

Unmanned Aircraft Systems (UAS) for Fog Research and Conducting an Operational Fog Abatement Program

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Introduction

Atmospheric scientists have a vested interest in understanding the complex processes surrounding fog. Numerous companies have interests in conducting weather modification operations to abate fog. The recent emergence of unmanned aircraft vehicles (UAVs) has resulted in an examination of how proven fog abatement projects could be advanced using UAV technology to clear airport runways. Within eastern North Dakota and western Minnesota, the Red River Valley represents an ideal location for a future fog-abatement project. The lower-elevation valley promotes year-round fog potential, with fog occurrences peaking during February and March. The high-latitude geographic location makes the Red River Valley particularly susceptible to long-duration, super-cooled (temperature below 0 °C) fog events. Dispersion of super-cooled fog is easily accomplished with the insertion of ice nuclei into the fog. The mobility of UAV facilitates a new design concept for the deployment of dispersive materials and implementation of in-situ instrumentation for obtaining validation measurements. Through an analysis of fog measurements, both the feasibility of operational programs and dispersive methods may be investigated.

The scientific processes behind weather modification and fog dispersal are well researched and have an extensive history. The serendipitous discovery of dry ice instigating high concentrations of ice embryos occurred in the early 1940s by Vincent Schaefer. (Schaefer 1968) The usage of silver iodide as a cloud nucleant for supercooled water droplets was realized shortly thereafter in 1946 and remains to this day the most used method for supercooled cloud modification. (Schaefer 1946; Vonnegut 1947) The North Dakota Cloud Modification Project followed in 1951, aimed to reduce hail damage to crops and property through the artificial nucleation of supercooled cloud droplets. (Knowles and Skidmore 2021) By the 1960s, the US Army began investigating fog dispersal methods using conventional aircraft to clear airport runways. (Hicks 1967) Beyond its post-war inception, research in weather modification, fog abatement, and fog processes remains steadfast well into the 21st century. (Gultepe et al. 2007)

This proposal's objective is to analyze the feasibility and constraints of an Unmanned Aircraft System (UAS) based operational fog abatement program at Hector International Airport in Fargo, North Dakota. Similar to existing weather modification projects, a design concept and plan of operations provide the foundation for future operations. Implications from this project are not limited to the Red River Valley but extend to areas where super-cooled fog occurrences are seasonal. As UAS technology becomes more integrated within society, public and private sectors should increasingly benefit from an investigation of this alternative method of fog dispersal. The potential safety and economic advantages of cleared near-surface cloudiness and/or fog on local communities may not be trivial, particularly for the travel industry.

Methods

While the diurnal bias towards morning fog formation is well understood, literature on seasonal fog climatology in the northern High Plains is quite limited. To that end, Automated Surface Observing Systems (ASOS) data through the National Oceanic and Atmospheric Administration (NOAA) climate data archive provide a foundation for longer-term analysis. Focused in and around the RRV for the past 30 years, pertinent ASOS stations include Jamestown, ND (KJMS),

Grand Forks Air Force Base (KRDR), Grand Forks International Airport (KGFK), and Hector International Airport (KFAR). Through examination of relevant atmospheric parameters (most applicably visibility, temperature, and moisture), diurnal and seasonal trends guide theoretical targeting of future supercooled fog events and implement a seasonal timeline/length for future fog dispersal projects.

Model analysis of past fog events in the Red River Valley help gauge how current UAS capabilities would have been implemented. The Weather Research and Forecasting (WRF) Model is a mesoscale numerical weather prediction system that has capabilities to resolve resolution-intensive fog events. The 1 km WRF resolution domain is centered along a line from Fargo to Grand Forks, ND, encompassing the entirety of the Red River Valley longitudinally. Boundary conditions use data from the 3-km High-Resolution Rapid Refresh (HRRR) model, with chosen physical and dynamical processes appropriate for emulating surface cloud behavior. Real-time verification of these events is provided from ASOS/AWOS stations within the Red River Valley, and from an existing suite of instrumentation on a Meteorological Trailer stationed on the north side of KFAR. Once properly modeled, a case-by-case analysis of theoretical UAS operations is conducted. Future operational application of WRF modeling may also be considered depending on the efficiency and accuracy of case studies.

A Federal Aviation Administration (FAA) approved unmanned aircraft system (UAS) is supplied by WMI in the form of a weather-resistant drone and a qualified UAS pilot. A 1.6 m (diameter) hexcopter frame with integrated water ingress protection allows for a desired blend of endurance and functionality. Lightweight carbon fiber propellers permit a total weight capacity of up to 25 kg and a range of payloads between 4 and 6 kg. The resulting approximate flight times for 4 and 6 kg payloads are 32.5 and 28.9 minutes respectively. Two sets of four 30,000 mAh charged batteries allow for potential maximum mission lengths of around an hour. Sensitive wiring and electronics are all shrouded within the body of the frame, protected from cloud and/or supercooled water droplets. FAA-approved airspace for UAS missions is located at Ice Crystal Engineering (ICE) headquarters in Kindred, ND.

To help support fog dispersal operations, relevant atmospheric measurements need to be recorded and examined in real-time. For verification purposes, identical instrumentation is attached to both the drone and a surface-based tripod. The International Met Systems iMet-XQ2 UAV sensor measures pressure, temperature, and humidity for both systems; inherent GPS capabilities of the sensor are cross-referenced with internal GPS systems on the drone. Virtual Hydromet's MiniOFS sensor measures optical parameters relevant for fog analysis, namely visibility, extinction coefficient, and ambient solar irradiance. The R.M. Young Anemometer (model 05103-5) and attached serial interface (model 32400) record wind speed and direction exclusively on the surface-based tripod. The Raspberry Pi 4 (model B) stores data for both systems; the tripod uploading data in real-time to a CHORDS data server (NSF EarthCube).

There are two main applications for UAS implementation related to fog processes; to conduct and analyze research measurements/methods, and to perform operational fog abatement procedures. Numerous avenues of research allow for a thorough analysis of regional fog processes and fog abatement. These research efforts support and guide operational decision-making and help determine the roadmap for future operational procedures. Eventual UAS test flights serve as the coagulation of research and operational endeavors. In this dual-purpose fashion, a more accurate examination of the feasibility of UAS technology in anthropogenic fog abatement may be achieved.

Broader Impacts

Private and public entities benefit from an examination of potential UAV technological advancements in fog abatement. Existing aviation industry safety protocols require grounding of aircraft below certain visibility thresholds, resulting in cancellation of flights and substantial economic losses. UAS-capable companies and airports may profit from implemented fog abatement methods to keep visibility at airport runways above aviation industry safety standards promoting therefore a safe and profitable aviation and UAS industry. Determining the potential of conducting fog abatement in the Red River Valley would have applications that not only extend to other regions with supercooled-fog, but have project design implications for operations in warmer fog regimes.

References

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