OPERATIONAL IMPROVEMENTS ON THE NORTH DAKOTA CLOUD MODIFICATION PROJECT

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Abstract: The North Dakota Cloud Modification Project (NDCMP) has benefited significantly from improvements in technology and upgrades in equipment over its 35-year history. NDCMP meteorologists and pilots, some with three to six years of experience, are working more effectively with new resources and tools such as upgraded radar technologies, higher performance aircraft, and Internet nowcasting products. The results are greatly improved response times between aircraft launch and on-station seeding and more precise targeting of seeding opportunities on the NDCMP.

1. INTRODUCTION

Cloud seeding for hail suppression and rain enhancement has been conducted in some fashion in North Dakota since 1951. Langerud and Moen (1998) most recently described the history of the program and methodologies used for rain enhancement and hail suppression in western North Dakota during the growing season. Since then, many beneficial upgrades and advancements to North Dakota Cloud Modification Project (NDCMP) operational equipment have occurred. These improvements include the upgrade of two Enterprise Electronics WSR-74C Weather Radars (2009-10), the advent of electronic recordkeeping (2003), improved Internet-based weather products for operational nowcasting at NDCMP remote radar sites, and the use of higher performance aircraft, including a Piper Cheyenne II (2010).

Figure 1 shows the NDCMP target area, including radar and aircraft locations where operations are conducted annually from June 1 to August 31. The NDCMP has two operational districts, District I in the southwest and District II in the northwest.

The NDCMP encompasses 27,001 km^2 (10,425 mi^2), approximately 15 percent of the area of the

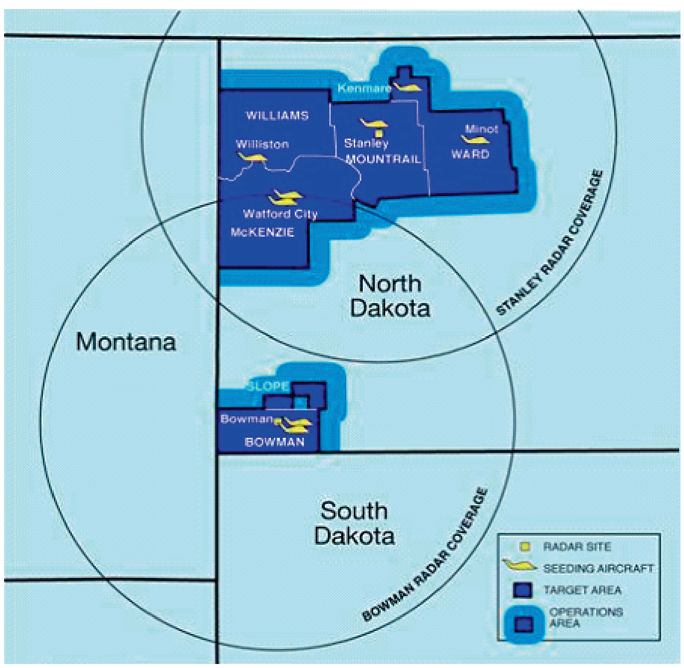

Figure 1: 2010 NDCMP target areas, radar sites, and aircraft locations.

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state. Agriculture is a large part of the economy of western North Dakota and a recent economic evaluation by Bangsund and Leistritz (2009) indicates the NDCMP provides significant benefit to the agricultural sector. The study analyzed the benefits based on rainfall enhancement of five and ten percent, and a 45 percent reduction in crop-hail losses: results supported by independent evaluations of the NDCMP (Dennis et al., 1975; Johnson, 1985; Schaffner et al., 1983; Smith et al., 1997; and Wise, 2005). It found that direct benefits to agricultural production for NDCMP counties ranged from $12 million to $19.7 million per year. When considering 2010 NDCMP costs of $801,000, the benefit to cost ratios range from 15-25 to 1. Further, gross economic benefits, which consider the turnover of additional dollars in the economy, are estimated at $37 million to $60.5 million annually.

Economics like these show why the program has had such long-standing support. Within the last two years, all six participating counties have made multi-year commitments to continue their participation in and funding of the NDCMP.

2. NDCMP METEOROLOGIST AND PILOT STAFF

Returning, experienced NDCMP meteorologists and pilots make the most significant contribution to improved operations for the program. Weather Modification, Inc. (WMI) has been awarded contracts to provide pilots in command (PICs) and aircraft since the establishment of the NDCMP in 1976. Generally, five or six of the eight PICs on the NDCMP return to the program each season with prior intern pilot or PIC experience. These experienced pilots respond quickly to launch orders given by NDCMP meteorologists and are constantly improving the timeliness of operations and targeting of convective development.

A downturn in the economy during the last few years has created an extremely competitive job market, providing the NDCMP with an increase in returning personnel, including many three to six year project veterans. This translates into improved efficiency of operations and an unprecedented level of training for interns working on the program.

To date, 309 pilots and 35 meteorologists have participated in NDCMP internships, a testament to the longevity of the two programs. The NDCMP Pilot Internship Program began in 1976, with initial funding by the Bureau of Reclamation through the University of North Dakota (UND). Students enrolled in weather modification coursework at UND who meet specific flight training requirements are eligible to work as NDCMP intern pilots. There are nine intern pilots chosen to work with the NDCMP annually and the internship provides them both piston and turbine multi-engine aircraft flight experience. Funding for the program is currently provided by state general funds.

In 1996, the NDCMP Meteorology Internship Program was established, providing hands-on learning opportunities to undergraduate meteorology students. Initially, there were two meteorologist interns working with the NDCMP each season (one intern was assigned to each of the NDCMP radar sites). In 2008, the number of NDCMP intern meteorologists increased from two to three annually, allowing for a rotation to be established between the two radar sites and the North Dakota Atmospheric Resource Board (NDARB) offices in Bismarck, ND where the NDCMP forecaster is based. This provides each intern with both operational radar and forecasting experience and increases the likelihood that the program will benefit from returning personnel in upcoming seasons.

2.1 Improvements in Personnel Training

Besides the NDCMP meteorologist and pilot intern programs, advancements within the Information Technology (IT) industry during the last decade have revolutionized the effectiveness of NDCMP personnel training. During the three-day pre-project ground school held each May at the NDARB offices, case studies with actual NDCMP forecast information, radar data, and operations logs are conducted so that “real-time” logistical decisions can be discussed between project meteorologists and pilots. Feedback from returning, experienced project veterans is quite common and invaluable to the learning process. Meteorologists and pilots are also able to practice completing electronic paperwork, such as radar and flight logs that will be required of them during summertime operations.

3. WEATHER RADAR

Prior to the 1997 NDCMP, radar services for the two operational districts were leased from WMI. These radar services included the use of two Enterprise Electronics WSR-100-2 Weather Radars and PC-based digital color radar display systems. The NDARB was able to purchase three WSR-74C radars in 1996 through the Government Service Agency. The first to be installed was at the Bowman County Airport for the 1997 operational season. The following year, a building was constructed at the Stanley Municipal Airport that houses the second NDCMP radar. The third WSR-74C radar has been utilized for spare parts in order to keep the two primary radars operational.

Thunderstorm Identification Tracking Analysis and Nowcasting (TITAN) software was incorporated into project operations on both radars by 1998, allowing for storm tracking and analysis. The Bowman and Stanley radars were upgraded in 2009-10 by Vaisala Inc. with Sigmet components, including RVP900 digital Doppler receivers/signal processors, RCP8 antenna controllers, and solid-state modulators. The upgrades added Doppler velocity to NDCMP operations and increased the radar's low-end sensitivity. Wind velocity fields increase operational safety and give meteorologists clues as to where additional convection may develop (along outflow boundaries etc.). An increase in low-end sensitivity helps meteorologists with first-echo recognition for rain enhancement operations.

In the event of an NDCMP radar outage, both sites have GRLevel3 Viewer, which allows real-time access to NEXRAD Level III data from National Weather Service (NWS) WSR-88D radars. The Stanley radar location has neighboring WSR-88D sites in Minot, ND (Department of Defense), Bismarck, ND, and Glasgow, MT for reasonably complete operations reference data. The Bowman radar site, however, is much further away from WSR-88D sites and has to rely on long-range radar data from Bismarck, Billings, MT, and Rapid City, SD radars. This radar coverage begins at mid-levels of the atmosphere over the District I operations area due to range limitations and provides only limited reference data.

Real-time radar data from Bowman and Stanley has been disseminated through the NDARB's website for several years. The public may access composite images from six-minute volume scans, with users having several options for creating loops or viewing historical data. In 2010, NEXRAD Level II data format files from both radars were produced and disseminated through a separate URL address. This allowed entities such as county emergency management agencies and the NWS to receive the data and readily use it for public safety. Any of several available Level II data viewers, such as GRLevel2 or GR2Analyst are capable of downloading and displaying the data.

4. AIRCRAFT

Significant upgrades in NDCMP aircraft have occurred in the last decade. Improvements include replacing all Piper Twin Comanche aircraft with Piper Seneca IIs in 2003, which enabled pilots to stay on–station longer due to larger fuel capacity and useful loads. Piper Seneca IIs used as base seeding aircraft on the NDCMP carry 30 percent more fuel and 37 percent greater useful loads than the Twin Comanche aircraft they replaced.

In 2010, the NDCMP replaced the venerable Cessna 340 with a Piper Cheyenne II turbo-prop aircraft. The Cheyenne II was based in Williston, ND, serving as the primary top-seeding aircraft for District II operations. It outperforms the Cessna 340 in rate of climb, cruise speed, and payload capacity, allowing it to carry more dry ice and silver iodide flares and remain on-station longer. Each of the two turbine engines on the Cheyenne II produces 620 horsepower (hp), which is twice that of the Cessna 340. Take-off to initial seed times for the years 2007-09, when a Cessna 340 was used as the NDCMP's primary top-seeding aircraft, versus 2010, when the Cheyenne was introduced, indicate substantial improvements (See Table 1).

Table 1. Median aircraft takeoff to initial seeding times (in minutes) for cloud top aircraft based in Williston, ND for years 2007-10.

2007	2008	2009	2010
33:25	31:57	25:06	18:31

5. PROJECT DOCUMENTATION

Prior to the 2003 NDCMP, project documentation was completed on paper forms and mailed to the NDARB office in Bismarck weekly. An independent review committee (Orville et al., 2003) recommended that the NDARB collect and store this information in electronic format, making it more readily accessible and useful.

In 2003, meteorologists were able to begin using an electronic database called 4th Dimension (4D) to document radar and aircraft operations. Dubbed RadLog, the 4D application automatically synchs up with a server located at the NDARB offices in Bismarck, allowing for instant retrieval of current operational information. The administrative staff of the NDARB now has the ability to review operations and seeding activities daily and provide feedback to project personnel.

To complete the goal of an electronic record keeping system, the Palm Aircraft Recordkeeping System (PARS) was created prior to the 2004 NDCMP. PARS was conceived, designed and built in-house with off-the-shelf equipment, giving pilots a customized interface for data collection and input. The PARS system utilizes Global Positioning Satellite (GPS) data with user input programs developed for Palm Personal Digital Assistants. To date, this configuration has been very successful at collecting aircraft position and seeding data, while providing a standardized data format. Flight data including aircraft engines on/off times, GPS position, altitude, seeding equipment type, and seeding start/stop times are uploaded to the NDARB server via modem on a daily basis. In addition to PARS, WMI seeding aircraft are equipped with data systems, providing operational redundancy.

6. SEEDING TIMELINESS AND OPERATIONS RESPONSE TIMES

Seeding of summer convective clouds must occur within a small window of time in order to have the prospect of success. Smith et al. (1985) analyzed seeding timeliness for the 1981 NDCMP. This study used NDCMP operational days when storms reached a radar reflectivity hail threshold of 45 dBZ at 1.5 km (5,000 ft.) or higher above the freezing level. The time that conditions met the hail threshold minus the time when cloud seeding for hail suppression began was used as an indicator of operational promptness. The results of the study showed that approximately 40 percent of the clouds during the 1981 season were seeded late.

Improving this area of operations has been a continuing goal since that time. Subsequent, in-house evaluations have shown marked improvement of operational seeding timeliness. Figure 2 shows seeding timeliness of NDCMP operations for two selected study periods (2002 and 2007-09). A significant increase in operational punctuality occurred between the 1981, 2002, and 2007-09 seasons due to a combination of all the previously mentioned operational improvements during this period.

Response times, including the verbal launching (LNH) of aircraft by radar meteorologists, the engines-on (EON) and takeoff times (TKOF), and time of initial seeding (SEED) are given primary consideration when determining how promptly project personnel are conducting operations once dispatched. Figure 3 illustrates the improved mean response times on the NDCMP during the last decade. Of marked significance are the last three years (2008-10) when launch to first initial seed times are the lowest of the seven years studied.

The median aircraft takeoff to first seed times for years 2007-10 are listed in Table 1 for the NDCMP top-seeding aircraft based in Williston. The same pilot flew the Cessna 340 in 2007-09 and the Piper Cheyenne II in 2010. There is a 39% decrease between the mean 2007-09 and 2010 takeoff to seed times, mostly attributed to the higher performance aircraft. Other considerations are the seasonal randomness of storm development and distance from the aircraft's launch site, which would affect the on-station times of the aircraft. The decrease in takeoff to seed times from 2007 to 2009 can be attributed to both pilot experience and storm development locations.

7. SUMMARY

Technological advancements, especially during the last decade, have greatly improved the efficiency and timeliness of operations on the NDCMP. Due to the narrow window of opportunity that summertime convective clouds present for glaciogenic seeding, it is critical that timely seeding occurs and that aircraft are able to deliver their seeding agents with accuracy. Upgrades in weather radar technology, aircraft performance, and IT utilization over the last decade have served the NDCMP well, ensuring that the program continues its success while building on well-established operational methodologies.

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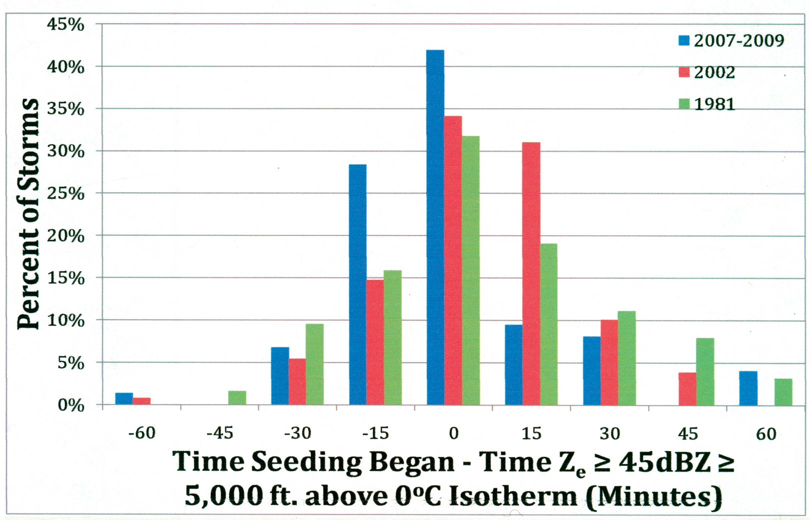

Figure 2: Tick marks represent 7-min. intervals (early/late times were rounded to nearest minute). Thus a storm seeded +/- 7-min. from reaching hail threat status is represented as being seeded right at the storm reaching hail threat criteria (time 0). Any storm seeded more than 53-min. AFTER reaching hail threat status was grouped into the 60-min. bin; any storms seeded more than 53-min. BEFORE a storm reached hail criteria was grouped into the -60-min. bin.

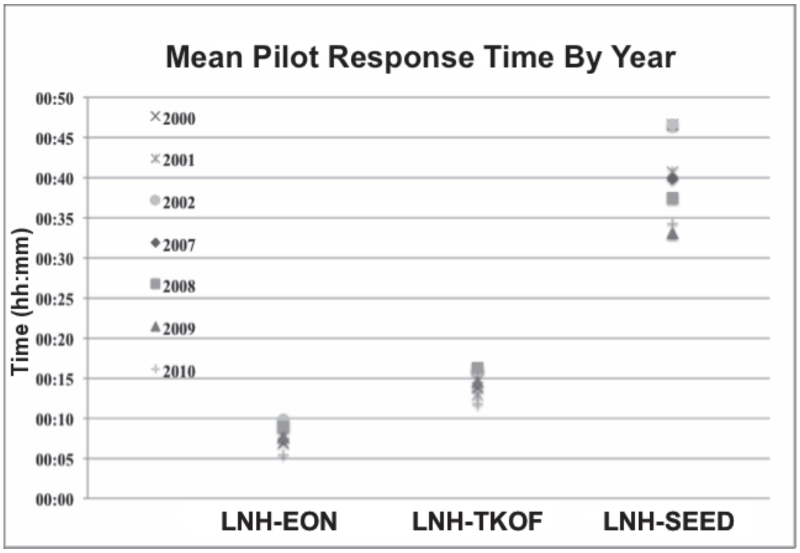

Figure 3: 2000-02, 2007-10 NDCMP aircraft mean response times.

response times. Appreciation is also extended to IT Specialist Paul Moen for his work designing and implementing the RadLog and PARS systems.

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