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Joint UAS-Balloon Activities (JUBA) Field Campaign Report

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ARM CLIMATE RESEARCH FACILITY

DISCLAIMER

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Acronyms and Abbreviations

AMF	ARM Mobile Facility
ARM	Atmospheric Radiation Measurement
DOE	U.S. Department of Energy
DTS	distributed temperature sensing
JUBA	Joint UAS-Balloon Activities
RH	relative humidity
RMSE	root-mean-square error
SNL	Sandia National Laboratories
TBS	tethered balloon system
UAS	Unmanned Aerial System

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1.0 Summary

Using internal investment funds within Sandia National Laboratories' (SNL) Division 6000, the Joint UAS-Balloon Activity (JUBA) was a collaborative exercise between SNL Organizations 6533 and 6913 (later 8863) to demonstrate simultaneous flights of tethered balloons and unmanned aerial systems (UAS) on the North Slope of Alaska. JUBA UAS and tethered balloon flights were conducted within the Restricted Airspace associated with the U.S. Department of Energy's Atmospheric Radiation Measurement (ARM) Climate Research Facility third ARM Mobile Facility (AMF3) site at Oliktok Point, Alaska. The Restricted Airspace occupies a two-nautical-mile radius around Oliktok Point. JUBA was conducted at the Sandia Arctic Site, which is approximately 2 km east-southeast of the AMF3. JUBA activities occurred from 08/08/17 and 08/10/17.

Atmospheric measurements from tethered balloons can occur for a long duration, but offer limited spatial variation. Measurements from UAS could offer increased spatial variability. To understand how balloon and UAS activities could occur together, JUBA activities included the following:

- Developing aviation safety plans for the simultaneous, collocated operation of tethered balloons and UAS
- Adapting tethered balloon-based fiber optic distributed temperature sensing (DTS) measurements to a UAS platform
- Creating solutions to technical challenges such as:
  - Developing a motor system to match the fiber deployment rate with the ascent/descent rate of the UAS
  - Evaluating methods of identifying the surface in the DTS temperature profile
  - Correlating simultaneous balloon and UAS DTS temperature measurements
  - Assessing the effects of a fiber optic rotary joint on the DTS temperature measurements
  - Determining what UAS-based sensors provided the best calibration source for the DTS temperature data.

A fiber guide and weak link mechanism were developed. The weak link prevented excessive strain on the fiber to avoid pulling the UAS. The link released at 10 lbs of force. A motorized fiber reel was operated to match the ascent or descent rate of the octocopter UAS. The reel was operated with a variable speed motor controlled by a foot pedal. At the surface the fiber was run through a two-meter-long heated tray. The heat tray was used to identify where the surface was in the DTS temperature profile, since the DTS measures continuously through the entire length of fiber, including what is left on the reel. A temperature reference was required at the end of the fiber in order to calibrate the DTS measurements. An iMet radiosonde was suspended directly below the Cinestar octocopter, along with a parachute that would deploy in the event of the weak link separating. An iMet-XQ UAV sensor was also attached to the octocopter and used to compare with data collected by the iMet radiosonde. Flights were conducted to 550m, which was the highest that could be achieved using a 1.25 m/s ascent rate and a relatively short flight time of 12-18 minutes. The optical fiber used with the DTS system on the tethered balloon was

damaged during JUBA and the resulting data set could not be processed. Comparison temperature profiles were obtained from free balloon radiosonde launches.

Figure 1. Tethered balloon and UAS at Sandia Arctic Site during JUBA.

Figure 2. UAS preparing to ascend with fiber guide and heat tray shown between the UAS and motorized fiber spool.

2.0 Results

The altitude, temperature, temperature from the relative humidity (RH) sensor, and RH from the iMet radiosonde and iMet XQ sensors were compared in multiple configurations. For all four measurements, if the iMet radiosonde was viewed as truth, the iMet XQ sensor was more accurate when mounted along the boom. When mounted along the boom the iMet XQ temperature sensor gave a root-mean-square error (RMSE) of 0.2 °C, which indicated it was accurate enough to be used as a calibration reference aloft for DTS flights with rotorcraft or balloons.

DTS data were analyzed to determine if the fiber would be sufficiently heated by the heat tray to observe a spike in the temperature data. The heat spike could be observed in the data set, but it skewed the temperature measurements aloft too warm. The octocopter ascent rate was increased in order to heat the fiber for a shorter period of time, but then we were unable to discern the spike in the data and it was difficult to identify the surface.

DTS measurements are collected by the ARM tethered balloon system (TBS) operated at the AMF3 site. After analyzing the JUBA results, DTS measurements were collected with the TBS in October 2017 using a saltwater bath rather than a heat tray to demarcate the surface. This methodology did not skew the DTS measurements and will be further investigated on future ARM TBS flights.

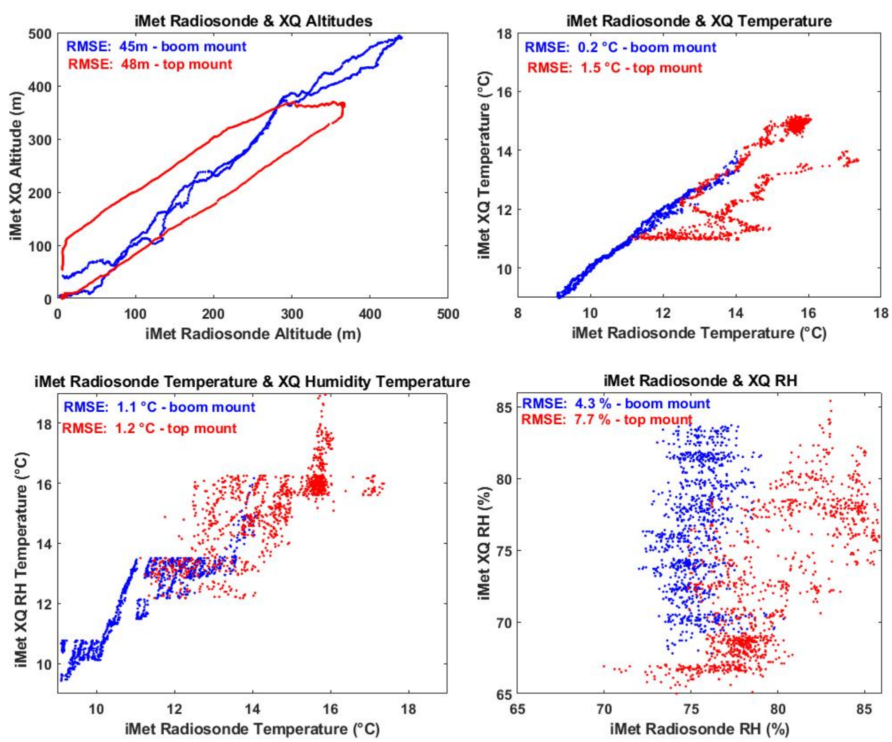

Figure 3. Comparison of iMet radiosonde and iMet-XQ UAV sensor measurements when iMet-XQ sensor was mounted along the UAV boom or on top of the UAV.

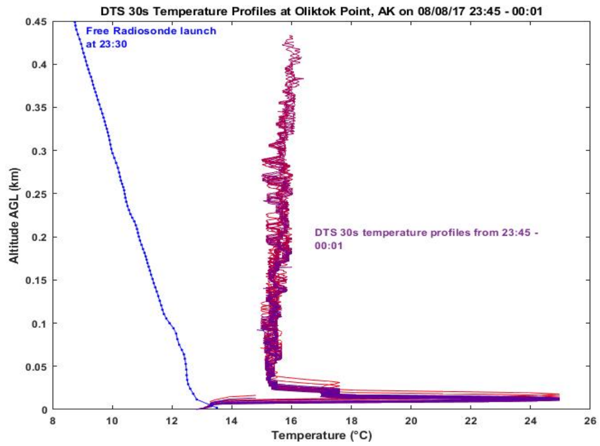

Figure 4. DTS profile where heat spike at surface is visible and corresponding radiosonde launch is several degrees cooler.

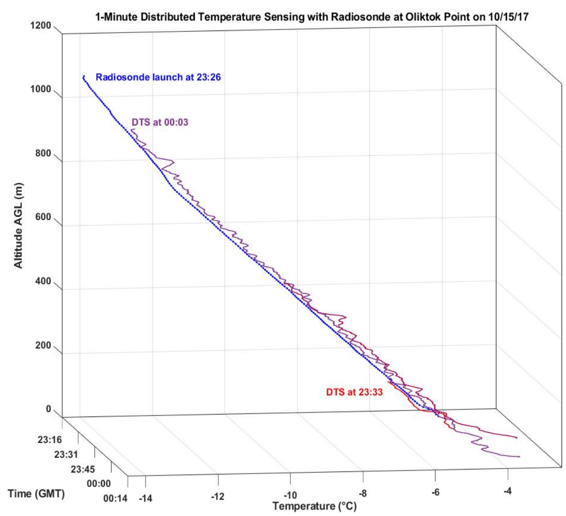

Figure 5. DTS profile from TBS in October 2017 when a saltwater bath, rather than a heat tray, was used at the surface.

3.0 Publications and References

Results were presented at the 2018 American Meteorological Society Annual Meeting on 1/9/18 in the session entitled “19th Symposium on Meteorological Observation and Instrumentation.”

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