Calibration of Temperature Sensors in Preparation for the 2017 Total Solar Eclipse

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Abstract

In preparation for the 2017 total solar eclipse, St. Catherine University developed a calibration protocol for the temperature sensors flown during thermal wake boom experiments. The calibration method used a standard two-point technique that corrected each individual sensor for both slope and offset errors using a high quality NIST certified thermocouple as the temperature standard. Our method is not absolute but corrects each sensor relative to the NIST standard so that we feel some confidence that individual sensor variations are mitigated. In preparation for the eclipse, calibration curves were generated for over 200 individual digital and thermistor temperature sensors.

Methodology and Equipment

It was essential that the sensors be ordered sequentially before calibration because each sensor was manufactured with a unique address. The sensors were placed on a bus in sequence from smallest to largest registration number. Once the sensors had been ordered, they were connected to an Arduino Mega fitted with an SD shield which recorded data. To perform the calibrations, the Dallas temperature sensors and GT probes were put through four tests. The tests being room temperature room pressure (RTRP), low temperature room pressure (LTRP), low temperature low pressure (LTLP). At low temperatures we used dry ice which allowed us to obtain temperatures as low as -54º C. To obtain a vacuum we used a rough pump which pulled pressure down to fractions of an atmosphere. As indicated in Fig. 4 the temperature profile levels off near -55º C which indicated that we had reached near equilibrium conditions.

Two-Point Calibration

Once the four data points were collected for each sensor, the near equilibrium temperature conditions were averaged and used as data points for calibration curves. For each individual sensor, a calibration curve was made using GT probe data as the input, and Dallas sensors temperatures as the output. A calibration equation was then extrapolated from the curve and used as the correction factor for all temperature collected by that unique sensor.

The Dallas sensors were flown on a 10ft wake boom with 22 sensors total on a single 1-D wake arm. Prior to a flight, the sensors were painted with a light coat of white out and the wires that run the length of the wake arms were wrapped using white tape. The white color helps reduce heating due to absorption of thermal energy. The Dallas sensors were used in conjunction with Onset corporation thermistor sensors.

Background

The sensors used in this process are digital Dallas DS18B20 temperature sensors. Each sensor is manufactured with a unique 64-bit serial code address allowing for multiple sensors to be arranged in a 1-wire multi-bus configuration. The GT probes used are NIST certified thermocouples. The Dallas sensors are calibrated against the GT probes, which serve as the gold standard for all calibration work. An Arduino Mega is used in conjunction with the Dallas sensors. The code utilized generates a record on an SD card which includes a timestamp along with the temperature of the particular sensor queried.

Motivation

St. Catherine University began measuring the thermal wake of ascending HABs in 2011 – see (Ref 1&2). Early in the process HBRD thermistors were primarily used. As we needed to fly more and more sensors but keep the weight down, we moved to using Dallas 18B20 digital sensors as they work using one-wire technology, meaning many sensors may be read using one input/output port. The manufacturer accuracy of these sensors is listed as ±0.5º C at -50º C to 100º C or ±2º C accuracy from -55º C to 125º C. However, we used 22 sensors total on a single 1-D wake arm. Prior to a flight, the sensors were painted with a light coat of white out and the wires that run the length of the wake arms were wrapped using white tape. The white color helps reduce heating due to absorption of thermal energy. The Dallas sensors were used in conjunction with Onset corporation thermistor sensors.

Implementation

The Dallas sensors had been ordered, they were connected to an Arduino Mega fitted with an SD shield which recorded data. To perform the calibrations, the Dallas temperature sensors and GT probes were put through four tests. The tests being room temperature room pressure (RTRP), low temperature room pressure (LTRP), low temperature low pressure (LTLP). At low temperatures we used dry ice which allowed us to obtain temperatures as low as -54º C. To obtain a vacuum we used a rough pump which pulled pressure down to fractions of an atmosphere. As indicated in Fig. 4 the temperature profile levels off near -55º C which indicated that we had reached near equilibrium conditions.

Future Steps

To improve the accuracy of calibrated data, future efforts will focus on:

- Multi-variable calibration curves
- Calibration curves using more than two points
- Executing advances in machine learning to find trends and patterns in the calibration data

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Sensors Accuracy Range

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Accuracy</th>
<th>Range</th>
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</thead>
<tbody>
<tr>
<td>GT-1</td>
<td>± 0.5º C</td>
<td>0º C to 50º C</td>
</tr>
<tr>
<td>DS18B20</td>
<td>± 0.5º C</td>
<td>-10º C to 85º C</td>
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</tbody>
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