CLOUD SEEDING PROGRAM DEVELOPMENT

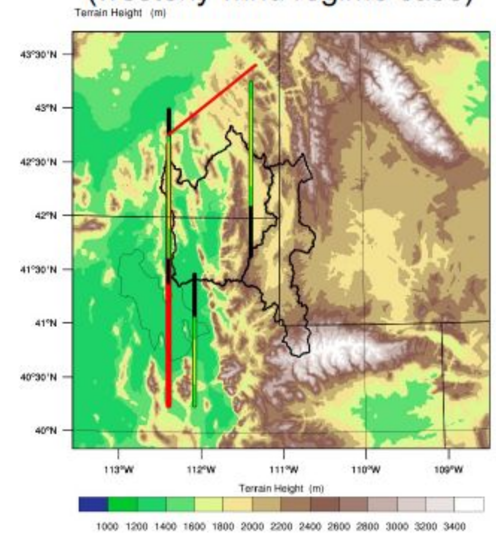
Feasibility & Design Studies

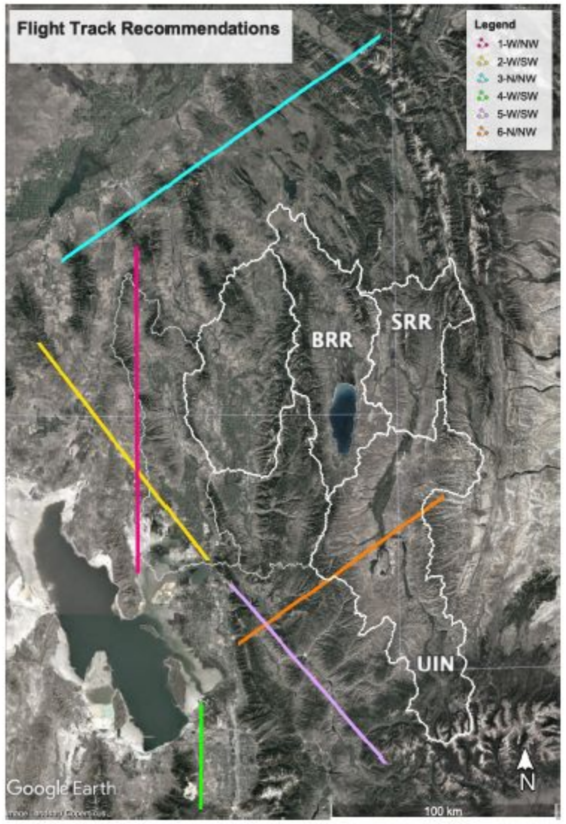
Bear River Basin Airborne Design

- WRF-WxMod simulations of cases representing different wind regimes provided guidance for which tracks are most feasible

- A single, long north-south track to target all three regions under westerly winds was shown to not be as efficient as using a shorter track to target the northern half of the domain
- A track upwind of BRR could effectively target both BRR and SRR, so no need for an SRR specific track

Example of flight tracks tested
(westerly wind regime case)

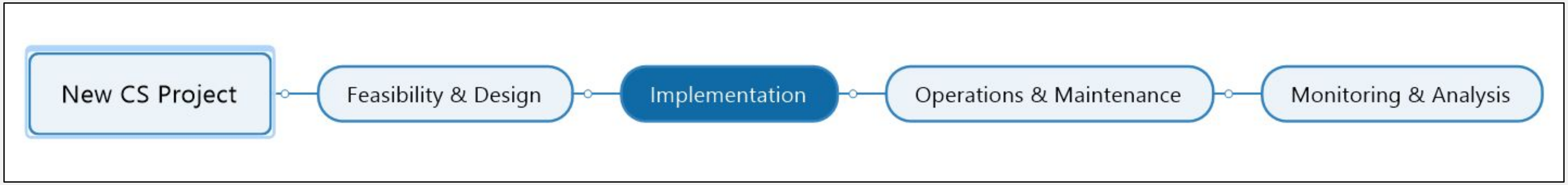




CLOUD SEEDING PROGRAM DEVELOPMENT

Implementation

1. Development of criteria for competitive bid
   – Based on results of feasibility and design study
2. Request for Proposal (RFP) for an operator
3. Contract Development
4. Build out of Infrastructure



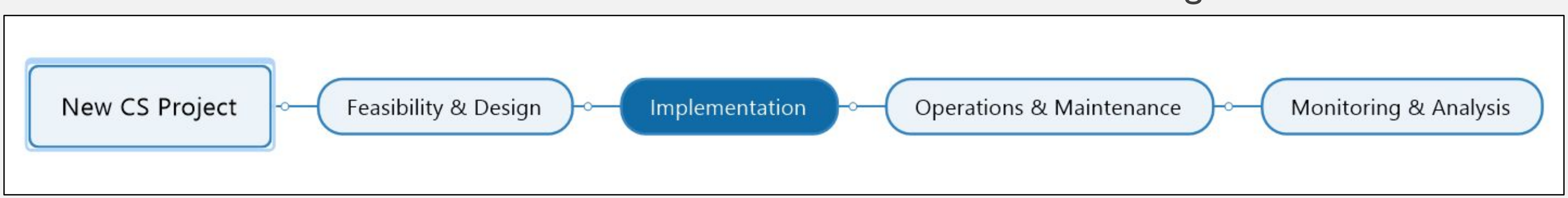
CLOUD SEEDING PROGRAM DEVELOPMENT

Implementation

1. Development of criteria for competitive bid
   - Based on results of feasibility and design study
2. Request for Proposal (RFP) for an operator
3. Contract Development
4. Build out of Infrastructure
   - Airborne
   - Ground

Considerations

- Availability of resources
  - Generators
  - Aircraft
  - Weather instrumentation
- Siting Equipment
  - Availability of suitable location
  - Accessibility– land leases
  - Installation & regular maintenance



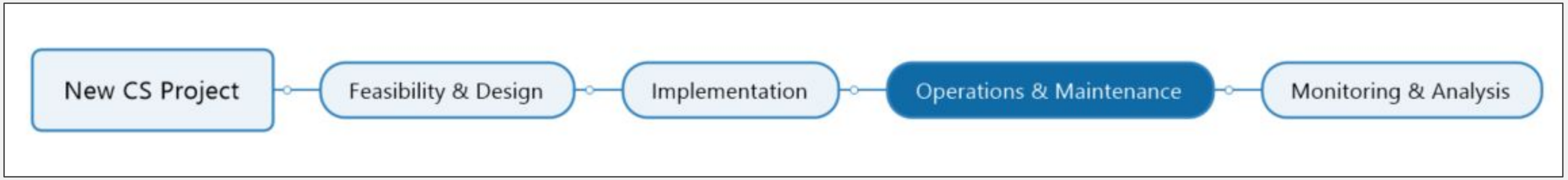
CLOUD SEEDING PROGRAM DEVELOPMENT

Operations & Maintenance

- Multi-year contracts
- Modeling
  - Forecasting
  - Analysis
  - Reporting
- Equipment Maintenance

Considerations

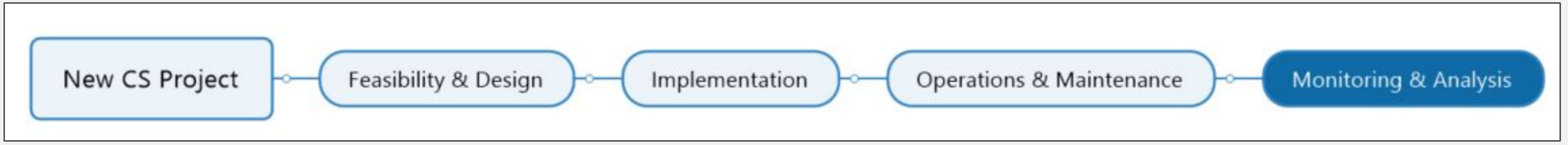
- WRF modeling
  - Licensing
  - Expansion of Domain
- Weather Instrumentation
- Coordination of multiple operations



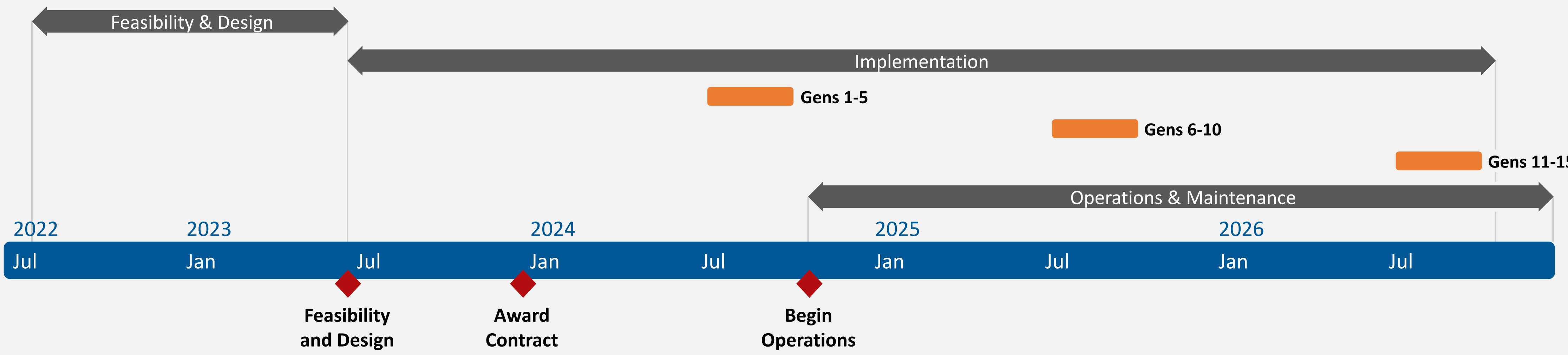
CLOUD SEEDING PROGRAM DEVELOPMENT

Monitoring & Analysis

- Ongoing for duration of operation
- Benefit Analysis
- Assessment of program design
- Ongoing communication/education



TIMELINE FOR DEVELOPMENT



Average timeline for illustrative purposes only. Actual timeline for development will vary by project.

CLOUD SEEDING KEY TAKE-AWAYS

- Cloud seeding should be approached as a long-term investment
- Cloud seeding should be used as a water management tool used to support other water management strategies
  - A well managed and scientifically based program can help mitigate water supply concerns
  - Cloud seeding cannot cure or reverse drought
- Cloud Seeding does not work in all areas
  - The specific climatology and geography of a basin determine whether it is "seedable"
- The scale of a program is dependent upon the "seedability" of the target basin and the program budget

CLOUD SEEDING WRAP UP

Considerations for the Development of Programs

- Educating stakeholders

- Development of realistic expectations:
  - Objectives: What problem are you trying to solve? What is the value of seeding?
  - Budget: Capital, operations, monitoring, analysis, etc; who will fund?
  - Timeline: Contracting, coordination of stakeholders, permitting & accessibility

- Long term program commitments

- Analysis and ongoing monitoring

- Legislation: what, if any, statutory hurdles are in place?
  (i.e. water user assessments, contracting, regulatory)

For more information on Idaho's Cloud Seeding Programs, please contact:
Kala Golden, IWRB Cloud Seeding Program Manager | Kala.Golden@idwr.idaho.gov (208) 287-4852

Environmental Considerations of AgI

- **Weather Modification Association (WMA) statement on AgI:**
  "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."

- **Australia's Natural Resource Commission's review of 5 year analysis on their seeded watersheds:**
  " Our review of Snowy Hydro's analysis of data from its environmental monitoring over the first phase of the trial (2004 to 2009) found that it provides no evidence that the trial has had adverse environmental impacts over this period. The analysis provides no evidence of accumulation of silver iodide or indium trioxide in sampled soils, sediment, potable water or moss in the areas being tested. It also provides no evidence of impacts on mountain riverine ecosystems or snow habitats. In addition, it detected no difference between the concentrations of ammonia and nitrogen oxides in seeded and unseeded snow."

- **Idaho DEQ Review**
  - Reviewed cloud seeding with respect to water and air quality
  - Water Quality: DEQ determined it is unlikely that cloud seeding will cause a detectable increase in silver concentrations in the target watershed or pose a chronic effect to sensitive aquatic organisms
  - Air quality permit not needed based on screening thresholds

Environmental Considerations of AgI

More than 20 comprehensive studies and data reviews of the environmental effect of the use of silver iodide for cloud seeding all concur that there is ***no evidence for adverse effects to human health or the environment*** from the use of silver iodide for cloud seeding.

– PG&E EA – 1995, 2006

– Snowy Hydro – 2004-2014, ongoing

– Williams and Denholm – 2009

– USBR Project SkyWater – 1977, 2009, 2013

– Cardno/Entrix Geochemistry and Impacts of Silver Iodide Use in Cloud Seeding (for PG&E) – 2011

– Santa Barbara County CEQA – 2013

– BSU and Heritage Environmental: Literature Review – 2015

– Sacramento Municipal Utility District – 2017

– State of Wyoming Level III Feasibility Study Laramie Range Siting and Design Final Report – 2017

– Placer County Water Agency CEQA – 2018