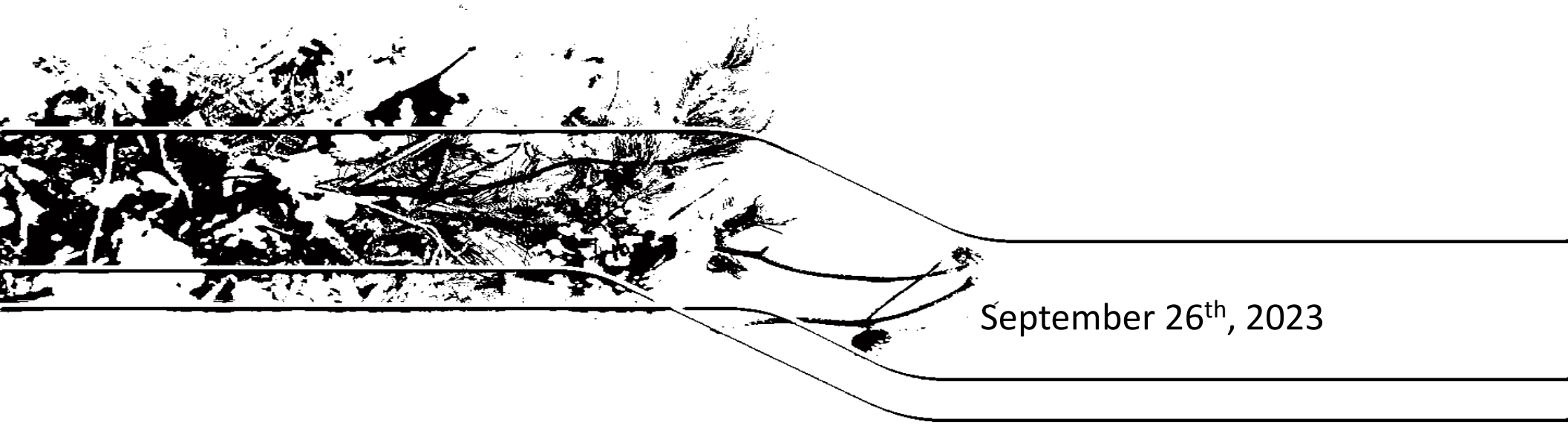
An Overview of Idaho Power's Operational Cloud Seeding Program



September 26th, 2023

Derek Blestrud

IDACORP

Presentation Outline

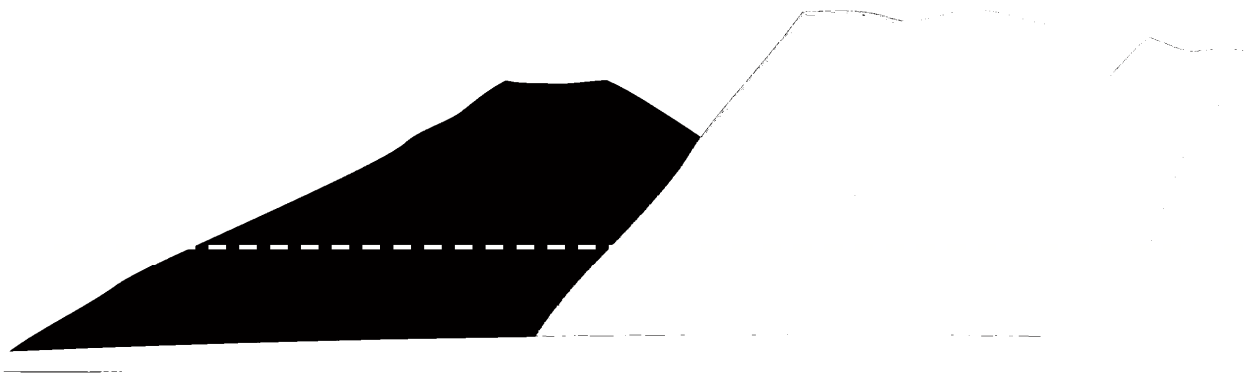
- What is cloud seeding
- How cloud seeding is conducted
- IPC's history of cloud seeding
- Cloud seeding in Idaho
- SNOWIE research project
- Benefit estimates
- Extra area effects
- Environmental concerns

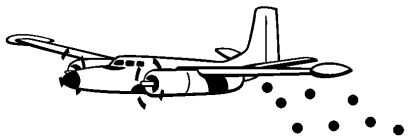
What is cloud seeding?

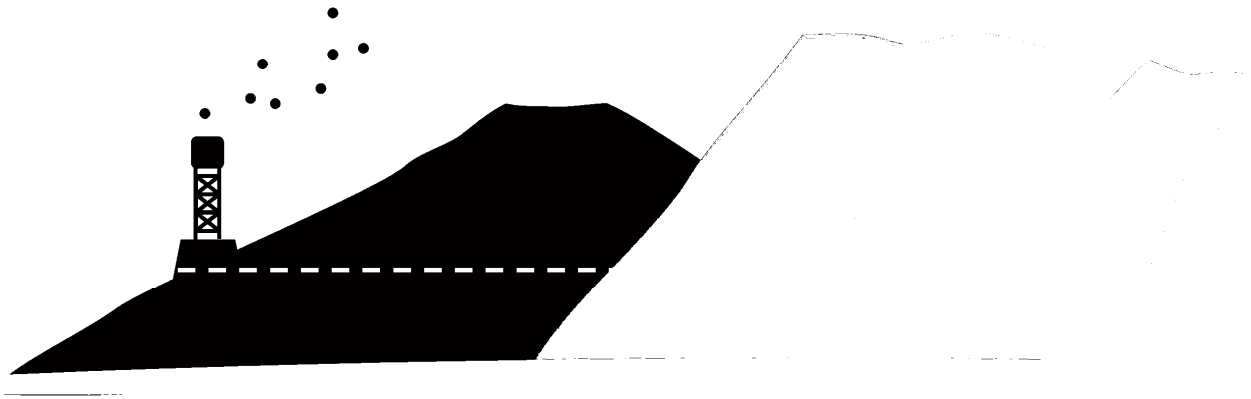
- Cloud seeding of **cold clouds** depends upon an abundance of supercooled liquid water (SLW)
- Cloud seeding of depends upon Collision-Coalescence
- Cloud seeding provides a mechanism to promote the growth of either a raindrop (warm cloud) or snowflake (cold cloud)
- The term cloud seeding has been used to describe:
  - Fog suppression (airports)
  - Hail suppression (reduce crop and property damage)
  - Rainfall enhancement (water supply augmentation)
  - Snowpack enhancement (snowpack augmentation)

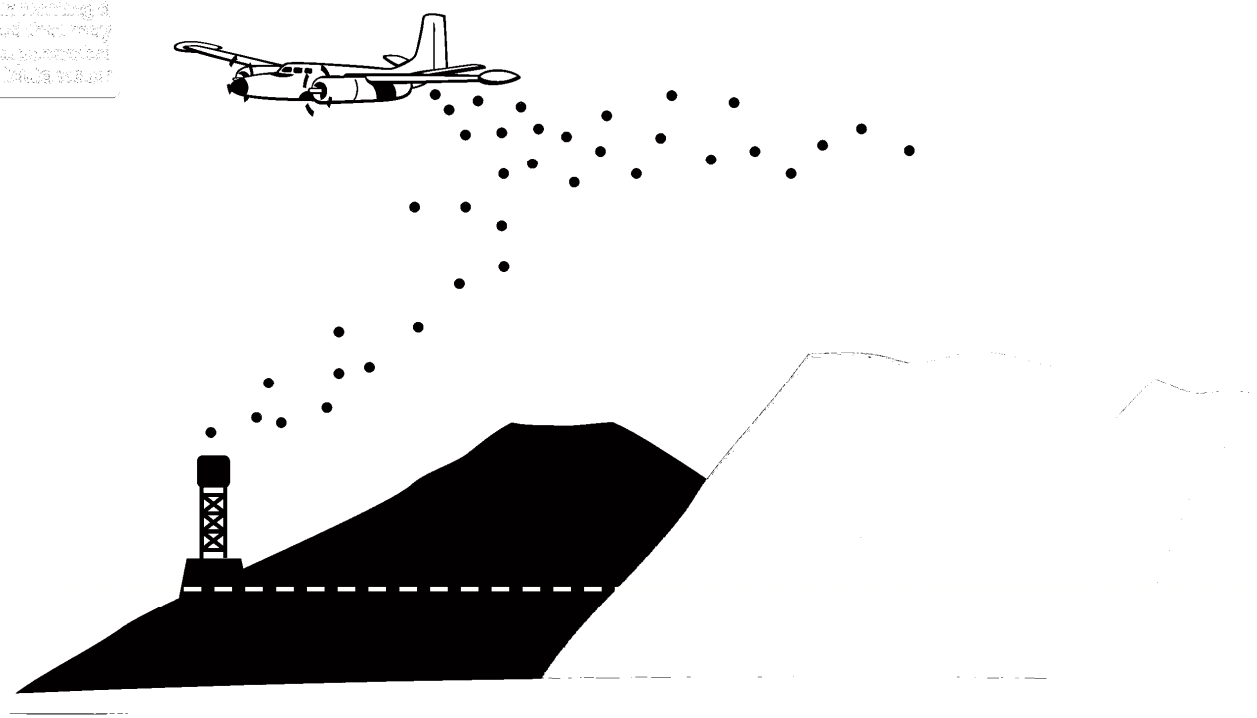
Cold Cloud Seeding Method

- Glaciogenic Seeding
  - Conducted in clouds cold enough to promote growth of ice.
  - Seeding Agents
    - Silver Iodide
    - Dry Ice
    - Liquid Propane (expands into gas form)





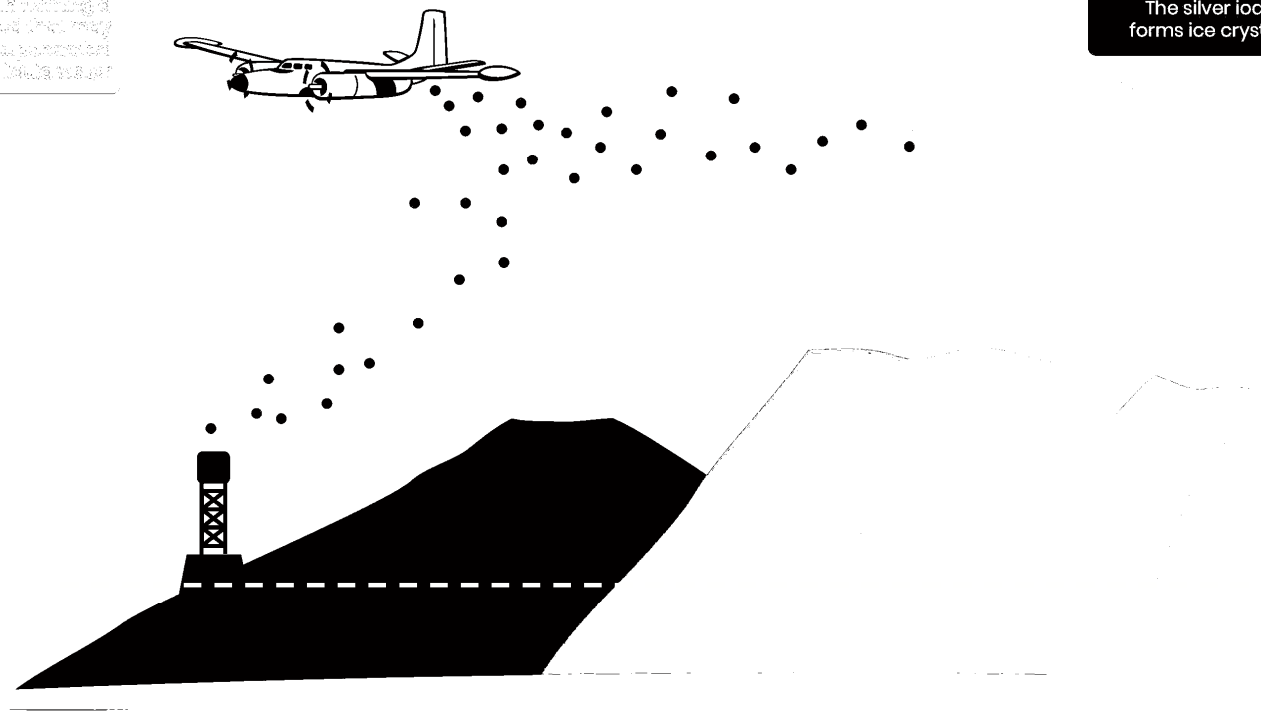


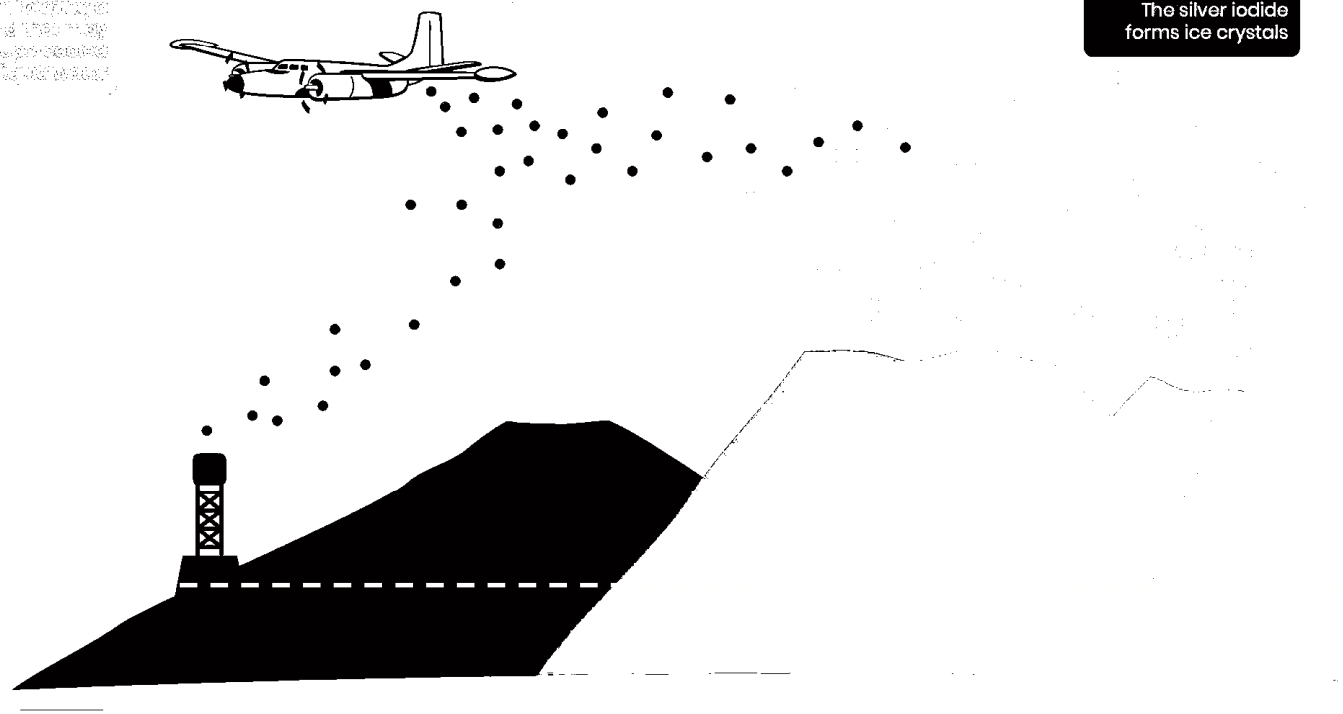


4

ICE

The silver iodide forms ice crystals

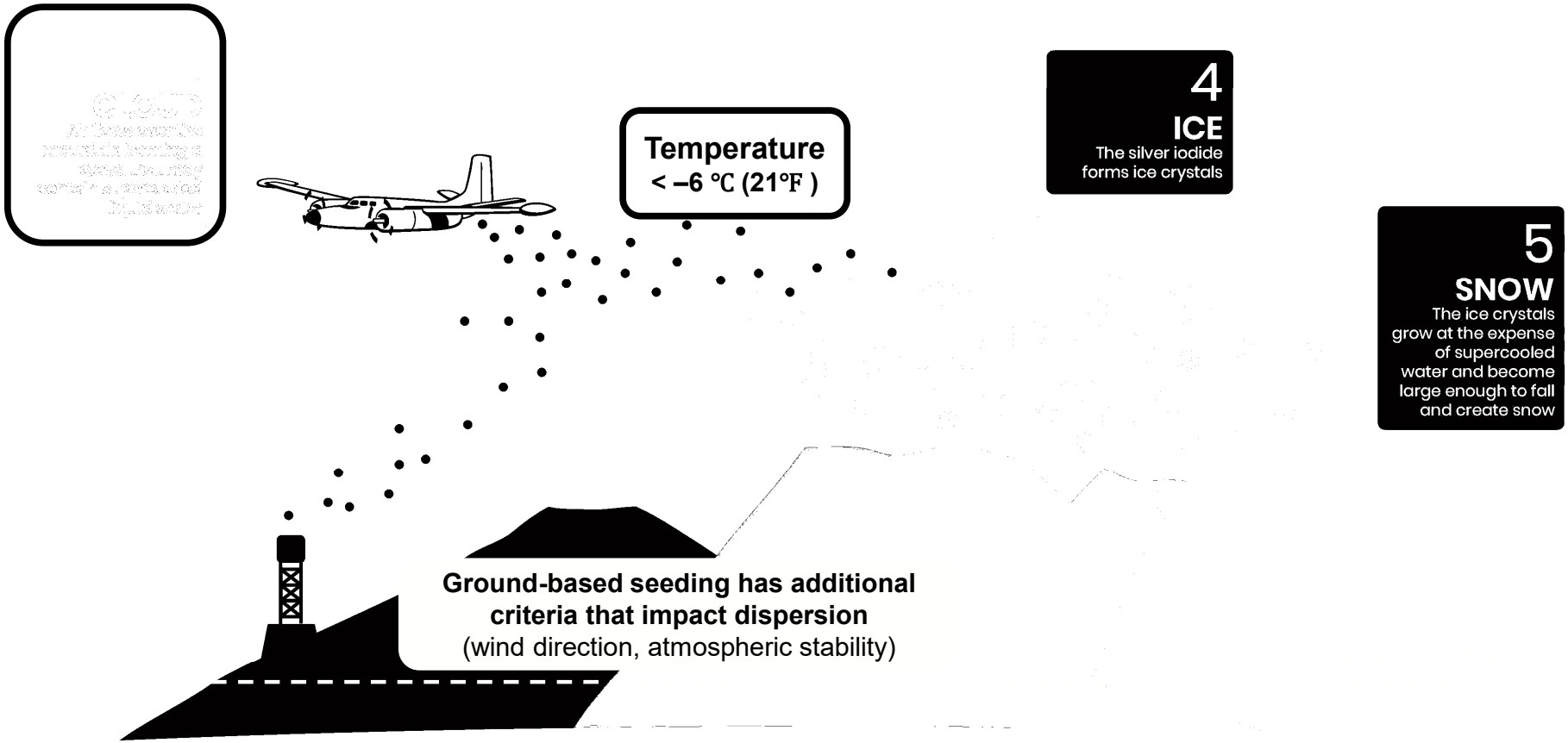


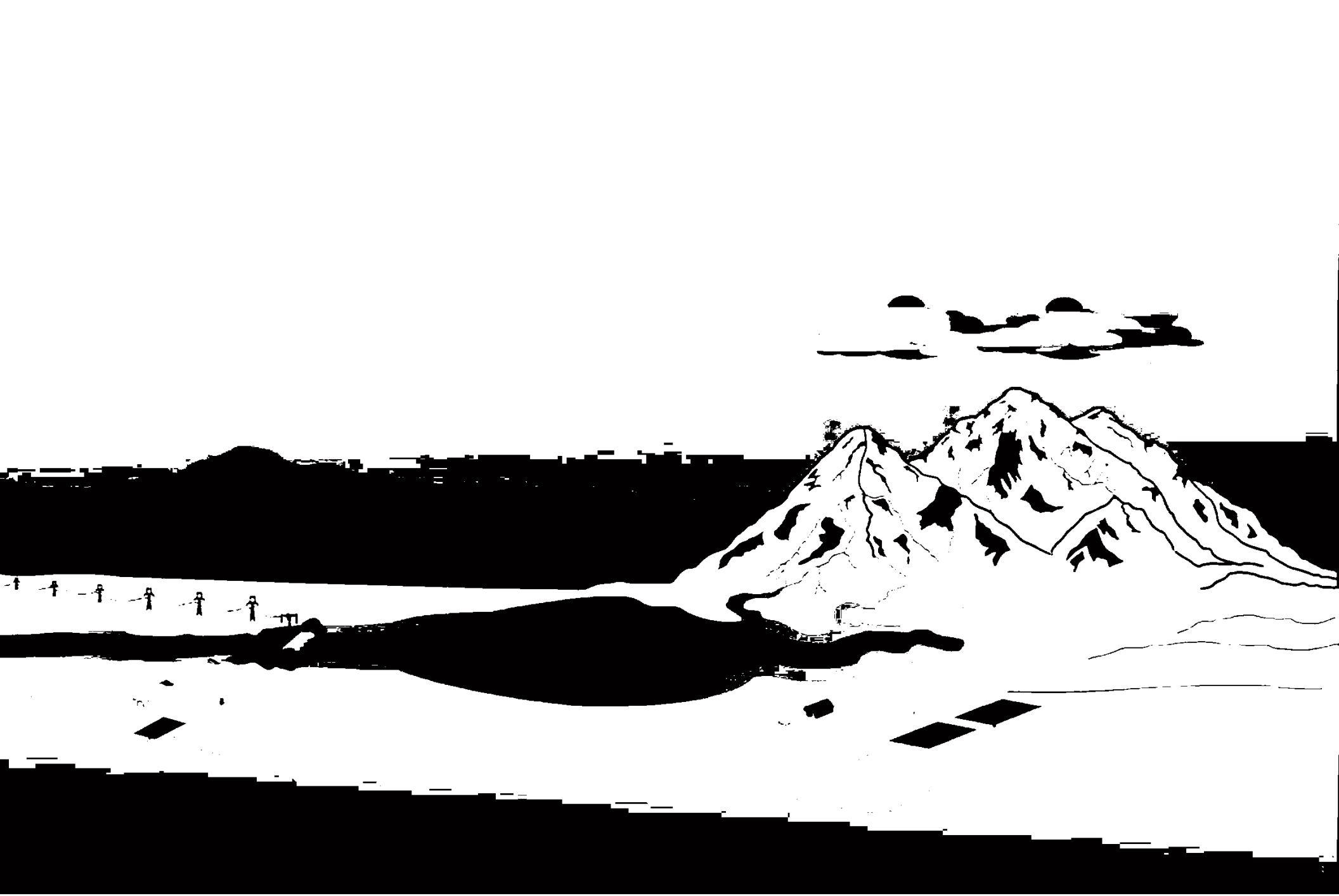


4
ICE
The silver iodide forms ice crystals

5
SNOW
The ice crystals grow at the expense of supercooled water and become large enough to fall and create snow

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

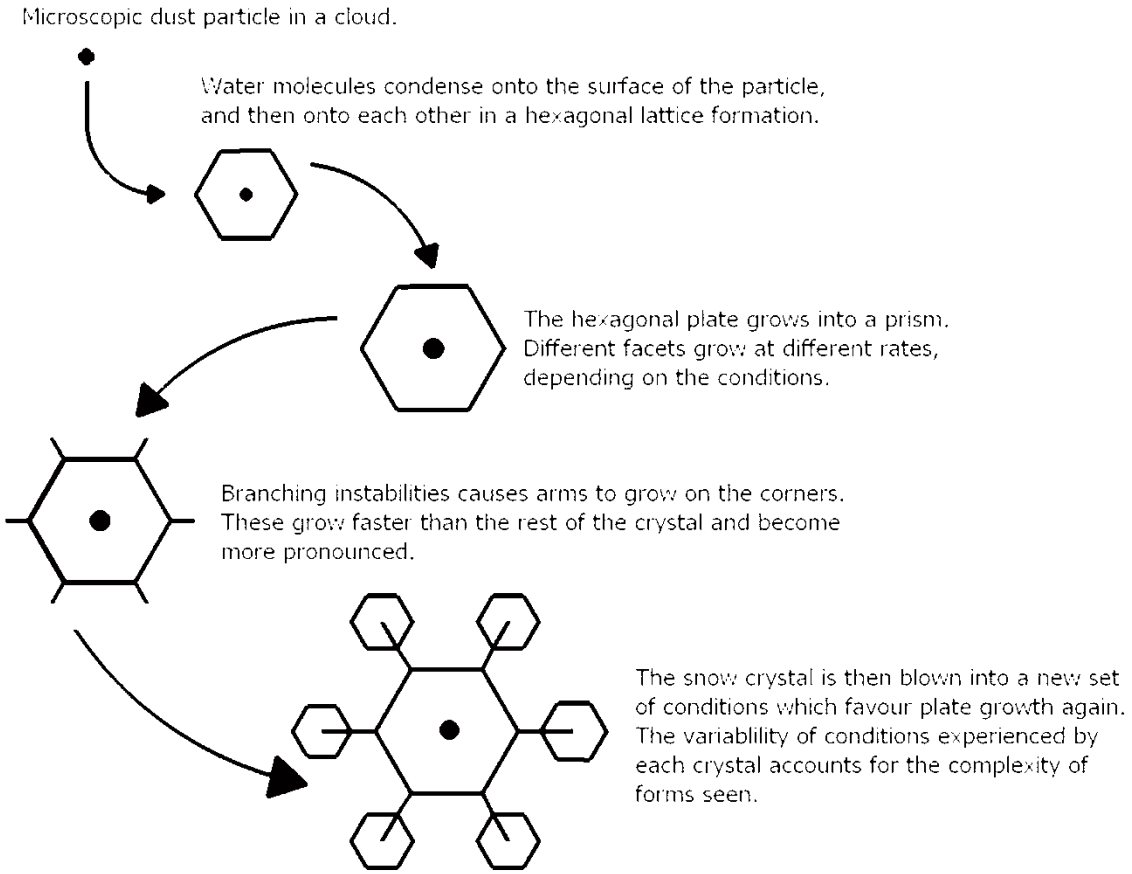




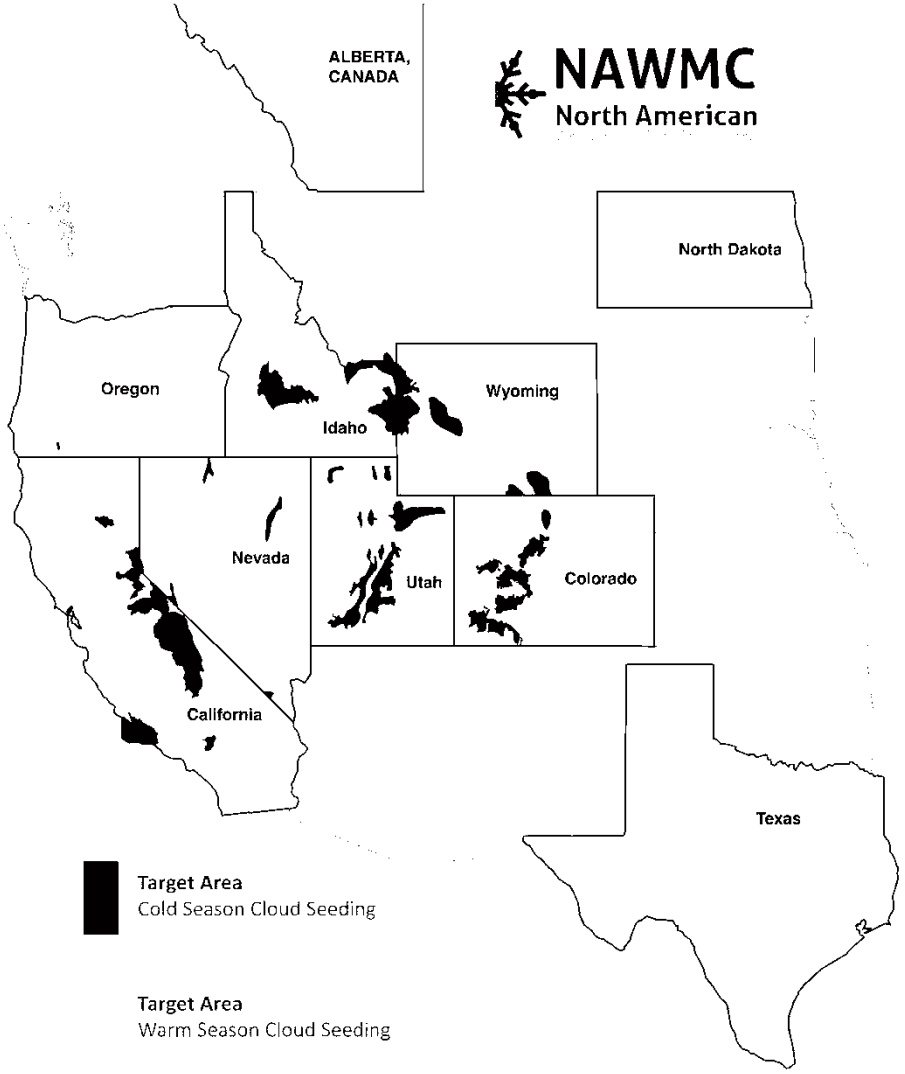
Supercooled Liquid Water (SLW)

- Water that is cold enough to freeze, but remains in the liquid state
  - Water ***<u>can</u>*** 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
    - Often down to 0°F or even colder

How does a snowflake/raindrop develop? (Cold Cloud)

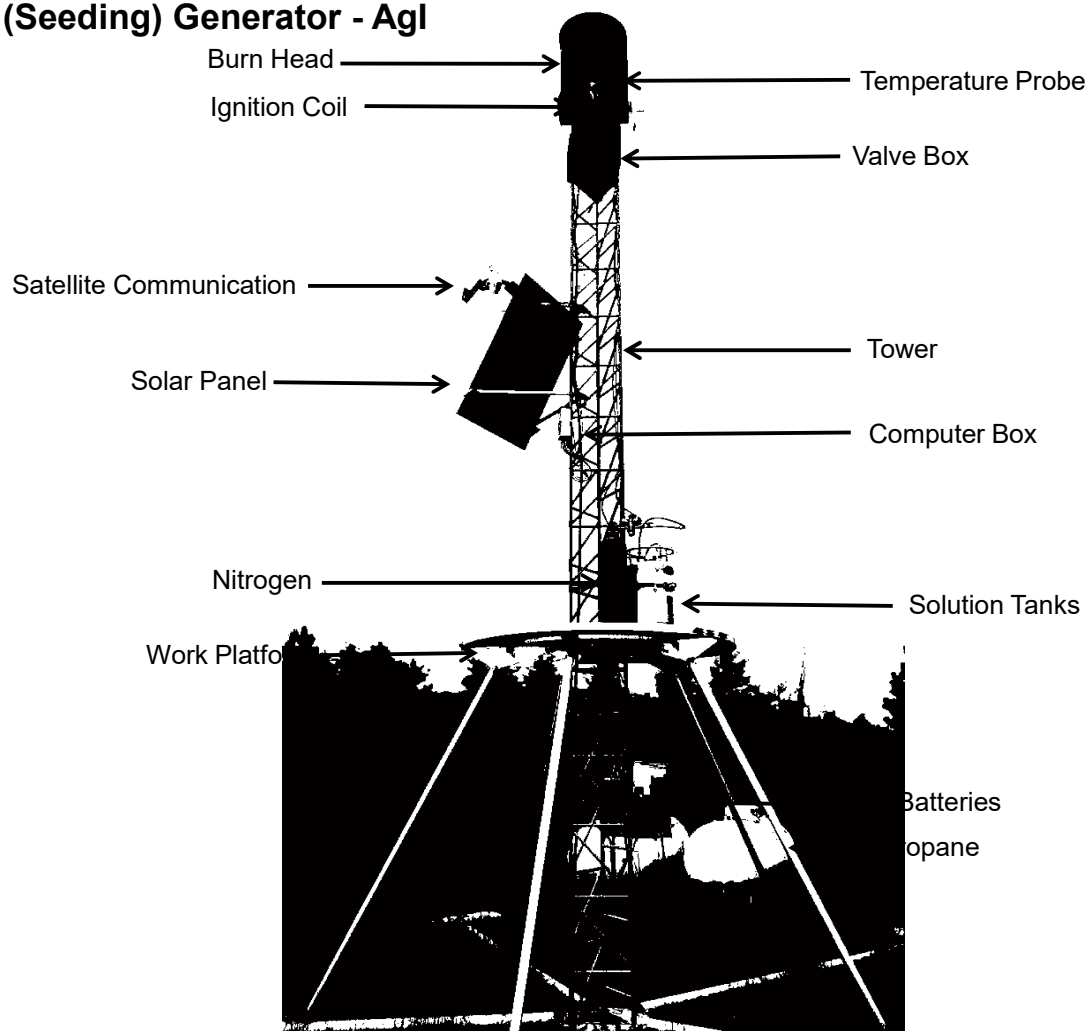


Cloud Seeding Programs

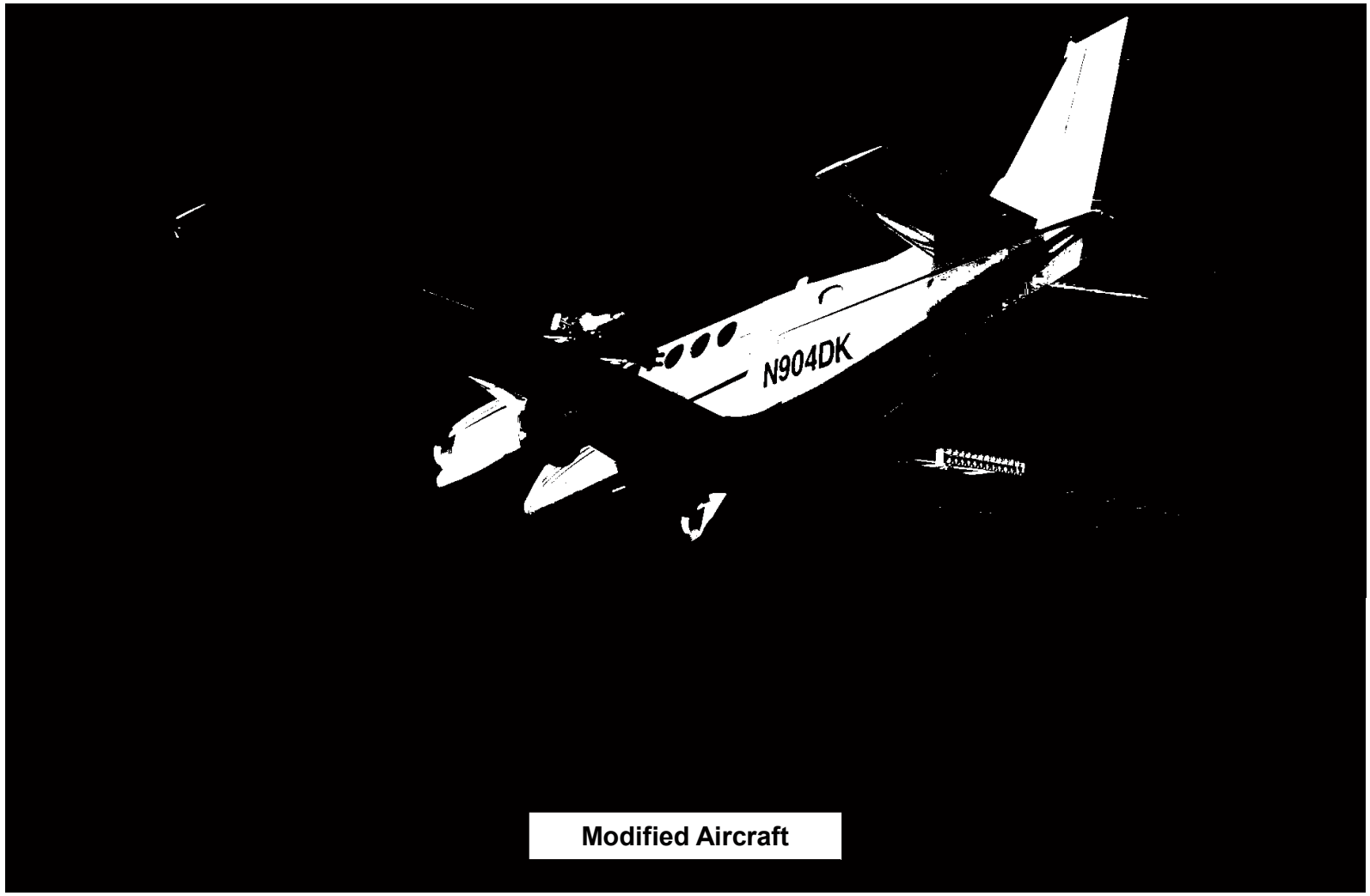


Seeding Mechanisms

Remote Cloud Nucleating (Seeding) Generator - AgI



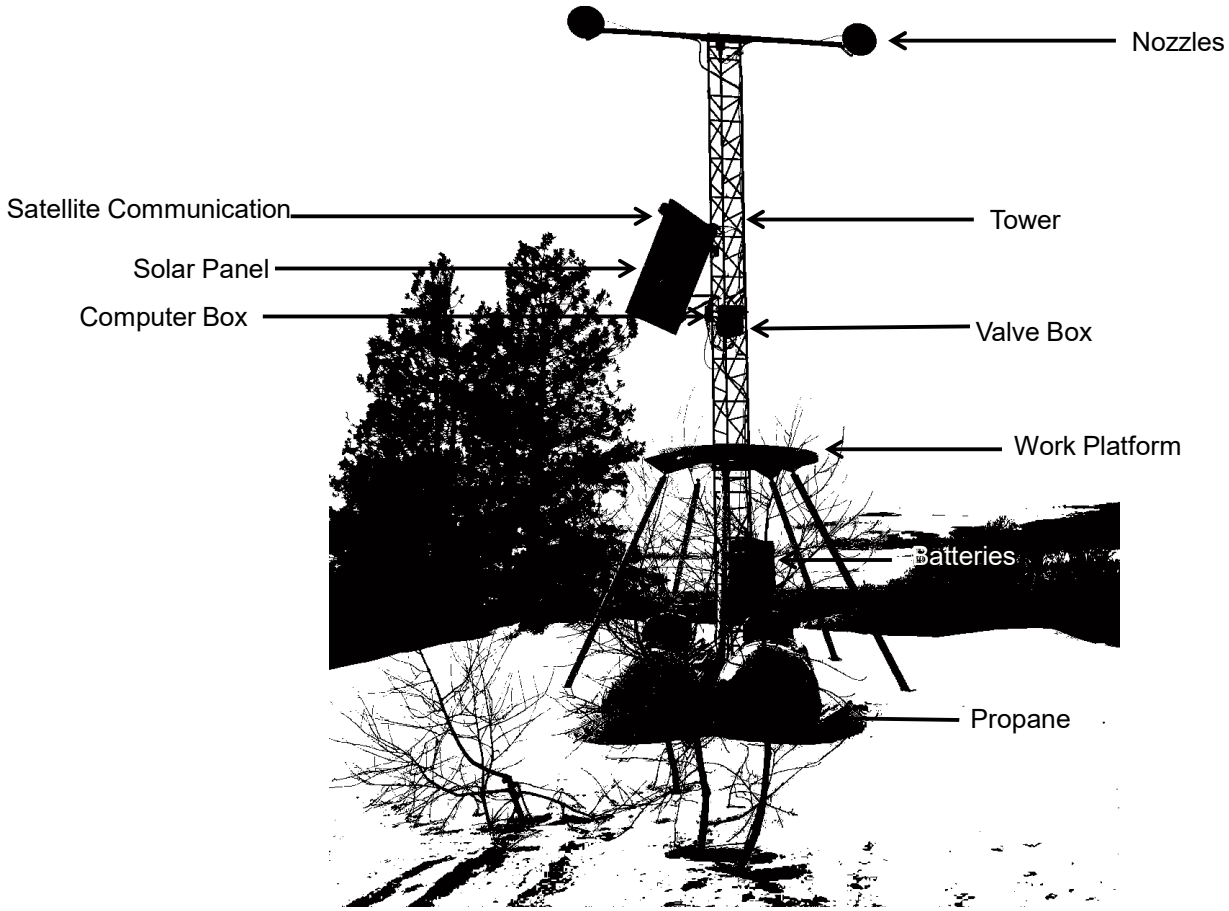
Seeding Mechanisms



Modified Aircraft

Seeding Mechanisms

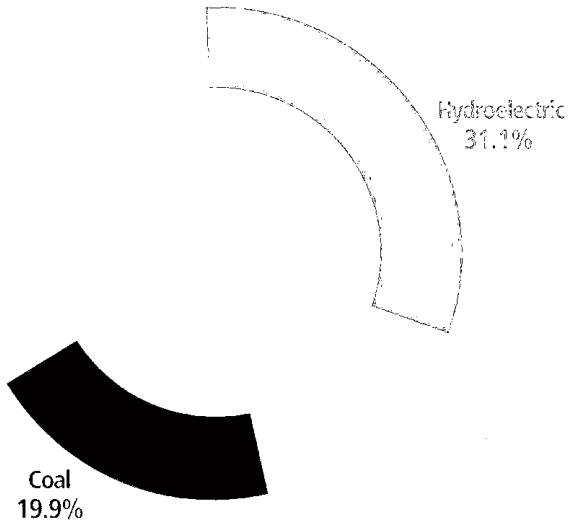
Remote Cloud Nucleating (Seeding) Generator - LP



IPC's Cloud Seeding History

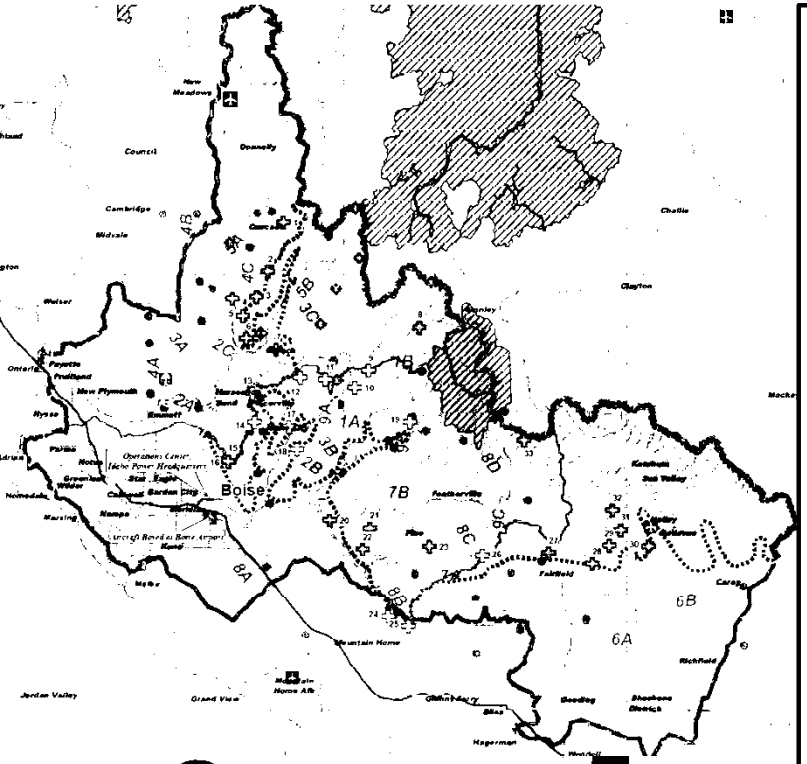
Potential to Augment Hydroelectricity

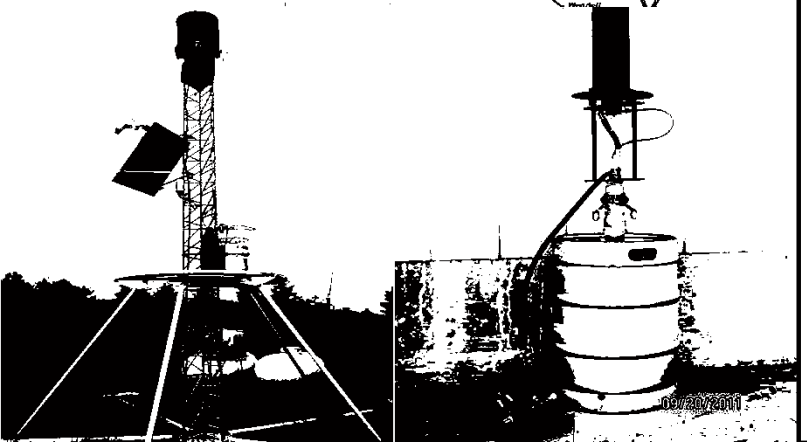
IPC's 2022 Energy Mix



Idaho Power's Cloud Seeding History

- Began investigating cloud seeding in 1993 (shareholder question)
  - Literature review 1993 and 1994
  - Climatology study 1994 and 1995
  - Feasibility and Project Design 1995 -
- Operational in fall of 2003 (Payette - 7 generators, aircraft, assessment)
  - Completed second year of assessment and third year of operations in May 2005
- In 2008 collaborated with HC RC&D and E Idaho Counties to enhance their program (motivated by CAMP)
- In 2010 started working with WW RC&D to evaluate cloud seeding opportunities in western Wyoming
- In 2011 started working with NCAR to develop WRF model to guide and evaluate CS operations and projects
- In 2013 – contracted with Big Wood Canal Company to seed Wood River with aircraft
- WY 2015 Expansion (44 generators, 2 aircraft)
  - Boise and Wood Basin's – remote generators and aircraft seeding
  - Continued expansion in Salt and Wyoming Ranges
  - IWRB funding a grant for equipment associated with expansion
- WY 2024 Current Program
  - 57 Generators AgI, 7 propane
  - 3 aircraft





WY 2024
Idaho Collaborative Cloud Seeding Program

<u>Central Mountains</u>

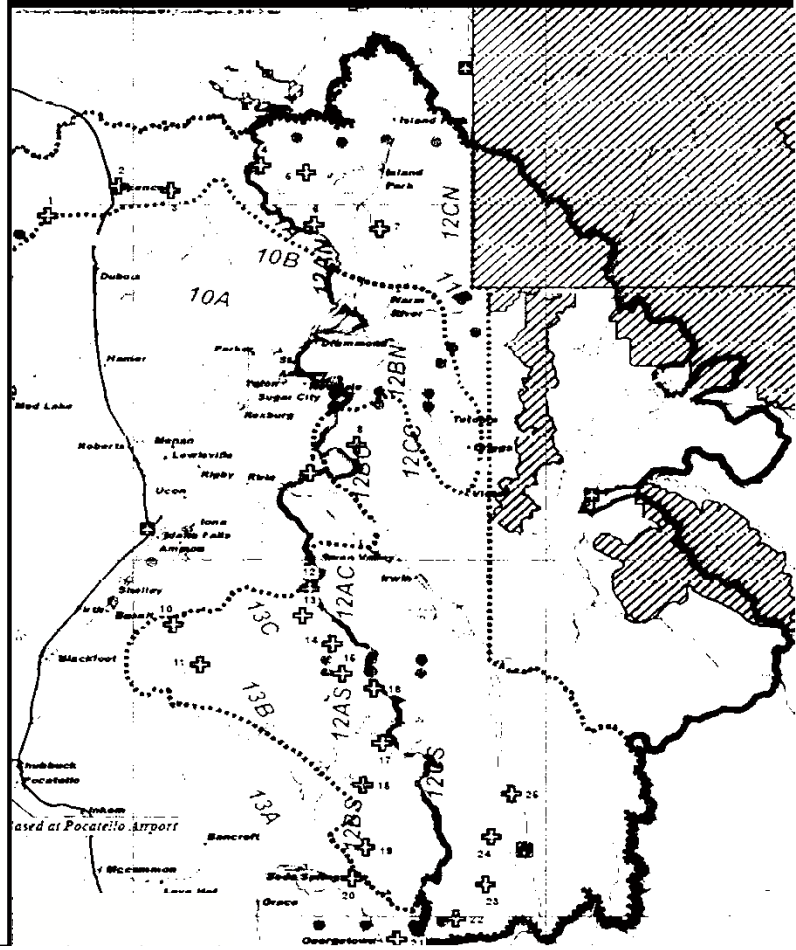
- 32 IPC Remote Ground AgI Generators
  - 17 Payette
  - 15 Boise/Wood
- 7 IPC Remote Ground Propane Generators
- 2 Aircraft

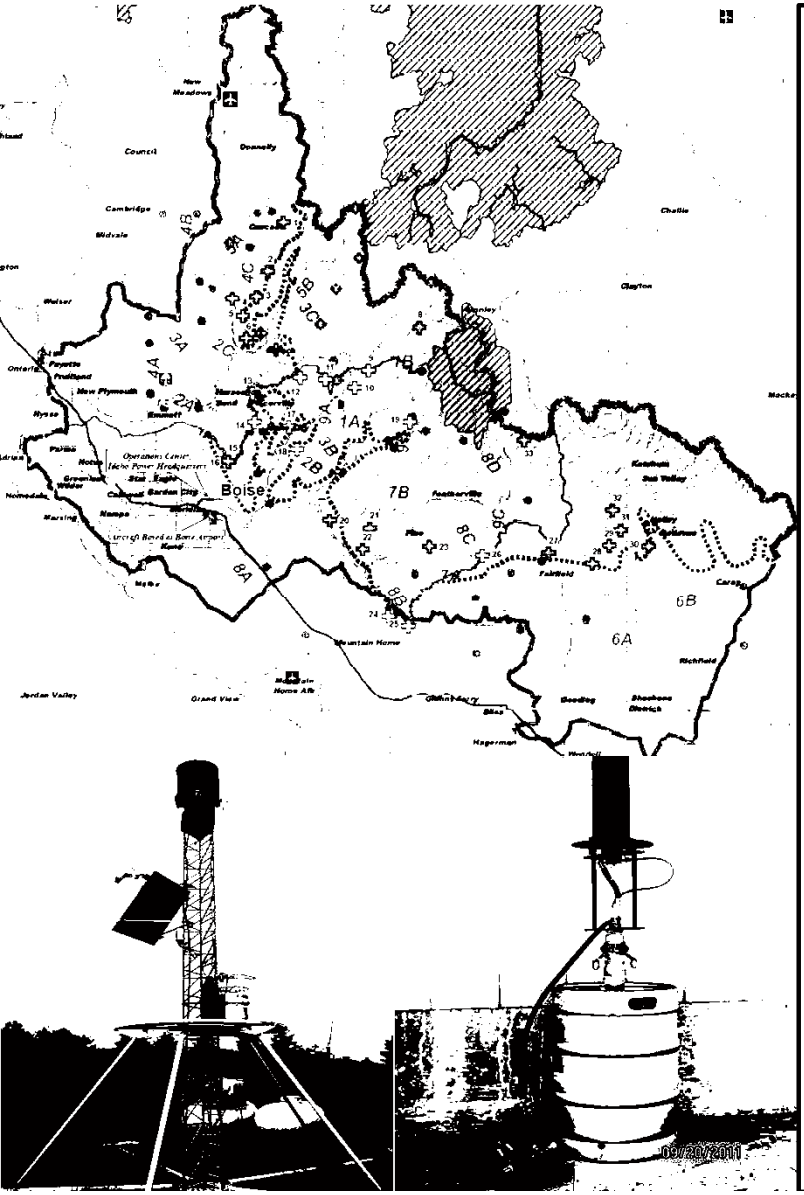
<u>Upper Snake</u>

- 25 IPC Remote Ground Generators
- 1 Aircraft
- 25 Let It Snow Manual Ground Generators

<u>Across the Program</u>

- High Performance Computing System
- High Resolution WRF Weather Model
- WRF-WxMod Module
- High Resolution weather instrumentation





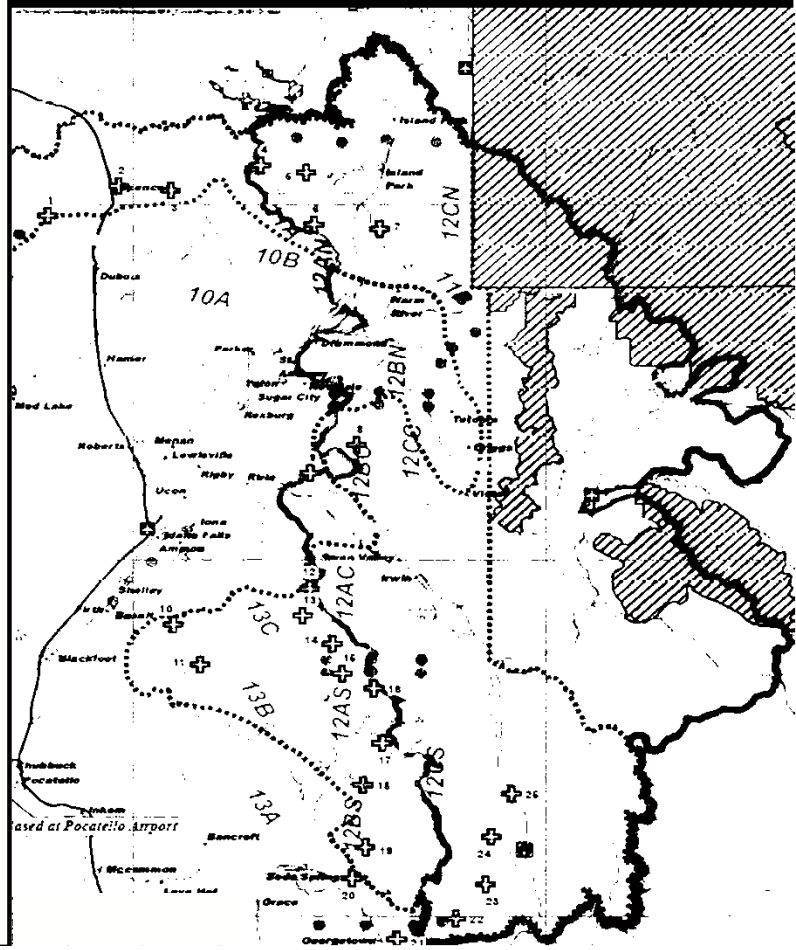
WY 2023
Idaho Collaborative Cloud Seeding Program

<u>Payette Basin</u>
- Idaho Power (IPC)

<u>Boise Basin</u>
- IPC
- IWRB
- Local Water Users

<u>Wood Basin</u>
- IPC
- IWRB
- Local Water Users

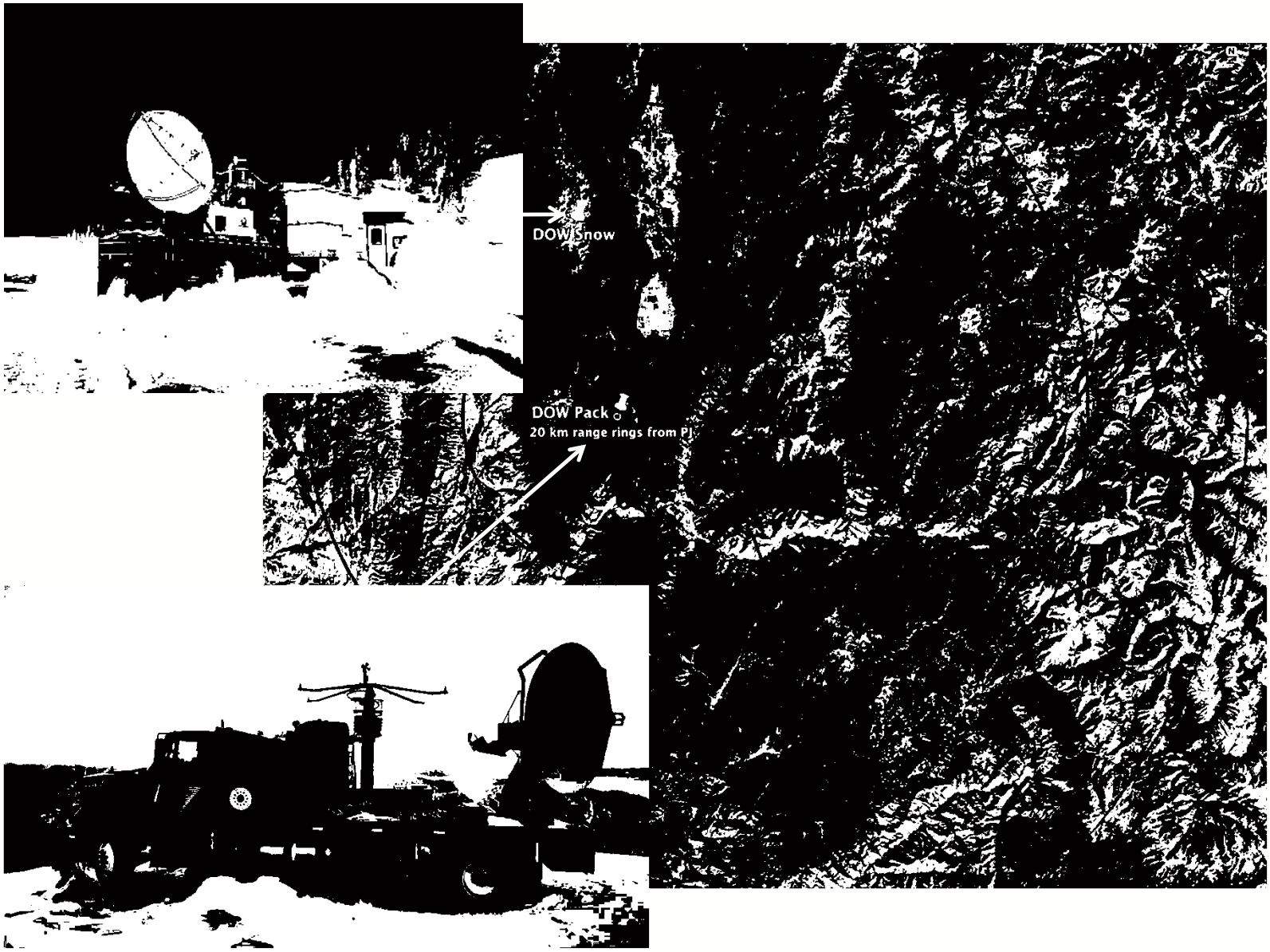
<u>Upper Snake Basin</u>
- IPC
- IWRB
- Local Water Users

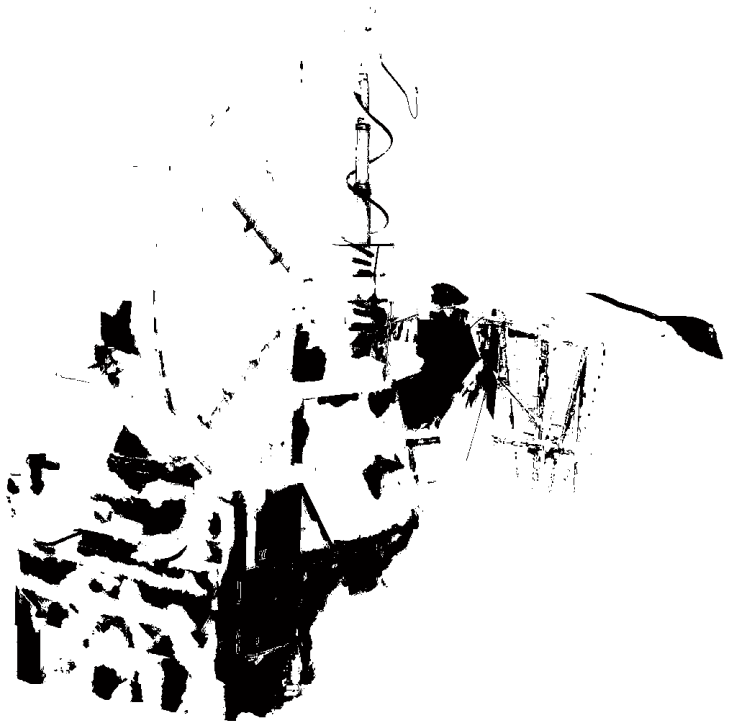


SNOWIE

Seeded & Natural Orographic Wintertime clouds: the Idaho Experiment

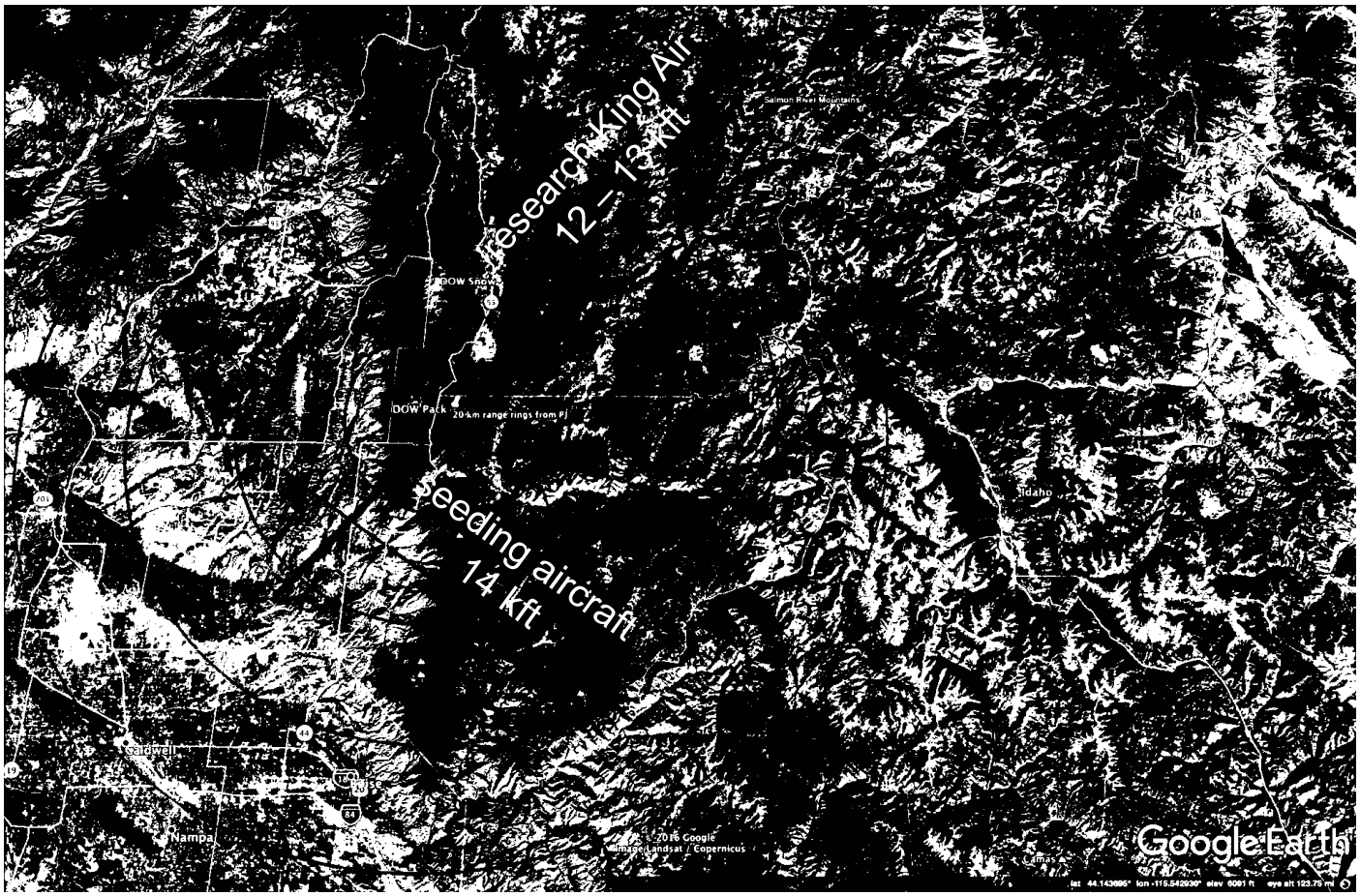
- National Science Foundation funded SNOWIE to study winter precipitation processes ($2.1M)
- Goal:
  - further understand natural and dynamic winter precipitation processes
  - determine physical processes by which cloud seeding effects winter precipitation
- Collaborative effort between:
  - National 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
- A Second NSF grant awarded to continue analyzing data from 2017

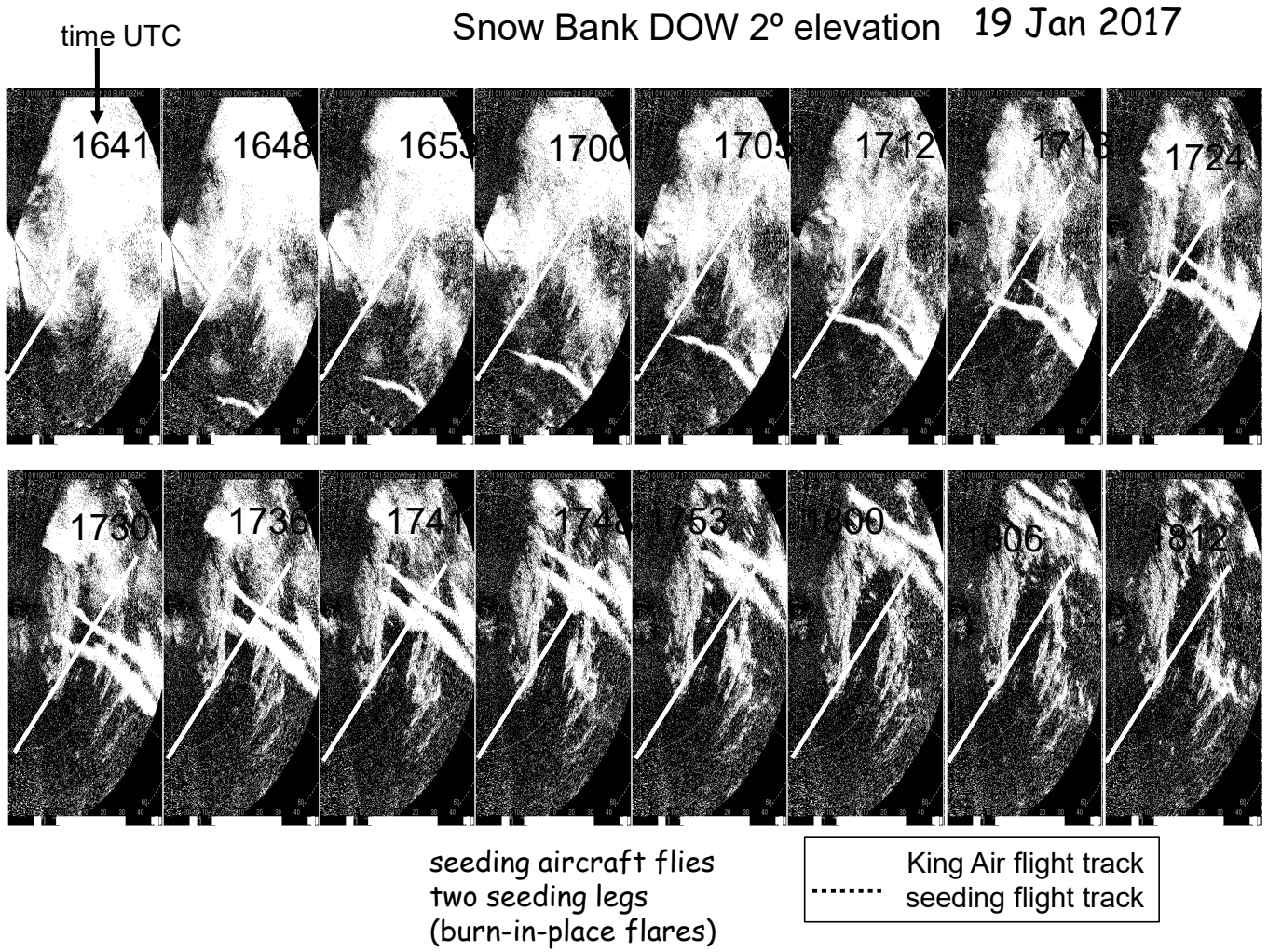

DOW Snow
DOW Pack
20 km range rings from PJ



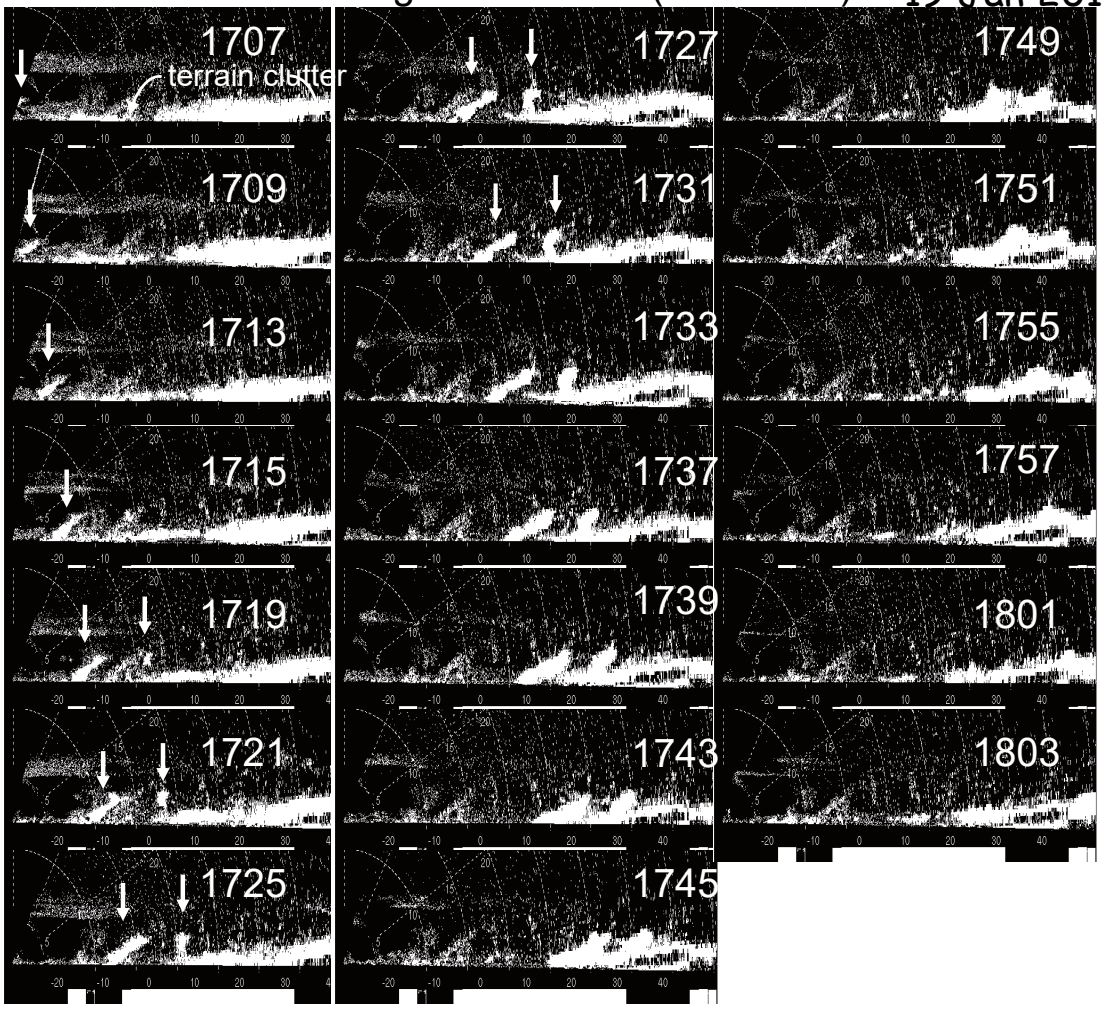
SNOWIE IOP

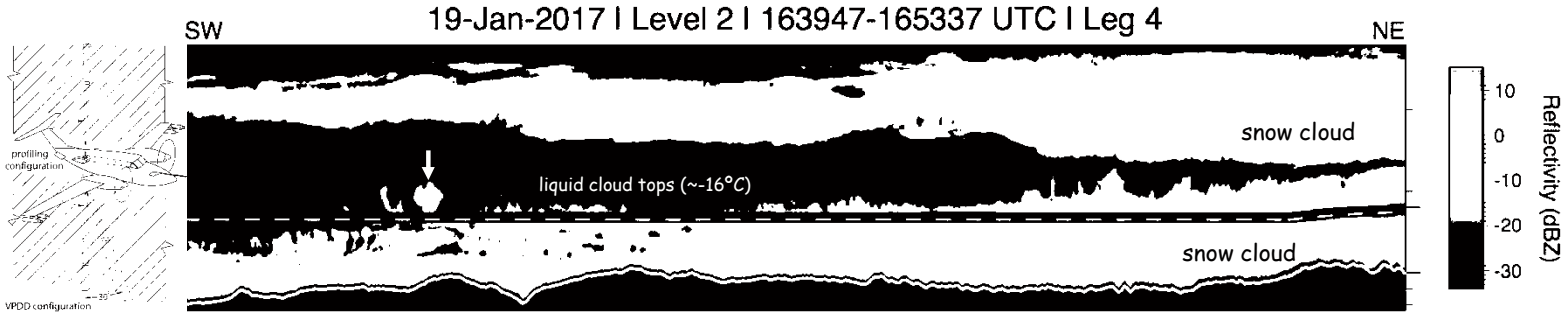
Seeded and Natural Orographic Wintertime clouds - the Idaho Experiment Intensive Observation Period

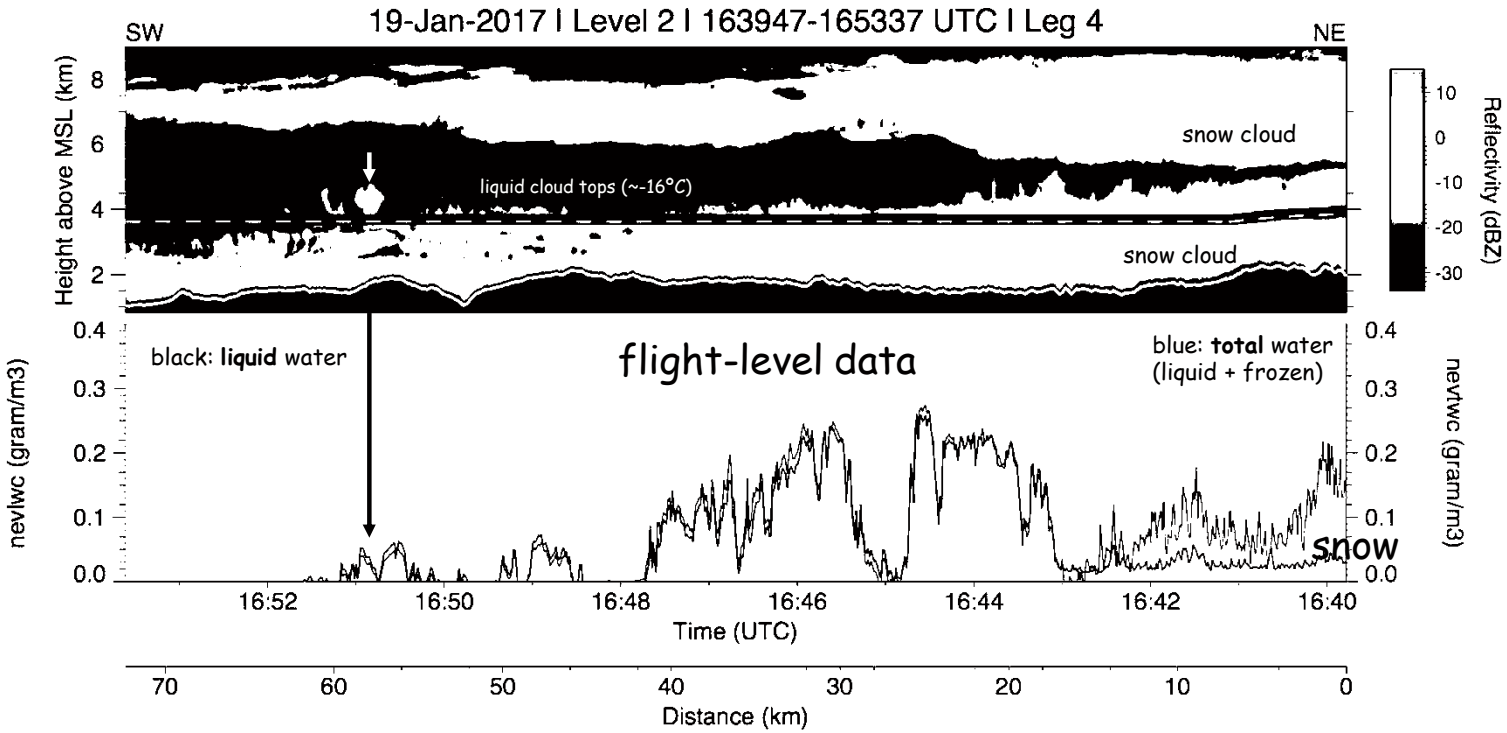


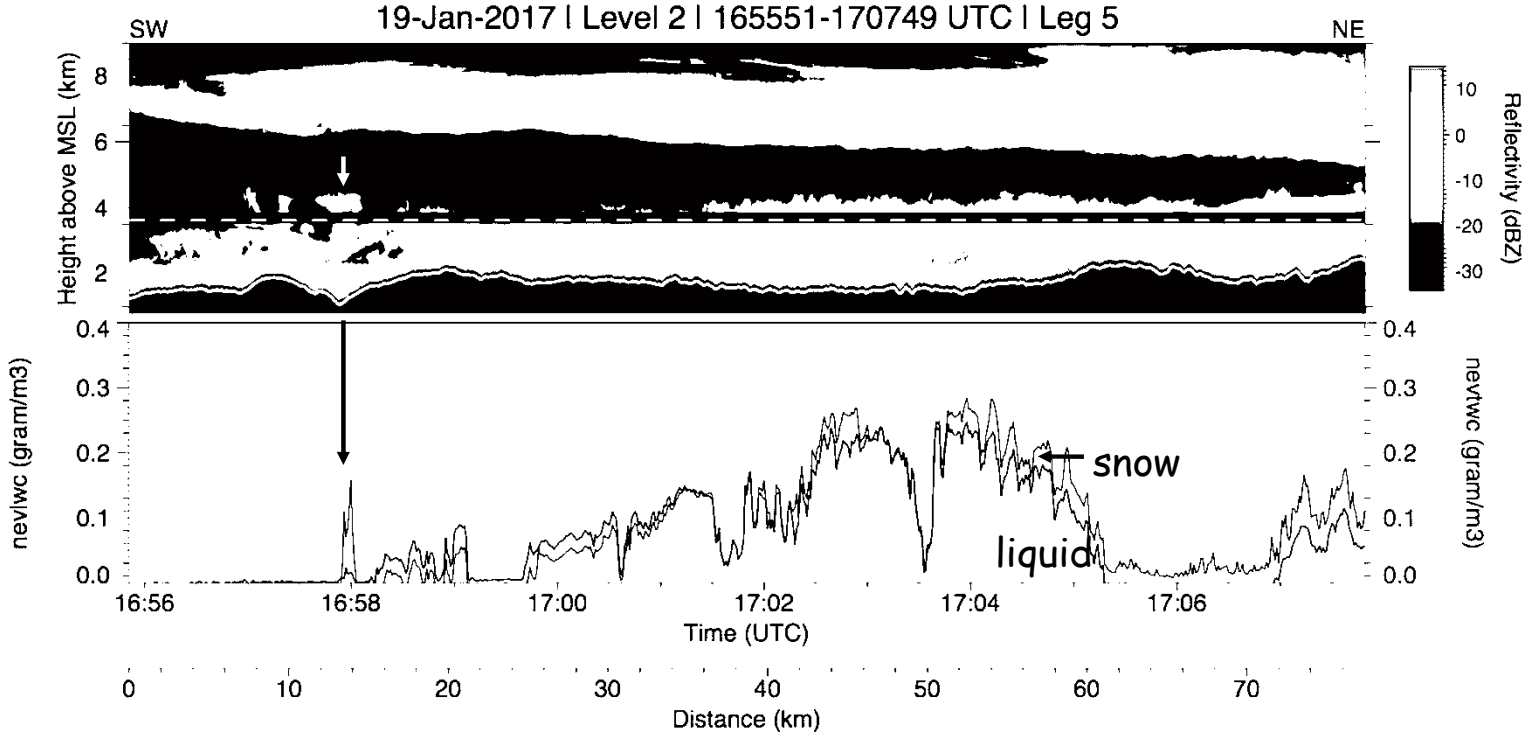

time UTC
Snow Bank DOW 2º elevation 19 Jan 2017
1641
1648
1653
1700
1712
1724
1730
1736
1800
1806
1812
seeding aircraft flies
two seeding legs
(burn-in-place flares)
King Air flight track
seeding flight track

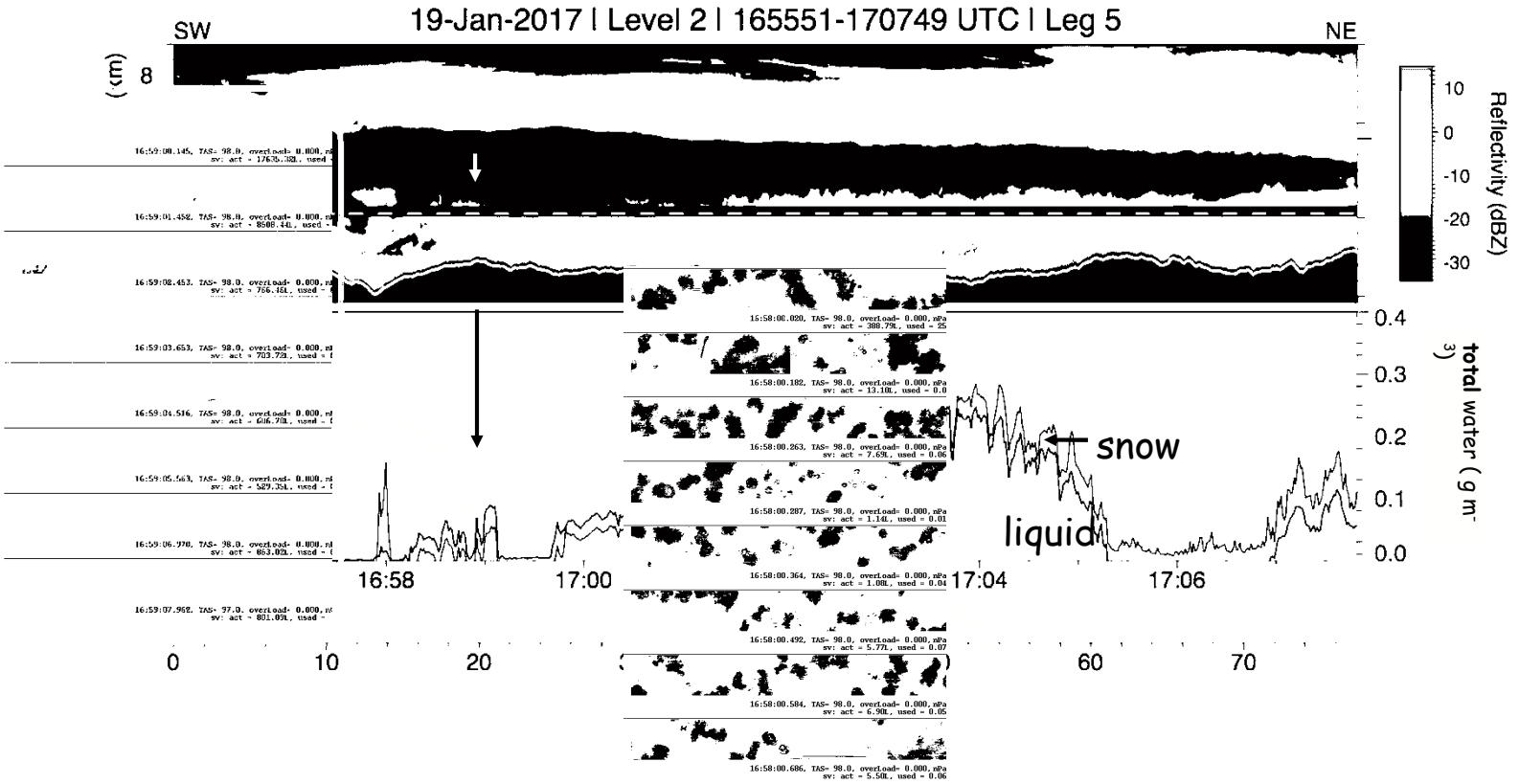
Packer John DOW7 RHIs along UWKA track (downwind) 19 Jan 2017

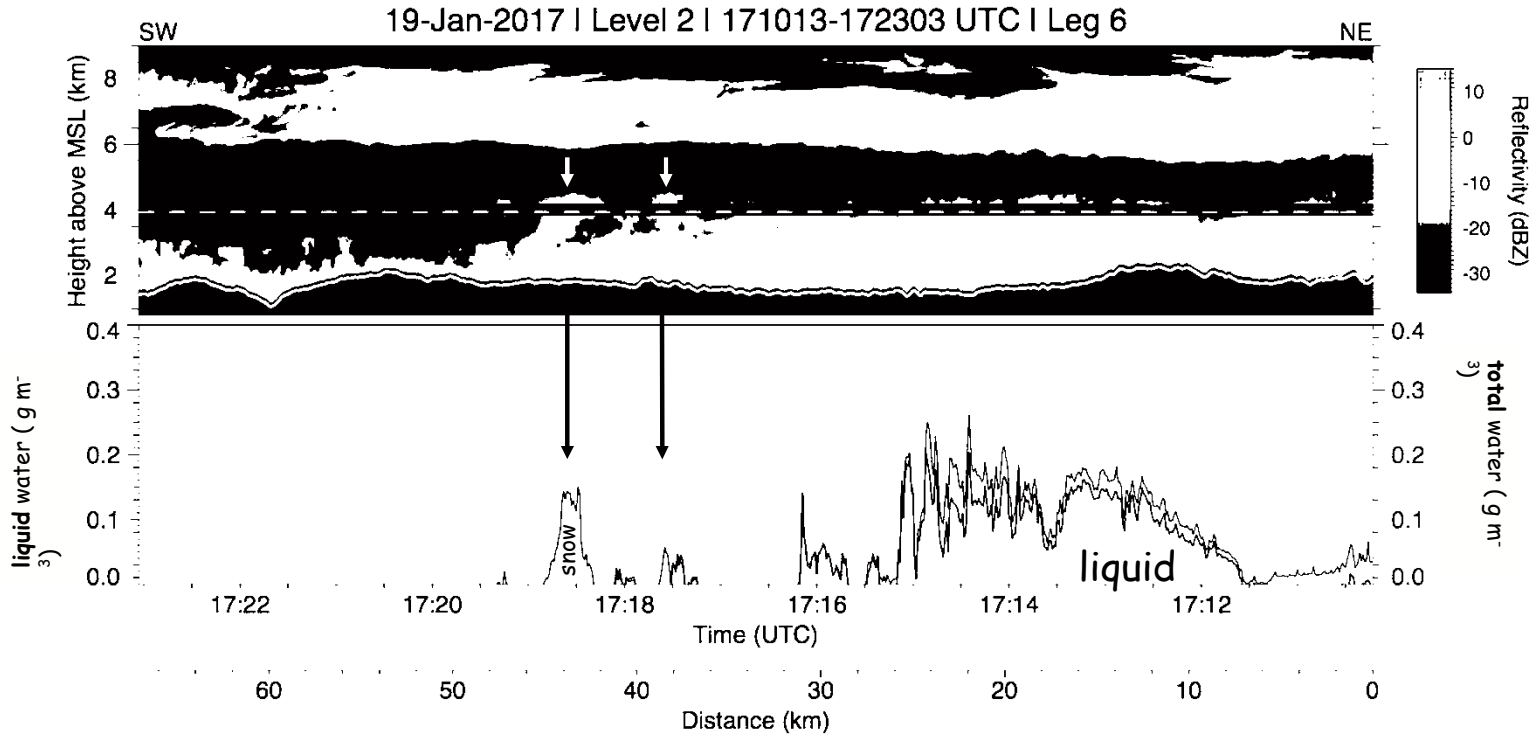


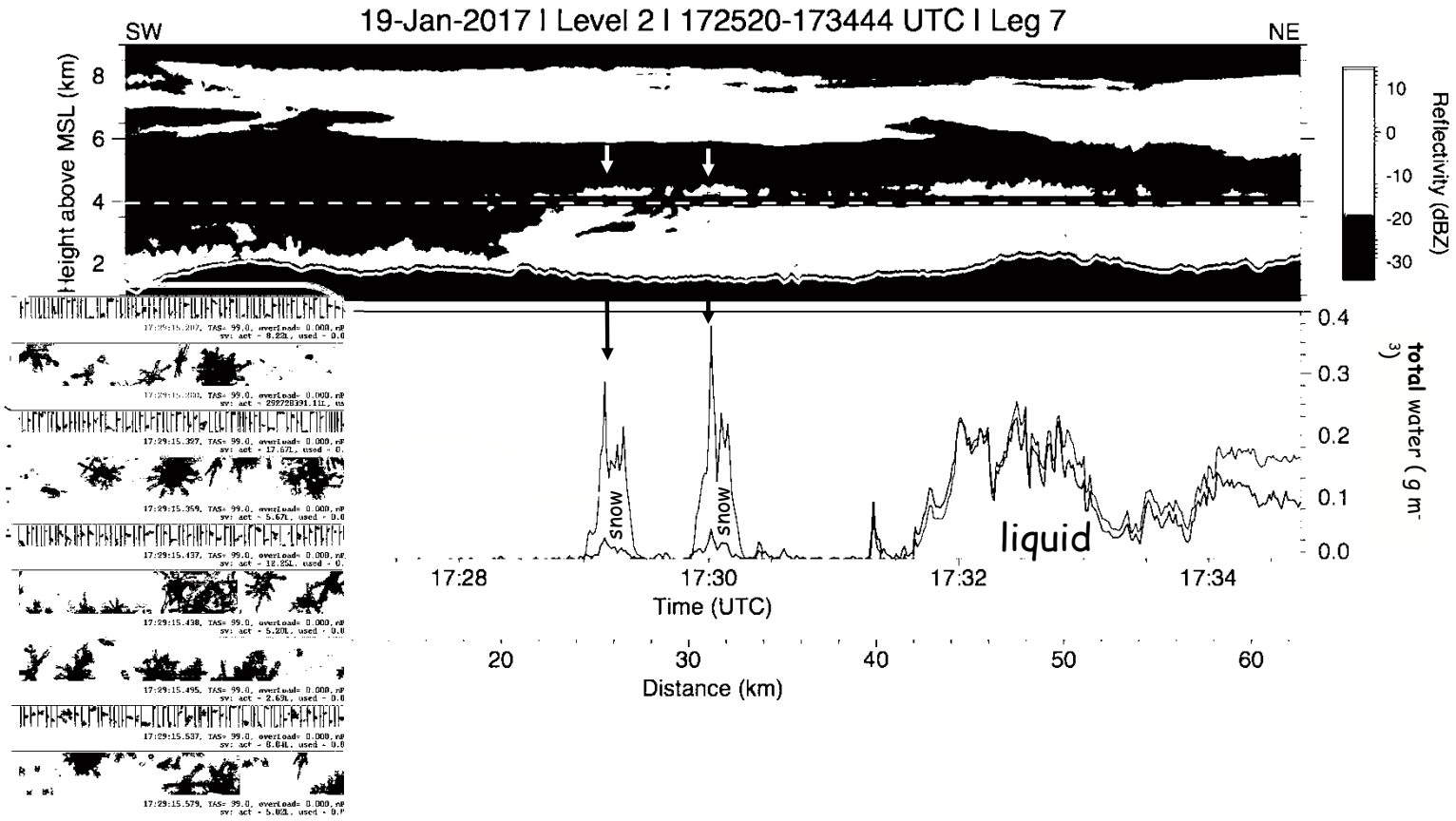

19-Jan-2017 I Level 2 I 163947-165337 UTC I Leg 4
SW
NE
profiling configuration
VPDD configuration
liquid cloud tops (~-16°C)
snow cloud
snow cloud
10
0
-10
-20
-30
Reflectivity (dBZ)


19-Jan-2017 I Level 2 I 163947-165337 UTC I Leg 4
SW
NE
Height above MSL (km)
8
6
4
2
liquid cloud tops (~-16°C)
snow cloud
snow cloud
Reflectivity (dBZ)
10
0
-10
-20
-30
flight-level data
black: liquid water
blue: total water
(liquid + frozen)
snow
nevlwc (gram/m3)
nevtwc (gram/m3)
0.4
0.3
0.2
0.1
0.0
16:52
16:50
16:48
16:46
16:44
16:42
16:40
Time (UTC)
70
60
50
40
30
20
10
0
Distance (km)


19-Jan-2017 | Level 2 | 165551-170749 UTC | Leg 5
SW
NE
Height above MSL (km)
8
6
4
2
Reflectivity (dBZ)
10
0
-10
-20
-30
nevlwc (gram/m3)
nevtwc (gram/m3)
0.4
0.3
0.2
0.1
0.0
snow
liquid
16:56
16:58
17:00
17:02
17:04
17:06
Time (UTC)
0
10
20
30
40
50
60
70
Distance (km)


19-Jan-2017 | Level 2 | 165551-170749 UTC | Leg 5
SW
NE
(km)
8
Reflectivity (dBZ)
10
0
-10
-20
-30
0.4
0.3
0.2
0.1
0.0
total water (g m-3)
snow
liquid
16:58
17:00
17:04
17:06
0
10
20
60
70


19-Jan-2017 I Level 2 I 171013-172303 UTC I Leg 6
SW
NE
Height above MSL (km)
8
6
4
2
Reflectivity (dBZ)
10
0
-10
-20
-30
0.4
0.3
0.2
0.1
0.0
liquid water (g m-3)
total water (g m-3)
snow
liquid
17:22
17:20
17:18
17:16
17:14
17:12
Time (UTC)
60
50
40
30
20
10
0
Distance (km)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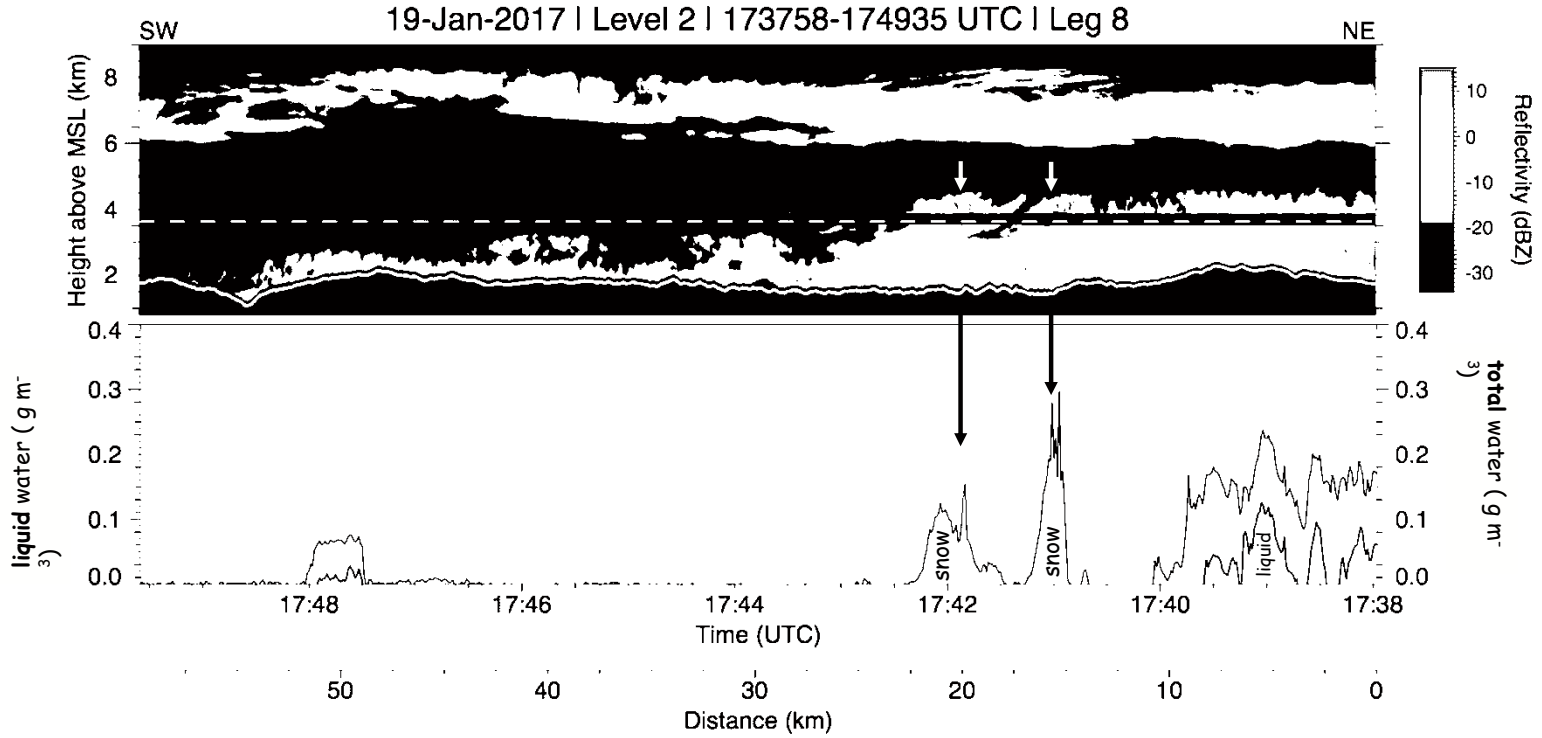
SW
NE
Height above MSL (km)
8
6
4
2
Reflectivity (dBZ)
10
0
-10
-20
-30
snow
snow
liquid
0.4
0.3
0.2
0.1
0.0
total water (g m-3)
17:28
17:30
17:32
17:34
Time (UTC)
20
30
40
50
60
Distance (km)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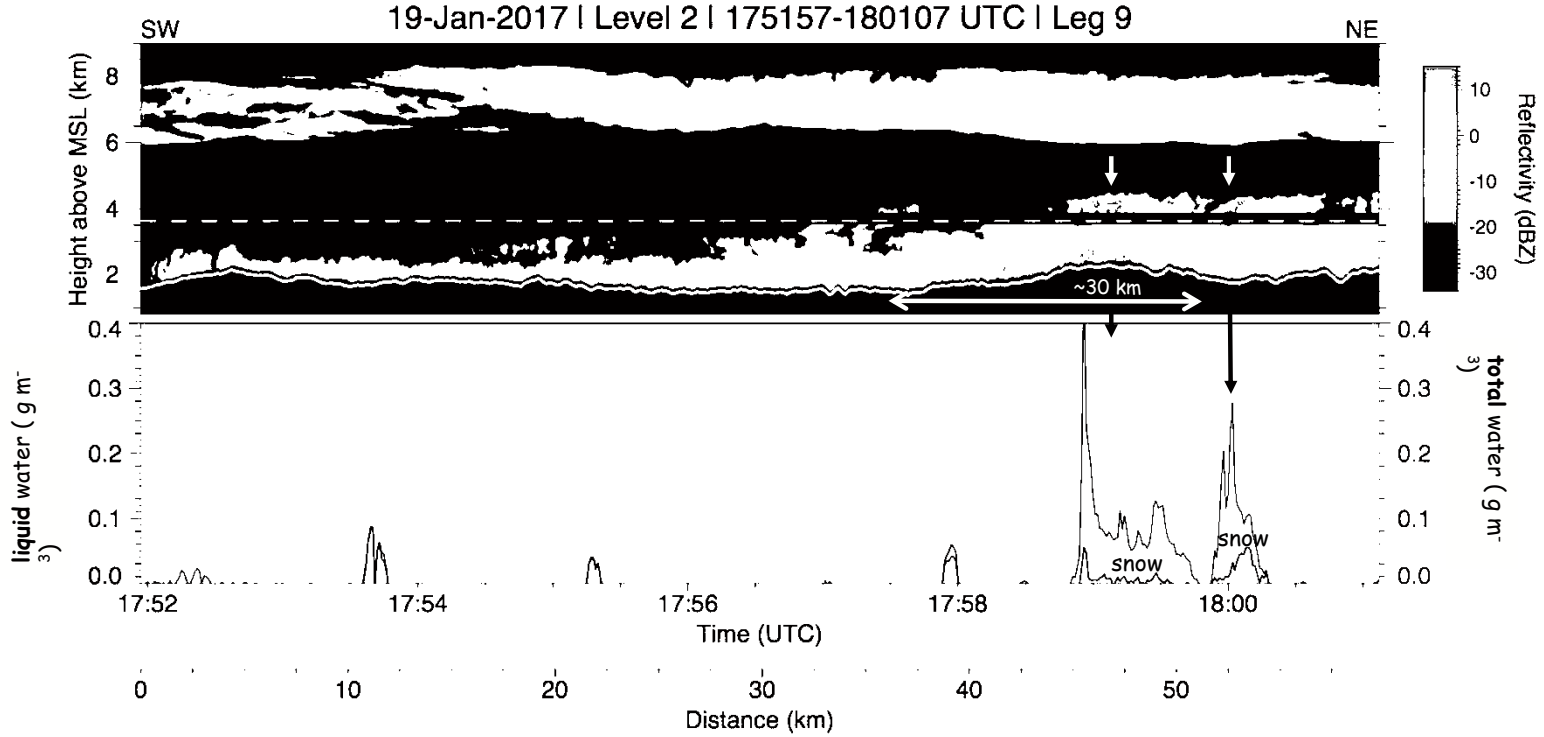
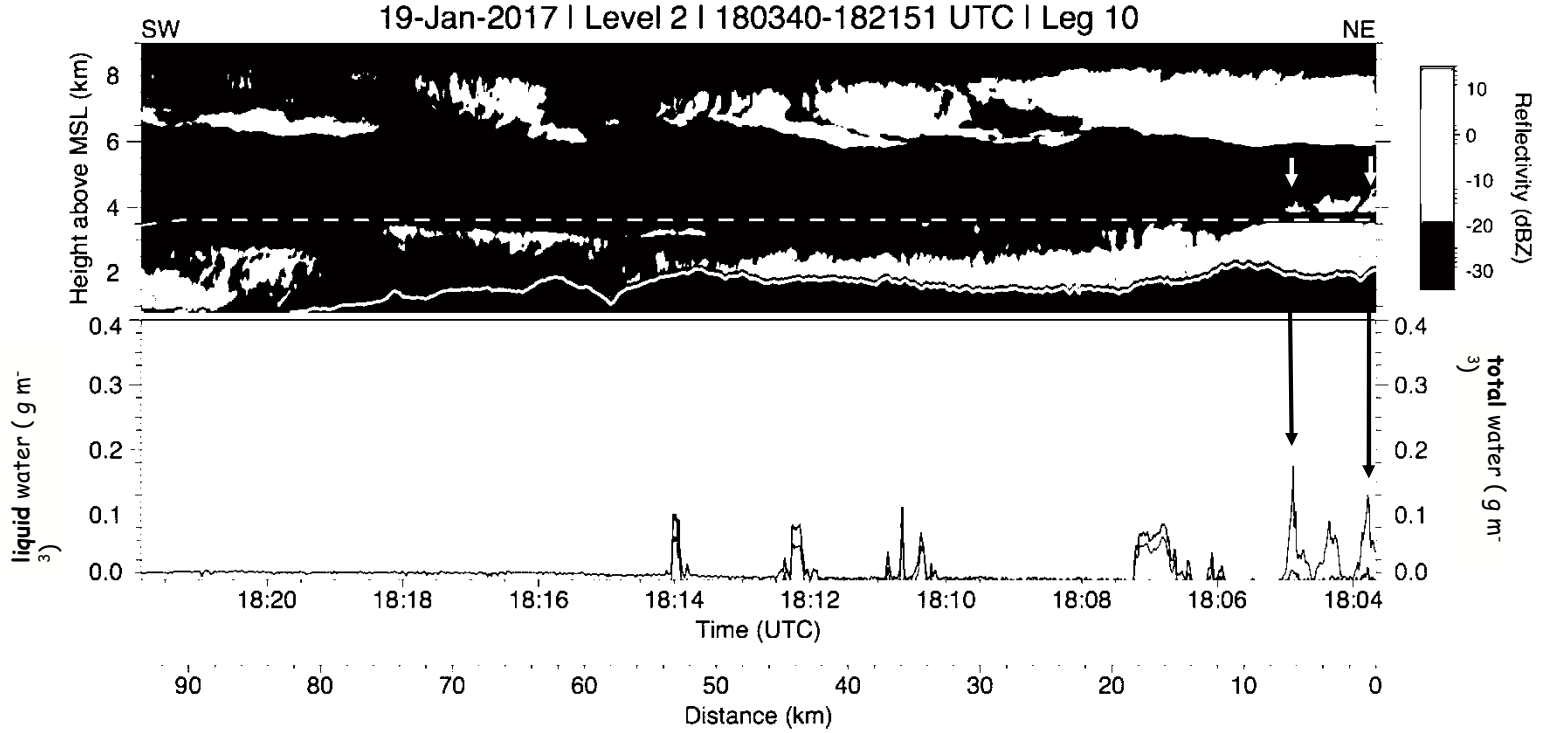
SW
NE
Height above MSL (km)
8
6
4
2
Reflectivity (dBZ)
10
0
-10
-20
-30
liquid water (g m-3)
total water (g m-3)
0.4
0.3
0.2
0.1
0.0
snow
snow
liquid
17:48
17:46
17:44
17:42
17:40
17:38
Time (UTC)
50
40
30
20
10
0
Distance (km)


19-Jan-2017 | Level 2 | 175157-180107 UTC | Leg 9
SW
NE
Height above MSL (km)
8
6
4
2
~30 km
Reflectivity (dBZ)
10
0
-10
-20
-30
liquid water (g m-3)
total water (g m-3)
0.4
0.3
0.2
0.1
0.0
snow
snow
17:52
17:54
17:56
17:58
18:00
Time (UTC)
0
10
20
30
40
50
Distance (km)


19-Jan-2017 | Level 2 | 180340-182151 UTC | Leg 10
SW
NE
Height above MSL (km)
8
6
4
2
Reflectivity (dBZ)
10
0
-10
-20
-30
liquid water (g m-3)
total water (g m-3)
0.4
0.3
0.2
0.1
0.0
18:20
18:18
18:16
18:14
18:12
18:10
18:08
18:06
18:04
Time (UTC)
90
80
70
60
50
40
30
20
10
0
Distance (km)

Original Cloud Seeding Racetrack Experiment

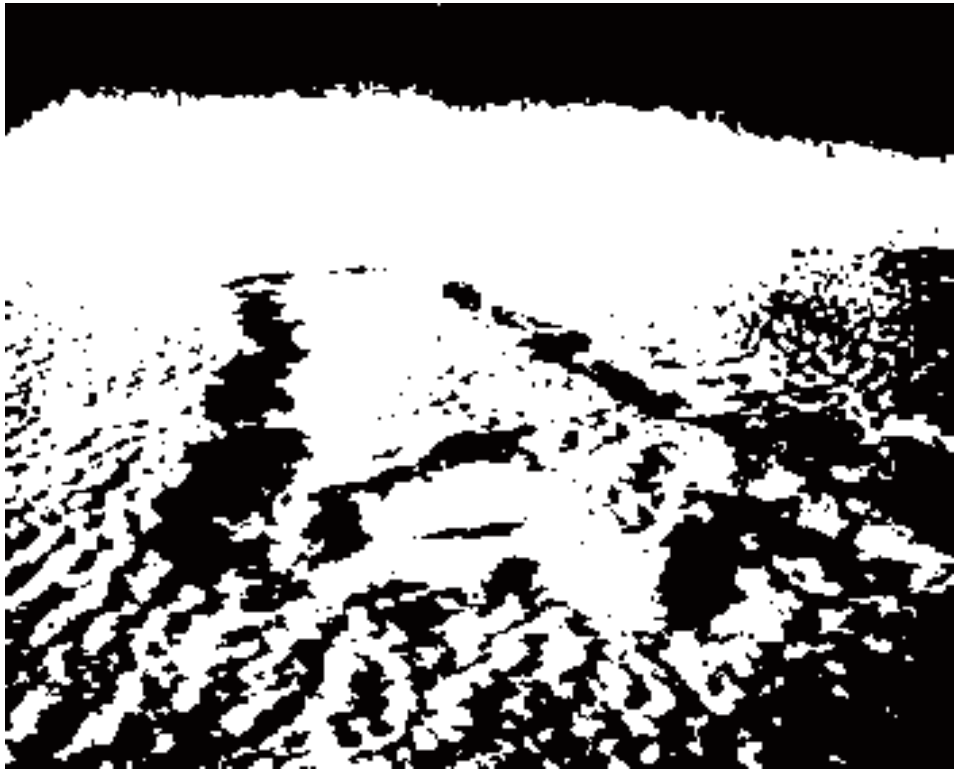
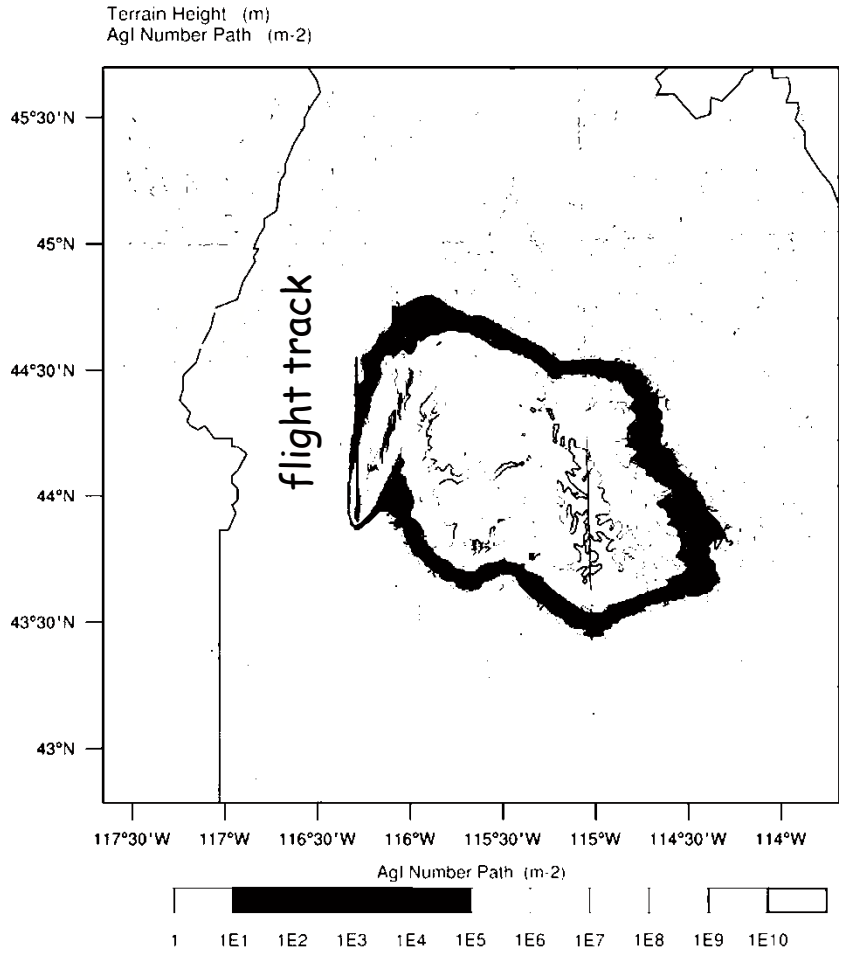
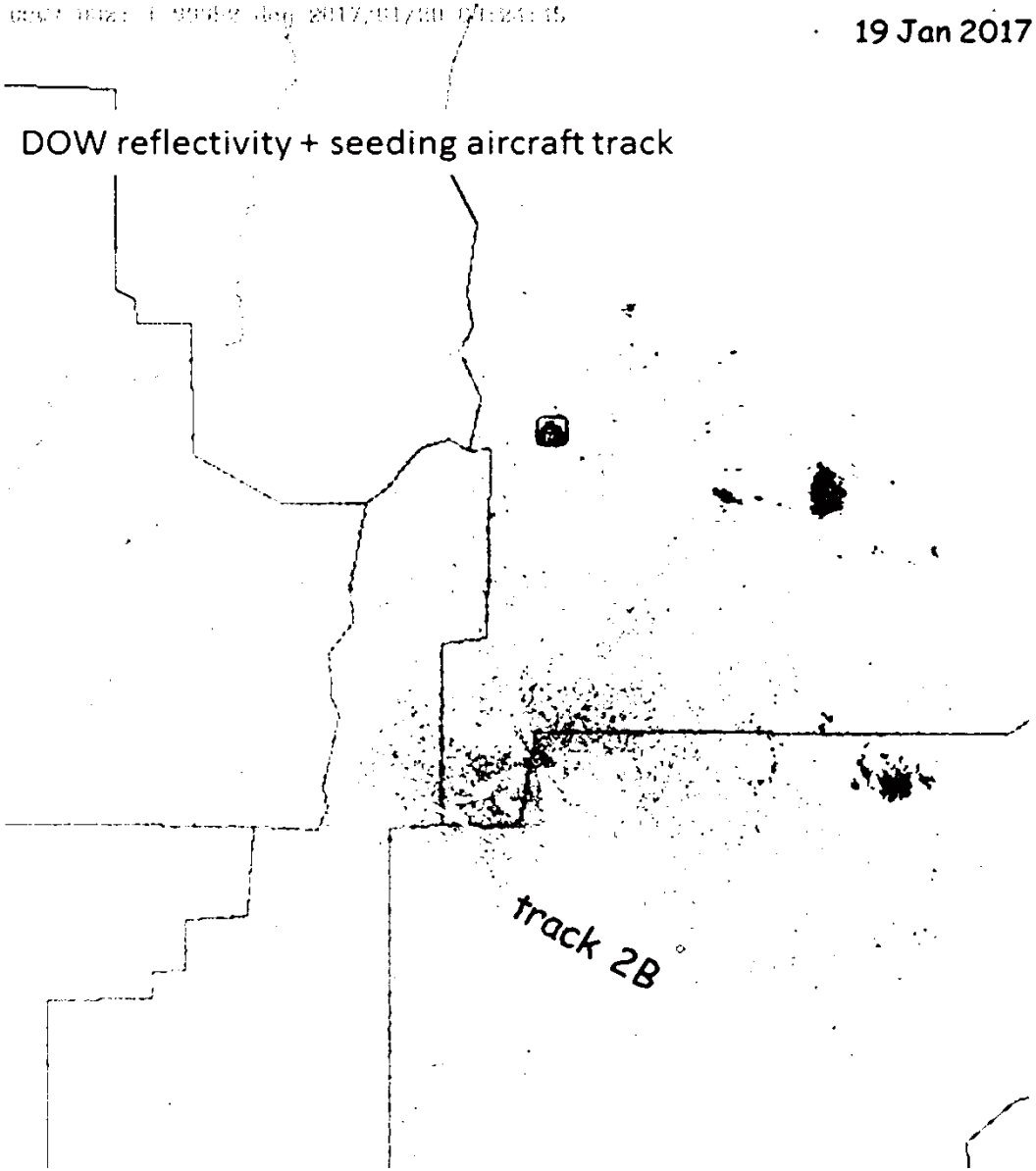


Photo Courtesy of Dr. Vincent Schaefer

NCAR airborne seeding simulator



19 Jan 2017

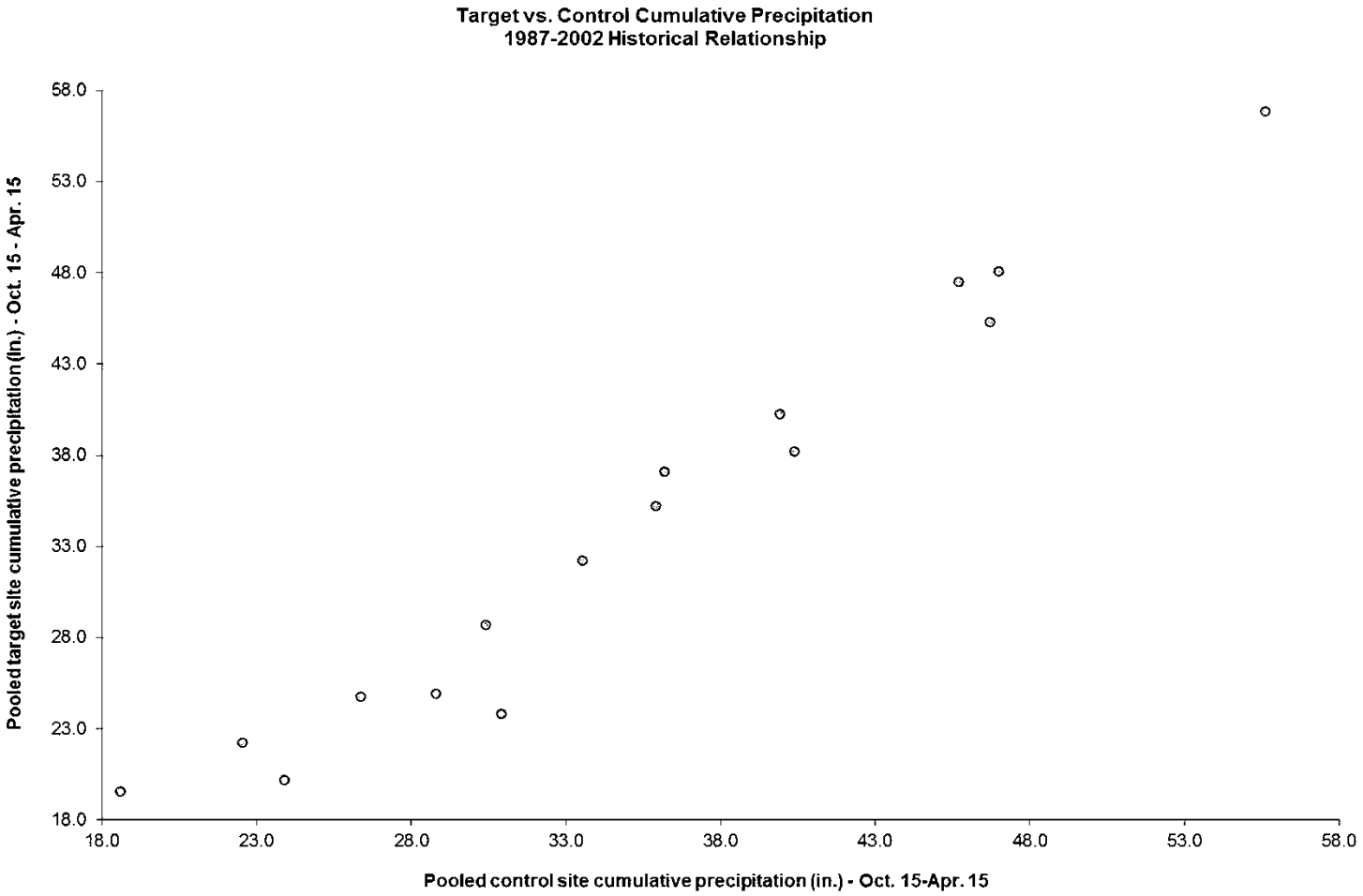


Benefit Estimation

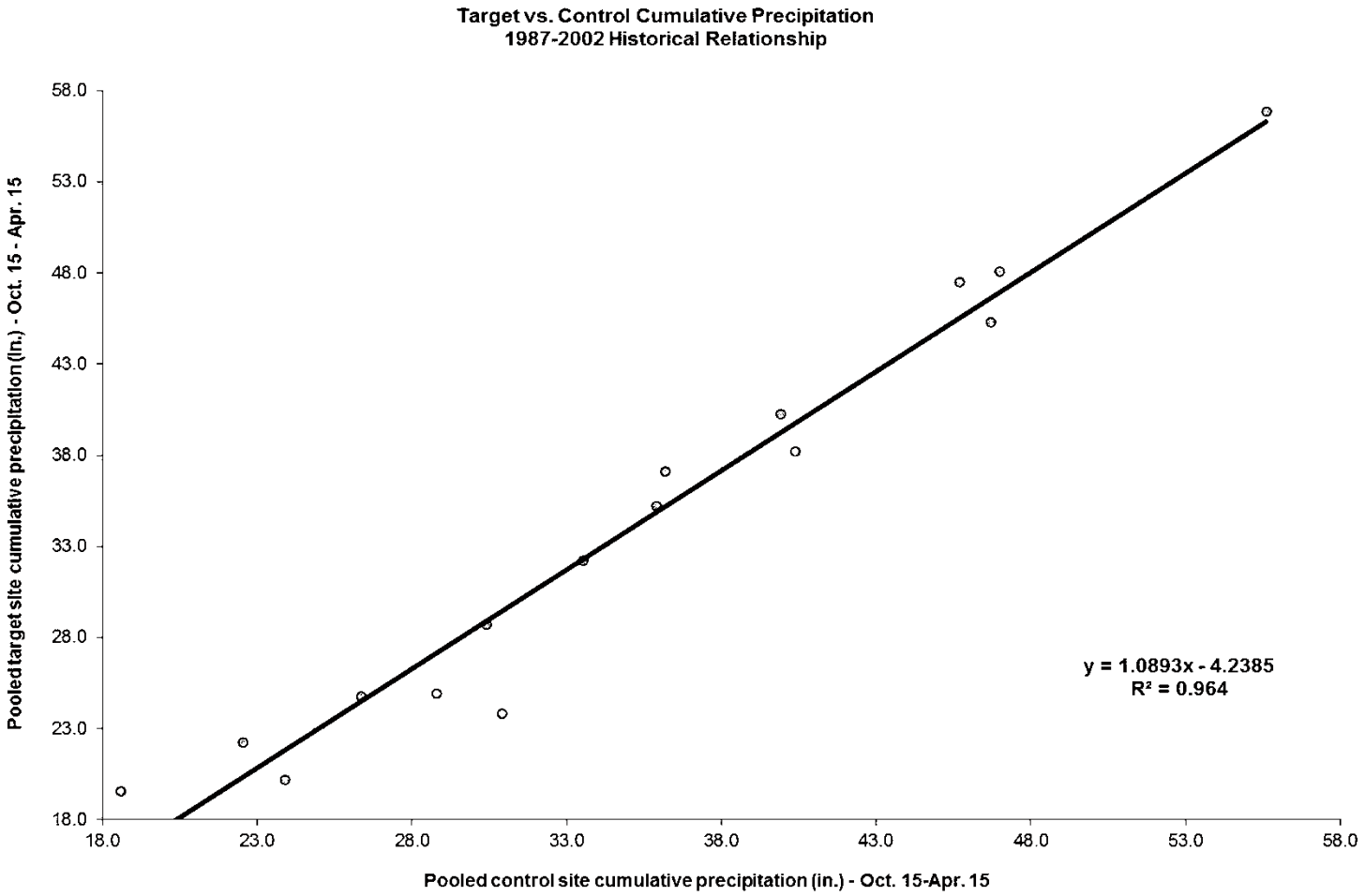
Several different approaches to assess benefits:

1) Target-Control Analysis
2) Hydrologic modeling
   - IPC's River Forecast System,
   - *WRF-Hydro (in development)*
3) *Weather Modeling (WRF / WRF-WxMod) (in development)*

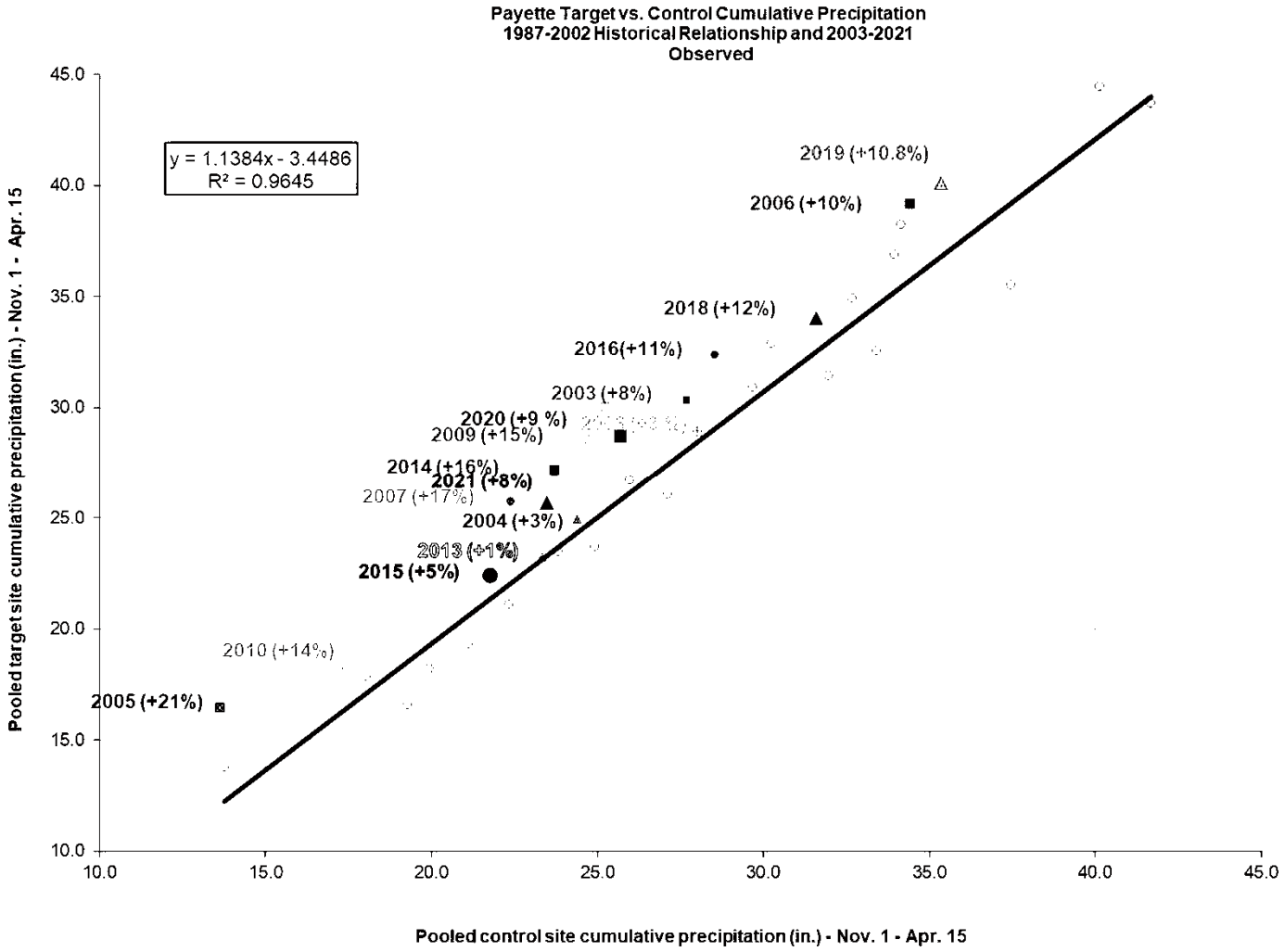
Target/Control - Development



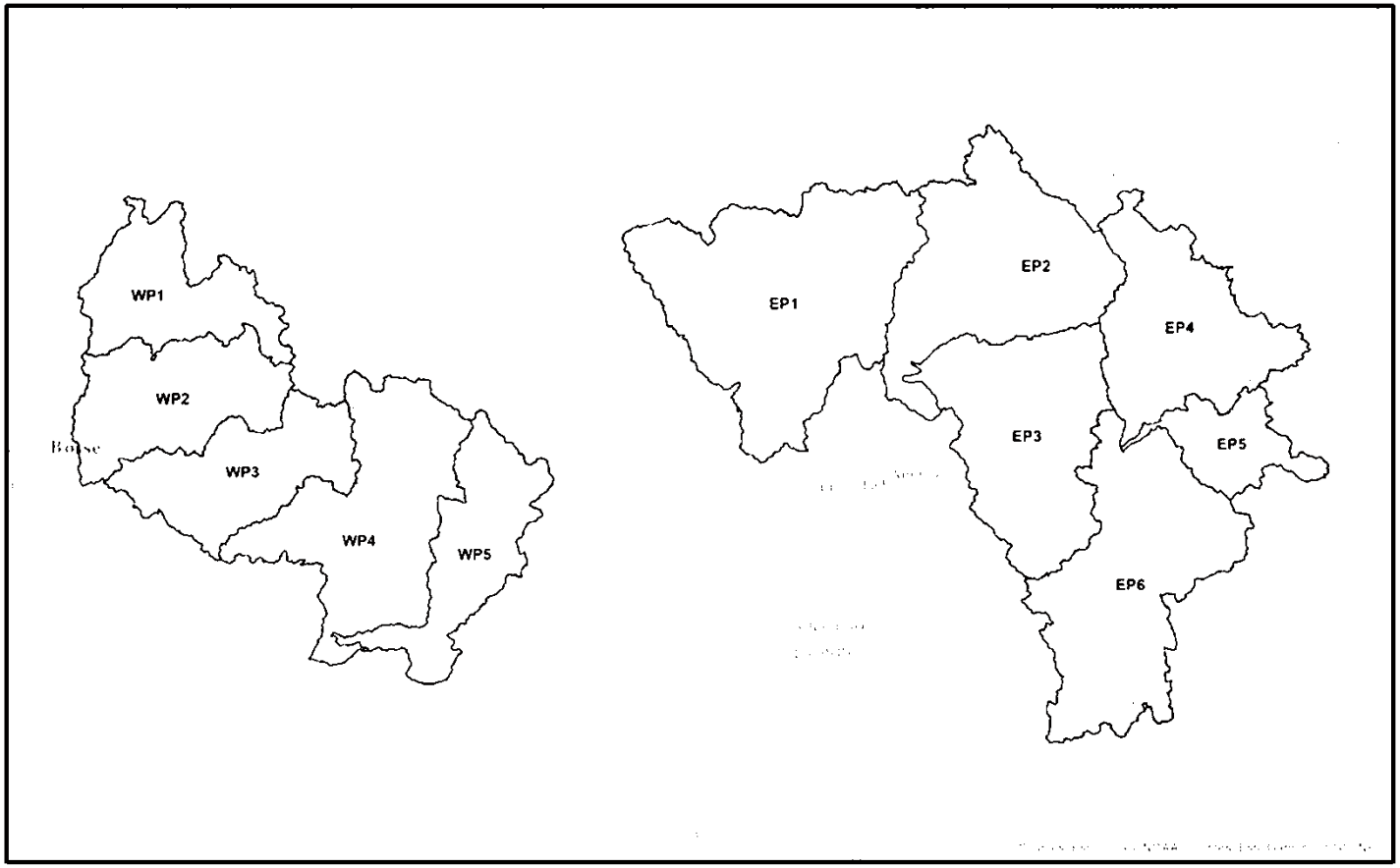
Target/Control - Development



Target Control



Target Control Areas

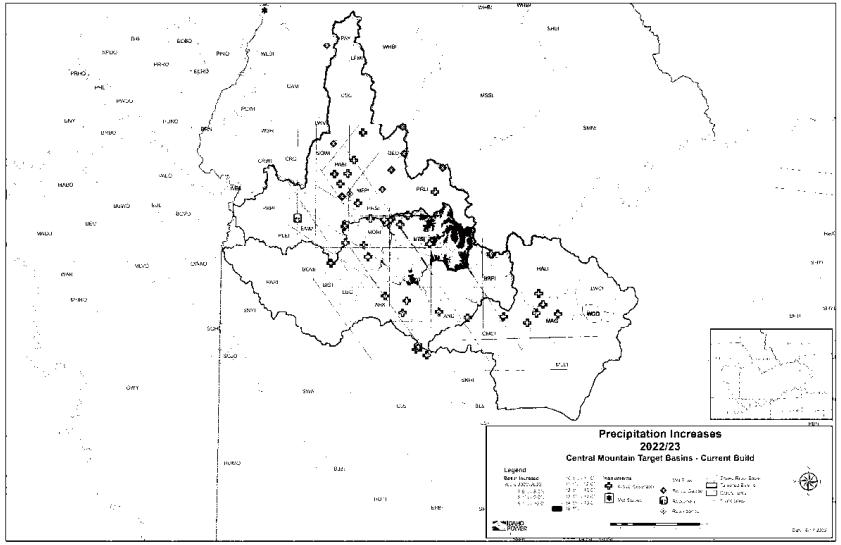


Basin Wide Target Control Results

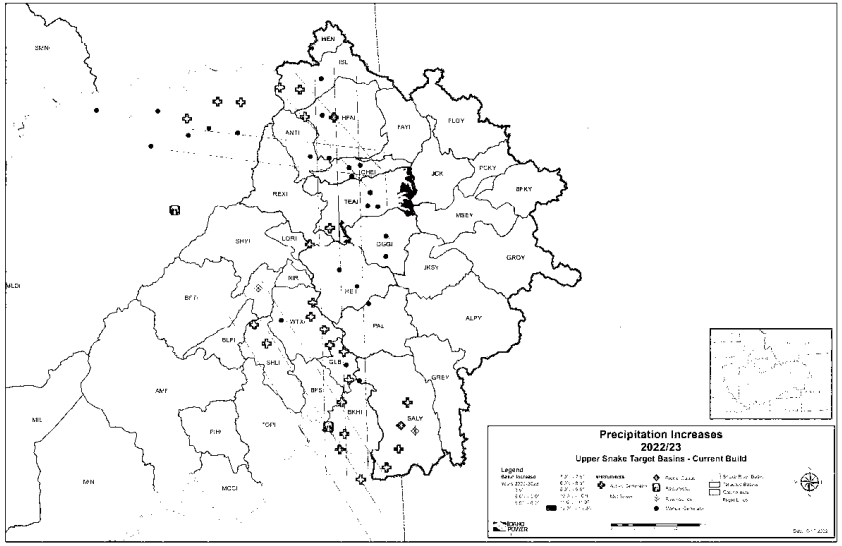
	Payette	Boise		Wood		Henrys Fork		Upper Snake			
Year	WP1	WP2	WP3	WP4	WP5	EP1	EP2	EP3	EP4	EP5	EP6
2003	8%										
2004	3%										
2005	19%										
2006	12%										
2007	14%										
2008	4%					2%	3%	3%	3%	3%	3%
2009	16%					6%	8%	12%	10%	11%	9%
2010	16%					3%	4%	13%	13%	13%	9%
2011	7%					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	7%	7%	6%	6%	7%	5%	4%	6%	6%	6%	5%
2023	16.9%	17.5%	19.1%	11.6%	14.6%	9.1%	10.9%	14.3%	12.9%	11.0%	11.2%
Average	11.5%	12.3%	11.4%	10.2%	9.7%	4.8%	6.2%	10.2%	9.2%	9.6%	7.9%

Estimated Runoff Benefits (Current)

Average Additional Runoff (Natural flow)



- Payette – 223 KAF
- Boise – 273 KAF
- Wood – 112 KAF



Upper Snake – 632 KAF

Abv Palisades – 464 KAF

Henry's Fork – 168 KAF

Total – 1,240 KAF

Extra Area Effects

- Other Names
  - Down Wind Effects
  - Down Range Effects
- One of the most commonly asked question about cloud seeding;
  - "Does increasing precipitation in a particular area decrease the amount of precipitation down range?"
    - This is the "Rob Peter to pay Paul" scenario.
- Research on the subject has shown there are neutral or positive effects (more precipitation) from a well run program

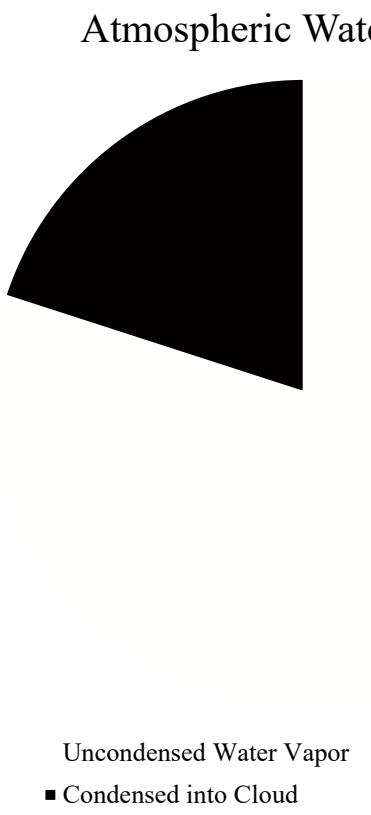
Extra Area Effects

Solak et al. (2003) used a target/control regression approach and concluded positive benefits up to 200 km down range of the target area in central and southern Utah. He also concluded that the apparent limit to extra area increases was about 160 – 200 km.

- North American Weather Consultants expanded this work and concluded that there was a:
  - 14% in the target area
  - 14% increase 0-120 km east of the target area
  - 5% increase 120-240 km east of the target area

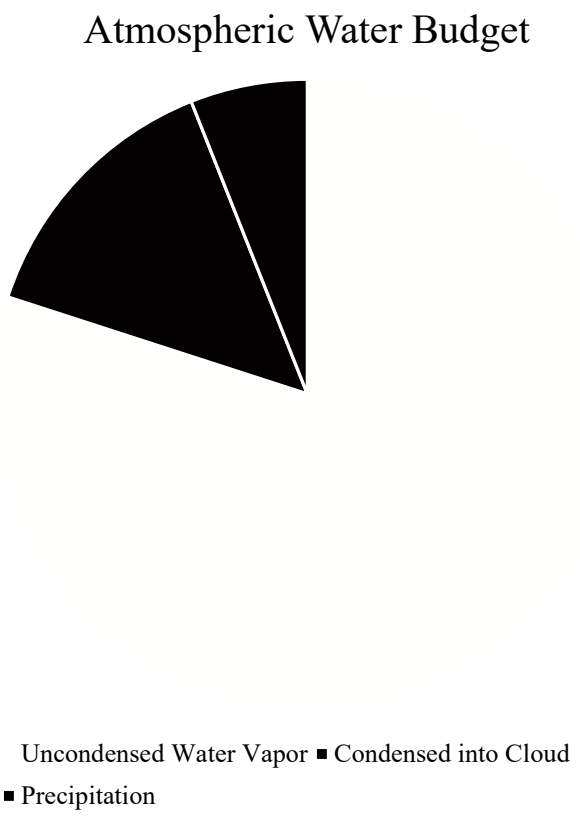
Extra Area Effects

- 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).



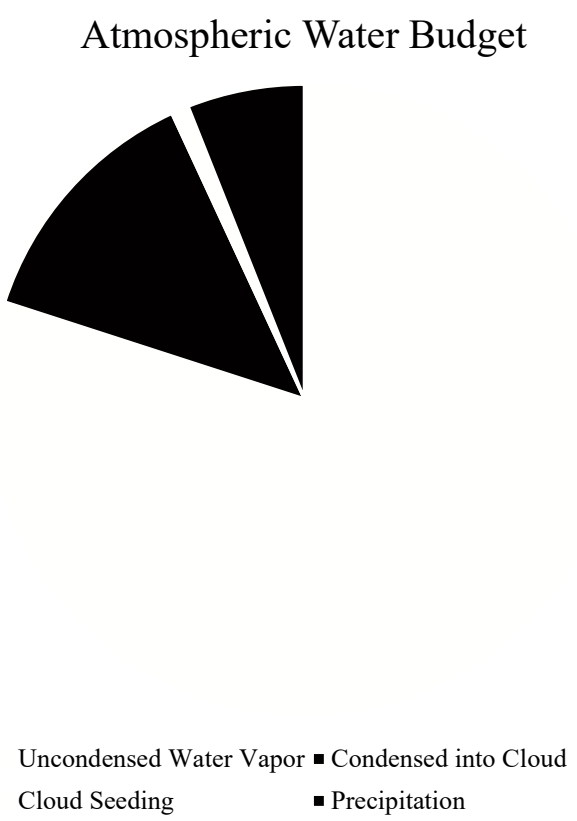
Extra Area Effects

- To put quantities into context…
  - Winter storms are typically about 30% efficient, meaning 30% of the 20%, or 6% of the total, reaches the ground.



Extra Area Effects

- To put quantities into context…
  - 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.



Environmental Safety of Silver Iodide

- The WMA has issued a statement on toxicity of silver originating from cloud seeding… EnvironmentalImpact.pdf (weathermod.org)
- "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 Snow Hydro's seeded watershed resulted in no evidence of adverse environmental impact. https://www.nrc.nsw.gov.au/accordion-content-main/publications-cloud-seeding
  - "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. "
- Other Technical Documents:
  - Publications (weathermod.org)

Environmental Safety

More than 20 comprehensive studies and data reviews of the environmental affect 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
- Sacramental 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

IDEQ Review

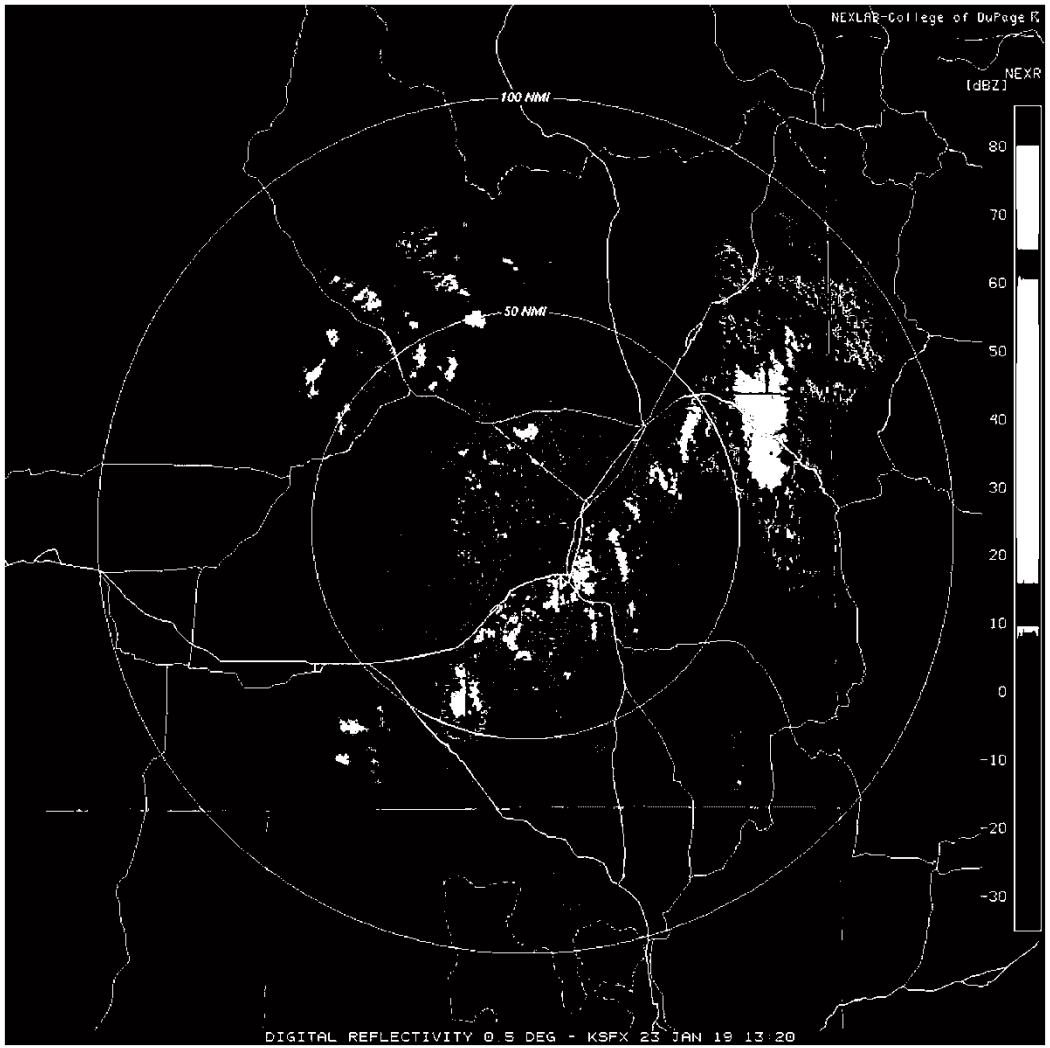
- IDEQ reviewed cloud seeding with respect to water and air quality.
- Water quality - DEQ determined it is **unlikely that cloud seeding will cause a detectable increase in silver concentrations in target area** or pose a chronic effect to sensitive aquatic organisms.
- Air quality permit not needed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

- IDEQ Water and Air Quality Presentation | ESPA CAMP | February 9, 2010 (idaho.gov)

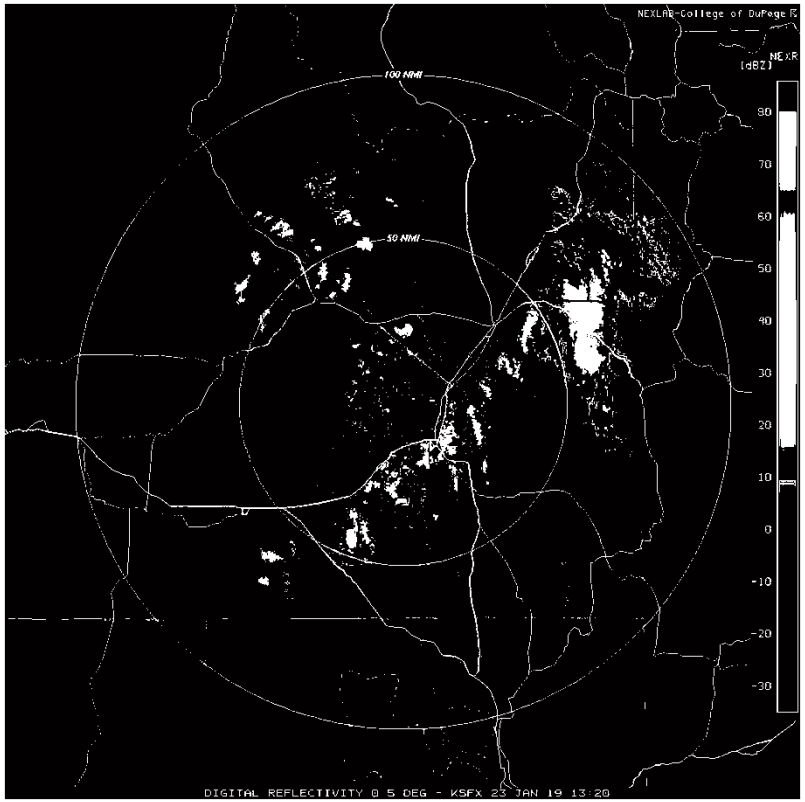
Flooding

- Cloud seeding has raised concerns about flooding from early on
  - Rain-on-snow
  - Excessive snowpack
- Well-designed and responsibly conducted programs include suspension criteria
- Suspension criteria was part of Idaho Power's original proposal to the IPUC
- Suspension criteria are reviewed and updated.
  - Ex. Suspension criteria for the Upper Snake were modified to incorporate reservoir conditions.

Pocatello NWS Radar



Questions?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