UAS Fog Operations and Measurements at a Continental Site

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Abstract

A research program was conducted to assess the efficacy of an Unmanned Aircraft System (UAS) platform for acquiring fog microphysical data and to evaluate the feasibility of a supercooled fog dispersal project in the Red River Valley of eastern North Dakota and western Minnesota. A 30-year climatology (1989–2019) derived from Automated Surface Observing System (ASOS) stations reveals a distinct seasonal window for supercooled fog development from early November through early April, peaking during March coincident with regional snow melt. Average yearly occurrence rates of only approximately 14 supercooled fog hours underscore the importance of targeting both supercooled and warm fog regimes to make an operational fog abatement program feasible in the northern Great Plains. Five March 2023 UAS flight missions conducted in Kindred, North Dakota, demonstrated successful in-situ boundary layer measurements in both clear-air and low-visibility fog conditions using a custom, icing-resistant UAS equipped with an IMet-XQ2 temperature/humidity sensor and a MiniOFS visibility sensor. Vertical profiling successfully resolved fog-layer structure and determined fog-top heights of approximately 114 m and 92 m AGL during two supercooled fog events, with a pronounced temperature inversion identified at the fog-layer top during the final mission. Instrument performance assessments indicate that the IMet-XQ2 temperature sensor achieves near one-to-one agreement with reference sensors ($r^2 \approx 0.999$), while the relative humidity sensor exhibits a systematic underestimate at high humidities. The MiniOFS overestimates visibility at ranges below 1 km relative to the forward-scatter reference instrument (CS125); however, correlation improved substantially during active fog events ($r^2 = 0.716$).

Building on the March 2023 results, ongoing work through the Weather Modification International and University of North Dakota partnership is focused on developing practical methods for the delivery of seeding agents and the rigorous evaluation of fog dispersal efficacy through atmospheric observations. UAS-based delivery methods are being developed for the dispersion of large hygroscopic particles to enable abatement operations under warm fog conditions. Fog seeding effectiveness will be assessed with a suite of ground-based instruments that include a ground-based cloud droplet probe (CDP) system and visibility sensors (CS125 and MiniOFS), remote sensing instruments such as the Vaisala CL61 ceilometer with depolarization capabilities, and UAS-mounted sensors including a miniCDP, IMet-XQ2, and MiniOFS. These efforts aim to advance both the scientific understanding of fog processes and the practical deployment of UAS platforms as an operational tool for mitigating aviation and transportation weather hazards across the northern Great Plains.