Quelccaya AWS – metadata for Air Temperature (CRN-compatible shield)

Location: Quelccaya Ice Cap summit (5,680 m), Cordillera Vilcanota of southern Perú, at 13.9°S and 70.8°W

Tower: interconnected aluminum tubing arranged in an equilateral triangular array, extending into the glacier and supplemented annually to accommodate accumulation. Cabling between tubes allows annual adjustment, to keep tower plumb (vertical). Horizontal tower members are spaced approximately 1.5 m apart. See image below.

Radiation Shield: Met One, Inc. model 076B, compatible with that used by NOAA CRN (U.S. Climate Reference Network). Complete specifications and performance information can be found on the CRN and Met One websites (http://www.ncdc.noaa.gov/crn/ and http://www.metone.com). Housed within the shield are two 12-volt DC-powered fans (Papst 4212) to aspirate the air temperature sensor; only one fan is active at any point in time, under datalogger control. To verify proper rotational speed of the fan, the datalogger records average speed each hour. Typically the fan moves ~100 ft^3/min through the shield.

Temperature Sensors: Housed within the radiation shield are Platinum Resistance Thermometers (PRTs) made by Thermometrics Corporation. As with the shield, these are also USCRN compatible. The manufacturer's stated repeatability and stability are better than ± 0.01°C per year, with an accuracy of ±0.04% over the full specified range or -60° to +300°C (yet 1^{st}/99^{th} percentiles of Quelccaya 5-minute temperatures only range -0.4 to -8.9°C). Four PRTs were calibrated and installed within the shield in June 2007, operating until May 2010. These were replaced by 3 new, calibrated PRTs in May 2010, along with a fourth PRT of a different design. The original 4 probes were recalibrated in July 2010. Temperature at the station is also measured by two other systems, and an intercomparison is underway.

Measurement Height: All air temperature measurements – with the various sensors – are made at the same height above the glacier surface. However, this height varies seasonally due to snow accumulation and ablation at the site, as tracked by two ultrasonic sensors mounted on horizontal arms extending from the tower. Anticipated annual accumulation to >4 m required sufficient measurement height to insure that the sensors remained well above the surface. In reality, mean measurement height for the 6-year record was 3.43 m, with median min/max of 2.3 and 4.3 m, respectively. In general, measurement height slowly increases from May or June through October, and then decreases during the wet season. Annual raising of the tower typically occurs in June or July, and results in an abrupt, ~1.5 m increase in measurement height. Empirical evidence indicates that this increase has minimal impact on air temperature measurement, likely because the temperature gradient is low higher than ~2 m above the snow. Wind speed at the station averages 4 m/s.

Period of Record: Air temperature measurements (hourly) as described above are currently available for the interval ***1 July 2007 through 30 June 2009*** – the first two years of measurements. This is the period which has no missing values after comprehensive processing as described below. Measurements to 15 July 2013 contain gaps of varying length which will require additional processing and assumptions. Battery replacement in July 2013 will hopefully minimize subsequent gaps.

Measurement Processing and QC: Under datalogger control, the measurement interval is 10 seconds. Values are averaged and recorded for each sensor every 5 minutes. Upon recovery, data underwent the following process of quality control (QC) following the logic discussed in Palecki & Groisman (2011):

1. Rotational speed of the fan used to aspirate the temperature sensors is recorded hourly, and these mean speeds are assumed to represent each of the prior 5-minute temperature intervals (n=12 each hour). On the basis of histograms, 107 Hz (53.5 revolutions/s) is considered the fully-functional speed at Quelccaya, a value slightly higher than the minimum of 90 Hz used by the USCRN. Temperature measurements at fan speeds less than 107 Hz were deleted.

2. Four PRTs operated within the radiation shield between 27 June 2007 and 3 June 2010. For each set of 5-minute averages during this period, the measurement deviating most from the other three was discarded, and the average 5-minute temperature was calculated.
3. Instrumentation changes were made on 3 June 2010, and three PRTs operated within the shield for the balance of the period of record (currently to 16 July 2013). For each set of 5-minute measurements with sufficient fan speed, a pairwise absolute difference was calculated and assessed relative to the USCRN pairwise tolerance of ±0.3°C (Palecki & Groisman, 2011). Tolerance was satisfied the vast majority of time (average pairwise difference = ±0.024°C).
4. A 5-minute mean temperature series was produced by averaging all remaining measurements. This series is missing 6.8 percent of all times (28 June 2007 through 15 July 2013), due primarily to insufficient power availability for intervals between the 2010 and 2012 field seasons, following installation of new instrumentation in 2010. Because these are systematically-missing values (i.e., most frequent just before sunrise), additional processing is underway to produce a composite air temperature series. Nonetheless, the daily maximum temperature record is nearly complete, as few measurements were lost at mid-day. Those that were lost are being filled through relationships with temperature measured in other shields.
5. The hourly series was produced by averaging 5-minute values for the preceding hour (n=12).

Figure. Quelccaya Ice Cap automated weather station at ~15:00 local time on 4 June 2010. Air temperatures are measured in the white shield, here highlighted within the red oval. The lower of the two upper shielding disks is 51 cm in diameter. Measurement height at the time was ~4.5 m. This view is looking approximately to the northeast.