Department of
MECHANICAL ENGINEERING
THE UNIVERSITY OF UTAH

Tethersonde: Meteorological Observation Device

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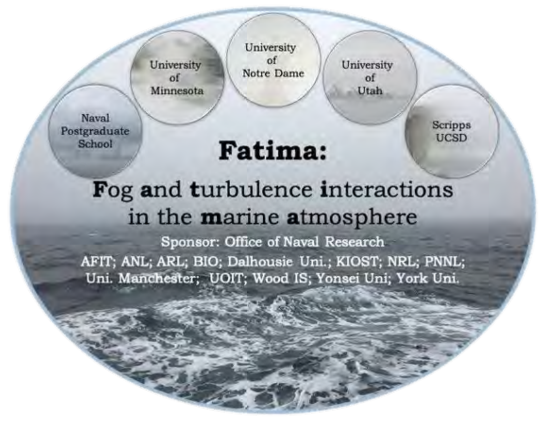

Intro/Abstract

The University of Utah's Environmental Fluid Dynamics Lab (EFD) utilizes a tethered meteorological device called a tethersonde to collect data for mapping and characterizing atmospheric boundary layers. Typically, multiple tethersondes are deployed on a moored helium-filled balloon that reaches heights of 1-3km. The device's fletching rotates the device into the wind and collects measurements such as wind velocity, direction, temperature, barometric pressure, and humidity. These measurements can then be used to model the boundary layer. The lab's current tethersonde technologies are outdated and/or lack certain functionalities that researchers have become accustomed to.

Objectives

Our team was tasked with adding additional sensors and controls to an existing custom tethersonde the EFD lab had quickly produced. The prototype was able to gather temperature, humidity, and barometric pressure, which was then saved to an onboard MicroSD card. The objective for our group was to add a wind velocity, wind direction, and wireless communication sensors in addition to the original sensor package. The specifications for the device are as follows

- < 400g
- > 2hr runtime
- > 1Hz sampling rate
- > 1km communication range
- Similar size to previous model
- Per Unit Cost < $500
- 0.5-10m/s wind velocity range
- ±0.1 m/s resolution
- ±5° azimuth

Methods

To achieve such objectives, a thermal anemometer (RevP) was used to collect wind velocity, an inertial measurement unit (IMU) was used for wind direction, and LoRa communication methods were selected. The Adafruit BN0085 IMU and the Modern Devices RevP were selected for their specifications and price. However, further research was needed to validate the accuracy of each device.

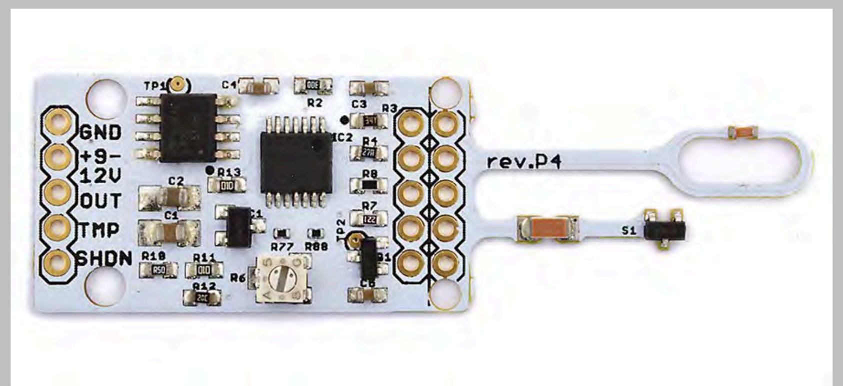
Figure 1: Modern Devices RevP Thermal Anemometer.

To validate the RevP, a study was conducted in a wind tunnel with flows ranging from 1-10 m/s. In addition, a CSAT3 3D sonic anemometer was used for sub-one m/s flow in a transient outdoor environment. A regression model of King's law was plotted to determine the relationship between the RevP's voltage output, ambient temperature, and true wind speed.

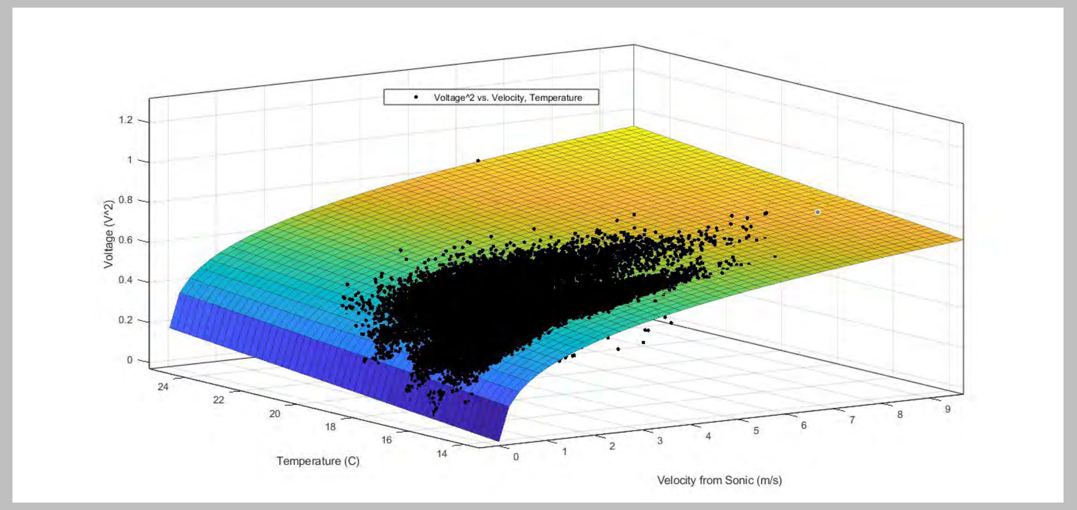
Figure 2: 3D regression relating voltage squared, wind speed, and ambient temperature.

Validation for the IMU consisted of a simulated deployment of the full prototype. Data was then collected for two hours, during which the 3D sonic anemometer collected wind direction data. Wind roses are shown below for each device.

Results

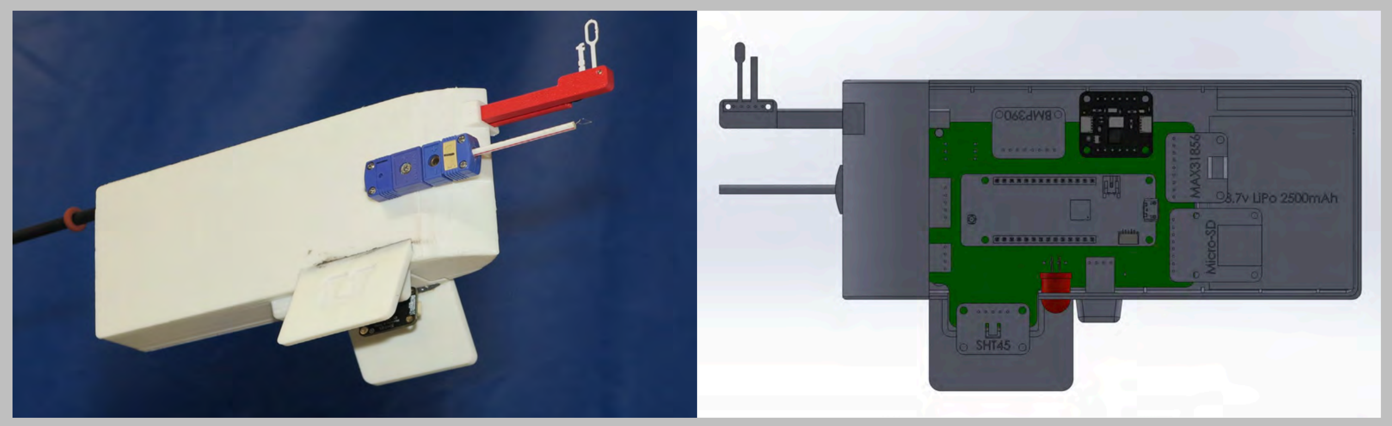
Figure 3: (Left) Front side view of fully assembled prototype. (Right) CAD rendering of tethersonde without its lid.

Our group produced an upgraded tethersonde that now features wind direction, wind velocity, wireless communication, and battery life indication. Ambient temperature, barometric pressure, and humidity sensors were included in the previous model and carried over. Selected sensors were then fixed to a custom-built printed circuit board (PCB) and placed into a 3D-printed ASA plastic housing. The design of the tethersonde includes placing the temperature/humidity sensor, thermocouple, and thermal anemometer away from the body to ensure unimpeded flows. Fins were added to the bottom to protect the temperature sensor from solar radiation.

Several small-scale deployments of the new prototype were conducted. To ensure the accuracy and precision of the chosen sensors, trusted and standardized instrumentation like the CSAT3 3D sonic anemometer, static tube, total station, and thermocouple were used. This was deemed necessary as older versions of tethersonde had become obsolete. Each small-scale test would have all measurements stored on board on a local MicroSD card as well as on a nearby computer via LoRa communication.

The Modern Devices RevP thermal anemometer was advertised for use in winds ranging from 1-67 m/s; however, the manufacturer neglected to state the device's accuracy. Through testing, it was found that the RevP has an average wind velocity error of 0.2 m/s in a transient environment, compared to the industry standard CSAT 3D sonic anemometer and static tube.

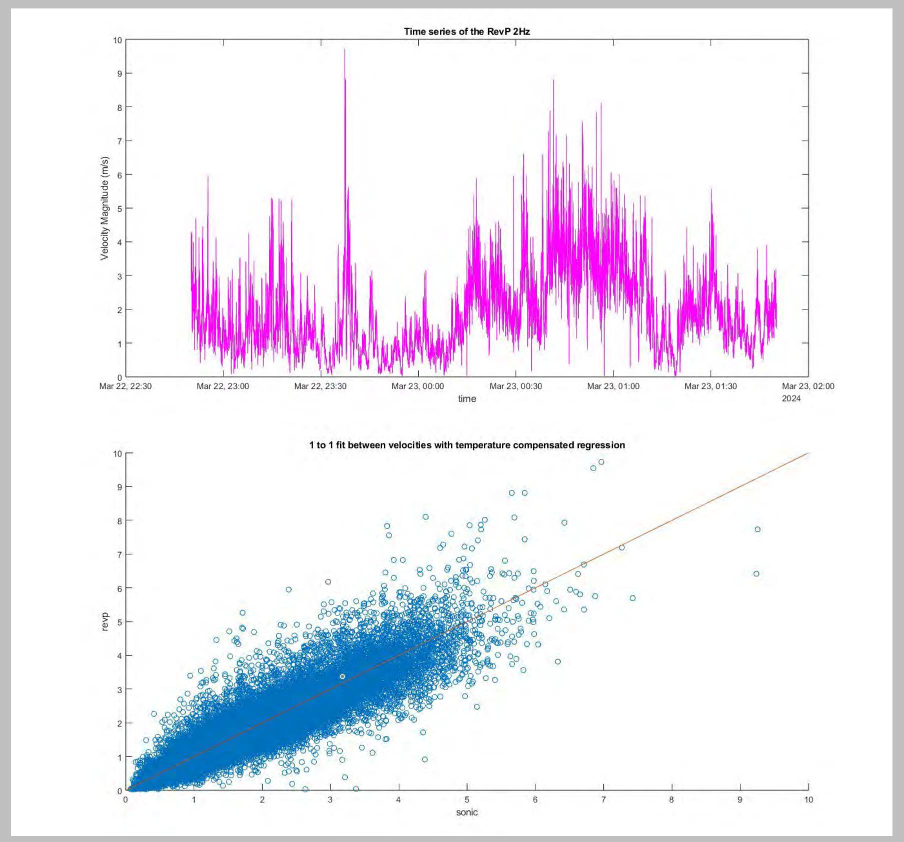
Figure 4: (Top) RevP wind velocity output over time. (Bottom) A one-to-one comparison of RevP output vs. CSAT 3D sonic anemometer.

Adafruit's BN0085 IMU was advertised to have accuracies of ±5°, and its magnetometer was within ±5° of true north. With the addition of a magnetometer calibration script, incorporating declination, the sensor was able to gather azimuth data with an average error of 0.433°.

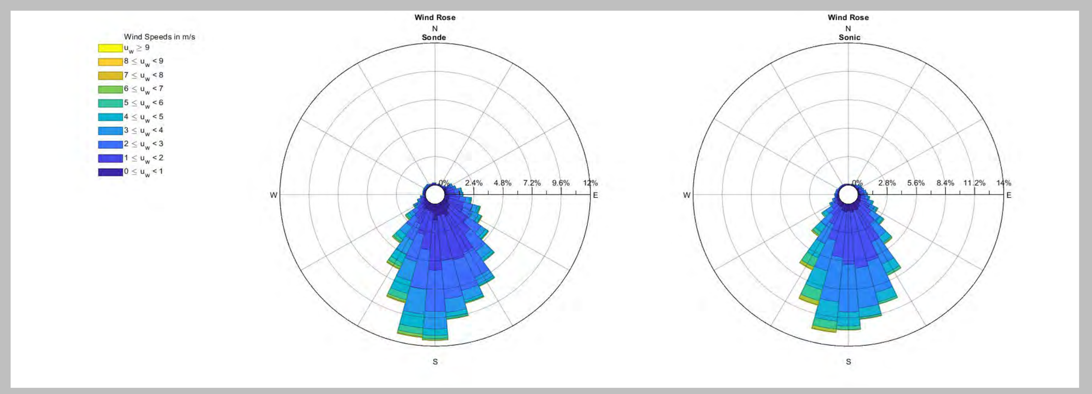
Figure 5: (Left) Wind rose displaying data collected from the tethersonde. (Right) Wind rose displaying data collected from the CSAT 3D sonic anemometer.

Cost	$230
Weight	272 g
Sampling Rate	10 Hz
Run time	+6hr
Range	+1km

Sensor	Avg Err	Description
BN0085 IMU	0.433°	Inertial Measurement Unit
RevP.	0.2 m/s	Thermal Anemometer
SHT45	0.1°C	Ambient Temperature & Hydrometer
BMP390	3 Pa	Barometric Pressure
Thermocouple Type E	1.0°C	Fast Response Ambient Temperature

Conclusion

The introduction of the enhanced tethersonde marks a significant advancement in atmospheric measurement technology. By incorporating wind speed, wind direction, and a communication protocol, the device has undergone substantial improvement, facilitating deeper insights into atmospheric layers. To further enhance its capabilities, future efforts should prioritize optimizing the wireless communication protocol to enable the deployment of a greater number of tethersondes simultaneously.