Use of POLCAST measurements to simulate droplet coalescence by hygroscopic flares

Duncan Axisa, Paul Kucera, David Delene, Istvan Geresdi, Darin Langerud

Aircraft observations have suggested that hygroscopic seeding material may increase the concentrations of large droplets and broaden the droplet size distribution. A few parcel model studies have attempted to explain how such seeding would modify the initial size distribution of cloud droplets and the subsequent evolution of that size distribution by coalescence. In this work, we utilize a simple coalescence box model to simulate the evolution of the size distributions. The model is initiated using a measured drop size distribution from the Polarimetric Cloud Analysis and Seeding Test (POLCAST) project in North Dakota. The size distribution is modified with a 'tail' of large drops that simulate a seeding effect. The evolution of the drop size distribution as calculated by the model is compared to the evolution of the rate of change of drizzle from radar measurements. Deficiencies exist in this modeling approach that may produce unrealistic results. Because the objective is to determine if hygroscopic seeding can accelerate the warm rain process, we rely on qualitative conclusions from these inexpensive calculations to guide operational seeding techniques.

WMA 2015 Annual Conference Abstract

"A Field Campaign to Verify High Resolution Modeling with Snow Sampling: Payette River Basin"

Derek Blestrud[1], Pat Holbrook[1], Mel Kunkel[1], Shaun Parkinson[1]
[1]Idaho Power Company, Boise, ID

Idaho Power Company (IPC) is an investor owned utility serving eastern Oregon and most of southern Idaho. About half of the electricity delivered to IPC's customers comes from its 17 hydroelectric projects on the Snake River and its tributaries. With hydropower being such a significant component of the company's generation portfolio, snowpack is critical to IPC operations and the company has invested in a winter orographic cloud seeding program for the Payette, Boise, Wood and Upper Snake River basins to augment the snowpack. IPC and the National Center for Atmospheric Research (NCAR) are in the middle of a multi-year study to determine precipitation enhancement due to winter orographic cloud seeding in the Payette River basin. Forecasts from a high resolution (1.8 km) WRF model, generated at the University of Arizona, are being compared to an NCAR developed Cloud Seeding Module to simulate cloud seeding enhancements. As part of a larger field campaign to verify these simulations, IPC has entered a multi-year field study with Heritage Environmental, Boise State University, and Curtain University to test and evaluate trace chemistry of the snowpack in and around the Payette River basin. Procedures for snow sampling will be evaluated and refined as well as laboratory procedures implemented to provide a higher degree of confidence in each sample. Sampling devices will also be designed and tested to provide both special and temporal resolution as well as providing a way of checking for contamination from each of the sampling devices.

Proposed Abstract

Weather Modification Association Annual Meeting – April 2015

Bruce Boe

LAST UPDATED 20150324

Working Title

Applications of Acoustic Ice Nucleus Counters in Weather Modification: A Recent Review

Abstract

The acoustic ice nucleus counter (AINC), also known by some as the "NCAR Counter" because it was developed at the National Center for Atmospheric Research, remains one of very few means available to readily detect the glaciogenic ice nuclei commonly used in cloud seeding. Developed in the later 1960s, the instrument has never gained great populatity because of its complexity. Nonetheless, it has always had its proponents, those who knew enough about it to make it function reliably. It has been used very successfully in a number of applications, both summer and winter, in every decade since. This paper will summarize the instrument's operating principles, offer some successful examples of field applications, and suggest possible applications that leverage the AINC measurements with other *in situ* sampling technologies.

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Hail, Health, and High Winds: Convective Storms in Western Kenya

Dan Breed*
NCAR/RAL, Boulder, CO

The highlands of western Kenya experience hailstorms on 100-150 days per year. Operational hail suppression programs in the late 1960's and early 1970's (Henderson, 1975) led to a short-term study of the microphysical characteristics of convective storms in this region (Dye and Breed, 1979). Recently, a renewed interest in the regional climate, particularly precipitation, of western Kenya has developed due to potential linkages to health concerns, particularly malaria, strong nocturnal wind events over Lake Victoria, as well as the agricultural problem of hail damage. Surprisingly few published studies on the precipitation characteristics in this region have been carried since 1979. This presentation will summarize results of the older studies, present a case study of mesoscale circulation relevant to convection and hailstorm formation, and conclude with the variety of impacts caused by strong convection in the region.

Presenter: breed@ucar.edu

Evaluation of the WWMPP

R. Rasmussen, S. Tessendorf, C. Weeks-Karkkainen, L. Xue, K. Ikeda, S. Landolt**,**
and **Dan Breed***
NCAR/RAL, Boulder, CO

The evaluation of the Wyoming Weather Modification Pilot Project (WWMPP) aimed to: 1) document seeding effects on precipitation - specifically snowpack - via statistical methods, including the use of numerical model simulations, and 2) document physical evidence of the seeding concept for winter orographic storms. While the randomized statistical experiment comprised the main effort of the WWMPP, the project also supported efforts to measure and model some of the physical effects of seeding. A brief description of the experiment and the various components will be presented to provide some context, along with acknowledgements of the multiple collaborations involved with the evaluation. Then we will walk through the progression of the evaluation analyses that lead to our conclusion of a 5-15% increase in precipitation per Experimental Unit (EU - 4-hr event). These include the results of primary statistical experiment, statistical analysis with partitioning of the EUs based on seeding coverage, and numerical model results using a silver iodide seeding parameterization. If time permits, the climatological context of the results, based on work performed by scientists at the University of Wyoming, and the hydrologic impacts from studies performed by scientists at the University of Alabama will be outlined.

**Presenter: breed@ucar.edu*

North Dakota Cloud Modification Project Forecasting Operations

Daniel Brothers

North Dakota Atmospheric Resource Board

Bismarck, ND

The North Dakota Cloud Modification Project (NDCMP) operates annually from June 1 through late August or early September depending on conditions. Due to the 24/7 nature of the NDCMP and the potential for rapidly developing convective storms, a daily convective forecast is produced to aid the operational meteorologists and pilots in planning operations for each day. NDCMP forecasts are delivered with a forecast summary similar to a National Weather Service forecast discussion. In addition, an overview containing a strength of convective development classification, a forecaster's confidence factor, and a transition time indicating when convective conditions are expected to change. In addition to typical forecasting methods, NDCMP forecasters use a collection of threshold values for various severe weather indices based off of prior work by NDCMP staff. The forecasts are presented to NDCMP staff at various locations throughout western North Dakota via an Internet web page.

A case study of radar observations and WRF LES simulations of the impact of ground-based glaciogenic seeding on shallow stratiform orographic clouds and precipitation

Xia Chu[a 1], Bart Geerts[a], Lulin Xue[b], and Binod Pokharel[a]

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[b] Research Applications Laboratory, National Center for Atmospheric Research, Boulder

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Abstract

A very shallow stratiform cloud partially blocked by terrain was sampled by a profiling airborne radar, the Wyoming Cloud Radar (WCR) on February 13, 2013, as part of the AgI Seeding Cloud Impact Investigation (ASCII) campaign. With a cloud base (top) temperature of -12°C (-14°C), weak wind, some liquid water, and no natural seeding from aloft, this event serves as a nice opportunity to examine the impact of ground-based glaciogenic seeding on snow growth, although very light snowfall was produced naturally by this cloud, notwithstanding its shallow depth and high cloud top temperature. This event also serves as an opportunity to test the ability of a model, the Weather Research and Forecasting (WRF) model in large-eddy-simulation (LES) mode, with glaciogenic seeding parameterization in the Thompson microphysics scheme, to reproduce the observed natural cloud, as well as the impact of seeding.

A control and a target area for the WCR reflectivity profiles were determined by the model's AgI dispersion pattern. A comparison of mean reflectivity during AgI seeding to that before seeding in the target area (relative to the natural trend in the control area), reveals a positive seeding effect near the ground. The 100-m resolution WRF LES captures the upstream

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environment and the horizontal extent and depth of the orographic cloud well, and also produces very light natural snowfall. The model also captures an increase in mean reflectivity during seeding over the same target area, relative to the trend in the control area.

A model sensitivity test shows that seeding reduces cloud supercooled liquid water and enhances snow mixing ratio through snow growth by vapor deposition. The precipitation rate almost doubles in the target area. Most of the increase is found within the rather narrow AgI dispersion plumes.

ASCE/EWRI Standards practice documents on weather modification

Presenter: Tom DeFelice

Abstract: I will summarize the status and content of the ASCE AWM SP Documents. The documents will cover Precip enhancement/augmentation, Hail Suppression, and Supercooled Fog Dispersal.

Title: Technology Innovations Wx Mod – XVI

Presenter: Tom DeFelice

Abstract: Our continuing series focused on highlighting newer technologies and techniques that might have an application to weather modification operations. The development and ultimate application of these technologies could improve forecasts, evaluation, and confidence that these technologies and techniques might help us resolve relevant socio-economic issues. This presentation digs deeper into the use of unmanned systems to carry out cloud seeding operations and evaluations.

Conference: 2015 Meeting of the Weather Modification Association (WMA) in Fargo, North Dakota on April 21-24, 2015.

Title: Analysis of In-situ Observations made during the POLCAST Field Projects

Authors: David Delene[1], Nicholas Gapp[1], Kurt Hibert[1] and Darin Langerud[2]

[1]Department of Atmospheric Sciences, University of North Dakota
[2]North Dakota Atmospheric Resource Board

Abstract: The North Dakota Atmospheric Resource Board has funded a series (2006, 2008, 2010, and 2012) of field projects, called Polarimetric Cloud Analysis and Seeding Test (POLCAST), to research the effectiveness of hygroscopic cloud seeding. The main objective of POLCAST is understanding effects of conducting cloud base hygroscopic seeding on convective clouds in North Dakota. Due to varying day-to-day conditions, it is important to measure the key atmospheric parameters of cloud condensation nuclei (CCN) concentration, cloud base temperature, cloud base height, and cloud microphysical properties during weather modification research projects. These key atmospheric parameters are important to natural precipitation formation; hence, scientists should stratify their analysis of randomized seeding using these measurements.

The 2012 field campaign made aircraft-based and surface-based CCN measurements using the University of Wyoming (UWyo) and Droplet Measurement Technologies (DMT) CCN counters. The DMT CCN counter measured at three different supersaturations (0.2 %, 0.3 %, and 0.6 %) and the UWyo CCN measured at 0.6 % supersaturation. Careful calibrations of both CCN counters provides consistent measurements. Cloud base CCN concentrations, at ambient supersaturation of 0.6 %, have a day-to-day variation from a minimum of 800 $\#/cm^3$ to a maximum of 2,500 $\#/cm^3$. Day-to-day variations in CCN concentration are larger than changes in concentration across North Dakota on a single day. Furthermore, daily variations are larger than the uncertainty in the CCN measurements.

Analysis of the 2008, 2010 and 2012 POLCAST aircraft measurements indicate that North Dakota has the following atmospheric hygroscopic seeding conditions: 1.) Daily cloud base CCN concentrations from 300 – 2,500 $\#/cm^3$. 2.) Daily cloud base temperatures from 4 – 20 ^{0}C. 3.) Daily cloud base heights of 1.0 – 2.5 km. Combining these measurements with our current theoretical understanding of hygroscopic seeding indicates that North Dakota is suitable for operational hygroscopic seeding.

Conference: 2015 Meeting of the Weather Modification Association (WMA) in Fargo, North Dakota on April 21-24, 2015.

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Abstract: The North Dakota Atmospheric Resource Board has funded a series (2006, 2008, 2010, and 2012) of field projects, called Polarimetric Cloud Analysis and Seeding Test (POLCAST), to research the effectiveness of hygroscopic cloud seeding. The main objective of POLCAST is to understand the effects of conducting cloud-base hygroscopic seeding on convective clouds in North Dakota. Due to varying day-to-day conditions, it is important to measure the key atmospheric parameters of cloud condensation nuclei (CCN) concentration, cloud base temperature, cloud base height, and cloud microphysical properties during weather modification research projects. These key atmospheric parameters are important to natural precipitation formation; hence, scientists should stratify their analysis of randomized seeding using these measurements.

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The Next Generation Storm Penetration Aircraft

Andy Detwiler
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In the fall of 2011, the National Science Foundation (NSF) entered into a $13.3M interagency agreement with the Center for Interdisciplinary Remotely-Piloted Aircraft Studies (CIRPAS) at the Naval Postgraduate School in Monterey, CA, to develop the Next Generation Storm Penetration Aircraft. The project involves obtaining an U.S. Air Force A-10 “Warthog” fighter-bomber and modifying it for use in airborne research involving in situ observations in convective storms. The principal investigator on the project is Haflidi Jonsson, principal scientist at CIRPAS. Contractors contributing to the project include Zivco Aeronautics (Guthrie, OK) and the South Dakota School of Mines and Technology. The actual pathway to completing this project has turned out to be significantly different than anticipated when the project was originally funded. Currently an aircraft has been loaned to the project, and plans for modifications are still being fine-tuned. Significant tasks remaining are (1)obtaining Air Force approval of proposed modifications, (2) obtaining agreement between the Air Force, the Navy, and the NSF on a memorandum of understanding for operating the aircraft and certifying air worthiness, (3)instrumenting the aircraft for research, and (4) conducting a test flight program to establish an operating envelope within which missions can be safely conducted. Detailed background on the project will be presented along with details of planned operational capabilities. The current timeline of tasks leading to availability of the aircraft for research will be discussed.

Conference: The 2015 Annual Meeting of the Weather Modification Association

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Presentation Format: Poster

Title: A Switch to Digital: The Transition of the Journal of Weather Modification to Online Publishing

Authors: Nicholas Gapp, David Delene, and Wanda Seyler

Department of Atmospheric Sciences, University of North Dakota

Abstract: The Journal of Weather Modification (Journal) is the official organ of the Weather Modification Association (WMA). The Journal publishes peer-reviewed scientific papers on weather modification and related subjects. Shorter notes and correspondence, including reports about weather-modification-related activities, are considered for publication at the discretion of the editor.

The Journal published its first issue in 1969 and added a peer-reviewed section in 1979. In 2010, the Journal started its transition to online publishing, which was completed in 2014 with all articles since 1979 available on the Journal's website. General updating of the information on the website and the addition of a Frequently Asked Questions section also helped to complete the transition. Titles, authors, and abstracts of online articles are fully searchable as part of the Open Journal Systems (OJS) software used to manage the website. The OJS software has been recently upgraded to version 2.4.5 and is hosted on the same server that supports the WMA website.

Over 330 scientific articles from 1979 to 2014 are available online which is an average of 9.43 articles per year with a standard deviation of 5.52 articles per year. More than 450 total articles are available online over the same 35-year period which is an average of 12.86 articles per year with a standard deviation of 5.38 articles per year. Since being released in early 2013, abstracts from articles published between 2009 and 2014 have been viewed over 7,500 times. Although there are currently 188 users enrolled in the Journal's website, there has been a decline in both active WMA members and the number of published Journal articles, especially since 1980. Future plans for the website include implementing a Completely Automated Public Turing Test To Tell Computers and Humans Apart (CAPTCHA) system to safeguard against automatic account creation on the Journal's website, implementing a Digital Object Identifier (DOI) numbering system for each article for easy reference tracking and individual article identification, and providing all members with Journal accounts and membership subscriptions.

The Extra-Area Effect of Orographic Cloud Seeding: Observational Evidence of Precipitation Enhancement Downwind the Target Mountain

Xiaoqin Jing[1], Bart Geerts[1], and Bruce A. Boe[2]

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This study provides an observational evidence of the extra-area seeding effect on the winter orographic clouds downwind the primary target mountain (50-70 km downwind AgI generators), using a high resolution scanning X-band Doppler on Wheels (DOW) radar. The data was collected from seven Intensive Observation Periods (IOPs) in the 2012 AgI Seeding Cloud Impact Investigation (ASCII) campaign over the Sierra Madre in southern Wyoming. In the seven cases, the Froude number exceeded one, indicating unblocked flow, west or southwest wind persisted, and supercooled liquid water presented. In order to examine the seeding impact, two study areas are designated (a control and a target region). And a comparison is made between the measurements from a treated period (SEED) and those from an untreated period (NOSEED). Results show that the AgI can possibly disperse more than 100 km downwind the seeding sources, based on the measurements of ice nuclei concentration. The increased radar reflectivity in the target region, compared to the control, suggests enhanced precipitation during SEED period, possibly due to the seeding impact. Analyses of DOW Range-Height Indicator (RHI) scans and echo height maps suggest the planetary boundary layer (PBL) mixing, convection and hydraulic jump are the possible mechanisms for silver iodide (AgI) mixing in the area downwind the primary target mountain.

A Multi-sensor Study of the Impact of Ground-based Glaciogenic Seeding on Clouds and Precipitation in the 2012-13 AgI Seeding Cloud Impact Investigation (ASCII)

Binod Pokharel[a], *Bart Geerts*[a], Roy Rasmussen, and Kyoko Ikeda[b]

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The AgI Seeding Cloud Impact Investigation (ASCII) campaign was conducted over the mountain ranges in southern Wyoming to examine the impact of ground-based glaciogenic seeding on winter orographic clouds and precipitation. The field experiment was conducted over the Sierra Madre and Medicine Bow mountains in early 2012 and 2013, respectively, in the context of the Wyoming Weather Modification Pilot Project. The campaign was supported by a network of ground-based instruments, including a microwave radiometer, two profiling Ka-band Micro-Rain Radars (MRRs), a Doppler on Wheels (DOW) X-band radar, rawinsonde launches, and a disdrometer. The University of Wyoming King Air with profiling Wyoming Cloud Radar (WCR) conducted 17 successful flights (9 over the Sierra Madre and 8 over the Medicine Bow mountians) in ASCII. Data from 7 flights over the Medicine Bow in 2008-09 are included in the composite analysis. This analysis also includes 9 cases with DOW data and 5 cases with paired MRR data over the Sierra Madre, not all of them overlapping with the 9 WCR cases over that range. In most cases, two hours without seeding (NOSEED) were followed by two hours of seeding (SEED).

TITLE: Alberta Hail Suppression Project Operational Update and Case Study from 7 August 2014

AUTHORS: Daniel B. Gilbert and Terry W. Krauss Ph.D.

ABSTRACT: The Alberta Hail Suppression Project is a program designed for the glaciogenic seeding of convective clouds with intent of reducing urban hail damage in southern Alberta, Canada including the cities of Calgary and Red Deer. The program has now completed its 19th season and is currently the largest privately funded hail suppression project in the world. The program is funded and overseen by the Alberta Severe Weather Management Society, which is comprised of over a dozen of the largest insurance companies in Alberta. This presentation is an operational update of the latest improvements to the project. A case study is also presented from the most severe hail event of the 2014 season which occurred on August 7th. An outbreak of five discrete supercells occurred, impacting the cities of Airdrie, Red Deer, Olds, and Innisfail. The estimated damage from the August 7th storms is greater than $500 Million.

Results of Hygroscopic Seeding Experiments for Warm Fog Dissipation in South Korea

Jin-Yim Jeong, Young-San Park, Jung-Ho Lee, Jun-Hwan Park, and Baek-Jo Kim
National Institute of Meteorological Research/KMA

In South Korea, warm fog dissipation is focused on because fog events over 80% are classified into warm fog which occurs at temperature above. We have taken attempts to modify the microstructure of warm advection fogs during summer and autumn seasons. A series of ground-based experiments to study the effects of hygroscopic particle seeding for clearing warm fogs has been conducted at an observatory located at mountain area in northeast side of South Korea. The final goal of this study is to figure out the best way of modifying warm fog in operational use at airports and highways. We define and calculate two variables related to visibility improvement from time-series graphs of the visibility to evaluate the seeding effects. The visibility improvement ratio is determined by the visibility improvement degree comparing before and after the seeding. And the visibility improved period is determined by the time maintaining the visibility improved. Among 21 experiments conducted for the last two years, 12 experiments are confirmed improvement of visibility. Successful experiments show the visibility improvement ratio, 1.45 and the visibility improved period, 29 minutes on average. Also, most of experiments that verified the seeding effects show the broadening of a fog droplet size distribution from the measurement by the optical particle counter. The increments of the number of raindrops are detected in some experiments by the optical disdrometer. Those results above imply the physical evidence of a growth of fog droplets which turn to raindrops by the collision-coalescence process.

Acknowledgements: This work was supported by the program, "Advanced Research on Applied Meteorology" of National Institute of Meteorological Research (NIMR) funded by the Korea Meteorological Administration (KMA).

Bureau of Reclamation report on weather modification policy review

David Keeney, David Reynolds

Abstract:

"From the 1960's through the 1980's, the Bureau of Reclamation was involved in a variety of weather modification initiatives across the western United States. From the 1990's until the early 2000's, Reclamation began to decrease its activity in weather modification until 2005 when it stopped involvement in weather modification efforts. This cessation was due to uncertainty regarding the efficacy of weather modification and questions raised over legal and liability issues. Recently, however, continuing drought conditions in the west and a strong interest amongst some Reclamation stakeholders has led to a renewed interest in the science and policy of weather modification. Reclamation's Research and Development office is currently supporting a NOAA CIRES evaluation of scientific advancements in weather modification since the National Research Council 2003 report "Critical Issues in Weather Modification Research". The purpose of this talk is to discuss Reclamation's process and status on this effort."

Radar Evaluation POLarimetric Cloud Analysis and Seeding Test (POLCAST) Field Program in Eastern North Dakota

Paul A. Kucera[1], Duncan Axisa[1], David Delene[2], Gretchen Mullendore[2], and Darin Langerud[3]

[1]Research Applications Laboratory, National Center for Atmospheric Research, Boulder, CO
[2]Department of Atmospheric Sciences, University of North Dakota, Grand Forks, ND
[3]North Dakota Atmospheric Resource Board, Bismarck, ND

The Polarimetric Cloud Analysis and Seeding Test (POLCAST) has been an ongoing field program with the goal of improving the understanding of the impact of hygroscopic cloud seeding at cloud base on continental convective clouds. The study has focused on sampling convective clouds observed in the eastern region of North Dakota. The project specifically focuses on determining if identifiable hygroscopic seeding signatures can be observed in polarimetric radar observables or derived fields. POLCAST is a cooperative study between the North Dakota Atmospheric Resource Board (NDARB), National Center for Atmospheric Research (NCAR), University of North Dakota (UND), and Weather Modification Inc. (WMI). A randomized seeding field program has been conducted for three summer convective seasons (June-July 2008, and June-July 2010, June-August 2012). Polarimetric radar data have been collected by the UND C-Band Polarimetric Doppler Weather Radar (NorthPol). In conjunction with NorthPol observations, a research aircraft operated by WMI has been used for the randomized targeting and has also been used to collect aerosol and microphysical observations. This study focuses on radar data analyses targeted convection with a focus on the randomized seeding cases from the POLCAST field campaigns. A total of 44 cases have been collected in the three study seasons. The radar analysis has focused on applying the NCAR hydrometeor identification (HID) algorithm tuned for C-band observations. Also, for each case, targeted cells are compared to comparable, not targeted storms to evaluate the representativeness of each case. This presentation gives a brief description of the experiment and a summary of the polarimetric radar evaluation results.

The North Dakota Atmospheric Resource Board/University of North Dakota Pilot Intern Program

Darin Langerud, North Dakota Atmospheric Resource Board, Bismarck, ND
Michael Poellot, University of North Dakota, Grand Forks, ND

In March 1974, the National Science Foundation provided a $274,000 grant to the University of North Dakota (UND) to create a weather modification pilot training program. The following year, the North Dakota Weather Modification Board (later named the Atmospheric Resource Board) partnered with the University of North Dakota to offer internships on the North Dakota Cloud Modification Project (NDCMP). Ongoing funding from the Bureau of Reclamation and the North Dakota Atmospheric Resource Board has continued to support student participation. Students pursuing an internship must meet curriculum and flight certification requirements at the John D. Odegard School of Aerospace Sciences at UND. In the 40 years since the program was established, more than 340 plots have participated as co-pilots on the NDCMP.

Abstract: Weather Modification Association Annual Meeting, Fargo ND, April 22-24, 2015

Winter Orographic Cloud Seeding in the Sierra Nevada and Colorado: Summary of Operations and Selected Case Studies

Frank McDonough and Kerwyn Texeira

Desert Research Institute

Reno, Nevada

The Desert Research Institute (DRI) is currently operating and supporting winter season glaciogenic cloud seeding in the western mountains of the US. Two of the cloud seeding programs are being conducted over the eastern slopes of the Sierra Nevada Mountains of California and Nevada, and a third is targeting the Winter Park Ski Area in the north-central Colorado Mountains. DRI is also supporting a fourth operational program on the Grand Mesa of western CO with weather instrumentation, a remote controlled liquid propane generator, and remote controlled silver iodide generators.

The clouds over the Sierra Nevada are often of maritime microphysical character and relatively warm, while the clouds over the Colorado locations are often of continental microphysical character and colder. The different characteristics of storms and clouds over the Sierra compared to Colorado lead to somewhat different seeding opportunities and require different forecasting methodologies. Forecasting 'seedable' clouds in these areas requires somewhat different techniques using the same observational data sets and numerical weather prediction models.

This presentation initially will present a brief review of previous research on observed winter cloud structures over the Sierra and Colorado. Next, a summary of the season and seeding operations at the various locations will be shown. The operational and forecast tools and methods currently being used to identify 'seedable' clouds will be discussed and several case studies will be presented. Finally the presentation will suggest a set of instruments that should be part of operational programs to maximize the efficiency of a project.

Pilot-Aircraft Record-Keeping System (PARS)

Paul Moen, North Dakota State Water Commission, Bismarck, ND

The North Dakota Cloud Modification Project (NDCMP) follows stringent requirements to document cloud seeding and aircraft operations. This talk takes a quick look into the hardware and software used for data collection, storage and access by the NDCMP. I will talk about the flow of data from the PARS web app to the 4th Dimension database as well as a PostgreSQL/PostGIS database where we store shared agency data. I will also take a look at the PARS application and QGIS, a GIS application we use to access flight track data.

Utilizing TITAN to Model Hail Size to Aid in Mission Guidance for the Future Storm Penetration A-10 Aircraft

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ABSTRACT

Past research studies by South Dakota School of Mines and Technology have evaluated radar software packages for future storm penetration A-10 (SPA-10) mission guidance. In this current research, the TITAN (Thunderstorm Identifying, Tracking, Analysis, and Nowcasting) software suite is evaluated for use in future SPA-10 missions. TITAN offers many useful parameters for SPA-10 mission guidance, but doesn't provide adequate hail size diagnostics. Thus, in this analysis, a multi-parameter linear regression model to diagnose maximum hail size at the ground was developed from radar and radar derived surface hail size predictors in TITAN. An initial model, called the South Dakota Radar Estimated Hail Size (SDREHS) was developed from a South Dakota dataset of hailstorms. The SDREHS model was tested on four independent datasets in South Dakota, Ohio, Florida, and Oklahoma. SDREHS performed well in South Dakota (r^2 = 0.81), but didn't perform well on other three datasets producing very low r^2 values of 0.30, 0.18, and 0.16 respectively. Because of the poor performance of the SDREHS model on independent data from the different regions, a new model called Radar Estimated Hail Size (REHS) was made using the entire dataset and included a new set of predictors and coefficients. The REHS model had an r^2 value to 0.60 on the training dataset. A normalized REHS model was derived using the non-outlier maximums to normalize hail size predictors, which decreased the r^2 value to 0.56. Sensitivity and variable dependence tests showed that by removing reflectivity from the model, it didn't significantly reduce the r^2 values as long as VIL and VIHM are still included in the predictor set. The REHS models (with and without reflectivity) were tested on a small independent dataset of storms from North Dakota, Iowa, Alabama, and Kansas. Both models performed poorly on the independent dataset (r^2 = 0.03). While the REHS models didn't perform well on the independent dataset, these results and findings serve as preliminary steps in the development of a tool for assessing hail size in convective storms.

Weather Modification Association

Call for Papers: ABSTRACT

Session: Instrumentation for aerosol and cloud physics research

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4/15/2015

In November 2014, a microwave profiling radiometer was deployed near Vail Pass Colorado to demonstrate its ability to detect cloud seeding targets and to continuously monitor boundary layer conditions around Vail Ski Resort and the I-70 corridor just west of Vail Pass. Three ground generators are located within the operative area of the radiometer. This research examines radiometer output during seeding operations in the Vail and Beaver Creek target areas. Continuous monitoring of boundary layer conditions in the mountain valley can help identify the existence and duration of seeding targets with respect to storm character. Validation and data assimilation of numerical models simulating mountain valley storm characteristics with radiometer data could provide insight into the effectiveness of cloud seeding.

The CWBC leased radiometer near Vail is customized to observe in sixteen different azimuth directions, at two elevation angles of 20 and 45 degrees above horizon. This scanning configuration is intended to give comprehensive data for all storms regardless of storm type and wind regime. Data from seeded and unseeded storms are considered with respect to wind direction and the existence of liquid and vapor in the radiometer retrievals.

If the individual mountain valley boundary layer conditions are sufficiently observed during winter weather, that observational data can be used to improve cold-season mountain numerical forecast models. The radiometer detects liquid and vapor in addition to temperature. With the addition of all other available meteorological data, mountain valley microclimates and cloud microstructure can be better understood and modeled.

This presentation incorporates data from Vail and past research to discuss the advantage of radiometric retrievals in winter mountain weather forecasting, modeling, and precipitation enhancement operations and suggests future implementation and research ideas.

A multi-sensor case study on the impact of ground-based glaciogenic seeding on orographic clouds and precipitation over a mountain in Wyoming: the 3 March 2012 case

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Abstract

We examine the impact of ground-based glaciogenic seeding on a shallow, lightly precipitating orographic cloud, observed on 03 March 2012 as part of the AgI Seeding Cloud Impact Investigation (ASCII) experiment in Wyoming. In this case, the cloud base temperature was -7 to -10 ^{o}C, the target orographic clouds contained supercooled liquid water, and the storm was fairly steady during the measurement period. Eight silver iodide (AgI) generators, located on the windward slopes of the target mountain, operated for four hours. The target mountain pass site was impacted by seeding, according to a trace element analysis of the falling snow, although Ag concentrations in the falling snow peaked rather late in the seeding period, consistent with other case studies over the same target mountain.

Data from three radar systems were used in the analysis of the impact of seeding on precipitation: the airborne W-band (3 mm wavelength) profiling Wyoming Cloud Radar (WCR), two Ka-band (1.2 cm) profiling Micro-Rain Radars (MRR), and a X-band (3 cm) scanning Doppler-on-Wheels (DOW) radar. The WCR was aboard a research aircraft flying geographically fixed tracks, the DOW and one MRR were located at the target mountain pass, and another MRR was upstream of the AgI generators. Composite data from the three radar systems, each with their own target and upwind control regions, all indicate increases in low-level reflectivity, after considering the natural trend in the upwind control region. In contrast with previous studies, the mean concentration of ice particles, especially small particles, was lower during seeding, according to data from a Parsivel disdrometer at the target site. But there were more large particles, and thus calculated reflectivity was higher during seeding, consistent with radar reflectivity measurements.

Update: The Colorado River Basin States Cooperative Weather Modification Programs

Abstract. In coordination with the Secretary of the Interior and as part of a process to address system-wide drought, the seven Colorado River Basin States have identified winter weather modification as an option to potentially increase snowpack and augment the flow of the Colorado River, which serves over 30 million people in the southwestern United States. The Basin States in cooperation with local agencies have implemented actions for their mutual benefit. Three multi-state agreements have been executed to provide funds from the Lower Basin to extend or improve weather modification operations in the Upper Basin. In 2006, the program started with one project, one partner and $45,000. In 2015 the program has grown to 20 projects and 35 partners. To date, the states of Arizona, California and Nevada have provided approximately $3.4 million to Colorado, Utah and Wyoming. This presentation will discuss the agreement principles and mechanics the seven states have used to implement these cooperative programs. The Basin States have prepared an Action Plan to assist in guiding their future cooperative weather modification activities.

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An Analysis of 2000-2014 North Dakota Cloud Modification Project TITAN Data Using Maximum Reflectivities and Observed Hail Reports

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Abstract. The primary purpose of the North Dakota Cloud Modification Project (NDCMP) is to suppress hail development in its two western North Dakota operations areas. The Bowman and Stanley radar sites have each collected 15 years of TITAN data for operations, archive and analysis. Using the NDCMP's operational hail threshold along with TITAN analysis tools, maximum reflectivity maps indicating possible hail were created. Observed hail reports for years 2000-2015 from the Atmospheric Resource Board Cooperative Observer Network (ARBCON) and the Storm Prediction Center (SPC) were then added for verification. The maps appear to indicate regions where hail is more prevalent and the effects of cloud seeding for hail suppression.

The effect of ground-based glaciogenic seeding on orographic clouds in South Korea

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The ground-based experiment for snow enhancement on orographic clouds at the mountain area in east side of Korea began in 2006 by National Institute of Meteorological Research (NIMR) and has been conducted every year. The experiments have been conducted by using AgI generator under following meteorological conditions: surface temperature < -4℃, wind direction between 45 and 130°, and wind speed < 5 m s^{-1}. Data from FM-120, MPS and PARSIVEL disdrometer were used in the analysis of the impact of seeding on snow enhancement. During the seeding, an increase of the concentration of small ice particles less than 1 mm diameter was observed. Results indicate that suitable conditions, such as wind field and sufficient super-cooled liquid water, are needed for snow enhancement by seeding.

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