WMO SPICE – Data logger summary

Version	Date	Notes
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2	Dec. 10, 2012	Incorporated edits from Jeff Hoover (EC – OSE)
3	Mar. 18, 2013	Final formatting for distribution to SPICE team

1. Introduction

1.1. Objectives

To compile details of the various data loggers to be used during WMO SPICE from site submissions and to conduct an informal assessment of measurement uncertainties related to their accuracy and resolution specifications. In short, we are looking to address the question of whether the use of different data loggers at different measurement sites will affect the intercomparison data. Hence, for the purposes of the intercomparison, it is important that any discrepancies between data sets related to the data loggers are identified and, to the extent possible, quantified.

The assessment will focus on the accuracy and resolution of analog frequency measurements, applicable to measurements from Geonor T-200B3 automatic weighing gauges (three vibrating wire transducers). For measurements from OTT Pluvio^2 automatic weighing gauges, the logger records the digital output from the gauge, and hence, the specific data logger used will not impact the Pluvio^2 precipitation data.

1.2. Overview

The makes, models, and specifications of the data loggers to be used at participating sites during WMO SPICE are provided in Section 2. The methodology for estimating frequency uncertainty from data logger specifications is outlined in Section 3, accompanied by estimates of the accuracy, resolution, and total uncertainty for applicable data loggers. In Section 4, the uncertainties in frequency are used to estimate the associated uncertainty in precipitation amount for a representative Geonor T-200B3 gauge. A summary of key findings and concluding remarks is provided in Sections 5.

2. Summary of data loggers

As compiled from SPICE site submissions, the data loggers to be used during the project are summarized in Table 1. In some instances, frequency input modules are used to add capacity for analog measurements; these modules are also specified in Table 1. Note that only those data loggers identified explicitly in site submissions are included in Table 1.

3. Accuracy, resolution, and associated uncertainties

The specified accuracy and resolution of frequency measurements for each data logger/frequency input module (Table 1) are given in Table 2a. In some instances, the accuracy specified by the manufacturer includes the resolution uncertainty; however, for consistency across all data loggers considered here, the contributions of accuracy and resolution to the overall uncertainty are considered separately in Table 2a.

For a frequency of 2851.3 Hz, corresponding to a full bucket for a representative Geonor gauge (this same gauge and its calibration parameters will be used throughout this document), the uncertainties associated with the accuracy and resolution are calculated using the manufacturer specifications. Where required for resolution uncertainty calculations, the number of sample cycles is taken as 250, corresponding to the sampling procedure used for Geonor gauges at the Centre for Atmospheric Research Experiments (CARE) field measurement site in Canada. The accuracy and resolution uncertainties are summed to give the total uncertainty in terms of frequency, which is considered to be an upper limit, given that the maximum frequency value (full Geonor bucket) for the representative gauge is used. A sample set of calculations demonstrating the approach is provided in Section 3.1, and the estimated uncertainties are provided in Table 2b.

3.1. Approach for uncertainty calculations

Sample calculations for computing the accuracy and resolution of frequency measurements are provided below for a Campbell Scientific CR3000 data logger sampling at 250 cycles and reading a frequency of 2851.3 Hz. Calculations are distinguished from descriptive text through the use of blue text below.

From Table 2a, the accuracy of this data logger (for period averaging) corresponds to ± 0.01% of the reading:

Accuracy uncertainty = 0.0001 x 2851.3 Hz = 0.285 Hz

The calculation of the uncertainty associated with the resolution is more involved.[1] From Table 2a, the resolution of the CR3000 is stated to be 96 ns/number of cycles.

96 ns/250 = 0.384 ns

Since a frequency of 2851.3 Hz corresponds to a period of 3.51×10^5 ns (Period = 1/Frequency):

0.384 ns/(3.51×10^5 ns) = 1.09×10^{-6}

Resolution uncertainty = 1.09×10^{-6} (2851.3 Hz) = 0.00312 Hz

[1] Note that the resolution uncertainty for the Scanmatic SM5049 with Dataforth SCM9B-D161 frequency input module can be computed directly using the expression provided in Table 2.

Considering the total uncertainty to be the sum of contributions from accuracy and resolution:

Total uncertainty = 0.285 Hz + 0.0031 Hz ≈ 0.3 Hz

4. Estimating errors in precipitation amount

Using the total uncertainties in Table 2b for a frequency reading of 2851.3 Hz (the full bucket frequency for a representative Geonor gauge), the upper limits of uncertainty for corresponding precipitation amounts can be estimated for each applicable data logger. Geonor weighing gauges compute the precipitation amount in mm from the frequency of a vibrating wire transducer using the formula below:

$$\text{Precipitation amount} = f_0 + A\,(f - f_0) + B\,(f - f_0)^2 \qquad (1)$$

where f is the measured frequency in Hz, f_0 is the frequency measured for an empty bucket during calibration in Hz, and A and B are calibration coefficients.

For a frequency reading of 2851.3 Hz, the precipitation amount can be computed using Eq. (1), propagating the frequency uncertainties in Table 2b to estimate the error associated with precipitation amounts for each applicable data logger. Using f_0, A, and B values for the same representative Geonor gauge considered above, the errors in precipitation amounts computed in this manner are provided in Table 3.

5. Summary and conclusions

The results in Table 3 demonstrate that the upper limits of uncertainties in precipitation amount for a Geonor gauge (full bucket) range from approximately 0.016 to 0.14 mm, depending upon the specific data logger used. Keep in mind that **these uncertainties are related only to the accuracy and resolution of frequency measurements specified by the data logger manufacturers**, and do not consider errors or uncertainties related to the principle of measurement, environmental conditions, or any other factors. Based on these results, the selection of data loggers to be used for WMO SPICE is expected neither to impact significantly the measurement results, nor to constitute a confounding factor for the intercomparison of results from different sites.

Table 1. Summary of data loggers to be used during WMO SPICE (listed alphabetically by manufacturer).

Manufacturer	Model	Sites	Frequency Input Module	Operational temperature range	Used for analog measurements?
Campbell Scientific	CR10X	CARE, Davos, Smeaton (Caribou Creek)	N/A	-25 °C to 50 °C	Yes
	CR23X	CARE, Marshall	N/A	-25 °C to 50 °C	Yes
	CR800	Marshall	N/A	-25 °C to 50 °C	Yes
	CR1000	Bratt's Lake, Davos, Marshall, Mueller Hut	N/A	-25 °C to 50 °C	Yes
	CR3000	Bratt's Lake, CARE, Marshall, Smeaton	N/A	-25 °C to 50 °C	Yes
Moxa	IA-240-T-LX	Sodankyla	N/A	-40 °C to 75 °C	No
Scanmatic	SM5049	Haukeliseter	Dataforth SCM9B-D161	-25 °C to 70 °C	Yes
Vaisala	QML102[a]	Hala, Zakopane	N/A	-35 °C to 55 °C	Yes

[a] Part of MAWS301 HydroMet System

Table 2a. Summary of data logger/analog input module specifications for accuracy and resolution of frequency measurements.

Manufacturer	Model	Stated accuracy uncertainty	Stated resolution uncertainty
Campbell Scientific[a]	CR10X	± (0.01% of reading)[b]	35 ns/number of cycles
	CR23X	± (0.03% of reading)	12 ns/number of cycles
	CR800	± (0.01% of reading)	136 ns/number of cycles
	CR1000	± (0.01% of reading)	136 ns/number of cycles
	CR3000	± (0.01% of reading)	96 ns/number of cycles
Dataforth	SCM9B-D161	± (0.005% of reading ± 0.01 Hz)	± (0.01% of reading ± 0.01 Hz)
Vaisala	QML102	± (0.003% of reading)	241 ns/number of cycles

[a] For the Campbell Scientific data loggers, the stated specifications pertain to the period averaging mode of operation.
[b] For number of cycles > 100. The CR10X manual states that the accuracy uncertainty is ± (0.03% of reading) for number of cycles < 100.

Table 2b. Estimates of upper limits for accuracy, resolution, and total uncertainty using the specifications for data loggers in Table 2a for a frequency reading of 2851.3 Hz at 250 cycles.[a]

Manufacturer	Model	Estimated accuracy uncertainty (Hz)	Estimated resolution uncertainty (Hz)	Total estimated uncertainty[b] (Hz)
Campbell Scientific	CR10X	0.285	1.14E-03	0.286
	CR23X	0.855	3.90E-04	0.856
	CR800	0.285	4.42E-03	0.290
	CR1000	0.285	4.42E-03	0.290
	CR3000	0.285	3.12E-03	0.288
Dataforth	SCM9B-D161	0.153	2.95E-01	0.448
Vaisala	QML102	0.086	7.84E-03	0.093

[a] This frequency corresponds to the full bucket value for a representative Geonor gauge. The number of cycles was selected to correspond with the sampling method for Geonor gauges at CARE.
[b] The total uncertainty is taken as the sum of contributions from accuracy and resolution.

Table 3. Total calculated precipitation amount and uncertainty for a representative Geonor gauge[a] measuring a frequency of 2851.3 Hz, subject to the frequency uncertainties in Table 2b.

Manufacturer	Model	Precipitation amount [mm]	Precipitation uncertainty [mm]
Campbell Scientific	CR10X	598.286	0.048
	CR23X	598.286	0.144
	CR800	598.286	0.049
	CR1000	598.286	0.049
	CR3000	598.286	0.048
Dataforth	SCM9B-D161	598.286	0.075
Vaisala	QML102	598.286	0.016

[a] For the representative gauge, f_0 = 1051.7 Hz, A = 1.67911E-01 mm/Hz, B = 9.14335E-05 mm/Hz^2.