Design Concept and Feasibility Analysis for Conducting Fog Abatement Using Unmanned Aircraft Vehicles

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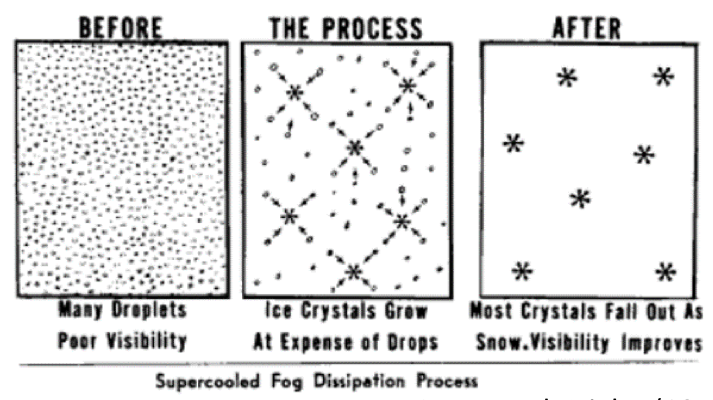
Introduction

Fog has adverse effects on the aviation industry by altering near-surface visibility. The recent emergence of unmanned aircraft vehicles (UAV) introduces the possibility of a new airborne platform for fog abatement projects to clear airport runways. The mobility of UAV compared to existing conventional aircraft or tethered balloon platforms facilitates a new project design concept for the dispersion of particles to promote fog dissipation. The Red River Valley (RRV) of eastern North Dakota and western Minnesota represents a suitable location for increased fog potential due to its low relative elevation to surrounding terrain. Limited research has been done on Red River Valley fog characteristics, prominently spatial/temporal extent, microphysical properties, and occurrence frequency. Conventional fog abatement projects involve in-situ injection of seeding agents to instigate coalescence of hydrometeors and eventual fallout. In the case of supercooled fogs (< 0 ˚C), seeding agents encourage ice crystal growth at the expense of supercooled droplets to initiate fallout and subsequent dispersal.



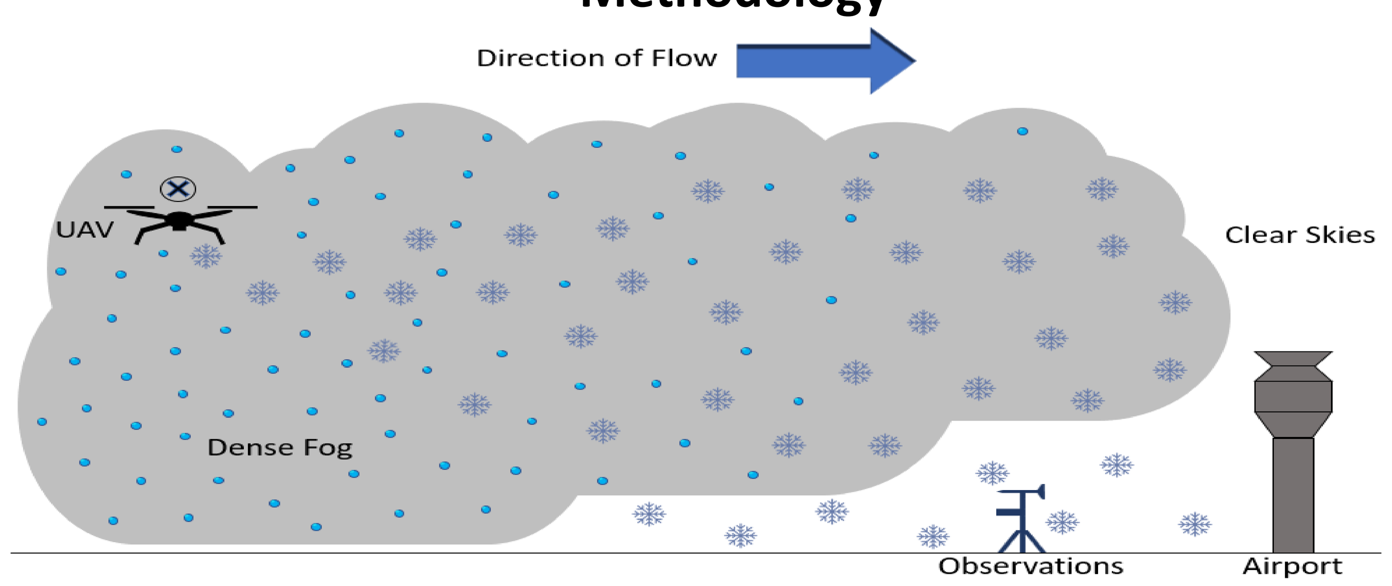
Lease and Zeigler (1972)

Objectives

Determine the potential for a UAV fog abatement project in the Red River Valley of North Dakota.

1. Design how a fog abatement project would operate using a small UAV
2. Evaluate the feasibility of conducting fog abatement at a Red River Valley airport

Methodology



To provide an initial framework for project methodology on fog abatement operation, initial research methods include:

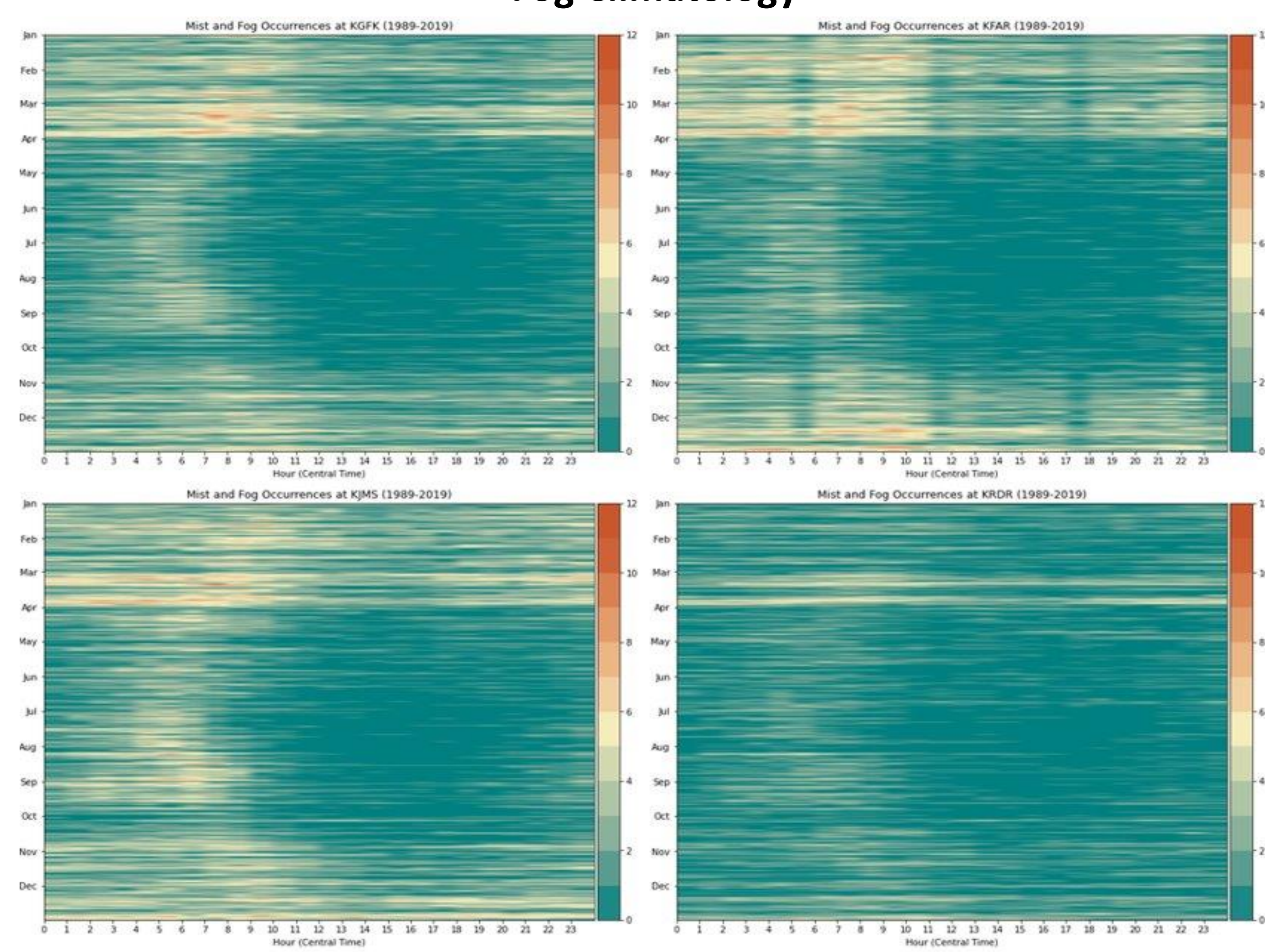
- Procure an UAV capable of low visibility and supercooled flight maneuvers
- Determine optimal intervals of potential for UAV fog abatement operations
- Utilize appropriate observational procedures, both on a surface-based station and on the UAV
- Implement real-time visualization of data

Unmanned Aircraft Vehicle

The drone and licensed pilot are both provided by Weather Modification International. A large hexacopter airframe with integrated water ingress protection allows for functionality with required payloads. The UAV has Federal Aviation Administration (FAA) approval to fly in visibilities below 0.25 statute miles and up to 400ft AGL during daytime hours. FAA approved airspace is located at Ice Crystal Engineering (ICE) headquarters in Kindred, ND, about 21 miles southwest of Fargo, ND.

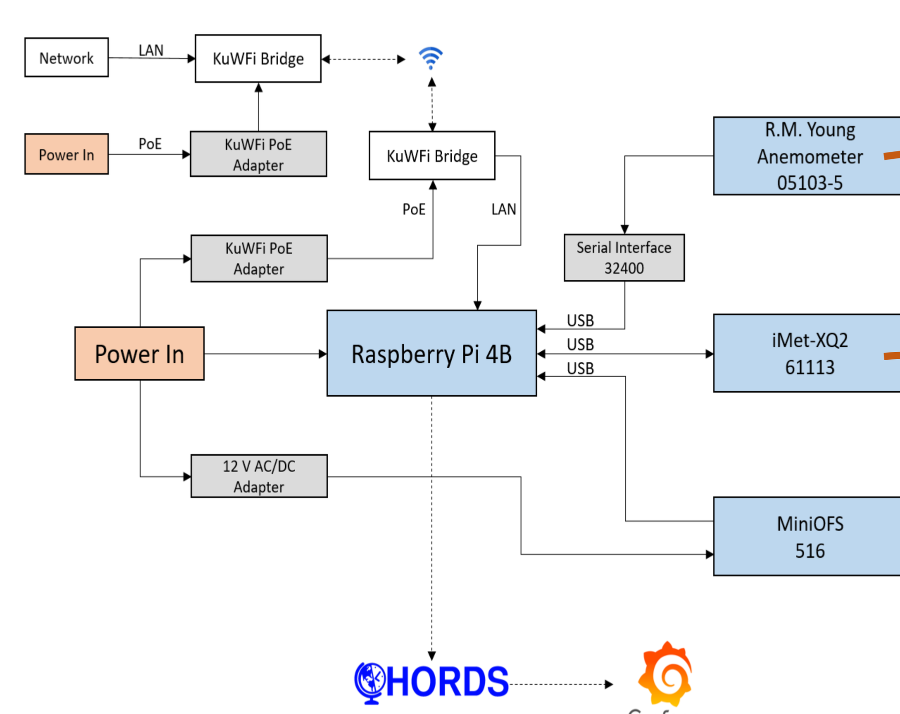
Manufacturer	Botlink
Design	Hexacopter
Diameter	1620mm (5.3ft)
Max Takeoff Weight	25kg
Payload	up to 6kg
Flight Time (4kg Payload)	32.5min
Flight Time (6kg Payload)	28.9min
Batteries (4) (8 total)	30,000mAh
Chargers (2)	25A
Instrumentation	iMet-XQ2 MiniOFS

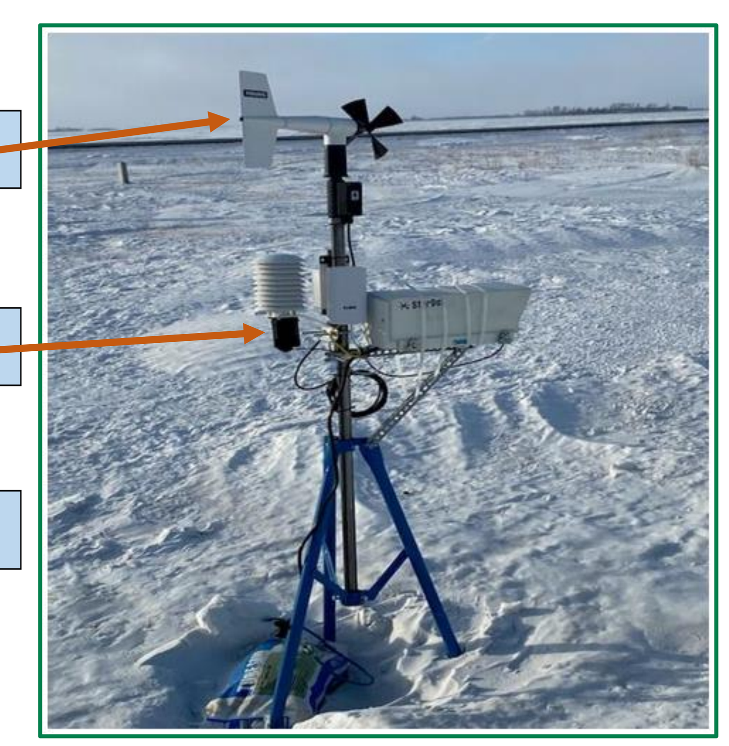
Fog Climatology



Mist and fog occurrences from various eastern North Dakota weather stations from 1989-2019 display both seasonal and diurnal trends. (From top left to bottom right: Grand Forks Airport, Hector International Airport, Jamestown Regional Airport, and Grand Forks Air Force Base.) Hydrometeor-instigated low visibility potential increases during the winter months and peaks during the month of March coincident with snowmelt. Occurrences reach a maximum of 12 events during the morning hours of March, indicating up to a 40% chance of yearly occurrence.

Observations: Surface-Based Station





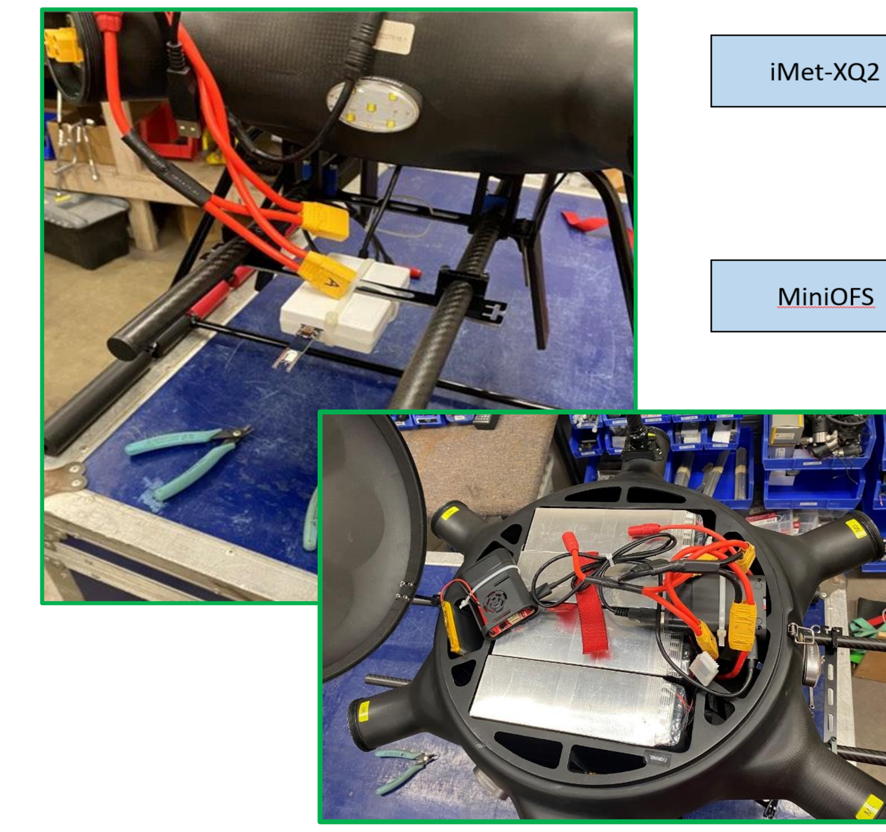
Instrumentation and Software

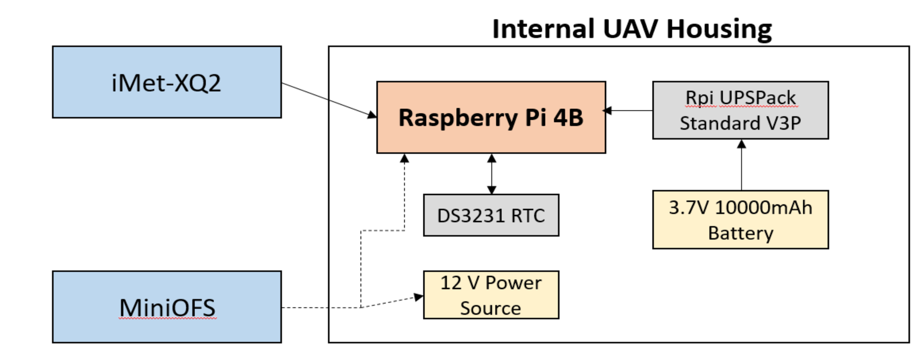
- R.M. Young Anemometer: Measures wind speed and direction
- iMet-XQ2: A UAV-designed temperature/humidity sensor
- MiniOFS: Optical sensor that measures visibility, solar irradiance, and extinction coefficient
- CHORDS: Web server and database for real-time distribution
- Grafana: Open-source observability platform for real-time data visualization

Hardware

- Raspberry Pi 4B: Runs data acquisition programs and stores data for instruments
- 12 V AC/DC Adapter: Power adapter for MiniOFS separate from Raspberry Pi 4B
- Serial Interface 32400: Interface that converts Young Anemometer analog signal to digital
- KuWFi Bridge: Internet source, one half of bridge on the station and other inside ICE headquarters
- Camera Module: Raspberry Pi 4B camera attached inside internal housing

Observations: UAV

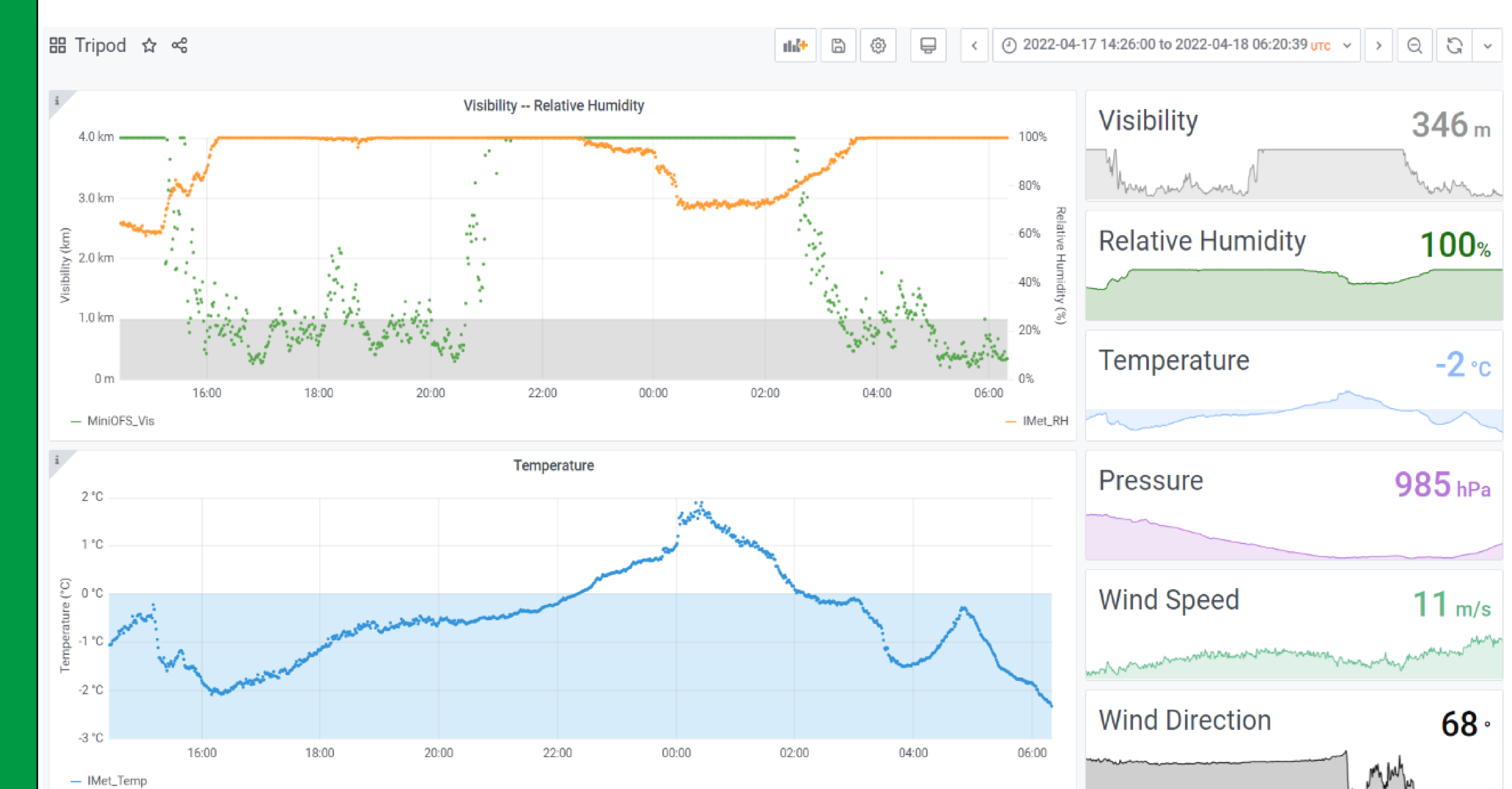




Instrumentation and Hardware

- iMet-XQ2: UAV-designed temperature/humidity sensor
- MiniOFS: Optical sensor that measures visibility, solar irradiance, and extinction coefficient
- DS3231 RTC: Real-time clock module
- RPi UPSPack: Uninterruptable Power Supply expansion board for battery

Data Visualization



Data visualization through the Grafana open-source observability platform in a real-time format. Two snow events were recorded by the surface-based station on April 17th and 18th, 2022, resulting in reductions of visibility below 1.0km.

March 2023 Fog Flights

As the climatological peak in fog potential approaches, UAV test flights plan to pursue various missions within low visibility:

- UAV hovering maneuvers adjacent to surface-based station for instrumentation comparisons
- Vertical maneuvers to examine the profile of fog layers, particularly for cloud tops
- Horizontal maneuvers to explore UAV longevity
- Observe icing/riming effects on UAV within supercooled fog
- Utilization of supplementary instrumentation (radiosondes) within low visibility UAV missions

Acknowledgements

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