Legacy Calibration of the Automatic Weather Station Model 2 of the United States Antarctic Program (A Primer)

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1. OVERVIEW

Automatic Weather Stations (AWS) developed originally at Stanford University in the 1970's and since 1980 by the University of Wisconsin have recorded air temperature and pressure, humidity and wind data for 35 years a few Antarctic sites. Some sites (e.g. Byrd Surface Camp) provide extensions of observations taken by station personnel prior to AWS deployment. As the data record has lengthened, some investigators are using the data in studies to determine if climatic trends are observed in the records. Last year we summarized results of the AWS2's temperature measurements. This year we provide an update on calibrations of retired AWS2s as they are replaced by CR1000 based AWS.

2. Background

Stanford produced an initial 20 AWS2A units with parts for about 4 spare units. Of the initial 20 units, eight AWS were designed to run from radioactive thermoelectric generators (RTGs). From 1982 to about 2002, the University of Wisconsin produced about 75 AWS2B units of various configurations. During this time, the AWS2B design was modified to accept new sensors and hardware. However, the basic circuitry that measured air temperature, pressure, humidity and wind speed was basically unchanged. There were however, improvements and changes in the various sensors used to measure the basic parameters.

3. AWS temperature measurements

The original Stanford AWS temperature circuit consisted of a modified bridge that had two bridge resisters - a one-percent precision resister and the Weed platinum resistance thermometer (PRT) in a two wire configuration. A fixed calibration point for the AWS was chosen to be 0.0 ^{o}C. A 1000 ohm (at 0.0 ^{o}C) PRT was selected as the temperature sensor. In order to set the PRT to 0C for a particular AWS, a 0.05% resister was substituted for the PRT and the AWS temperature output was observed. The output was set to 0C by setting an offset value in the AWS onboard software that compensated for the variation of the resistors in the bridge from their stated values. Typical "errors" from the PRT calibration table were less than 1.0 C over the temperature range from 25C to -75C.

As the AWS2B units are replaced with the new CR1000 based units, the returned AWS are again calibrated to determine if the calibration point at 0C is still valid and at simulated temperatures down to -75C. As noted last year, the AWS2B legacy calibration depends on both AWS2B system drift and any change in the Weed PRT. Legacy calibrations to date indicate very little change in overall calibration at room temperature and excellent calibration over the entire temperature range for the few AWS2B units that have been tested to date.

4. AWS pressure measurements

The only pressure sensor used for all AWS2 stations has been the Paroscientific model 215A pressure transducer. The 215A coupled with the AWS2 provided an initial accuracy of +/-0.1 hPa. There have been four generations (my classification) of 215As, with each generation

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achieving better accuracy and lower long term drift. The long term drift results in an error in pressure with a negative bias due to out gassing in the reference vacuum chamber and water vapor migration through sealants in early models (later generations this problem).

The output signal is a frequency (nominal 40 KHz) that is a function of both the air pressure and the temperature. Early models required a separate temperature measurement which the AWS2 provided with a Weed PRT laid against the outer case of the 215A. Later 215A models incorporated an onboard temperature sensor at the point of the pressure sensor. However, all AWS2B units continued to use the Weed PRT temperature to compute the pressure from the observed output frequency of the 215A.
The early 215A models (the original 20 or so gauges purchased for the AWS2A units) that have been returned for calibration have a long term drift of between 2 and 6 hPa over 30 years. Second and third generation models have shown a drift of around 2 to 3 hPa over 15 to 20 years. The latest generation of 215A have less than 2 hPa of drift observed over 10 years.

5. AWS humidity measurements

One of the original Stanford AWS2A units (8908) had a Vaisala HMP1 sensor that provided humidity data. It required an additional circuit in order to provide necessary voltage output for the AWS2A. Stated accuracy was +/- 5%. Vaisala improved the humidity sensor with the HMP31UT humidity and temperature probe. A regulated 3.6 Vdc supply was provided by the AWS2B's and a new amplifier board was added to increase the HMP31UT output by a factor of 10 to match the input range of the AWS2B's analog-to-digital converter. All AWS2B units were capable of using the HMP31UT. The humidity value was with respect to water and the dynamic range of the output decrease with lower temperatures so that at temperatures below -40C, the HMP31UT output essentially tracked the temperature. For this reason, the HMP31UT was used primarily at sites on the Ross Ice Shelf. In the late 1980s, Vaisala introduced the HMP35A, which had its own regulated power supply and could operate at colder temperatures. The HMP35A provided an output of 0 to 1.0 Volts that matched the AWS2B A/D, thereby eliminating the need for an amplifier board for this measurement.
In the mid 1990's, Vaisala introduced the HMP45A which again improved the performance of the humidity probe. The last few AWS2B units used HMP45A probes along with any replacements of older model probes on other units.
Several HMP31UT probes were returned for recalibration. Others were so degraded by the long exposure to the Antarctic environment, it was not possible to check their calibration. Many HMP35A probes have been returned in good shape. For these probes, calibration checks show humidity readings typically read high by about 5 to 10 percent of the reference humidity. For a lab humidity of 40% most returned HMP35As would read 42 to 44% after 20 years.

6. AWS wind speed measurements

Wind measurements were by far the most difficult of the basic meteorological parameters. These sensors have moving parts that wear with time and easily degrade under conditions in the Antarctic. The original Bendix Aerovane was used until the mid 1980's, when Belfort bought the Bendix corporation's environmental division. There were some problems with the first Belfort Aerovanes. A decision was made in the early 1990's to use the RM Young model 05103 wind sensor standard on the AWS2B. Adapting the AWS2B for the new wind sensor required only minor wiring and circuit changes.
The Bendix Aerovane was very robust and would function within stated specifications for many years. The RM Young wind sensors also have proved very reliable at most sites. However, at sites with very high winds or near marine environments, both sensors were prone to failure. At a few very windy sites we deployed Taylor Scientifics High Wind Speed sensors that could survive more than one season.
At sites with very cold temperatures the Aerovanes wind speed bearings would not function properly, resulting in lower wind speed readings. The RM Young sensor appears to behave better at the coldest temperatures, but operation is likely degraded as well.

6. Legacy calibration procedure

The goal of our legacy calibration of AWS2 units is to provide a data base of best estimate calibration data for each AWS unit at any given site over time. This is not a trivial process in that some AWS sites had several AWS units installed there with different sensors. Even AWS units identified by the Argos ID may in fact have different hardware from year to year as we would often make new units with the same Argos ID to replace a nonworking AWS. This was done to facilitate the transmission of data onto the Global Telecommunication System which was tied to a particular Argos ID. The nonworking AWS2B would be repaired and given a new Argos ID for use elsewhere.

For these reasons, we tried to make the AWS2B calibrations as independent of the hardware as possible. Thus any sensor boom could be used with any AWS2B unit. If the AWS2B system calibration changed very little over time then as long as a sensor maintained its calibration as well overall AWS2B calibration would remain within stated accuracy over time and over the Antarctic temperatures.
The complete legacy calibration consists of the following steps.

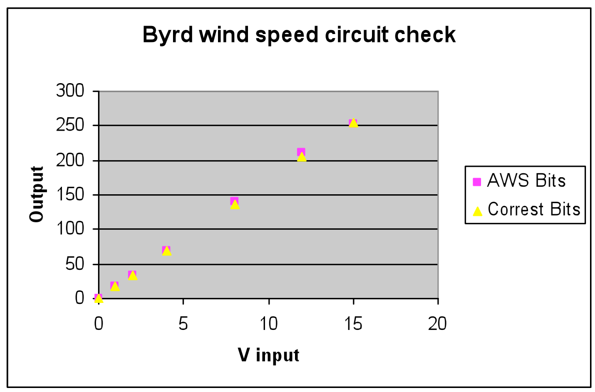
All sensors are checked at room temperature for deviations from original specifications. When appropriate the wind sensor will be included along with the Weed PRT and humidity probe on the sensor boom.
Next the AWS2B hardware calibration will be checked at room temperature (including the pressure sensor housed in the AWS2B electronics). This will be done with known good sensors or simulated inputs.
Finally, the sensors (except for wind sensors at t h is time) and the AWS2B electronics will be placed in an environmental chamber capable of simulating the temperatures of the Antarctic. Sensor data will be recorded versus an appropriate reference. This part of the calibration will be most important for pressure and temperature measurements.

To date this has only been done for one AWS unit, namely the two AWS2A and AWS2B 8903 units from Byrd Station. Below is the environmental test for a PRT resistance of 1000 ohms (0.0 C) and the AWS temperature.

Chamber T	**Calibration Resistance/ Temperature**	**AWS Temperature**
22 C	1000 / 0 C	-0.125 C
+/-0 C	1000 / 0 C	0.000 C
-20 C	1000 / 0 C	0.000 C
-40 C	1000 / 0 C	0.125 C
-60 C	1000 / 0 C	0.250 C

Sample Table: Byrd AWS 0.0 C

Below is the simulated wind speed calibration for the AWS2B form Byrd Station.



The overall accuracy of the wind speed circuit was within 2% after 30 years.

7. ACKNOWLEDGEMENTS

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