AGENDA

IDAHO WATER RESOURCE BOARD

Cloud Seeding Committee Meeting No. 2-22
Thursday, February 24, 2022
1:00 p.m. (MT)

Water Center
Conference Rooms 602 C&D / Online Zoom Meeting
322 E. Front St.
BOISE

Board Members & the Public may participate via Zoom
Click here to join our Zoom Meeting
Dial in Option: 1(253) 215-8782
Meeting ID: 897 2673 8981 Passcode: 101626

1. Introductions and Attendance
2. Cloud Seeding Program Development
   a. Statewide Assessment Initial Results
   b. Requirements for Developing a Cloud Seeding Program
3. Cloud Seeding Program Update
4. Other Items
5. Adjourn

Committee Members: Chair Roger Chase, Jeff Raybould, Pete Van Der Meulen, and Al Barker.

* Action Item: A vote regarding this item may be made this meeting. Identifying an item as an action item on the agenda does not require a vote to be taken on the item.

Americans with Disabilities
The meeting will be held telephonically. If you require special accommodations to attend, participate in, or understand the meeting, please make advance arrangements by contacting Department staff by email jennifer.strange@idwr.idaho.gov or by phone at (208) 287-4800.

Idaho Cloud Seeding Program

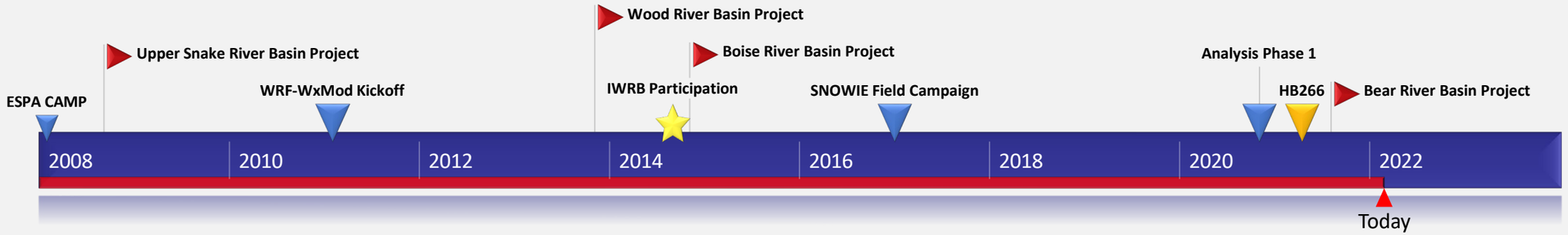
Idaho Water Resource Board | Cloud Seeding Committee Meeting

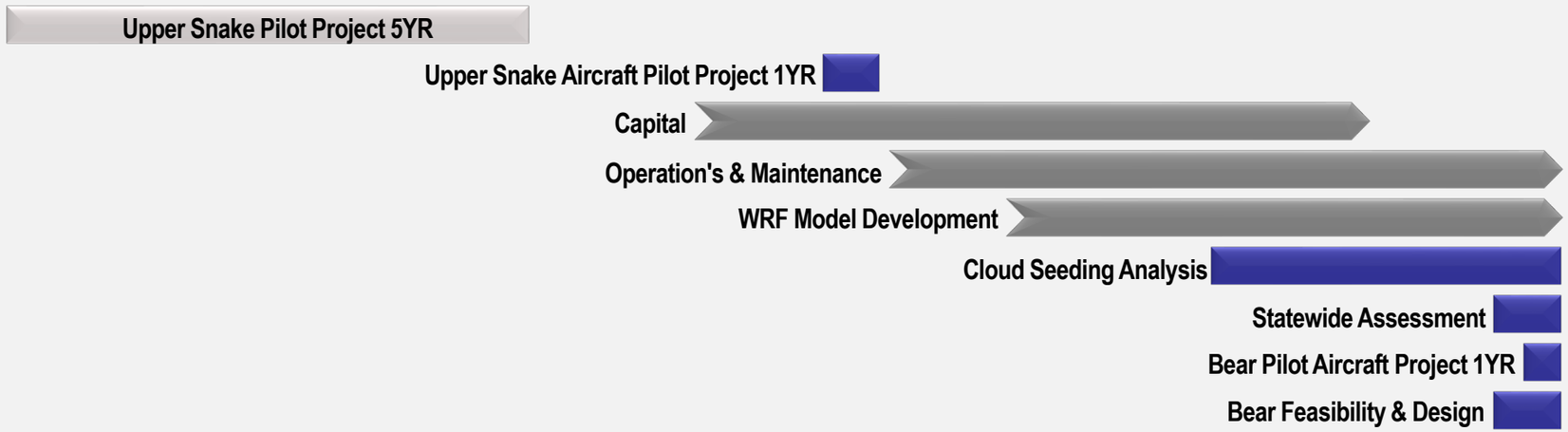
February 24, 2022

OVERVIEW

- Program Summary
- Cloud Seeding Program Development
  - Statewide Assessment
  - Feasibility and Design
  - Implementation
  - Operations & Maintenance
  - Monitoring
- Cloud Seeding Program Update

PROGRAM SUMMARY



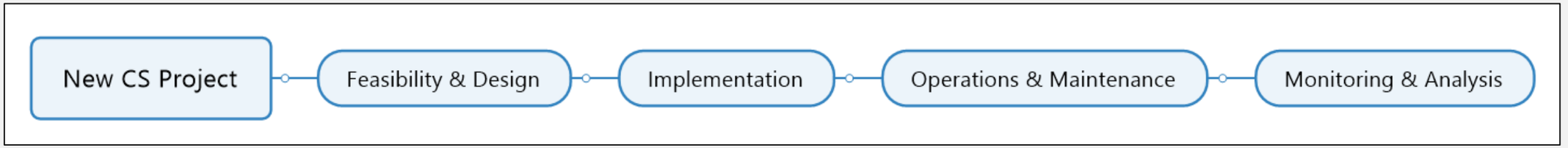


PROGRAM SUMMARY

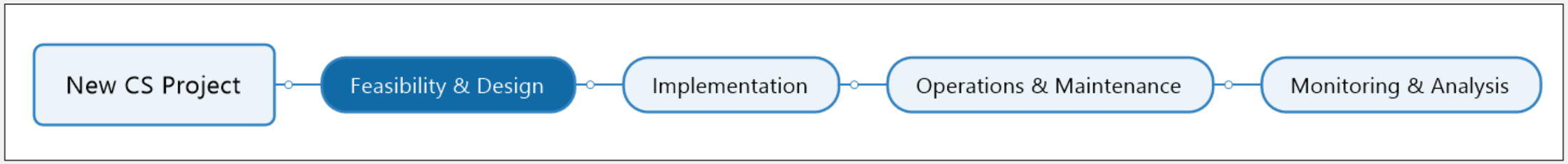
- Idaho House Bill 266 (*HB266, 2021*)
  - Directed the IWRB to:
    1. Continue analysis of existing cloud seeding projects
    2. Complete an assessment of opportunities for cloud seeding in other basins
    3. Authorize cloud seeding programs in Idaho
  - Provides the IWRB authority to:
    - Sponsor 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
  - Initial look, more detailed feasibility required for basins of interest
  - Ground and airborne seeding opportunities (AgI)
  - Opportunities for propane seeding



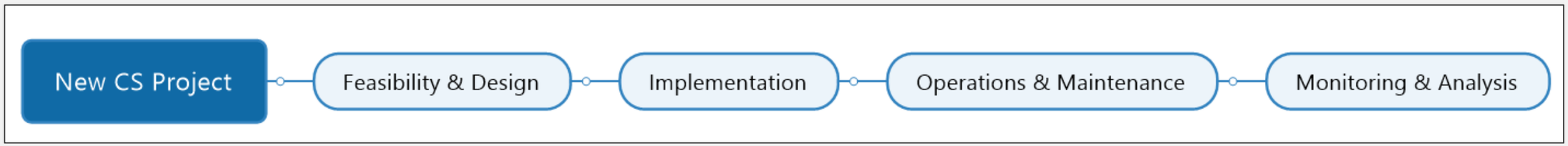
CLOUD SEEDING PROGRAM DEVELOPMENT



* NCAR Presentation

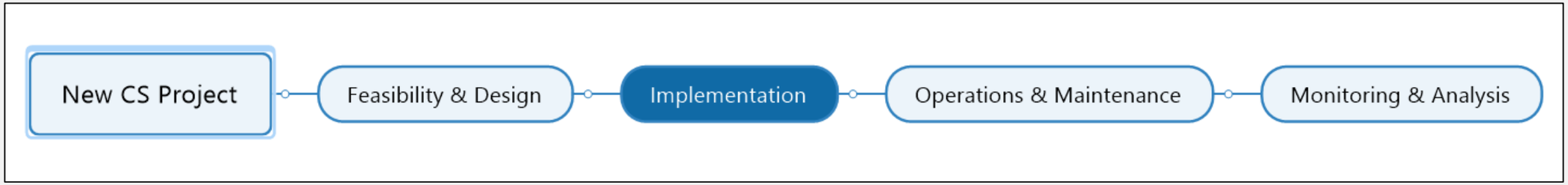
CLOUD SEEDING PROGRAM DEVELOPMENT

- Prioritizing new projects
  - Develop criteria for Board participation
  - Funding requirements
- Significant stakeholder interest in new projects



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

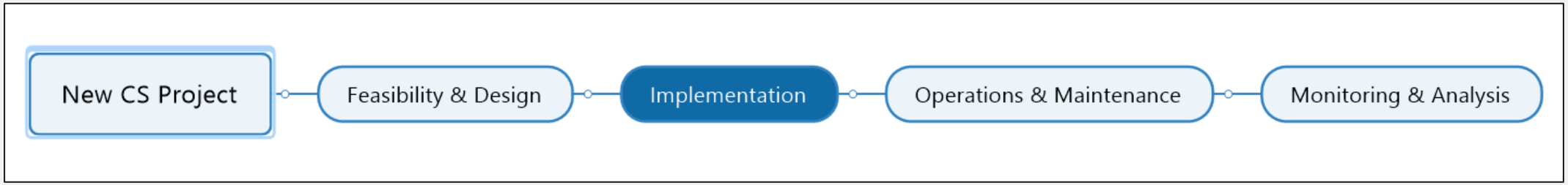


CLOUD SEEDING PROGRAM DEVELOPMENT

- 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

- Seeding equipment
  - Generators
  - Aircraft
  - Weather instrumentation
- Availability of resources
- Siting Equipment
  - Availability of suitable location
  - Accessibility
  - Development of land lease
  - Installation

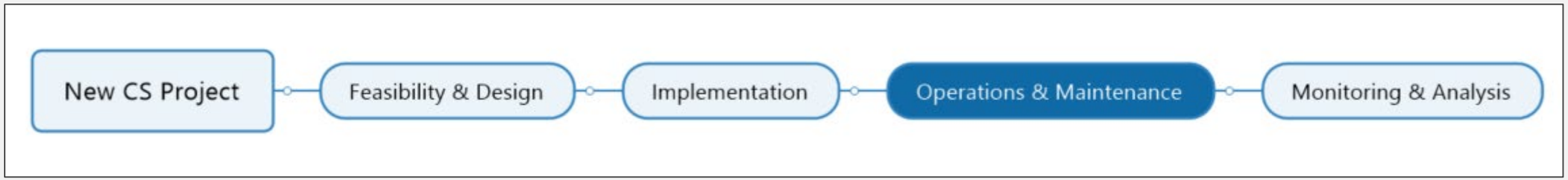


CLOUD SEEDING PROGRAM DEVELOPMENT

- Operations & Maintenance
  - Typically 3-5 year contract
  - Modeling
    - Forecasting
    - Analysis
    - Reporting
  - Equipment Maintenance

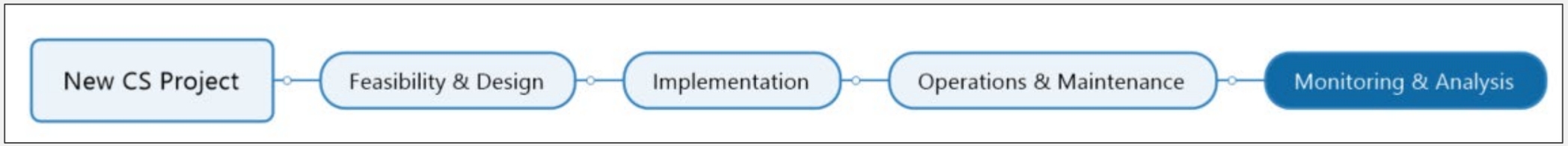
Considerations

- Existing WRF-WxMod
  - Licensing
  - Operator
  - Expansion of Domain
- Weather Instrumentation
- Coordination of multiple operations

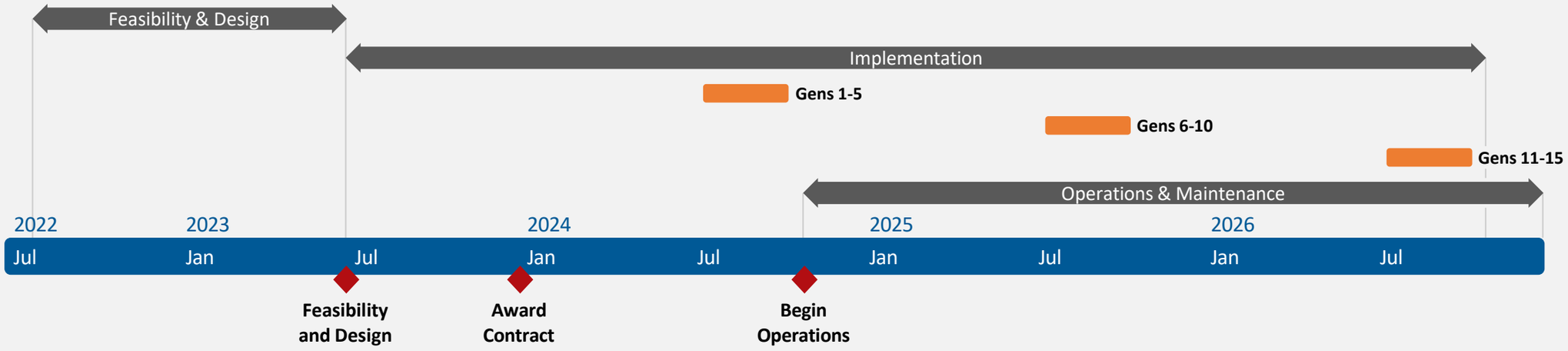


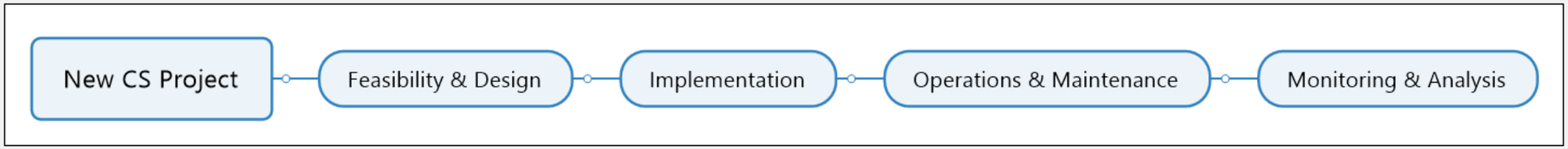
CLOUD SEEDING PROGRAM DEVELOPMENT

- Monitoring & Analysis
  - Ongoing for duration of operation
  - Benefit Analysis
  - Assessment of program design

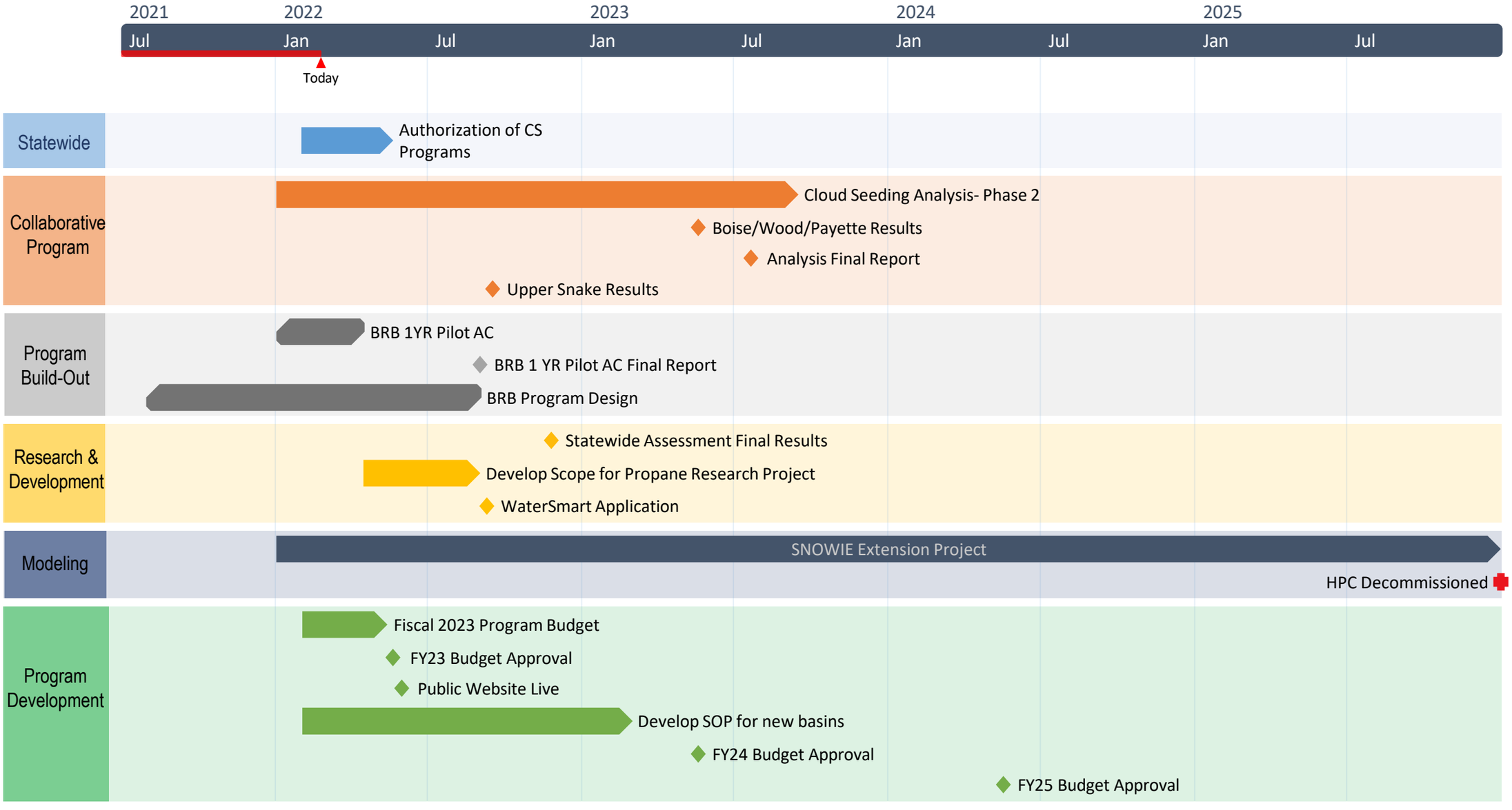


TIMELINE FOR DEVELOPMENT





CLOUD SEEDING PROGRAM UPDATE

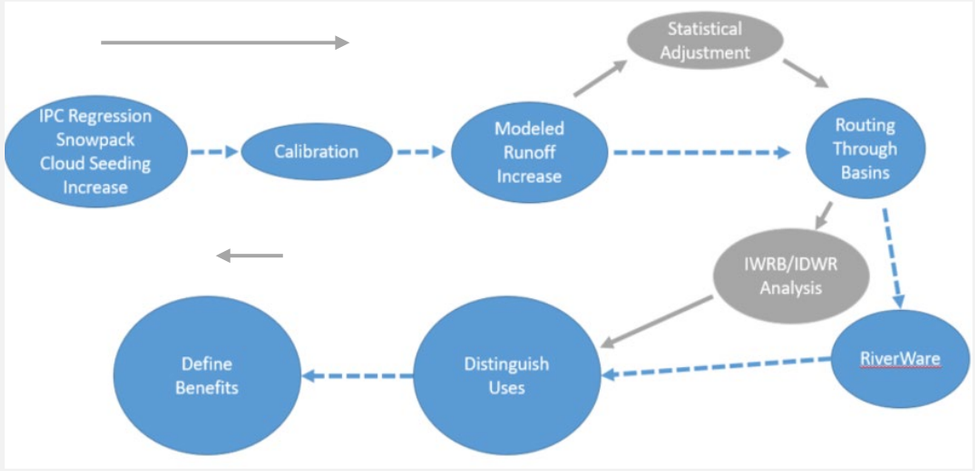


CLOUD SEEDING ANALYSIS

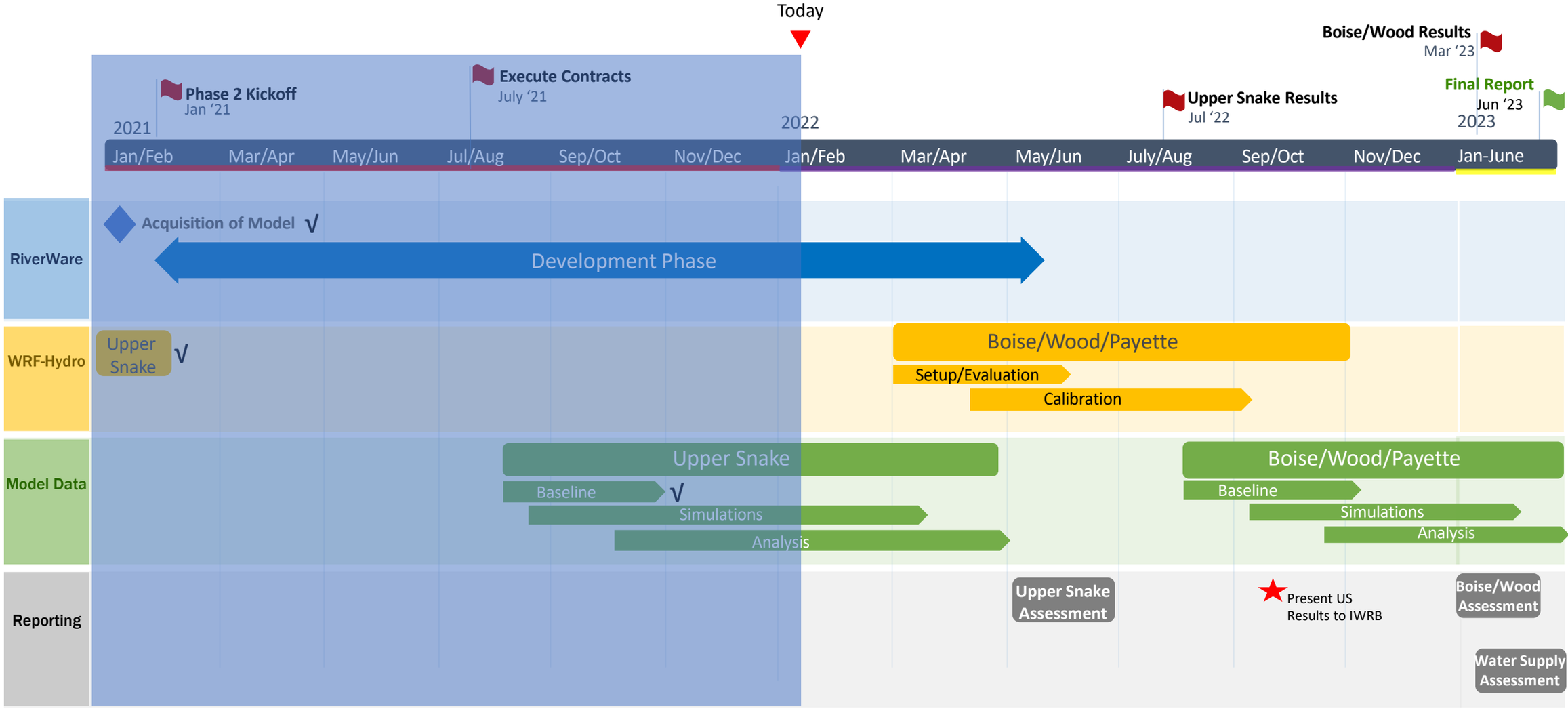
- Cloud Seeding Analysis
  - Objective: Determine the impact of cloud seeding operations in the Payette, Boise, Wood, Upper Snake River Basins
  - Phase 1 completed 2020; preliminary estimates, several assumptions used
  - Phase 2 began early 2021, refine results using sophisticated modeling tools
    1. WRF-Hydro model calibration & impacts analysis (NCAR)
       - Physically based hydrologic model used to simulate runoff from snow
       - Calibrate model for each region → run historical data with & without CS → determine estimated qty of water generated
       - Upper Snake first, then West Central Mountains
    2. RiverWare model refinement (IDWR/IPC)
       - System operations model
       - Modified version of the BOR Snake River RiverWare model
    3. Route WRF-Hydro data through RiverWare → Determine impacts

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%



Cloud Seeding Analysis Project Schedule



√ Complete

Secondary Fund Program Costs

- Paid through IWRB's Secondary Aquifer fund
  - $5M annually from General Fund
  - $5M annually from Cigarette Tax (will decline in future)

• Average IWRB Recharge Program costs (2017-2021)	**$6.20M**
• Average IWRB Cloud Seeding program costs (2017-2021)	**$1.62M**
• Average Hydrology cost (2017-2021) (modeling, monitoring, technical studies)	**$0.52M**
TOTAL	**$8.34M**

Remaining from the $10M - $1.66M

Investigating the potential for cloud seeding in Idaho

Statewide Assessment Results and Recommendations

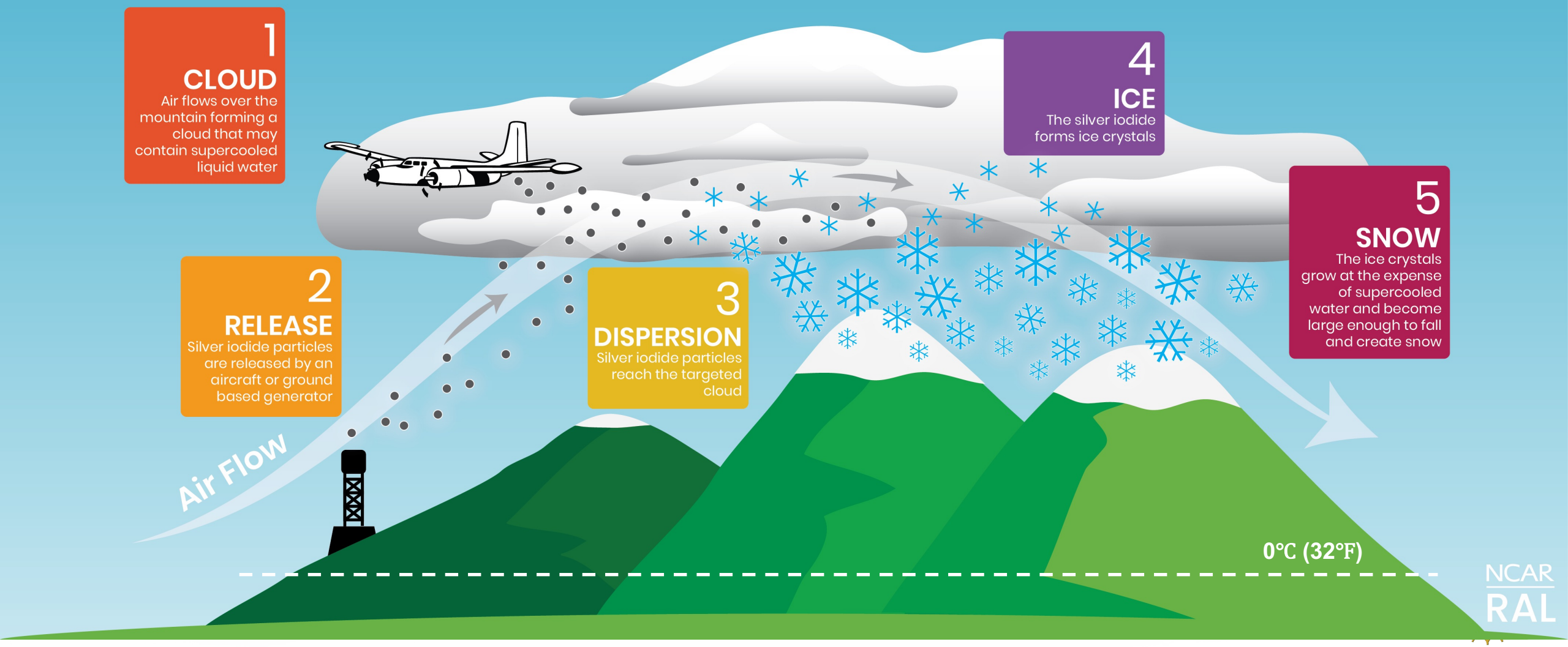
Sarah Tessendorf
Research Applications Laboratory
National Center for Atmospheric Research, Boulder, CO

NCAR

February 24, 2022

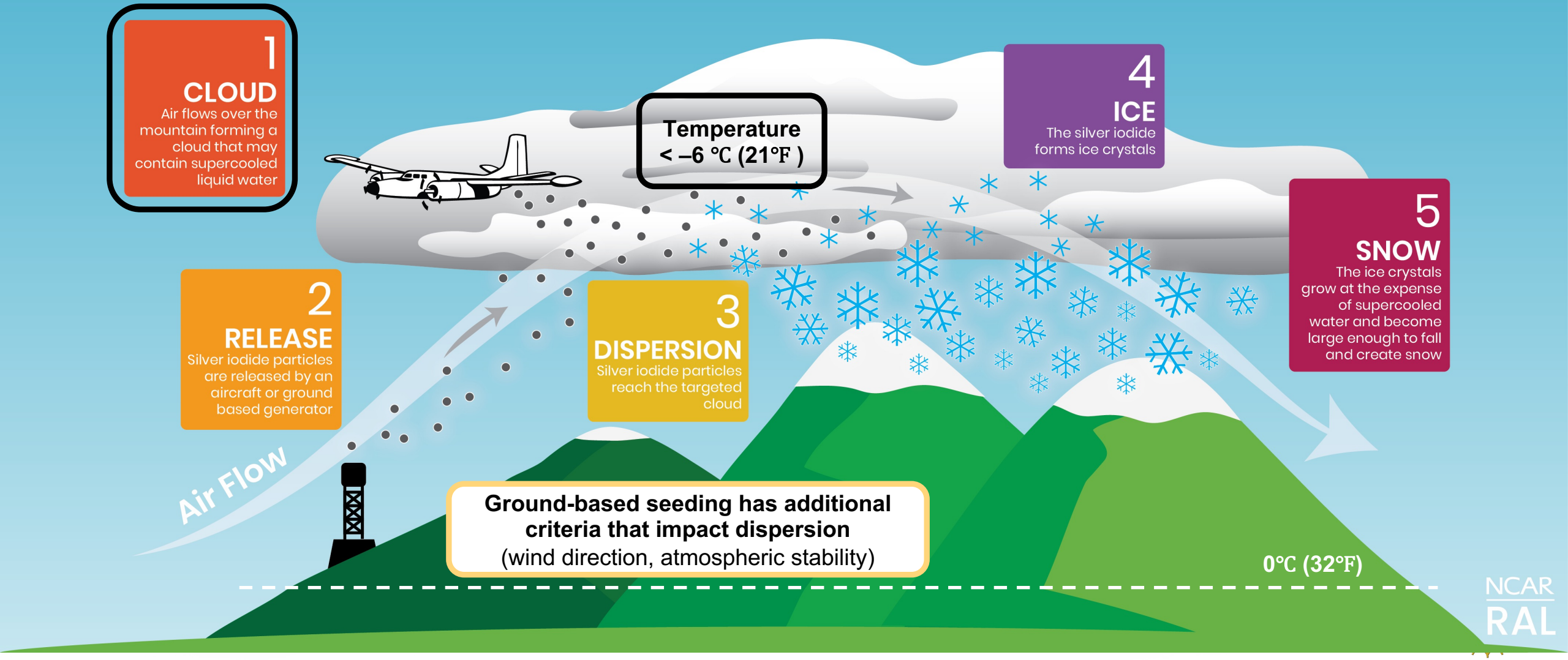
This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.

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.

Two key criteria : 1) Supercooled liquid water (SLW) 2) Temperature for silver iodide to nucleate ice



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Transforming the way we design and evaluate cloud-seeding programs

WRF-WxMod® cloud-seeding modeling

Supercomputing has enabled high-resolution modeling and more sophisticated modeling

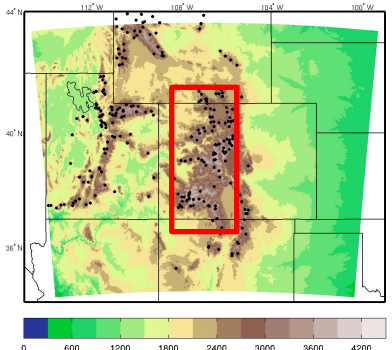
+

Observations of clouds, precipitation, and atmospheric conditions

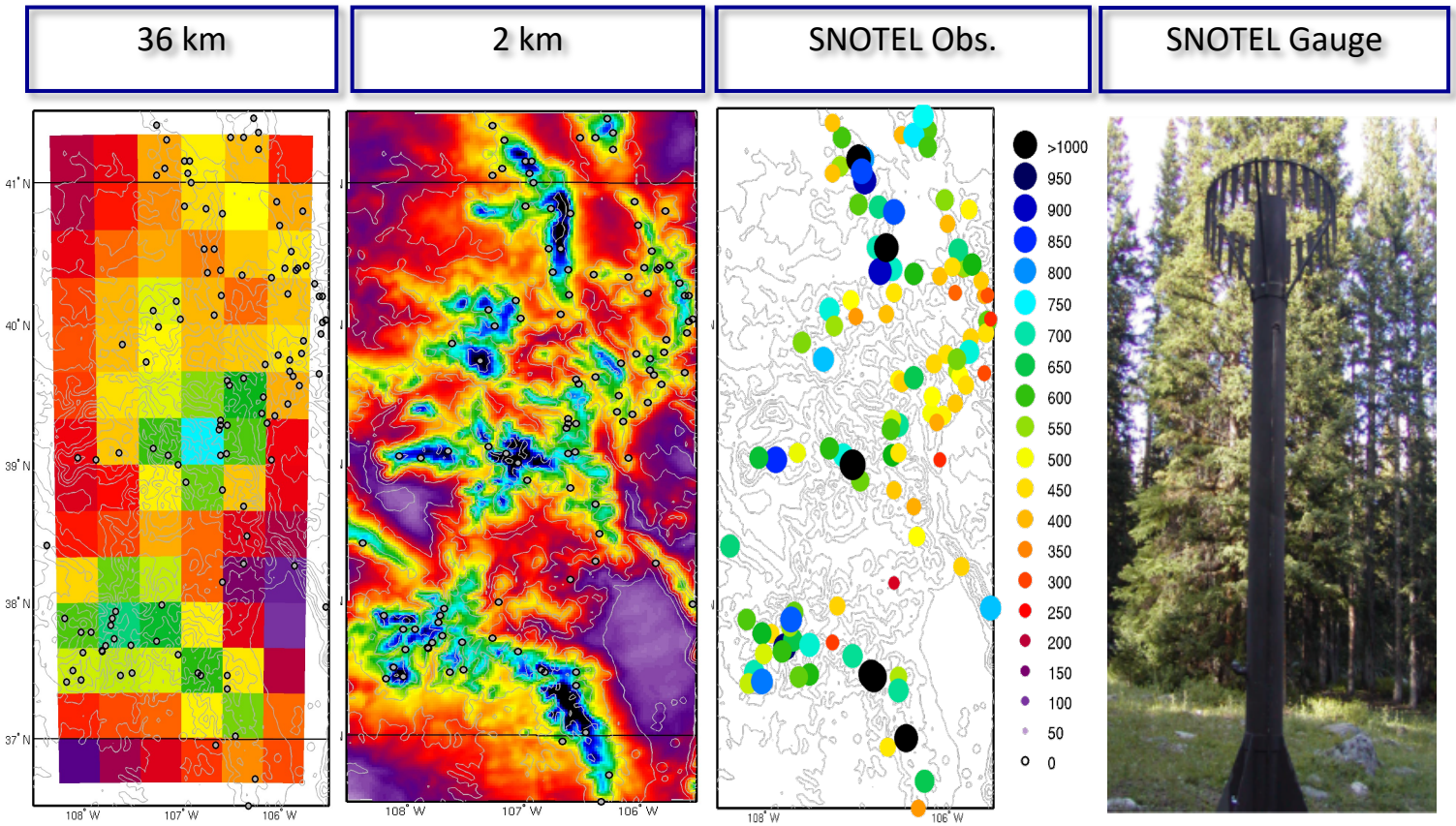
A breakthrough in modeling for cloud seeding

- **High-resolution models can simulate precipitation in mountains quite well**

- Multi-year simulations (Colorado Headwaters and CONUS) provided valuable information for studying winter orographic precipitation and cloud seeding potential
  - Ritzman et al. (2015), Tessendorf et al. (2020)



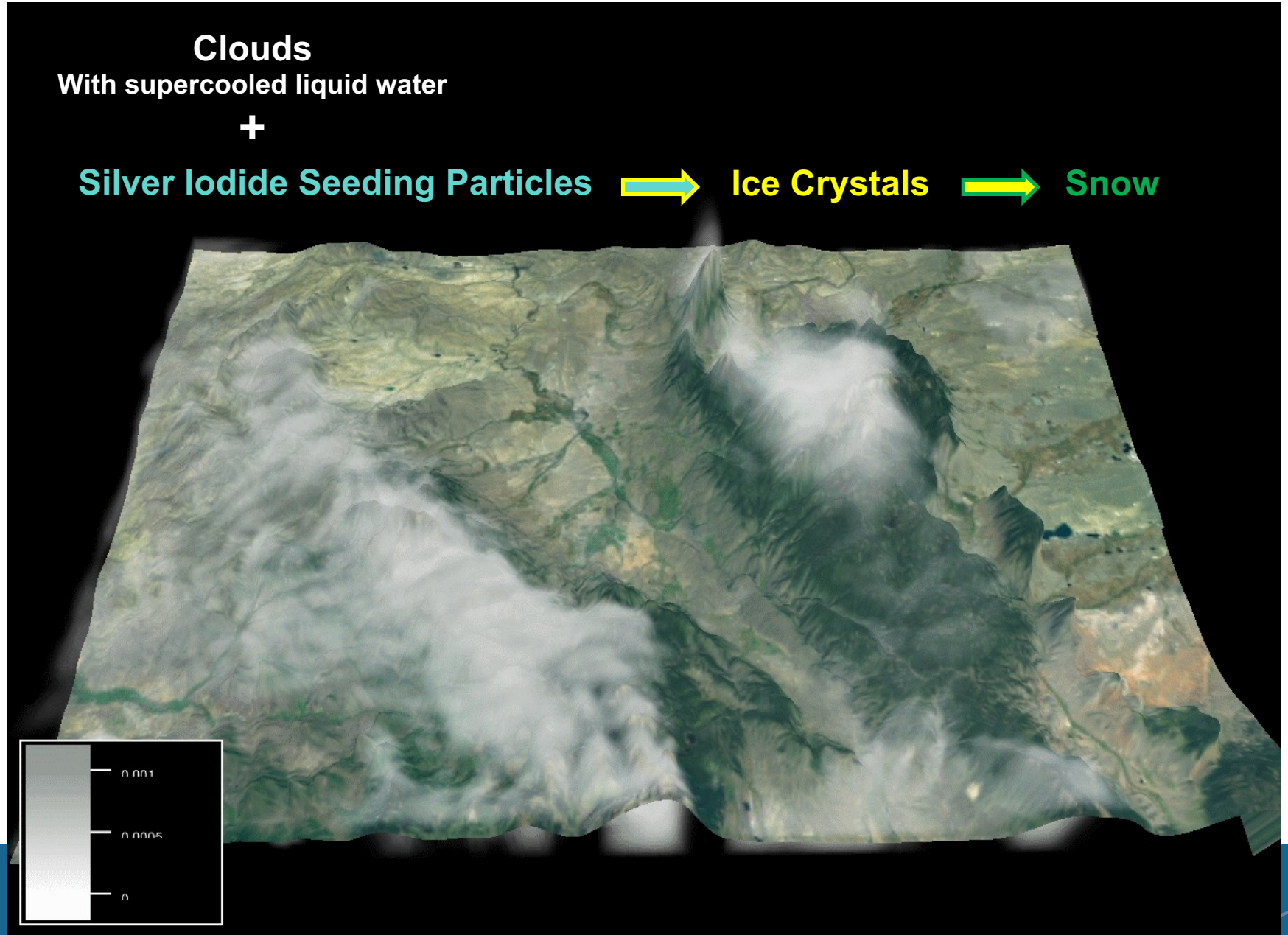
Precipitation accumulation over one water year



Colorado Headwaters Region

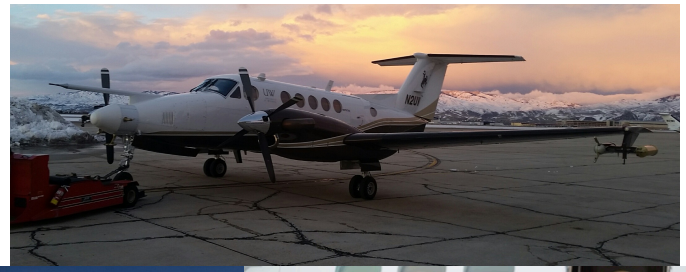
Rasmussen et al. (2011)

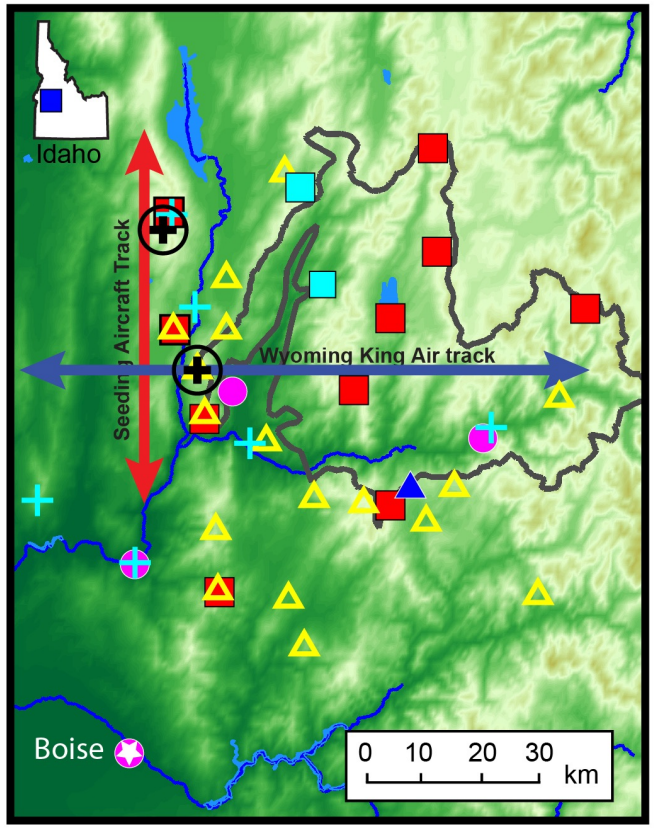
WRF-WxMod: Simulating the impact of cloud seeding

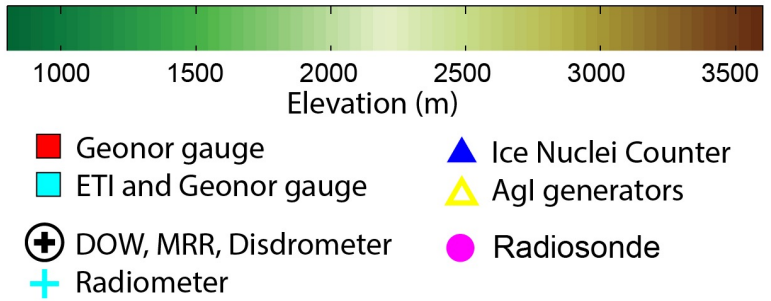


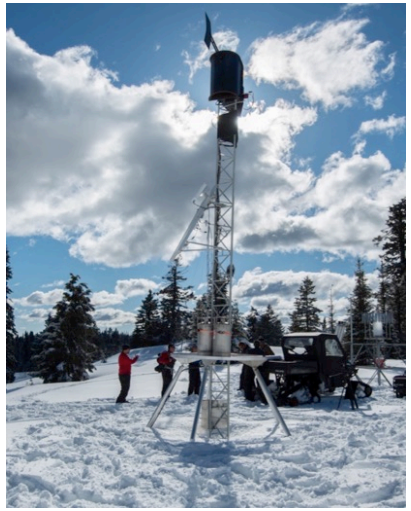
Observations of Cloud Seeding from SNOWIE

Seeded and **N**atural **O**rographic **W**intertime clouds: the **I**daho **E**xperiment







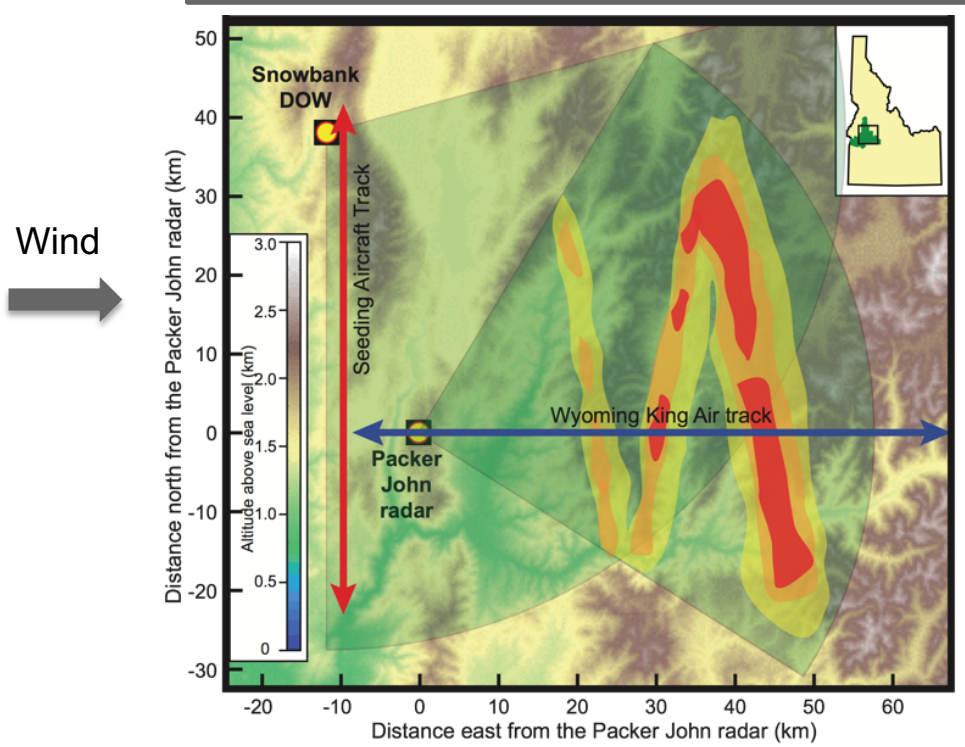


Tessendorf et al. (2019)

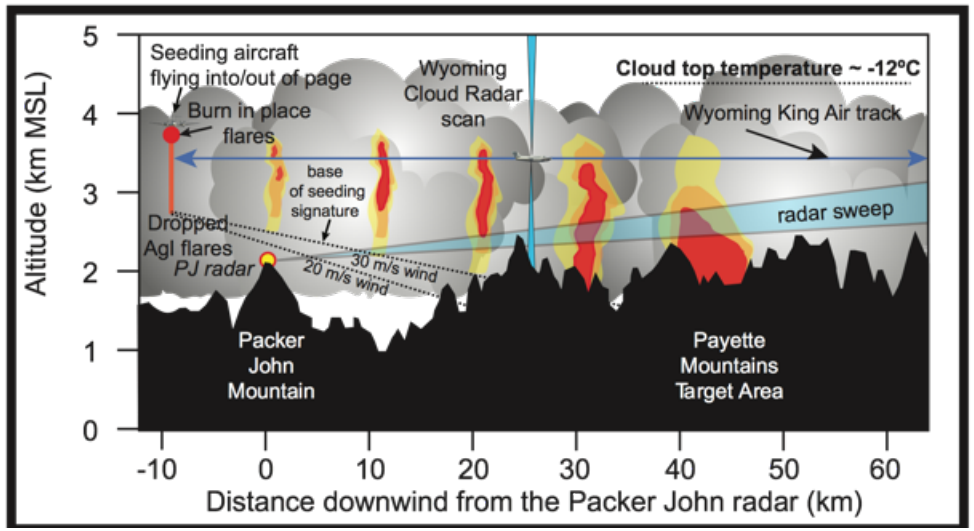
SNOWIE Experimental Design and Strategy

- 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

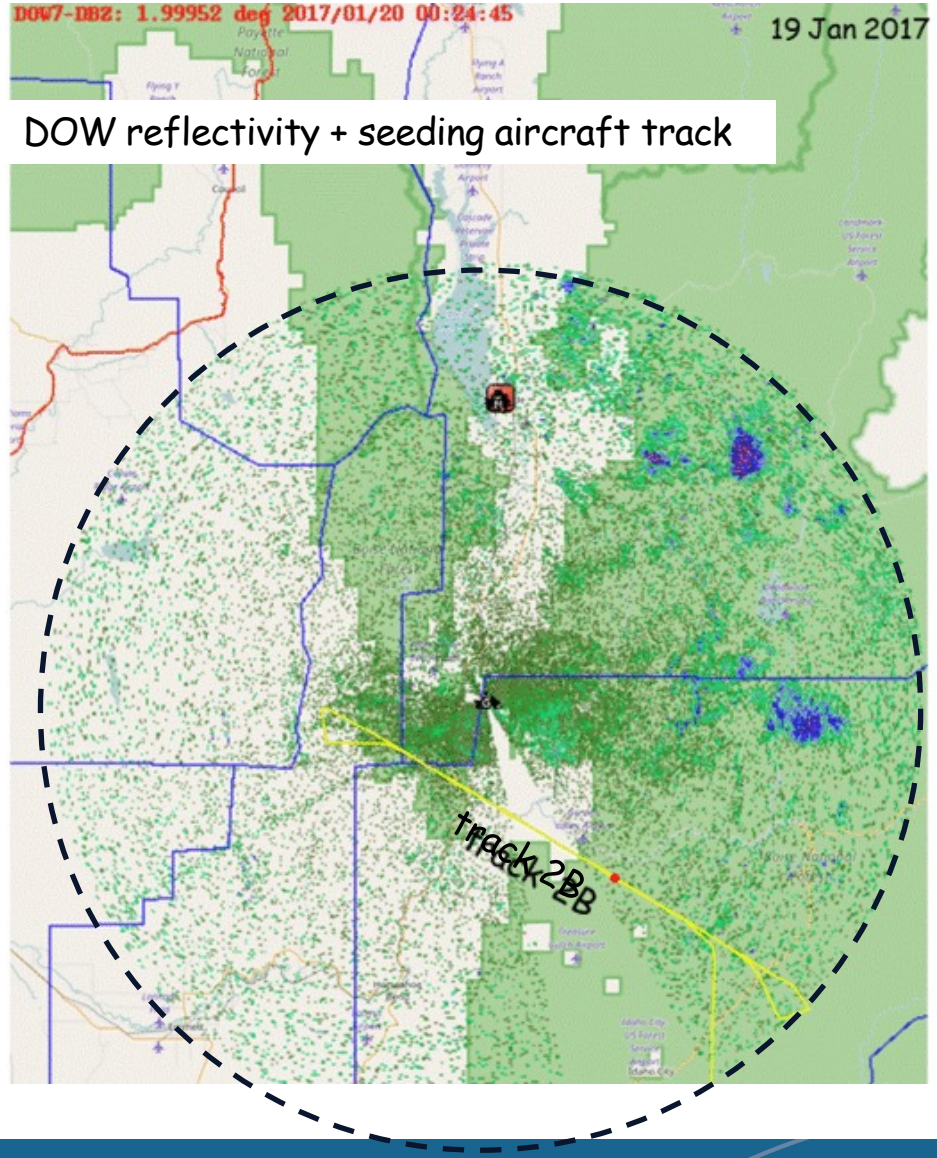


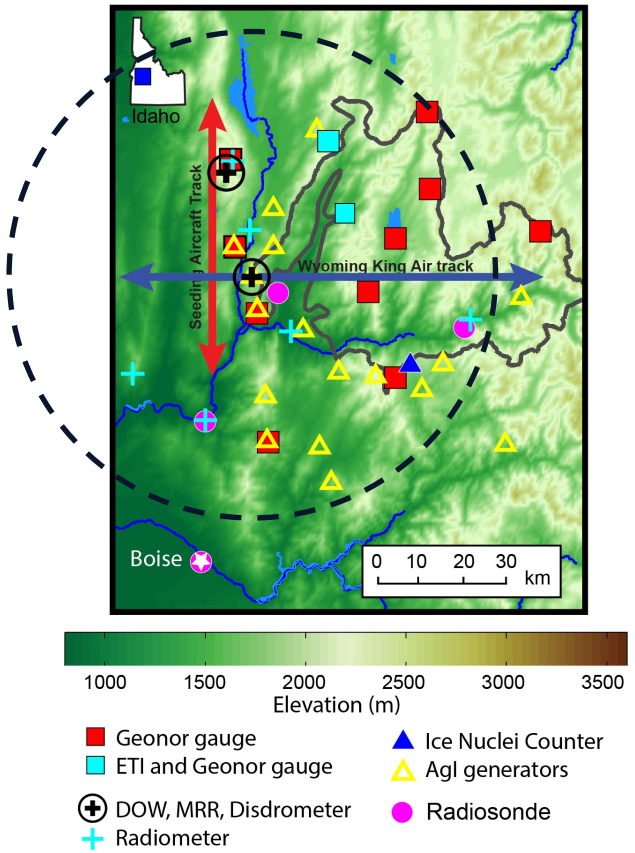
French et al. (2018) and Tessendorf et al. (2019)

A major highlight from SNOWIE

Unambiguous seeding lines were observed and radar and in situ data was collected that quantified the impacts of seeding in these cases!

We are comparing these data with WRF-WxMod simulations to validate and improve the model.





Recent advances provide new opportunities

Research

1) SNOWIE data are being used to study impacts of cloud seeding and validate WRF-WxMod

Design & Guidance

2) WRF-WxMod can be used to determine when, where, and how to seed

Evaluation

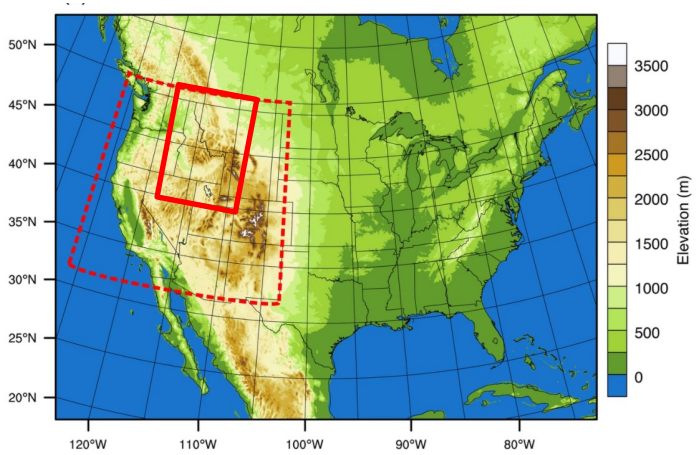
3) WRF-WxMod can be a cost-effective way to quantify the impacts of seeding programs

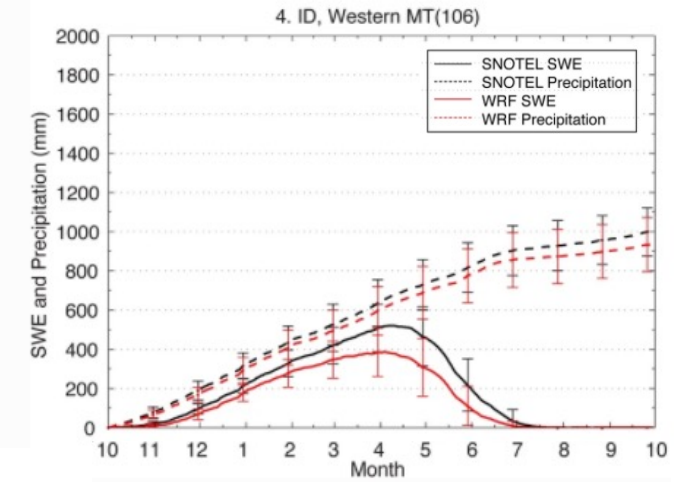
Approach for Statewide Assessment

Goal: Identify areas in the state of Idaho with potential for cloud seeding to conduct more detailed feasibility and design

- Observations required for assessing the potential for cloud seeding are not routinely collected
  - Weather balloons provide vertical profiles of temperature (limited)
  - No routine measurements of SLW
- High-resolution, long-term model simulations provide a new opportunity
  - 13-year (2000-2013) 4-km grid spacing WRF simulation over the CONUS
  - Shown to realistically reproduce precipitation observations
  - Includes 3D information on temperature, SLW, winds, etc.

Weather Research and Forecasting (WRF) model CONUS Simulation Domain





Ikeda et al. (2021)

Wintertime Precipitation over Idaho

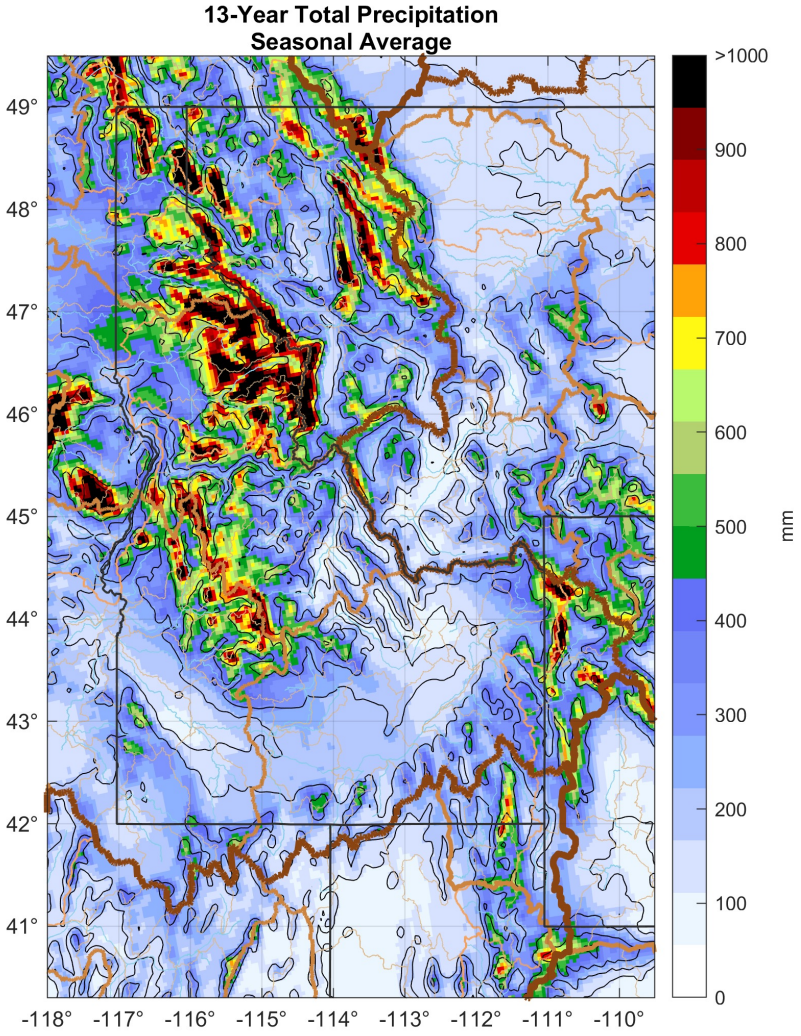
Some locations have a lot of precipitation and large mean SLW

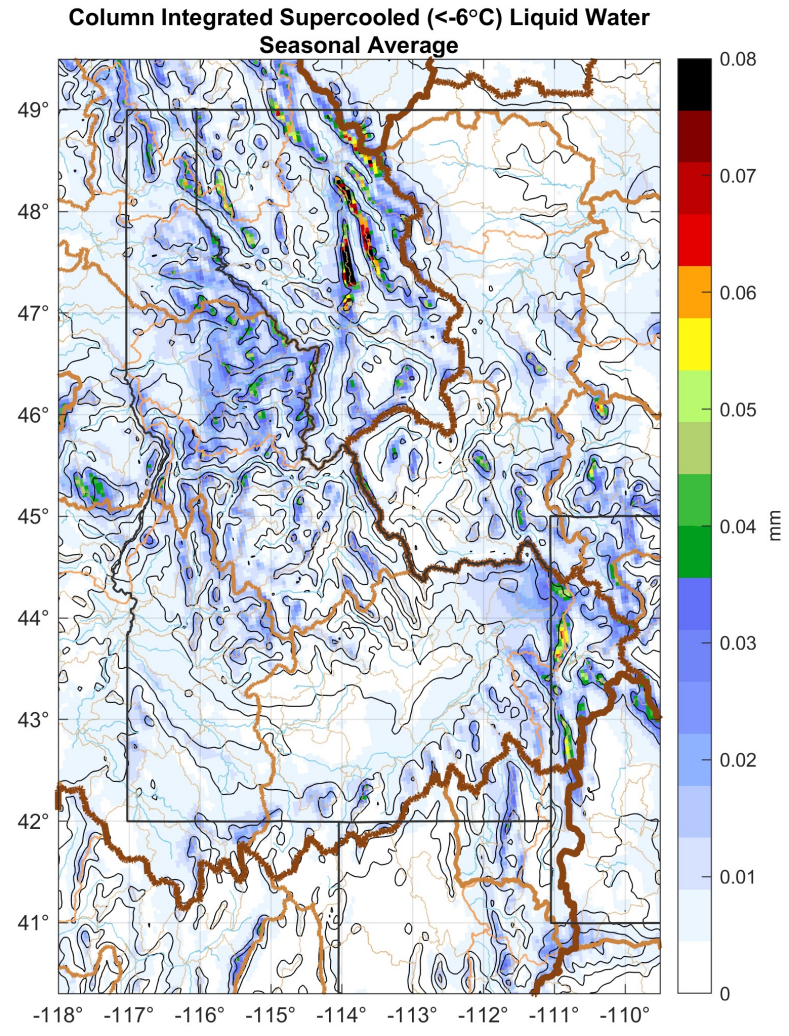
- Northern Idaho and western Montana, Tetons

Some locations have less precipitation, but still large mean SLW

- Salt River Range, Bear River Range vs Lemhi Mtns, Beaverhead Mtns

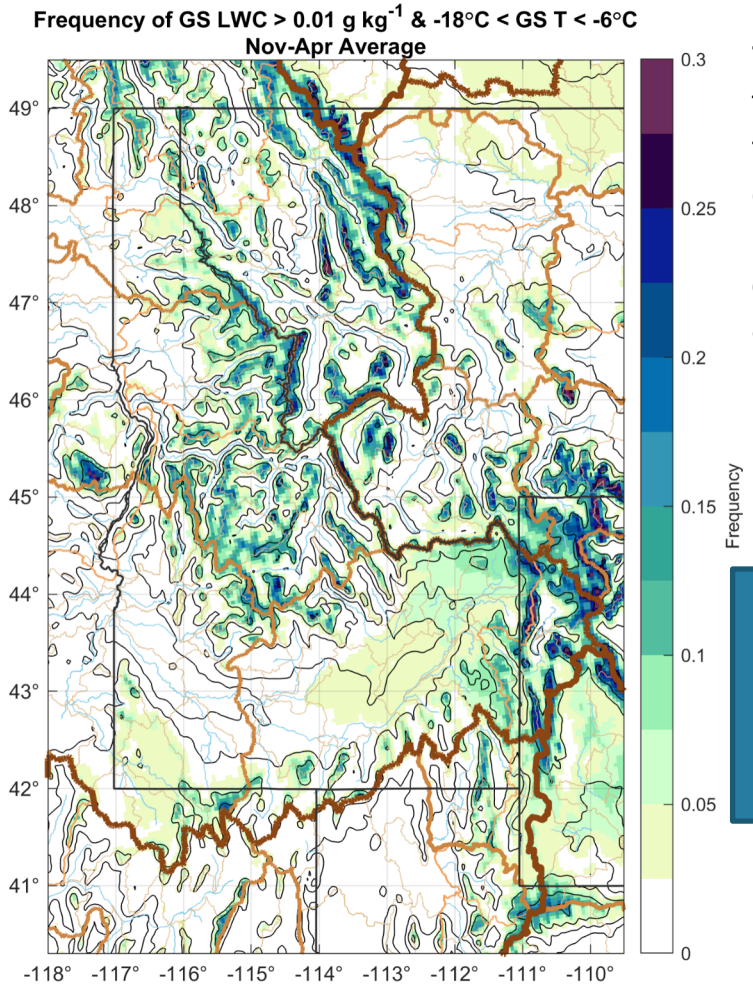
Any location with some SLW is a potential candidate for cloud seeding





Frequency of Cloud Seeding Opportunities

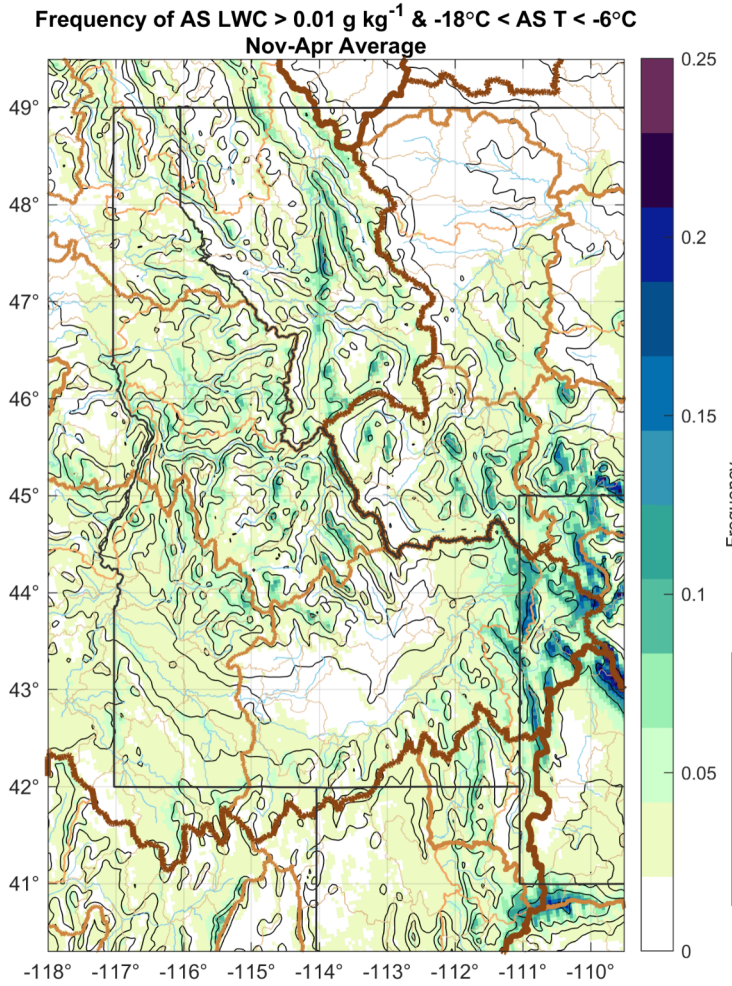
Ground seeding layer (0-1 km AGL)



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)

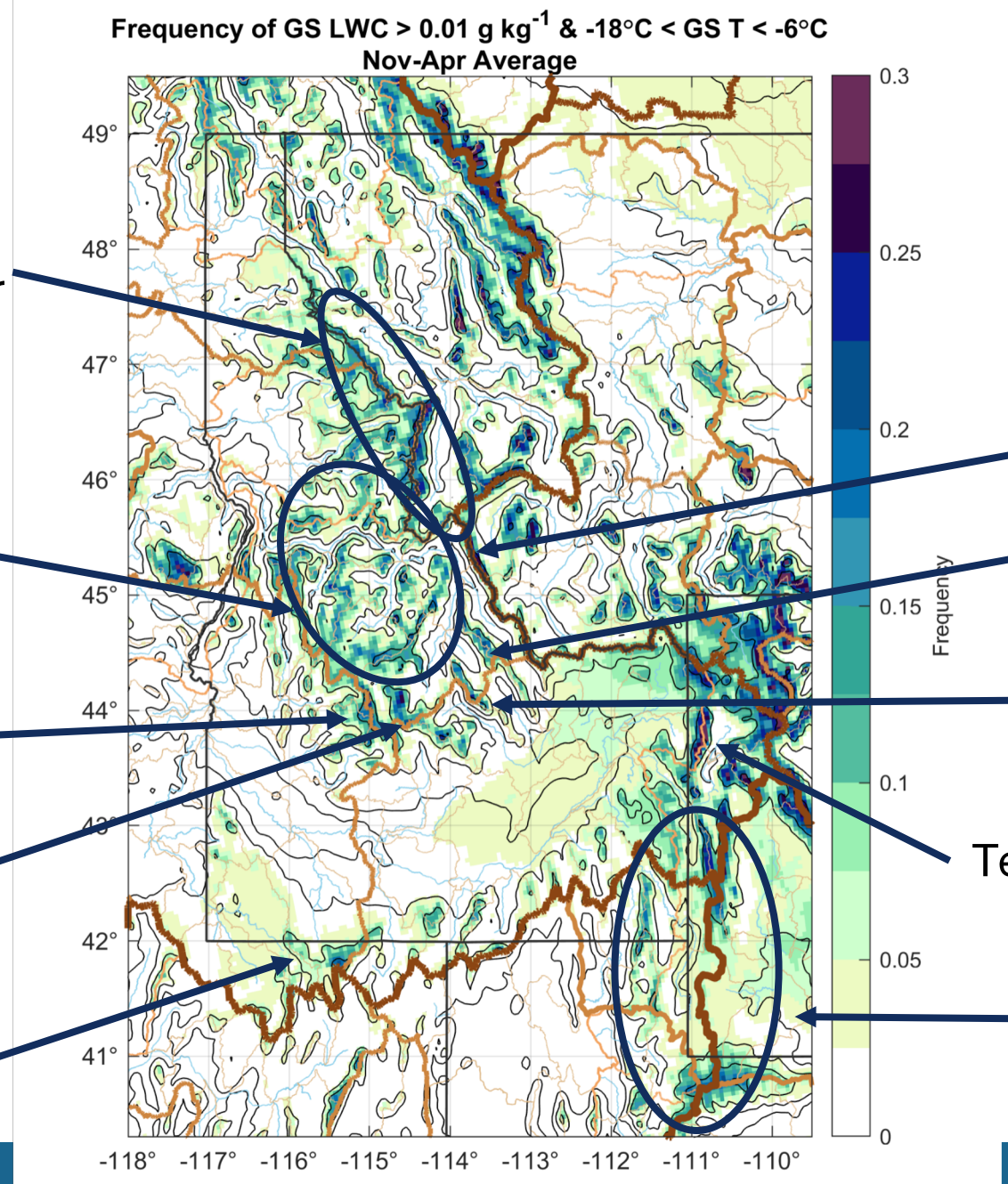


This layer was determined based upon minimum safe flight altitudes over most of the state. Regions with lower altitude mountains may have more potential than shown here since SLW decreases with altitude.

More detailed analysis by basin or mountain barrier is needed

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

NCAR | UCAR



Bitterroot Mountains/Some parts of Clearwater

Salmon River Mountains

Boise/Sawtooth Mtns

Boulder/White Cloud Mtns

Independence Mountains (flows into ID)

Beaverhead Mtns (on divide)

Lemhi Mtns

Lost River Range

Teton Range

Current Study Area (incl. Bear River Range, Salt River Range, Uintas)

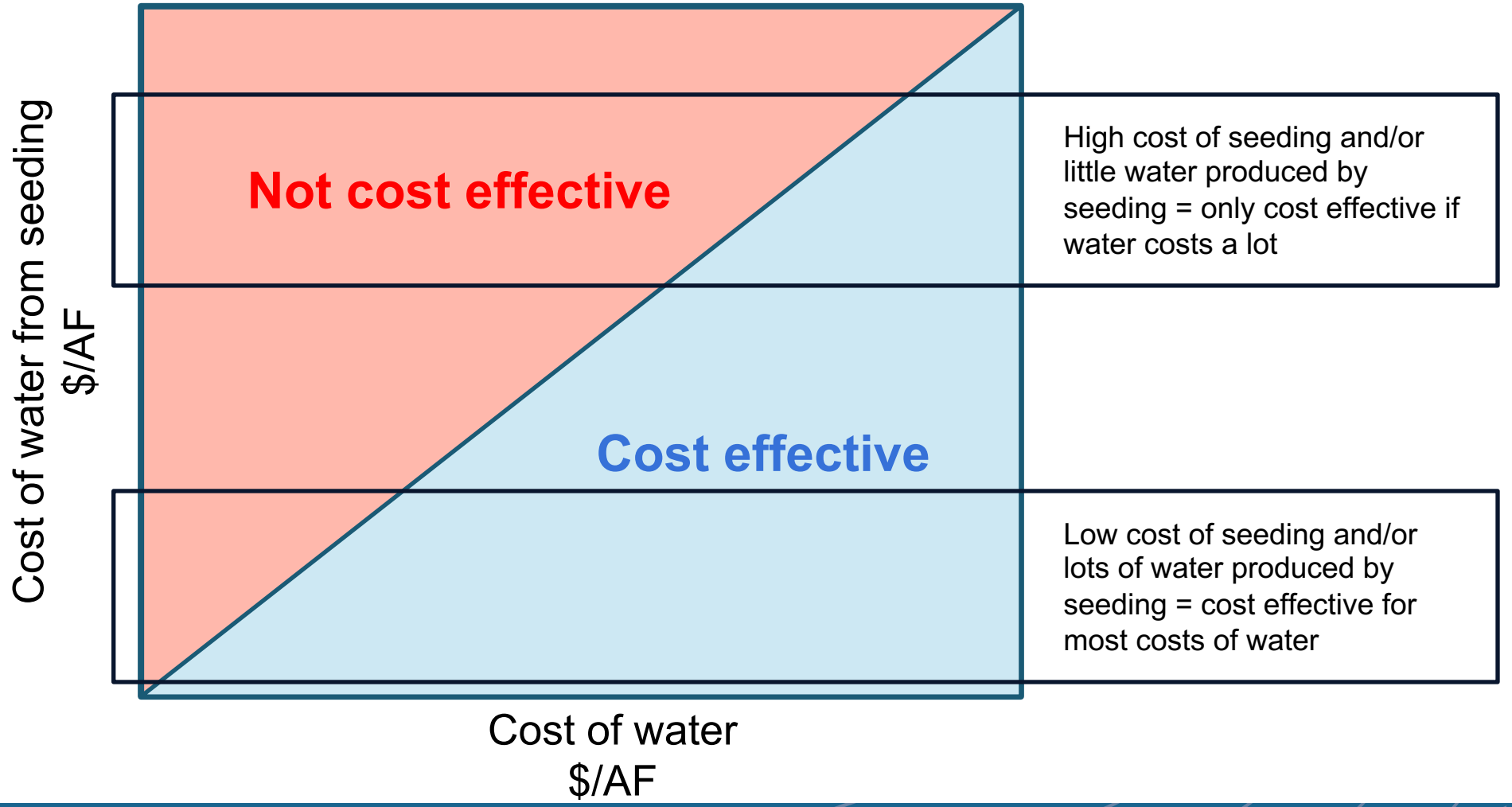
Next steps once areas with potential have been identified

Feasibility & Design Study (for new programs)

- **Detailed climatological analysis**
  - Investigate the atmospheric characteristics specific to each mountain barrier (wind flow, vertical distribution of SLW, etc)
  - Determine if ground and/or airborne seeding is feasible (include dispersion criteria in analysis)
- **Develop and test designs**
  - Where to place generators or aircraft tracks
  - Use WRF-WxMod to test, iterate, and optimize designs
- **Estimate cost effectiveness of program**
  - Estimate program costs
  - Estimate potential streamflow benefits from program

Cost Benefits of Cloud Seeding

Cost of water from seeding
=
Cost of seeding operation
÷
Acre Feet of water produced

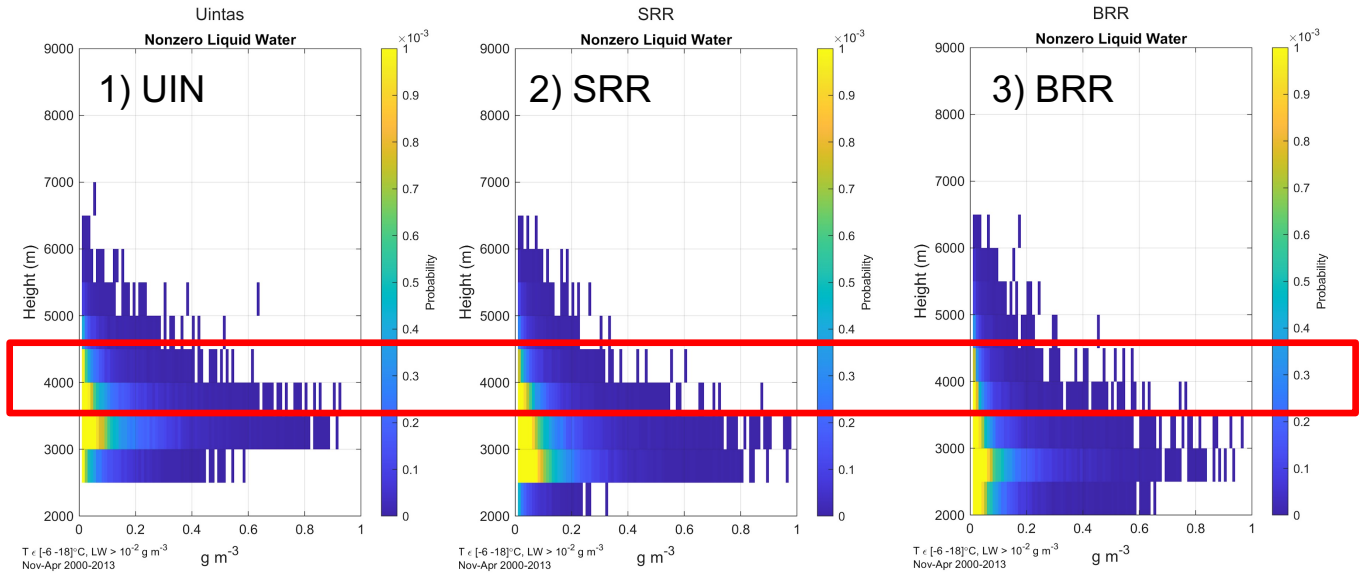


Cloud-seeding Feasibility and Design Study: Bear River Basin of Idaho

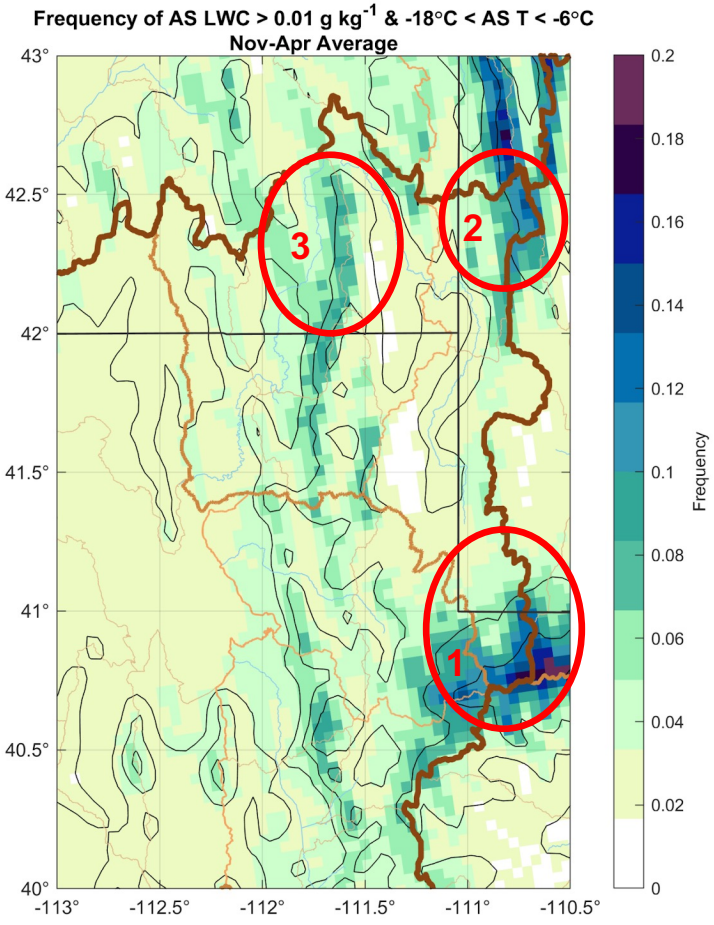
Three regions feed the Bear River Basin:

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



Flight level
3.5-4.5 km MSL



Research sponsored by the Idaho Water Resource Board

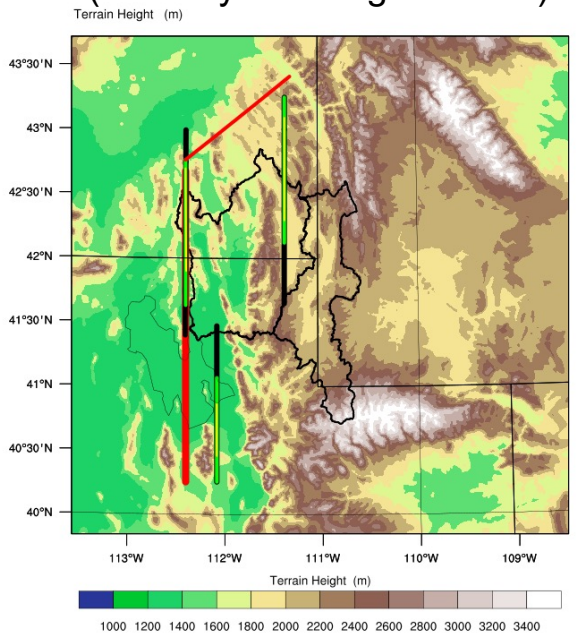
NCAR | UCAR

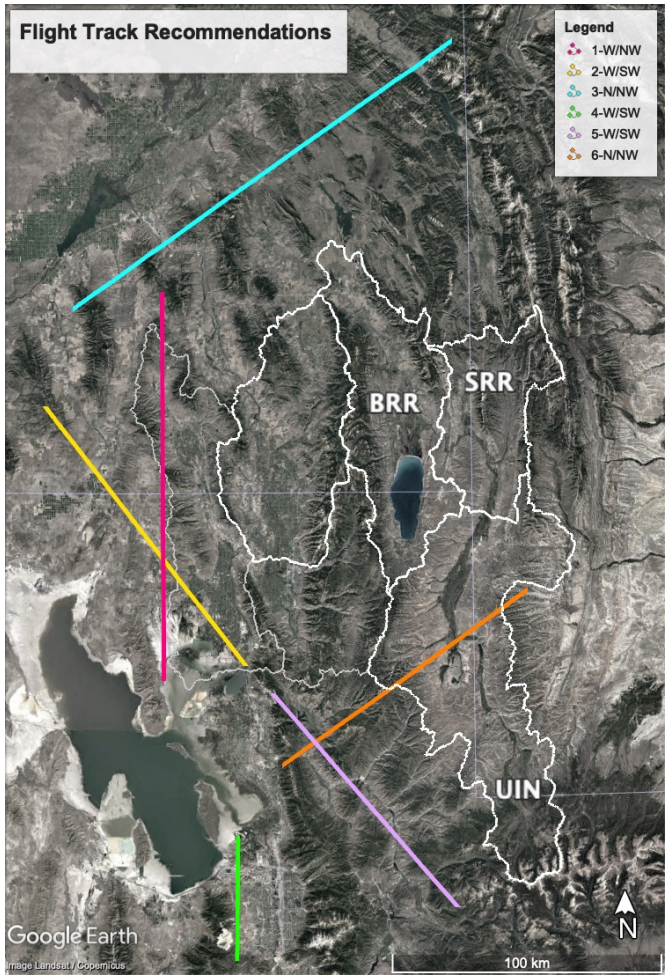
Bear River Basin Airborne Design

- 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)



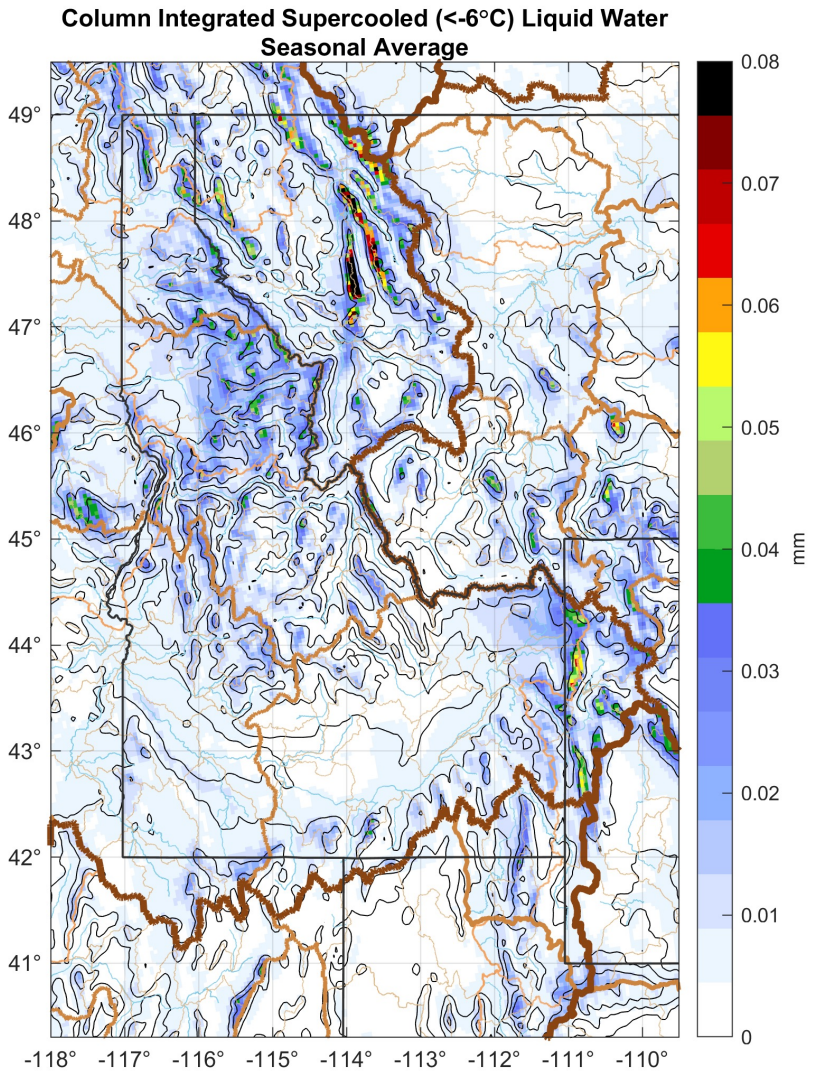


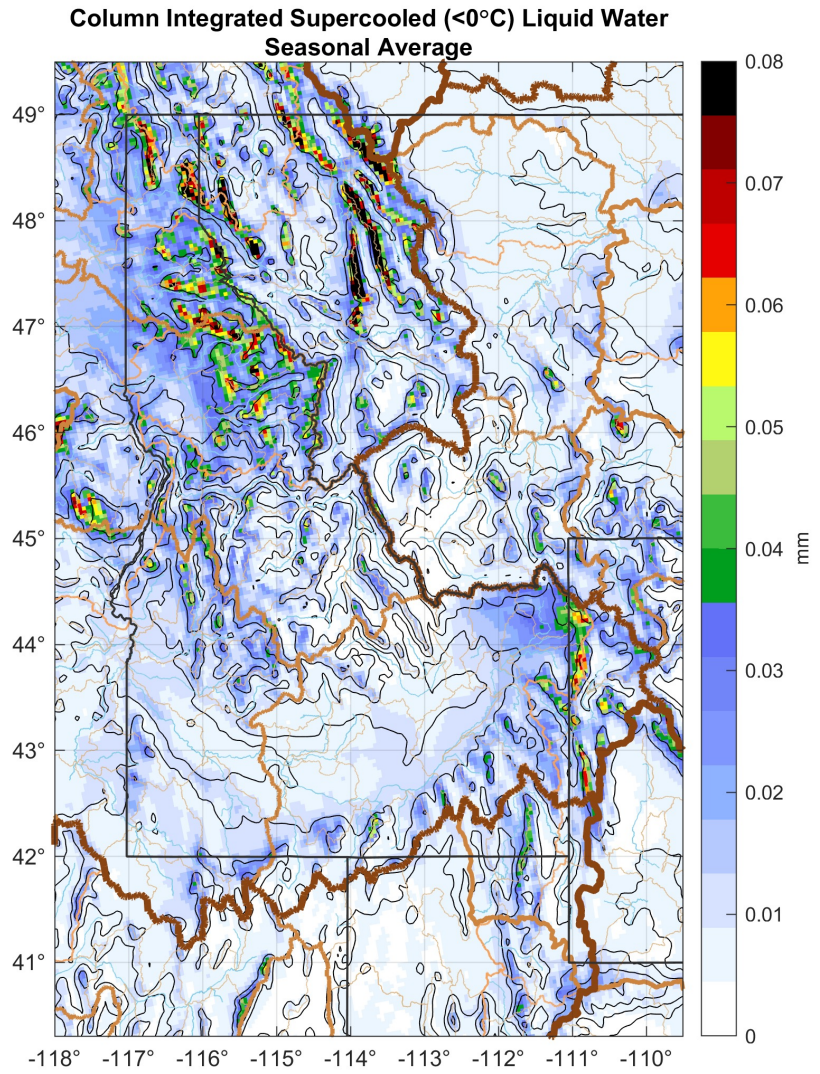
Potential for Liquid Propane Seeding

We know that a considerable amount of SLW exists at temperatures warmer than -6°C (where silver iodide nucleates ice)

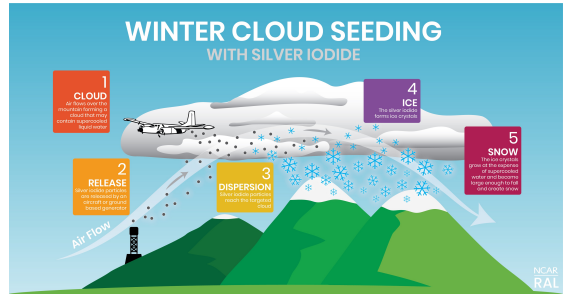
- Potential for liquid propane seeding

A statewide assessment could be done to look more closely at the criteria needed for liquid propane seeding





Summary



Clouds with SLW are candidates for cloud seeding to enhance the efficiency of their snow formation process

- **Not every mountain range or storm is the same**; some locations and storms are more amenable to cloud seeding than others
  - Important to study the climatology of weather conditions to determine when, where, and how to seed
    - Ground-based and/or airborne seeding, silver iodide and/or liquid propane

- **The statewide assessment highlighted areas with potential for cloud seeding with silver iodide**
  - In those areas, the next step is to conduct a detailed feasibility and design study

Recommended Path Forward

- **Pursue detailed feasibility and design studies for highlighted mountain barriers with potential for cloud seeding**
  - Investigate both ground and airborne seeding potential and program design
  - Estimate cost effectiveness to prioritize program planning

- Cloud seeding potential is most frequent in the following areas:
  - Bitterroot and Clearwater mountains
  - Lemhi and Lost River mountains
  - Sawtooth and Boulder/White Cloud mountains
  - Beaverhead mountains
  - Salmon River mountains