This presentation premiered at WaterSmart Innovations

watersmartinnovations.com

watersmart
INNOVATIONS

Forecast 2025: Water Wars by Weather Modification?

October 8, 2015

Amy Vickers
Amy Vickers & Associates, Inc.
Amherst, MA

Masked Kachinas,
Hopi Indian "Rain-makers,"
Village of Shonghopavi,
Arizona, circa 1900
–Library of Congress

Chief Turtle giving his interpretation of the Indians' storm dance, just before the rain came down in torrents, at the Indian celebration in Two Medicine Valley, Glacier National Park, Montana, circa 1920 *–Library of Congress*

Drones Offer New Horizon, Solutions for Weather Modification

By **Katy Galimberti**, AccuWeather.com Staff Writer
June 10, 2014; 4:28 AM ET

Share |

Cloud seeding may be the next frontier for Unmanned Aircraft Systems (UAS), more commonly known as drones, with potential global implications.

The state of Nevada was one of six selected test sites by the Federal Aviation Administration (FAA) in December 2013. One of the state's focuses is how UAS can make cloud seeding an easier, more economical process.

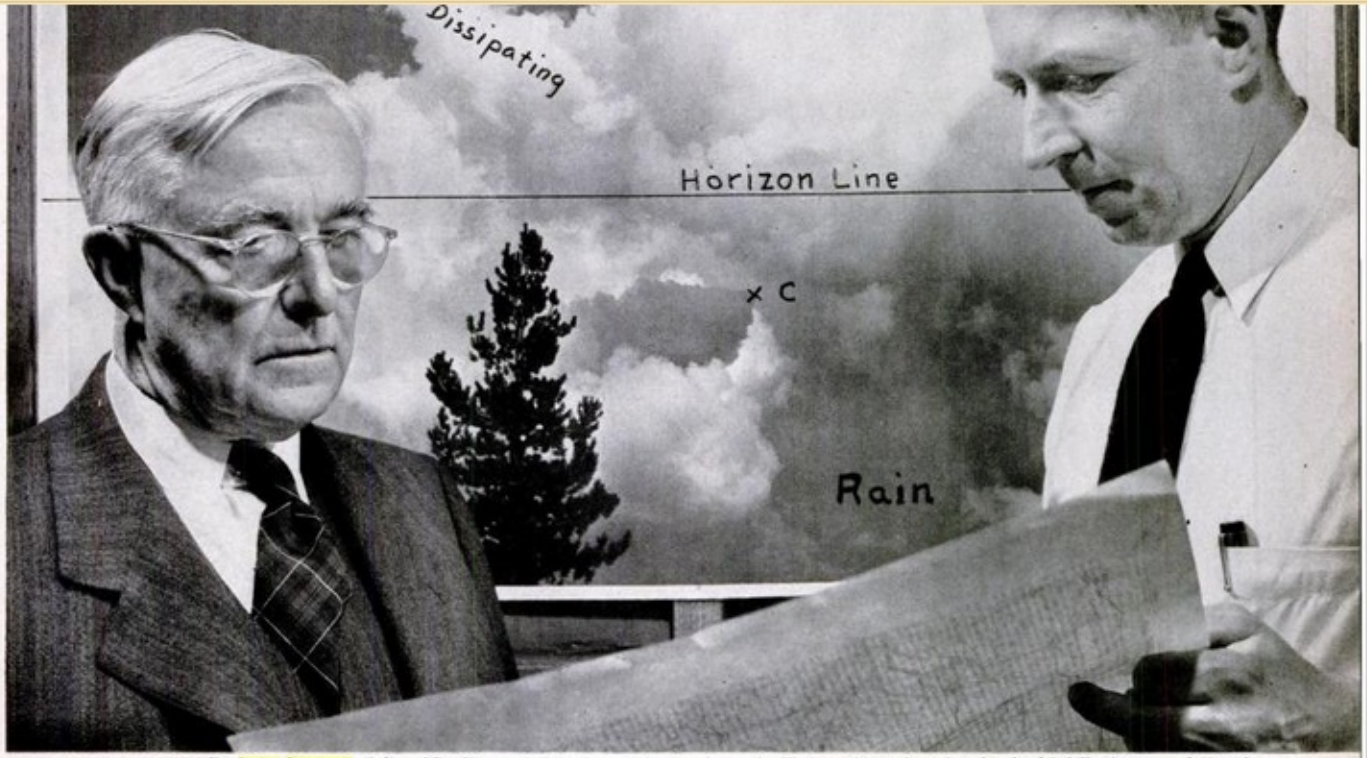
Overview

- History of weather modification
- Science of weather modification
- Water supply and the business of weather modification
- Pros and Cons
- Who controls the weather?

- **Cloud seeding**
- **Weather modification**
- *Weather engineering*
- *Weather forcing*
- *Climate engineering*
- *Geoengineering*
- *Solar radiation management*
- *Weather warfare*

History Of Weather Modification (WM)

- **1860s** Rainfall observed to occur after artillery fire used in major battles of the Civil War
- **1890s** USDA cloud tests in Wash DC and West TX
- **1940s** GE uses CO2 and silver iodide (AgI) to create ice particles over New England
- **1950s** industrial and government research continues
- **1966-72** U.S. “Project Popeye” disperses AgI nuclei in Vietnam, including the Ho Chi Minh trail
- **Today**: weather modification used for water supply, agricultural, commercial, and military purposes in the U.S. and many other countries



WEATHER CHANGERS Dr. Irving Langmuir (*left*) and Dr. Vincent J. Schaefer confer in G.E. laboratory. Behind them is a photo-diagram of a towering cumulus cloud under study. Their markings show that the cloud is billowing upward (A and B), is supercooled, and that moisture is escaping as snow (*upper right*) and rain (C).

SOLUTION TO WATER SHORTAGE?

Rain makers' success shows how New York could fill its reservoirs

One day each week conscientious residents of New York City go bathless, shaveless and half-thirsty to save water in the drought-depleted reservoirs of the metropolis. So far their best day's effort has saved 394 million gallons, a feat of self-denial which raised the level of the reservoirs less than one percent and left them still critically low. Recently, in almost their driest hour, they heard about the startling results of rain-making experiments in New Mexico, which in a few hours produced enough water to fill New York's reservoirs to the brim with enough over to fill them half again.

The test was made by a U.S. government group known as Project Cirrus, master-minded by Dr. Irving Langmuir, 1932 Nobel prizewinner and recently retired associate director of the General Electric Research Laboratory, and his colleague, Dr. Vincent J. Schaefer. The crew fed 10 ounces of a common chemical worth $20 into a blowtorch apparatus and brought down 320 billion gallons of water. The rainfall was produced at a time of year when rain normally is scarce in New Mexico, and Dr. Langmuir figured that the odds against this heavy volume's falling without the scientists' help were 100,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000 to 1.

Other attempts to produce rain artificially in the last three years depended mostly on seeding of clouds with dry ice from airplanes. The new method is carried out entirely from the ground, but both techniques have been most successful with fleecy cumulus clouds which are less stable than either stratus or cirrus clouds. Dr. Langmuir thinks the work is now conclusive enough to warrant serious study by New York, and New York authorities last week asked him to meet with them. Said City Water Commissioner Stephen J. Carney, "We are looking into the legal side of it. Maybe we would have to get permission from the state or the federal government. We aren't sure what our responsibility would be to anyone who didn't want rain, and we don't even know who owns the clouds."

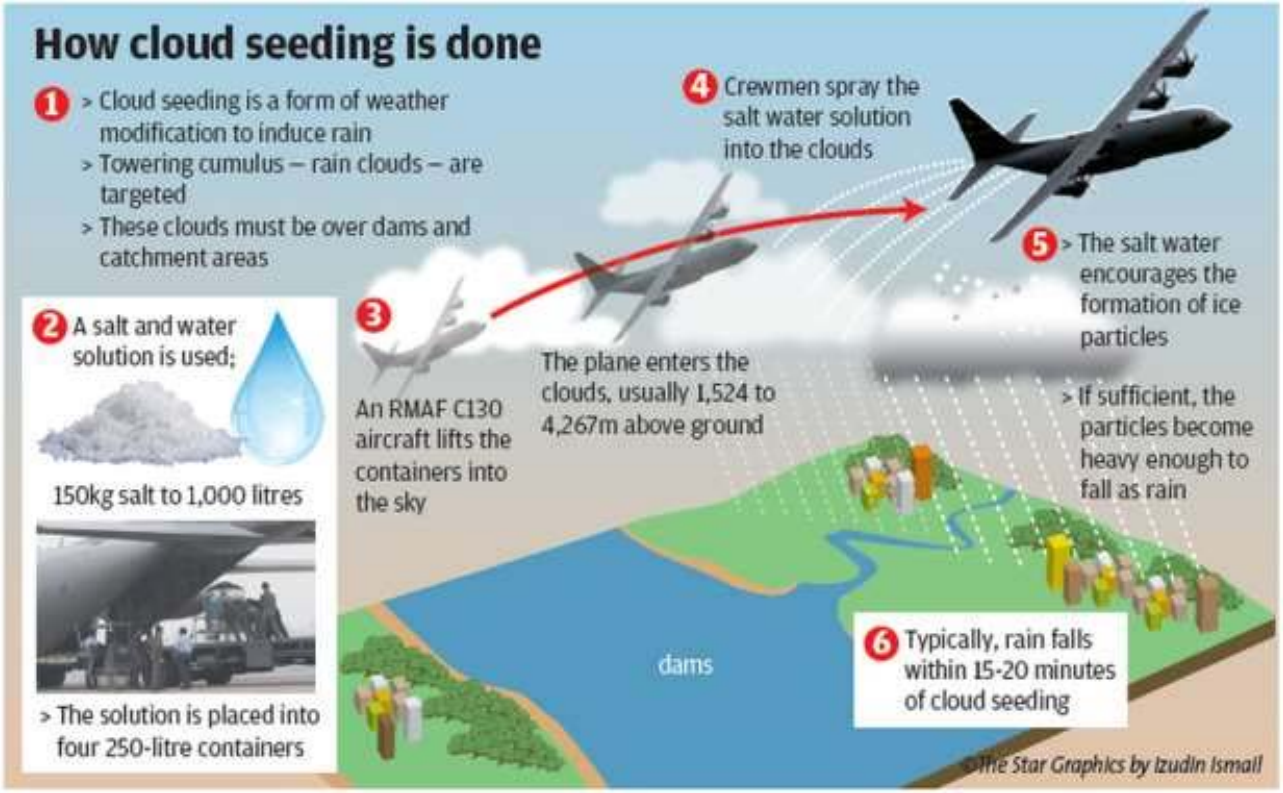
GLASS-WALLED CLOUD BOX, examined by Dr. Schaefer, is used to simulate natural cloud conditions.

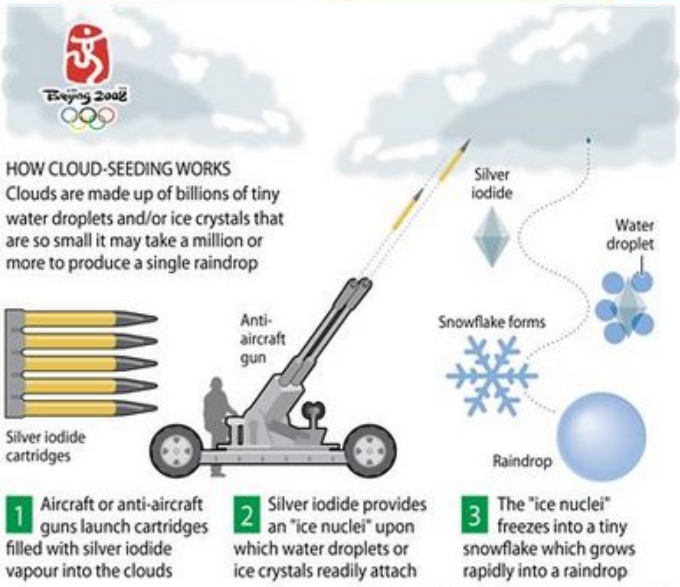
The Rainmaker, 1956

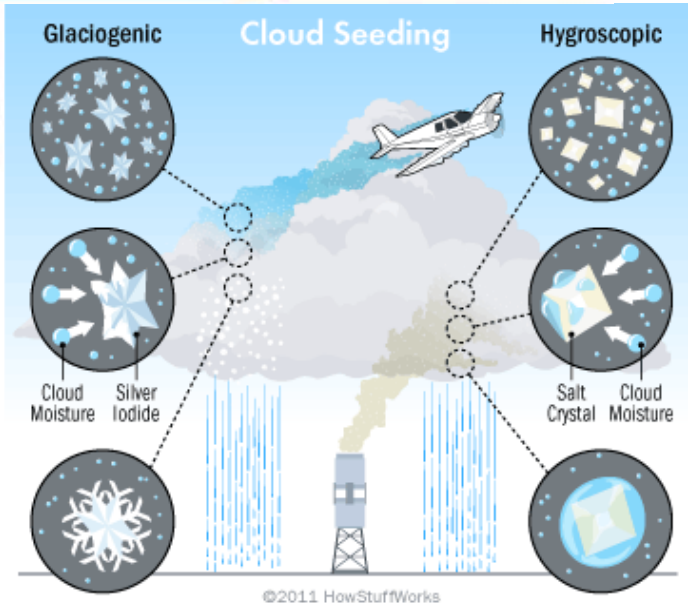
Advertising poster for General Dynamics showing a stylized weather system within a beaker.
"Exploring the universe - weather control: General Dynamics."
–Erik Nitsche,1957

Science Of Weather Modification (WM)

- **Alteration of weather and weather patterns**
  - Suppression and intensification
- **Basic/Older: Cloud seeding to increase rainfall in a local area**
  - Nucleating agents silver iodide (AgI) or dry ice introduced into clouds cause water vapor to freeze or reduce to hail
    - water vapor/gaseous -> solid state
  - Ground-based generators or aircraft
  - Precipitation increases of about 5% to 15%
- **Advanced/Newer: WM used to affect larger areas, weather *systems***
  - Rain, snow, hail, clouds, fog
  - Wind, temperature, solar radiation
  - Storm systems, weather patterns, space weather (communications)
  - Chemicals, particles, fibers, electromagnetic, lasers
  - Ground and atmospheric arrays
  - Example: Injection of chemical vapors, aerosols, heating or charging of particles via electromagnetic radiation or particle beams


How cloud seeding is done
1 > Cloud seeding is a form of weather modification to induce rain
> Towering cumulus – rain clouds – are targeted
> These clouds must be over dams and catchment areas
2 A salt and water solution is used;
150kg salt to 1,000 litres
> The solution is placed into four 250-litre containers
3 An RMAF C130 aircraft lifts the containers into the sky
The plane enters the clouds, usually 1,524 to 4,267m above ground
4 Crewmen spray the salt water solution into the clouds
5 > The salt water encourages the formation of ice particles
> If sufficient, the particles become heavy enough to fall as rain
dams
6 Typically, rain falls within 15-20 minutes of cloud seeding
©The Star Graphics by Izudin Ismail


Beijing 2008
HOW CLOUD-SEEDING WORKS
Clouds are made up of billions of tiny water droplets and/or ice crystals that are so small it may take a million or more to produce a single raindrop
Silver iodide
Water droplet
Snowflake forms
Anti-aircraft gun
Silver iodide cartridges
Raindrop
1 Aircraft or anti-aircraft guns launch cartridges filled with silver iodide vapour into the clouds
2 Silver iodide provides an "ice nuclei" upon which water droplets or ice crystals readily attach
3 The "ice nuclei" freezes into a tiny snowflake which grows rapidly into a raindrop
Beijing 2008 logo and pictograms ™ © BOCOG


Glaciogenic
Cloud Seeding
Hygroscopic
Cloud Moisture
Silver Iodide
Salt Crystal
Cloud Moisture
©2011 HowStuffWorks

“IT IS NOT UNREALISTIC to expect that mankind will eventually have the power to influence weather, and even climate, on a large scale. However, the complexity of the atmospheric processes is such that a change in the weather induced artificially in one part of the world will necessarily have repercussions elsewhere.”

World Meteorological Organization, Second Report On The Advancement Of Atmospheric Sciences And Their Application In The Light Of Developments In Outer Space (1963).

Water Supply and the Business of Weather Modification

- Water supply
- Snow-making
- Smog control
- “Have a nice day!”

DRI
Desert Research Institute

DRI Home / DRI News & Communications / DRI In The News / 2013 News Archive / DRI's Cloud Seeding program discussed on WNYC's Leonard Lepate Show

DRI News & Communications

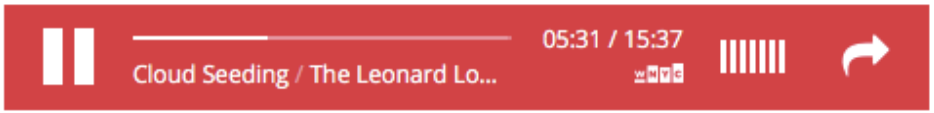
- DRI News and Press Releases
- DRI Media Advisories
- DRI In The News
  - 2014 News Archive
  - 2013 News Archive
  - 2012 News Archive
- DRI Video Gallery
- DRI Photo Gallery

DRI's Cloud Seeding program discussed on WNYC's Leonard Lepate Show

Source: WNYC
Date: 10/02/13
Keywords: DRI, cloud seeding, leonard lopate show

Jeff Tilley Cloud Seeding

Description: Writer Ginger Strand explains cloud-seeding, the process of spraying silver iodide into clouds to make it rain. Her article "Silver-Lining Playbook" appears in the Fall 2013 edition of On Earth magazine. She's joined by Jeff Tilley, Desert Research Institute's director of weather modification.



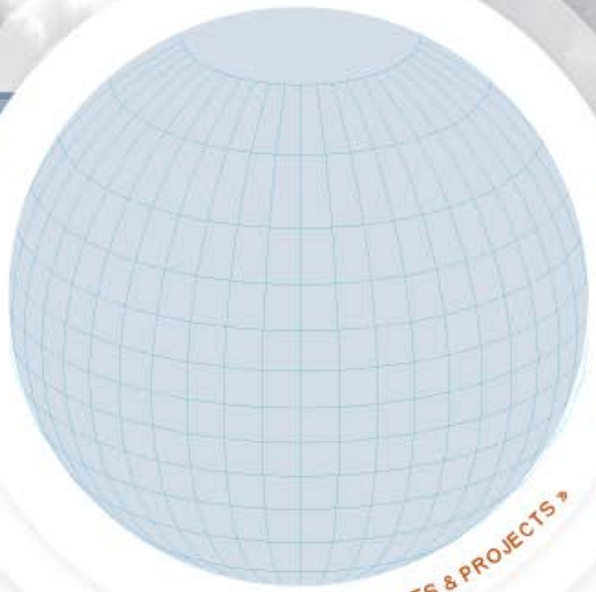
"We make clouds more efficient."

"We're really interested in making it snow in the winter rather than rain in the summer." –Jeff Tilley, Desert

WEATHER MODIFICATION
INCORPORATED

When most people look up they see clouds.

WE SEE POTENTIAL.



VIEW ALL CLIENTS & PROJECTS »

ABOUT US >

Now, more than ever, the worldwide need for solutions to atmospheric necessities such as water resource management and environmental quality monitoring, is critical. With nearly a half-century of successful programs, our experience speaks for itself.

Let us help you better manage your atmospheric and water resources.

Learn More

SERVICES & OFFERINGS >

- Program Services
- Meteorological Services
- Atmospheric Assessment & Evaluation
- Cloud Seeding
- Weather Radar Systems
- Environmental Monitoring
- Aircraft

www.weathermodification.com/projects.php

nts & Projects | Weather Modification, Inc.

- Aeromet, Inc. (L-3 Communications) - U.S Department of Defense
- BAMEX - Bow Echo and Mesoscale Convective Vortex Experiment
- CALIPSO - CloudSat Validation Experiment
- Delaware Department of Agriculture Cloud Seeding Program
- Edwards Aquifer Authority
- Federal Aviation Administration - Great Lakes Division
- Gratiot Weather Modification Project
- Illinois Weather Modification Projects
- National Oceanic and Atmospheric Administration (NOAA)
- National Oceanic and Atmospheric Administration - National Hurricane Center
- Naval Surface Warfare Center
- Nevada State Cloud Seeding Program
- New Mexico BLAST (Burst Light and Stratus Transmission) Project
- North Dakota Cloud Modification Project (NDCMP)
- North Dakota Thunderstorm Project - North Dakota Atmospheric Resou Board
- North Dakota Tracer Experiment - North Dakota Atmospheric Resource Board
- Northeast Sampling Program - Sonoma Technology, Inc.
- NSF/NCAR ICE-L Field Campaign
- Oklahoma Weather Modification Project (OWMP)
- Panhandle Groundwater Conservation District Rainfall Enhancement Program

www.weathermodification.com/projects.php

Clients & Projects | Weather Modification, Inc.

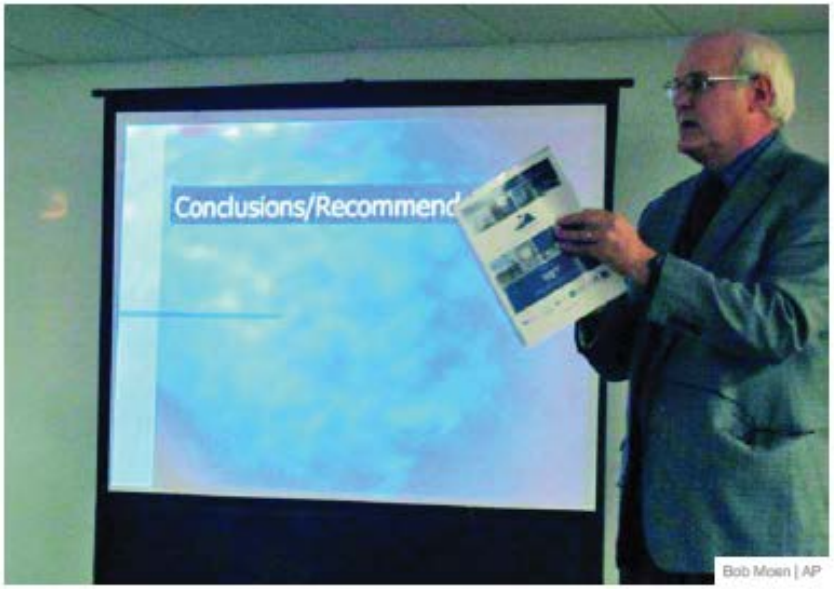
- Santa Barbara County Water Agency
- Sonoma Technology, Inc.
- Stanislaus Weather Modification Program
- State of South Dakota - Department of Natural Resources Division Weather Modification
- Texas Central High Plains Rainfall Enhancement Program
- Texas Experiment in Augmenting Rainfall through Cloud Seeding (TEXARC)
- Texas Weather Modification Program
- The University of North Dakota - US Environmental Protection Ag
- University of Arizona - National Oceanic and Atmospheric Adminis (NOAA)
- Upper American River Cloud Seeding Project
- Upper Payette River Basin Cloud Seeding Program
- Upper Tuolumne River Weather Modification Program
- Utah Division of Water Resources
- Utah Division of Water Resources
- West Central Texas Council of Governments Rainfall Enhancemer Program
- Western Dakota Water Development District - Black Hills Council Government
- Wyoming Weather Modification Pilot Program

CASPER Star Tribune COMMUNICATIONS

CLOUD

Wyoming study: Cloud seeding can increase snowpack

"…up to 15 percent a year"



Bob Moen | AP

Roy M. Rasmussen, senior scientist at the National Center for Atmospheric Research, addresses Wyoming state lawmakers and water managers in Cheyenne on Wednesday while presenting findings of a study of cloud seeding.

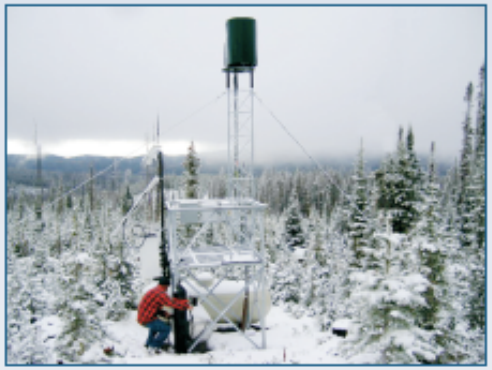
15 hours ago • By BOB MOEN The Associated Press (1) Comments

CHEYENNE — State-funded research in Wyoming suggests that cloud seeding can increase mountain snowfall by up to 15 percent a year, has negligible environmental effects and almost no impact on precipitation in surrounding areas.

In a nearly decade-long study, researchers found that the increased snowpack produced more water in nearby rivers and streams that provide water for cities and farms.

Weather Modification

Cloud seeding—a form of weather modification—is a safe, scientific, time-tested, and proven set of technologies used to enhance rain and snow, reduce hail damage, and alleviate fog. The benefits of cloud seeding can be measured in additional water for cities and agriculture, as well as the reduction of damage from severe weather.



A ground-based generator is used to burn a silver iodide solution to release microscopic silver-iodide particles which can create additional ice crystals, then snow, in winter clouds. Research has shown that placing equipment at high elevations increases cloud seeding effectiveness.

Cold Season Seeding

When moist air flows over the mountains, water vapor condenses and forms clouds composed of water droplets. These droplets become "super cooled" and have the unique quality to remain liquid even at temperatures below freezing. Given enough time and mixing with surrounding air, many of the droplets will evaporate, but under the correct conditions some will eventually become ice crystals, grow into snowflakes and precipitate to the ground. Cloud seeding provides an opportunity to increase the number of ice crystals that can become snowflakes.

Burn-in-place flares are mounted on the aircraft wing to disperse silver iodide in a cloud.

Warm Season Cloud Seeding

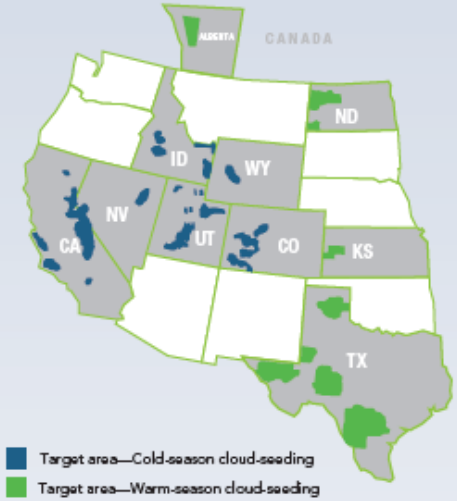
When the top of a growing cumulus cloud cools below freezing, water droplets don't immediately freeze. Instead, they become "super cooled". Windblown dust and soil particles provide the "seeds"—ice nuclei—for the development of ice crystals. Many times, however, these dust particles are either too inefficient or too few in number to provide sufficient nucleation. Summer cloud seeding provides an opportunity to increase the number of efficient ice nuclei in the seeded cloud increasing the amount, frequency, and distribution of rain.

Cumulonimbus (thunderstorm) clouds can also generate damaging hail. Cloud seeding can be used to reduce a storm's severity by adding efficient nuclei and increasing competition for cloud water, altering energy transfer in the cloud, changing the trajectory of cloud particles, and ultimately modifying the size of ice particles.

Who Conducts Cloud Seeding?

In North America, cloud-seeding programs are conducted in California, Colorado, Idaho, Nevada, Utah, Wyoming, Kansas, North Dakota, and Texas, as well as Alberta, Canada.

Cloud seeding is also conducted through major programs in the countries of Australia, Chile, China, France, Greece, India, Israel, Saudi Arabia, and Spain.



NAWMC
North American
Weather Modification Council

NAWMC Members

California Department of Water Resources
Colorado Water Conservation Board
Desert Research Institute
North Dakota Atmospheric Resource Board
Texas Department of Licensing and Regulation
Utah Division of Water Resources
Wyoming Water Development Office

NAWMC Associate Members

Central Arizona Water Conservation District
Metropolitan Water District of Southern California
Santa Barbara County Water Agency
Idaho Power Company
North Dakota Weather Modification Association
Sandy Land Underground Water Conservation District

MIT Technology Review

COMPUTING NEWS

Weather Engineering in China

How the Chinese plan to modify the weather in Beijing during the Olympics, using supercomputers and artillery.

By Mark Williams on March 25, 2008

Rainmakers: Inside the

To prevent rain over the roofless 91,000-seat Olympic stadium that Beijing natives have nicknamed the Bird's Nest, the city's branch of the national Weather Modification Office–itself a department of the larger China Meteorological Administration–has prepared a three-stage program for the 2008 Olympics this August.

First, Beijing's Weather Modification Office will track the region's weather via satellites, planes, radar, and an IBM p575 supercomputer, purchased from Big Blue last year, that executes 9.8 trillion floating point operations per second. It models an area of 44,000 square kilometers (17,000 square miles) accurately enough to generate hourly forecasts for each kilometer.

Then, using their two aircraft and an array of twenty artillery and rocket-launch sites around Beijing, the city's weather engineers will shoot and spray silver iodide and dry ice into incoming clouds that are still far enough away that their rain can be flushed out before

China's 'weather modification' works li magic

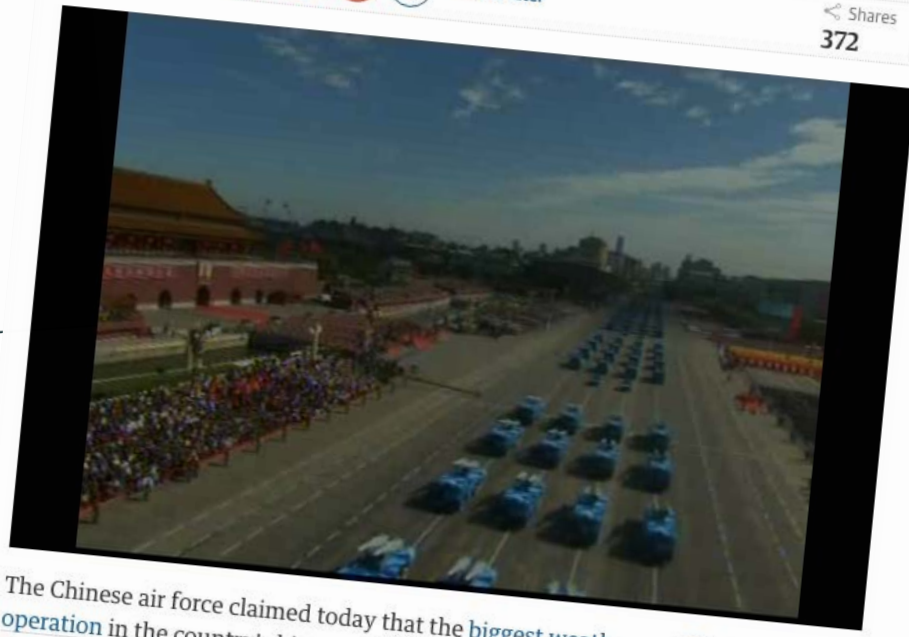
Beijing transformed by clear blue skies after massive cloud seeding operation

Jonathan Watts

Thursday 1 October 2009 10.58 EDT

Save for later

Shares 372



The Chinese air force claimed today that the biggest weather modification operation in the country's history cleared the skies over Tiananmen Square just in time for the National Day parade.

Published on Wednesday, January 14, 2015 by Common Dreams

China Goes 'Rogue' With 'Artificial Weather' Scheme

Geoengineering technique of 'cloud seeding' involves rocket-launching chemicals such as silver iodide into the clouds to boost rainfall

by Deirdre Fulton, staff writer

Seeded cirrocumulus clouds. (Photo: Ian Jacobs/flickr/cc)

RAINMAKING

China creates 55 billion tons of artificia rain a year—and it plans to quintuple th

One of China's cloud-splitters. (AP Photo/Ng Han Guan)

Within five years, China intends to use a dubious geoengineering technology known as 'cloud seeding' to induce more than 60 billion cubic meters of additional rain each year, its government said this week.

Backers of the program—which involves rocket-launching chemicals such as silver iodide into the clouds to allegedly boost rainfall—say the strategy aims to mitigate China's severe and growing water scarcity problem, which is exacerbated by demand from the industrial and power-generating sectors. The silver iodide droplets provide a nucleus within a cloud around which water can coalesce, forming raindrops or snowflakes.

Critics have long warned that geoengineering projects could have unintended, unknown side effects. Last year, former vice president Al Gore called geoengineered solutions to global warming "insane, utterly mad and delusional in the extreme."

Riau prepares for smog with artificial rain

Rizal Harahap, The Jakarta Post, Pekanbaru | Archipelago | Mon, February 23 2015, 5:55 PM

Archipelago News

300 foreign workers employed in South Sumatra

6.0 quake jolts Pariaman

Fish project

Riau Environmental Agency head Yulwiriawati Moesa has said the provincial administration will request the central government to create artificial rain using its weather-modification technology (TMC).

Acting Riau governor Arsyadjuliandi Rachman would also request the government to prepare fire-fighting helicopters and other aircraft at the smog alert post in Roesmin Nurjadin Airport in Pekanbaru, she added.

"Concerning the risks of declining air quality caused by smog, weather modification should be conducted by the beginning of March so that in areas prone to land and forest fires such as Bengkalis and Dumai, which have entered a dry period for the past month, fires can be reduced," Yulwiriawati said on Monday.

She said it was not possible for the government to create artificial rain now because according to the Agency for the Assessment and Application of Technology (BPPT), the TMC implementing body, the chances for success in creating artificial rain were higher in March.

"It's also impossible for us to postpone the weather modification operation to April because in that month, Riau will experience a very dry period so that the cloud seeds we need to create artificial rain will no longer be available," said Yulwiriawati.

$150,000 cloud-bursting service guarantees sunny wedding weather

Rain, rain, go away. A UK company offers an unusual service with the promise of clear skies and sun for your wedding day.

by Amanda Kooser @akooser / February 5, 2015 2:15 PM PST

Weddings can be expensive and fraught with stress as brides and grooms fret over every last detail, from the color of the cake icing to how to handle the weather if it decides to rain all over them and their 250 guests on the lawn of a dream chateau in the country. Oliver's Travels, a luxury holiday rental company, is offering to play weather god...for a price.

Hire an airplane to make your wedding day bright and sunny.

Oliver's Travels

For now only available in France, Oliver's Travel's cloud-

Pros and Cons of Weather Modification

- ***Pros***
  - Drought: emergency water supplies for cities
  - Long-term water supply enhancement
  - Agricultural productivity, crop protection
  - Wildfire control
  - Military: control the battle space
- ***Cons***
  - "Rain robbing," competing interests: one area benefits at the cost of another ("extra-area effects")
  - Public policy: who decides when and where WM is allowed?
  - Interference with natural hydrologic processes
  - Tampering with Nature: Long-term environmental and health implications are unknown

Who Controls The Weather?

- To what extent are water suppliers engaging in WM to enhance supplies?
- Does WM impact the hydrologic cycle, especially “extra-area effects”?
  - More water in streams, reservoirs, aquifer
  - Water quality, soil, food, and health?
- Do extra-area effects and competing WM events cause unintended consequences?
- Is WM playing a role in climate change?
- As climate change increases, and WM increases, will we create a vicious cycle?

And if…

Weather = current conditions

Climate = prevailing weather conditions

Does persistent weather modification not change the climate?

Weather as a Force Multiplier:
Owning the Weather in 2025

A Research Paper
Presented To

Air Force *2025*

by

Col Tamzy J. House
Lt Col James B. Near, Jr.
LTC William B. Shields (USA)
Maj Ronald J. Celentano
Maj David M. Husband
Maj Ann E. Mercer
Maj James E. Pugh

August 1996

Link: http://csat.au.af.mil/2025/volume3/vol3ch15.pdf

"**In 2025**, US aerospace forces can "own the weather" by capitalizing on emerging technologies and focusing development of those technologies to war-fighting applications."

"From enhancing friendly operations or disrupting those of the enemy via small-scale tailoring of natural weather patterns to complete dominance of global communications and counterspace control, weather-modification offers the war fighter a wide-range of possible options to defeat or coerce an adversary."

Weather as a Force Multiplier:
Owning the Weather in 2025

A Research Paper
Presented To

Air Force *2025*

by

Col Tamzy J. House
Lt Col James B. Near, Jr.
LTC William B. Shields (USA)
Maj Ronald J. Celentano
Maj David M. Husband
Maj Ann E. Mercer
Maj James E. Pugh

August 1996

Link: http://csat.au.af.mil/2025/volume3/vol3ch15.pdf

"…weather-modification is a force multiplier with tremendous power that could be exploited across the full spectrum of war-fighting environments.
…it is clear that we cannot afford to allow an adversary to obtain an exclusive weather-modification capability."

"**In 2025**, uninhabited aerospace vehicles (UAV) are routinely used for weather-modification operations."

"This scenario may seem far-fetched, but by 2025 it is within the realm of possibility."

Amy Vickers

Amy Vickers & Associates, Inc.
Amherst Office Park
441 West Street
Amherst, MA 01002
www.amyvickers.com
ava-inc@amyvickers.com