U.S. DEPARTMENT OF ENERGY | Office of Science

DOE/SC-ARM-TR-232

Weighing Bucket Rain Gauge Instrument Handbook

MJ Bartholomew

June 2020

ARM

DISCLAIMER

DOE/SC-ARM-TR-232

Weighing Bucket Rain Gauge Instrument Handbook

MJ Bartholomew, Brookhaven National Laboratory

June 2020

Work supported by the U.S. Department of Energy,
Office of Science, Office of Biological and Environmental Research

Acronyms and Abbreviations

AC	alternating current
ARM	Atmospheric Radiation Measurement
ASCII	American Standard Code for Information Interchange
COMBLE	Cold-Air Outbreaks in the Marine Boundary Layer Experiment
DC	direct current
LED	light-emitting diode
MOSAiC	Multidisciplinary Drifting Observatory for the Study of Arctic Climate
NRT	non-real-time
NWS	National Weather Service
PM	preventive maintenance
RT	real-time
USB	universal serial bus
UV	ultraviolet
WMO	World Meteorological Organization

Contents

Figures

1.0 Instrument Title

Pluvio2-L weighing bucket rain gauge

2.0 Mentor Contact Information

Mary Jane Bartholomew
Bldg 490D
Brookhaven National Laboratory
Upton, New York 11973
631-344-2444

3.0 Vendor/Developer Contact Information

Ott Hydromet GmbH
87437 Kempten
Ludwigstrasse 16
Germany
+49-831-5617-0
www.ott.com

4.0 Instrument Description

The Ott precipitation gauge is used for automatic determination of the intensity and amount of precipitation. In contrast to conventional precipitation gauges, the Pluvio2 works using the balance principle. The gauge reliably recognizes precipitation by determining the weight of the collecting bucket. A high-precision stainless-steel load cell, hermetically sealed against environmental influences, is used as the sensor element. An integrated temperature sensor compensates for the temperature changes in the weighing mechanism. These sensors have been found to be stable for years. The orifice of the gauge is heated and when snow/ice precipitation occurs, the weight of its water equivalent is the amount observed. To prevent the influence of evaporation on the bucket contents, two liters of mineral oil are kept in the bucket at all times.

Figure 1. Two-dimensional video disdrometer on left; Pluvio2 weighing bucket rain gauge on right.

5.0 Measurements Taken

The U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facility's Pluvio2 gauges measure the weight of the collection bucket once a minute. As precipitation falls into the bucket, the difference between the measurements determines the amount of rainfall that has occurred over the previous sampling interval. Each bucket has a 400 cm^2 collection area and a capacity equivalent to a rainfall accumulation of 750 mm. Instrument health and instrument status indicators are collected as well.

5.1 Difficulties Interpreting Pluvio2 (wbpluvio datastream) Observations During Periods of Frozen Precipitation

The Pluvio2 weighing bucket rain gauge consists of a collection bucket resting on a load cell housed within an outer shell. As the bucket fills, the load cell registers increasing weight that is directly related to the amount of falling precipitation. In climates where freezing might occur, antifreeze is used in the collection bucket. In addition, weighing bucket rain gauges are usually deployed with a film of oil (mineral oil or similar substance) floating on top of the water/antifreeze mixture. The oil eliminates evaporation. A suitable oil was not found for the extreme cold conditions experienced during ARM's Cold-Air Outbreaks in the Marine Boundary Layer Experiment (COMBLE) and Multidisciplinary Drifting Observatory for the Study of Arctic Climate (MOSAiC) campaigns and negative rain amounts and negative rain rates may occur in the data. These should be interpreted as periods without rain or snow.

Because wind can have a large impact on snow collection in weighing bucket rain gauges, the World Meteorological Organization recommends the use of a double-fence wind shield or other shielding method. Usually the double-fence setup consists of two large octagonal or twelve-sided, vertical or inclined lath fences; one fence with the diameter of between 6-12 m and that of the inner fence between 3-4 m (Goodison, 1998). The Pluvio2 gauges used by ARM during the MOSAiC and COMBLE field

campaigns had a double-fence wind-type shield but the fencing was not as tall as that recommended by the World Meteorological Organization (WMO 1998). Furthermore, corrections for wind were not made to the data. A good reference for wind corrections is Kochendorfer et al. 2017.

5.2 Data Object Description — datastream wbpluvio2

Some of the Ott Pluvio2 variables are unusual. For example, intensity is the variable name for rain rate as is convention. This variable, however, has a lower threshold of 6 mm/hour and is intended only to flag heavy rainfall. The ARM ingest calculates additional rain rate values (variable name rain_rate) where the threshold is 3 mm/hour. This “rain_rate” is determined by the product of the accum_rtnrt result extrapolated to 60 minutes (rain_rate=accum_rtnrt * 60). Accum_rtnrt is the rainfall amount collected over the last sample interval (one minute). Accum_rtnrt is an example of Ott’s “real-time variables”. Ott’s “not-real-time” variables are delayed by five minutes and these results have additional processing carried out by software internal to the instrument to correct for wind, temperature, and evaporation. The exact nature of the additional processing is proprietary. The “not-real-time” data are the highest quality available from the instrument but it important to note their time stamp is five minutes delayed from the actual time of observation. The full header for all variables can be found below.

```
dimensions:
      time = UNLIMITED ; // (1440 currently)
      bound = 2 ;
variables:
      int base_time ;
            base_time:string = "2017-01-16 00:00:00 0:00" ;
            base_time:long_name = "Base time in Epoch" ;
            base_time:units = "seconds since 1970-1-1 0:00:00 0:00" ;
            base_time:ancillary_variables = "time_offset" ;
      double time_offset(time) ;
            time_offset:long_name = "Time offset from base_time" ;
            time_offset:units = "seconds since 2017-01-16 00:00:00 0:00" ;
            time_offset:ancillary_variables = "base_time" ;
      double time(time) ;
            time:long_name = "Time offset from midnight" ;
            time:units = "seconds since 2017-01-16 00:00:00 0:00" ;
            time:calendar = "gregorian" ;
            time:standard_name = "time" ;
      float intensity_rt(time) ;
            intensity_rt:long_name = "Heavy precipitation alarm" ;
            intensity_rt:units = "mm/hr" ;
            intensity_rt:ancillary_variables = "pluvio_status
maintenance_flag reset_flag" ;
            intensity_rt:valid_min = 0.f ;
            intensity_rt:valid_max = 3000.f ;
            intensity_rt:missing_value = -9999.f ;
            intensity_rt:threshold = "6 mm/hr" ;
            intensity_rt:absolute_accuracy = "plus/minus 6" ;
            intensity_rt:comment_1 = "Only measurements that exceed the
threshold are recorded. Any measurement below the threshold is reported as
0 mm/hr." ;
            intensity_rt:comment_2 = "The time bounds for the sum is [-60,
0]" ;
```

```
      float accum_rtnrt(time) ;
            accum_rtnrt:long_name = "Accumulated amounts of precipitation
over the sampling interval exceeding a threshold of 0.05mm or the
accumulated amount of fine precipitation observed over the last hour" ;
            accum_rtnrt:units = "mm" ;
            accum_rtnrt:ancillary_variables = "pluvio_status
maintenance_flag reset_flag" ;
            accum_rtnrt:valid_min = 0.f ;
            accum_rtnrt:valid_max = 500.f ;
            accum_rtnrt:missing_value = -9999.f ;
            accum_rtnrt:threshold = "0.05 mm" ;
            accum_rtnrt:absolute_accuracy = "plus/minus 0.1" ;
            accum_rtnrt:equation = "The accum_rtnrt variable is calculated
by first measuring the accumulated amount of rain in the last minute. If
this measurement exceeds the threshold, it reports this real time value.
If the real time measurement does not reach the threshold, it reports the
non real time measurement using the same equation as the accum_nrt
variable." ;
            accum_rtnrt:comment = "Only measurements that exceed the
threshold are recorded. Any measurement below the threshold is reported as
0 mm." ;
      float accum_nrt(time) ;
            accum_nrt:long_name = "Accumulated precipitation over the
sampling interval filtered and delayed by 5 minute" ;
            accum_nrt:units = "mm" ;
            accum_nrt:ancillary_variables = "pluvio_status
maintenance_flag reset_flag" ;
            accum_nrt:valid_min = 0.f ;
            accum_nrt:valid_max = 500.f ;
            accum_nrt:missing_value = -9999.f ;
            accum_nrt:threshold = "0.05 mm" ;
            accum_nrt:absolute_accuracy = "plus/minus 0.1" ;
            accum_nrt:equation = "The accum_nrt variable is calculated by
measuring the amount of rain accumulate in a sampling interval at most 1
hour long, with the end of the interval at the given time. The start of
the sampling interval occurs within the past hour, but is unknown. The
start of the interval is determined once the accumulated sum either
exceeds 0.05 or the interval length reaches an hour" ;
            accum_nrt:comment = "Only measurements that exceed the
threshold are recorded. Any measurement below the threshold is reported as
0 mm." ;
      float accum_total_nrt(time) ;
            accum_total_nrt:long_name = "Sum of accum_nrt values since the
last device start" ;
            accum_total_nrt:units = "mm" ;
            accum_total_nrt:ancillary_variables = "pluvio_status
maintenance_flag reset_flag" ;
            accum_total_nrt:valid_min = 0.f ;
            accum_total_nrt:valid_max = 500.f ;
            accum_total_nrt:missing_value = -9999.f ;
            accum_total_nrt:threshold = "0.05 mm" ;
            accum_total_nrt:absolute_accuracy = "plus/minus 0.1" ;
```

```
            accum_total_nrt:comment = "Only measurements that exceed the
threshold are recorded. Any measurement below the threshold is reported as
0 mm." ;
      float bucket_rt(time) ;
            bucket_rt:long_name = "The currently measured, unfiltered
bucket contents since last reset" ;
            bucket_rt:units = "mm" ;
            bucket_rt:ancillary_variables = "pluvio_status
maintenance_flag reset_flag" ;
            bucket_rt:valid_min = 20.f ;
            bucket_rt:valid_max = 1800.f ;
            bucket_rt:missing_value = -9999.f ;
            bucket_rt:threshold = "0.01 mm" ;
            bucket_rt:absolute_accuracy = "plus/minus 0.1" ;
            bucket_rt:comment = "Only increases that exceed the threshold
are recorded. Any increase less than threshold is reported as no increase"
;
      float bucket_nrt(time) ;
            bucket_nrt:long_name = "The currently measured, filtered
bucket contents since last reset" ;
            bucket_nrt:units = "mm" ;
            bucket_nrt:ancillary_variables = "pluvio_status
maintenance_flag reset_flag" ;
            bucket_nrt:valid_min = 20.f ;
            bucket_nrt:valid_max = 1800.f ;
            bucket_nrt:missing_value = -9999.f ;
            bucket_nrt:threshold = "0.01 mm" ;
            bucket_nrt:absolute_accuracy = "plus/minus 0.1" ;
            bucket_nrt:comment = "Only increases that exceed the threshold
are recorded. Any increase less than threshold is reported as no increase"
;
      float load_cell_temp(time) ;
            load_cell_temp:long_name = "Temperature of load cell" ;
            load_cell_temp:units = "degC" ;
            load_cell_temp:valid_min = -50.f ;
            load_cell_temp:valid_max = 70.f ;
            load_cell_temp:missing_value = -9999.f ;
            load_cell_temp:absolute_accuracy = "plus/minus 1" ;
      int heater_status(time) ;
            heater_status:long_name = "Heater status" ;
            heater_status:units = "unitless" ;
            heater_status:comment = "This flag can indicate several
statuses. This will be reflected as the sum of the status values: 0
indicates heater is operating properly" ;
            heater_status:missing_value = -9999 ;
            heater_status:flag_masks = 1, 2, 4, 8, 16, 32, 128 ;
            heater_status:flag_meanings = "orifice_rim_temp_above_40C
orifice_rim_temp_below_neg_20C temp_sensor_not_connected
temp_sensor_short_circuit
comm_to_heating_module_defective_or_instr_housing_removed
func_check_defective deactivated" ;
            heater_status:bit_1_description = "orifice rim temperature >
40 degC" ;
```

```
            heater_status:bit_2_description = "orifice rim temperature < -
20 degC" ;
            heater_status:bit_3_description = "temperature sensor not
connected" ;
            heater_status:bit_4_description = "temperature sensor short
circuit" ;
            heater_status:bit_5_description = "communication to ring
heating module defective or instrument housing was removed" ;
            heater_status:bit_6_description = "functional check of orifice
rim was defective" ;
            heater_status:bit_8_description = "orifice heating
deactivated" ;
      int pluvio_status(time) ;
            pluvio_status:long_name = "Pluvio status" ;
            pluvio_status:units = "unitless" ;
            pluvio_status:comment = "This flag can indicate several
statuses. This will be reflected as the sum of the status values. 0
indicates gauge is operating properly" ;
            pluvio_status:missing_value = -9999 ;
            pluvio_status:flag_masks = 1, 2, 4, 8, 16, 32, 64, 128, 256,
512, 1024 ;
            pluvio_status:flag_meanings =
"bucket_fill_level_above_80_percent USB_interface_connected
restart_power_failure restart_firmware weight_change_not_permitted
volt_supply_below_7V weight_measure_unstable weight_measure_defective
weight_below_min weight_above_max no_weight_calib" ;
            pluvio_status:bit_1_description = "bucket fill level > 80%" ;
            pluvio_status:bit_2_description = "USB interface is/was
connected" ;
            pluvio_status:bit_3_description = "restart due to power
failure" ;
            pluvio_status:bit_4_description = "restart due to firmware" ;
            pluvio_status:bit_5_description = "weight change not
permitted" ;
            pluvio_status:bit_6_description = "voltage supply < 7V" ;
            pluvio_status:bit_7_description = "weight measurement
unstable" ;
            pluvio_status:bit_8_description = "weight measurement
defective" ;
            pluvio_status:bit_9_description = "weight less than minimum" ;
            pluvio_status:bit_10_description = "weight greater than
maximum" ;
            pluvio_status:bit_11_description = "no weight calibration" ;
      float elec_unit_temp(time) ;
            elec_unit_temp:long_name = "Temperature of electronics unit" ;
            elec_unit_temp:units = "degC" ;
            elec_unit_temp:valid_min = -50.f ;
            elec_unit_temp:valid_max = 70.f ;
            elec_unit_temp:missing_value = -9999.f ;
            elec_unit_temp:absolute_accuracy = "plus/minus 1" ;
      float supply_volts(time) ;
            supply_volts:long_name = "Supply voltage" ;
            supply_volts:units = "V" ;
            supply_volts:valid_min = 4.5f ;
```

```
            supply_volts:valid_max = 28.f ;
            supply_volts:missing_value = -9999.f ;
            supply_volts:absolute_accuracy = "plus/minus 0.5" ;
      float orifice_temp(time) ;
            orifice_temp:long_name = "Temperature of orifice rim" ;
            orifice_temp:units = "degC" ;
            orifice_temp:ancillary_variables = "heater_status" ;
            orifice_temp:valid_min = -50.f ;
            orifice_temp:valid_max = 70.f ;
            orifice_temp:missing_value = -9999.f ;
      int maintenance_flag(time) ;
            maintenance_flag:long_name = "Bucket is being emptied or
serviced" ;
            maintenance_flag:units = "count" ;
            maintenance_flag:valid_min = 0 ;
            maintenance_flag:valid_max = 20 ;
            maintenance_flag:missing_value = -9999 ;
            maintenance_flag:comment = "If the flag is not 0, then the
instrument is being serviced or the bucket is being empty. This only
occurs when it is not raining. Therefore, if the flag is not 0, then it is
not raining and any values for the bucket or accum variables should be
ignored" ;
      short reset_flag(time) ;
            reset_flag:long_name = "Bucket emptied" ;
            reset_flag:units = "count" ;
            reset_flag:valid_min = 0s ;
            reset_flag:valid_max = 20s ;
            reset_flag:missing_value = -9999s ;
            reset_flag:comment = "If the flag is not 0, then the bucket on
the instrument is being empty. This only occurs when it is not raining.
Therefore, if the flag is not 0, then it is not raining and any values for
the bucket or accum variables should be ignored" ;
      float volt_min(time) ;
            volt_min:long_name = "Minimum supply voltage of logger" ;
            volt_min:units = "V" ;
            volt_min:valid_min = 0.f ;
            volt_min:valid_max = 20.f ;
            volt_min:missing_value = -9999.f ;
            volt_min:comment = "The time bounds for the minimum is [-
60,0]" ;
      float ptemp(time) ;
            ptemp:long_name = "Panel temperature average" ;
            ptemp:units = "degC" ;
            ptemp:valid_min = -50.f ;
            ptemp:valid_max = 70.f ;
            ptemp:missing_value = -9999.f ;
            ptemp:comment = "The time bounds for the average is [-60, 0]"
;
      float intensity_rtnrt(time) ;
            intensity_rtnrt:long_name = "Rain intensity based upon
accum_rtnrt" ;
            intensity_rtnrt:units = "mm/hr" ;
            intensity_rtnrt:ancillary_variables = "pluvio_status
maintenance_flag reset_flag" ;
```

```
            intensity_rtnrt:valid_min = 0.f ;
            intensity_rtnrt:valid_max = 30000.f ;
            intensity_rtnrt:missing_value = -9999.f ;
            intensity_rtnrt:threshold = "0.3 mm/hr" ;
            intensity_rtnrt:absolute_accuracy = "plus/minus 6" ;
            intensity_rtnrt:equation = "Calculated by accum_rtnrt * 60" ;
            intensity_rtnrt:comment = "Only measurements that exceed the
threshold are recorded. Any measurement below the threshold is reported as
0 mm/hr." ;
      float lat ;
            lat:long_name = "North latitude" ;
            lat:units = "degree_N" ;
            lat:valid_min = -90.f ;
            lat:valid_max = 90.f ;
            lat:standard_name = "latitude" ;
      float lon ;
            lon:long_name = "East longitude" ;
            lon:units = "degree_E" ;
            lon:valid_min = -180.f ;
            lon:valid_max = 180.f ;
            lon:standard_name = "longitude" ;
      float alt ;
            alt:long_name = "Altitude above mean sea level" ;
            alt:units = "m" ;
            alt:standard_name = "altitude" ;

// global attributes:
            :command_line = "wbpluvio2_ingest -a dsdb_data -s sgp -f C1" ;
            :Conventions = "ARM-1.2" ;
            :process_version = "adi-create_adi_project-1.17-0wbpluvio2-
1.0-devel" ;
            :dod_version = "wbpluvio2-a1-1.0" ;
            :input_source =
"/data/home/dev/ingest/wbpluvio2/DATA/data/collection/sgp/sgpwbpluvio2C1.0
0/DL2.wbpluvio2-20170116000000.dat" ;
            :site_id = "sgp" ;
            :platform_id = "wbpluvio2" ;
            :facility_id = "C1" ;
            :data_level = "a1" ;
            :location_description = "Southern Great Plains (SGP), Lamont,
Oklahoma" ;
            :datastream = "sgpwbpluvio2C1.a1" ;
            :serial_number = "398906" ;
            :sampling_interval = "1 minute" ;
            :doi = "10.5439/1338194" ;
            :history = "created by user cromwell on machine lead at 2017-
04-12 17:41:31, using adi-create_adi_project-1.17-0wbpluvio2-1.0-devel" ;
data:
```

5.3 Data Ordering

The data are available from the ARM Data Center: http://www.archive.arm.gov/discovery/

5.4 Data Plots

Plots of the data are available from: http://plot.dmf.arm.gov/plotbrowser/

5.5 Data Quality

The instrument mentor and the ARM Data Quality Office work together to develop automated means to review the data. The results of the automated efforts are backed up by weekly inspections.

5.6 Instrument Mentor Monthly Summary

N/A

5.7 Calibration Database

The Pluvio2 arrives from the manufacturer fully calibrated. After initial setup, the system is tested for accuracy with calibrated weights. Once this test is passed, no further calibration is needed. This test is done yearly.

6.0 Technical Specification

Recordable precipitation	Liquid, solid, and mixed
Collecting area	400 cm²
Recordable precipitation amount	750 mm
Measurement method	Weighing measurement method
Sensor element	Sealed load cell
Measuring ranges	
Precipitation	0 ... 50 mm/min or 0 ... 3000 mm/h
Cumulative precipitation threshold at 60 min collection time	0.05 mm/h
Precipitation intensity threshold	0.1 mm/min or 6 mm/h
Accuracy (at -25 ... +45 °C)	
Amount	±0.1 mm or ±1 % of measured value
Intensity	±0.1 mm/min, ±6 mm/h or ±1 % of measured value
Resolution	
SDI-12- and RS-485 interface	0.01 mm, 0.01 mm/min or mm/h
Impulse output	0.05/0.1/0.2 mm
Measurement intervals	
Intensity output interval	1 minute
Query interval	1 minute ... 60 minutes
Output delay	

Real-time (RT)	< 1 minute
Non-real-time (NRT)	5 minutes
Output data	
Measurement output	Intensity RT, amount RT/NRT, amount NRT, amount total NRT, bucket content RT and NRT, temperature load cell
Status output	OTT Pluvio2-L Status, Heating status (if present)
Interfaces	
Digital interfaces	SDI-12 V1.3, RS-485 2- or 4-wire (SDI-12 protocol and ASCII)
Digital outputs (2/5 Hz)	Impulse: 0.05/0.1/0.2 mm (adjustable) Status: 0 ... 120 impulses/min
USB	USB 2.0 (for service mode)
Electrical data	
Power supply	5.5 ... 28V DC, typically 12V DC
Current consumption	typ. 9.2 mA at 12V (without heating)
Power consumption	≤ 110 mW (without heating)
Ring heating, optional	
Power supply	12 ... 28V DC, typ. 12/24V DC
Current consumption	Pluvio2-L 200: typ. 2.1 A; max. 2.2 A Pluvio2-L 400: typ. 4.2 A; max. 4.4 A
Power consumption	
Pluvio2-L 400	max. 100 Watt at 24V DC; max. 25 Watt at 12V DC
Modes of operation	Disabled, continuously enabled, continuously enabled within a specified temperature range, US NWS standard (time-controlled), enabled in case of precipitation (adjustable after-run time)
Dimensions and weight	
Pluvio2-L 400 (Ø x h)	450 mm x 677 mm
Pedestal (Ø)	4"
Weight (bucket empty)	16 kg / 16.6 kg
Material	
Base plate	Stainless steel/aluminum
Collecting bucket	Polyethylene
Bucket support, pipe housing	ASA, UV-resistant
Environmental conditions	
Temperature, in operation	- 40 ... +60 °C

Temperature, storage	-50 ... +70 °C
Relative humidity	0 ... 100 % (non-condensing)
Protection	
Housing (closed)	IP65
Housing (open)	IP63
Load cell	IP68, resistant to salt fog
Standards	EMV: 2004/108/EG; EN 61326-1:2013

6.1 Units

Specified in section 6.1 Data Object Description.

6.2 Range

Specified in section 7 Technical Specification.

6.3 Accuracy

Specified in section 7 Technical Specification

6.4 Repeatability

Unknown

6.5 Sensitivity

Specified in section 7 Technical Specification.

6.6 Uncertainty

Specified in section 7 Technical Specification.

6.7 Input Voltage

Specified in section 7 Technical Specification.

6.8 Input Current

Specified in section 7 Technical Specification.

6.9 Input Values

Specified in section 7 Technical Specification.

6.10 Output Values

Specified in section 6.1 Data Object Description.

7.0 Instrument System Functional Diagram

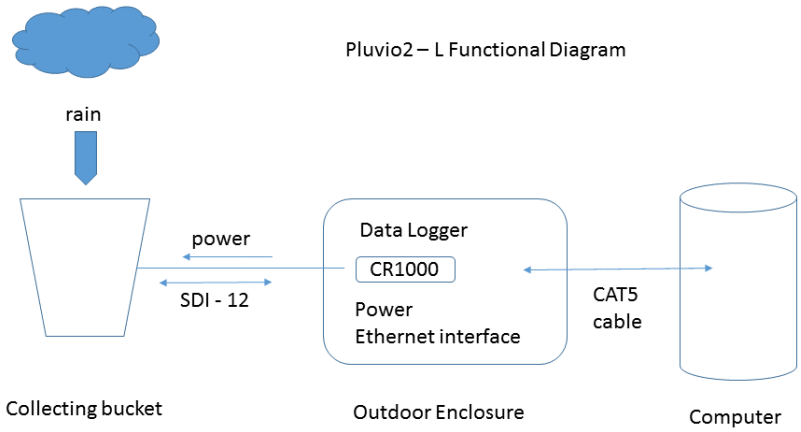


Figure 2. Instrument system functional diagram.

8.0 Instrument/Measurement Theory

The instrument is quite simple. The heavier the collecting bucket, the more rainfall has occurred. The collecting bucket is housed within a shield and it sits on a scale. Observations of the weight are made once a minute and are reset to zero after polled by a data logger, in this case a Campbell Scientific CR1000.

9.0 Setup and Operation of Instrument

Typically a 4-inch round pipe is mounted vertically in a concrete pad to support the gauge. The base of the gauge is designed to be directly bolted to the pipe. The ARM Mobile Operations staff try to avoid concrete pads for their instrument deployments and a custom stand has been designed. The concrete pads/custom stand also provide a base for the wind shield that accompanies each instrument. Cables between the major components must be protected from weather and animals. Data collection is fully automated from instrument in the field to ARM's Data Management Facility at Pacific Northwest National Laboratory.

Before data collection can start, an accuracy test must be carried out to insure no damage has occurred during shipping. The software for this is provided by Ott on a CD-ROM that comes with the instrument or can be downloaded from www.ott.com. The test requires a light weight (~50 grams) and a heavier weight (~300 grams) of known accuracy. The software directs the operator through the procedure. Once the test has been passed, it is needed only once a year thereafter.

10.0 Software

Software for the "Guided Accuracy Test" mentioned above runs on Microsoft Windows operating systems. Otherwise, software is needed for data logger operation. ARM typically uses Campbell Scientific CR1000 data loggers programmed with CRBasic. The full logger code can be found in Appendix B.

11.0 Calibration

None required.

12.0 Maintenance

Frequency: weekly

12.1 Inspection of Site Grounds Near the Instrument

Visually check the site grounds around the instrument for hazards such as rodent burrows, buried conduit trench settling, and insect nests.

Checklist response:

No problems noted.
Problem − Enter any applicable comments for this preventive maintenance (PM) activity.

12.2 Visual Inspection of Instrument Components

Conduit, cables, and connectors

Check that all the conduits on the bottom of the control boxes are secure. Check all conduits from the control boxes to the sensors for damage. Check all sensor wires inside the control box for tightness and damage. Check all the connections at the sensors for damage, water intrusion, and tightness.

Checklist response:

No problems noted.
Problem − Enter any applicable comments for this PM activity.

12.3 Check Status of Port 8 LED on CR1000 Data Logger

LED should flash once every minute during normal operation.

Checklist response:

No problems noted.
Problem − Enter any applicable comments for this PM activity.

12.4 Check Clock Values Shown on LoggerNet Connect Screen

The station clock should automatically be set to server clock if times differ by 1 second or more. This automatic check is done once a day by the LoggerNet program. The times should never differ by more than 1 minute.

Checklist response:

No problems noted.
Problem − Enter any applicable comments for this PM activity.

12.5 Active Maintenance and Testing Procedures

Pluvio2 rain gauge

Check to insure that oil is floating on precipitation caught in bucket.
Remove any leaves or debris from bucket if necessary.

Checklist response:

No problems noted.
Problem − Enter any applicable comments for this PM activity.

Empty bucket as needed:

1) set maintenance flag (port 1) to on
2) empty bucket

3) load bucket with 2 liters of mineral or baby oil
4) set maintenance flag (port1) to off.

Checklist response:

No problems noted.
Problem − Enter any applicable comments for this PM activity.

13.0 Safety

When installing the instrument, care must be taken with hand tools, low-voltage DC within the device (24V DC), and high voltage in the electronics enclosure (120V AC). Some parts of the wind shield weigh 20kg and all care needed for lifting such a weight should be taken.

Operation staff must periodically empty the bucket (maximum 36kg) and care should be taken in lifting the bucket when it is very full.

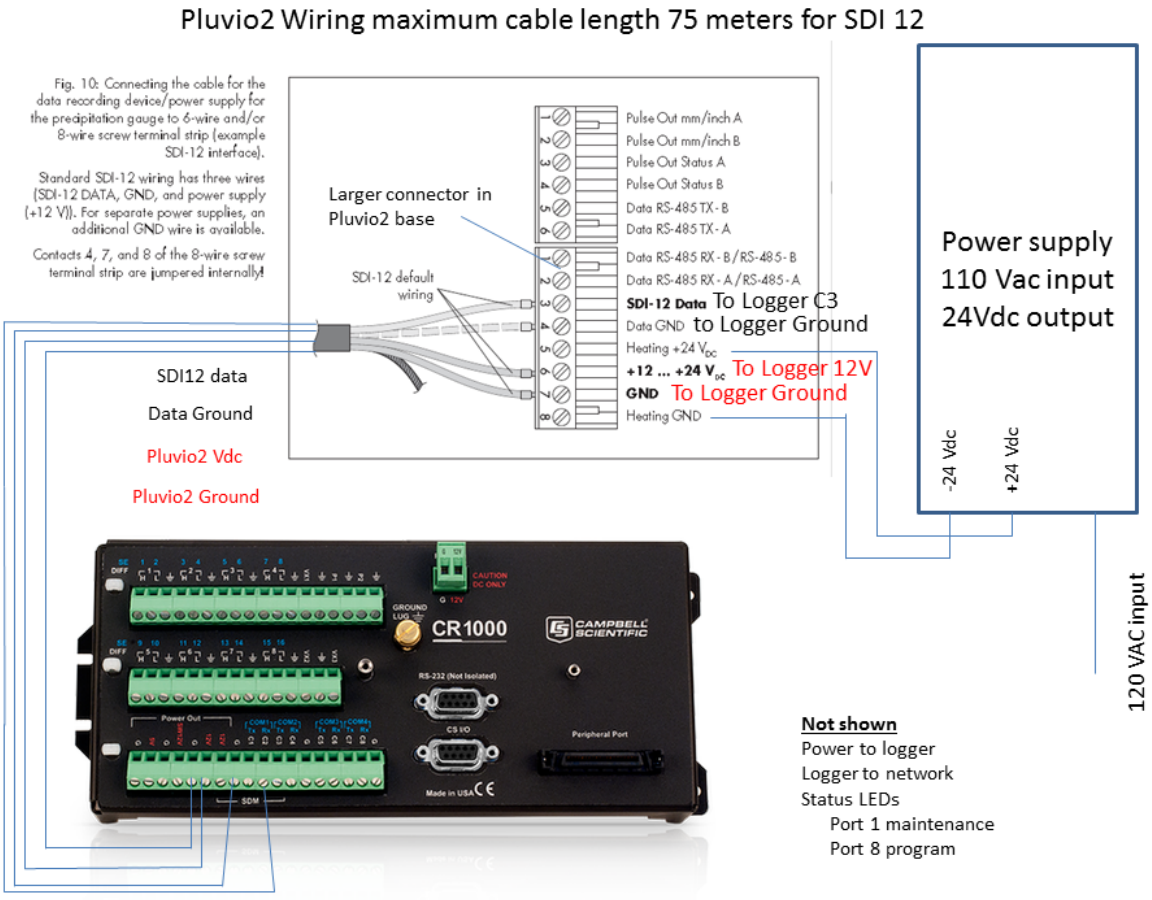
14.0 Citable References

Kochendorfer, J, R Rassmussen, M Wolff, B Baker, ME Hall, T Meyers, S Landolt, A Jahcik, K Isaksen, R Braekkam, and R Leeper. 2017. “The quantification and correction of wind-induced precipitation measurement errors.” *Hydrology and Earth System Sciences* 21(4): 1973–1989, https://doi.org/10.5194/hess-21-1973-2017

Goodison, BE, PYT Louie, and D Yang. 1998. Instruments and Observing Methods: WMO Solid Precipitation Measurement Intercomparison Final Report. World Meteorological Organization. Report No. 67.

Appendix A

Wiring Diagram



Appendix B

CR1000 Logger Code for Pluvio2

```
‘CR1000 Series Datalogger
' Program for Ott Pluio2 Weighing Bucket Rain Gauge
' Programmers: Mary Jane Bartholomew, John Nagy
' v1 2016-09-26   Begin version numbers

Const CPort_1 = 1              'Arguments:    Port
Const CPort_2 = 2              'Instructions: CheckPort, PortGet,
Const CPort_3 = 3              '              PortSet, PulsePort
Const CPort_4 = 4
Const CPort_5 = 5
Const CPort_6 = 6
Const CPort_7 = 7
Const CPort_8 = 8

Const CPort_Mask_1   = &B00000001  'Arguments:    Mask
Const CPort_Mask_2   = &B00000010  'Instructions: PortsConfig,
Const CPort_Mask_3   = &B00000100  '              ReadIO, WriteIO
Const CPort_Mask_4   = &B00001000
Const CPort_Mask_5   = &B00010000
Const CPort_Mask_6   = &B00100000
Const CPort_Mask_7   = &B01000000
Const CPort_Mask_8   = &B10000000
Const CPort_Mask_All = &B11111111
```

```
Const CPort_Input  = &B00000000    'Arguments:    Function
Const CPort_Output = &B11111111    'Instructions: PortsConfig

Const CPort_Off    = &B00000000    'Arguments:    State, Source
Const CPort_On     = &B11111111    'Instructions: PortSet, WriteIO

'Const DIFFPORT_1 = 1                    'Arguments:    Port
'Const DIFFPORT_2 = 2                    'Instructions: Voltdiff
'Const DIFFPORT_3 = 3

Const  heartbeat_port    = CPort_8         'Heartbeat LED
Const  heartbeat_mask    = CPort_Mask_8
Const  heartbeat_cfg     = CPort_Output

Const  maintenance_port  = CPort_1         'Maintenance port/LED
Const  maintenance_mask  = CPort_Mask_1
Const  maintenance_cfg   = CPort_Output

'Constants for Data Table
Const AllRemainingMemory = -1      'Use all remaining memory
Const TrigVar = True    ' Always trigger
Const Lapses = 0                         ' every record time stamped

'Constants defining recording interval
'Used in Data Table definition and for clearing latched variables
Const RecordTimeInto = 0        'When into interval to trigger
Const RecordInterval = 1        'Size of the interval
Const RecordUnit = Min                  'Unit of the interval
Const SampleInterval = 1        'period of sampling
Const SampleUnit = Min          'unit of interval
```

```
' MISC
Const OneRep = 1                'Input/Output instructions
Const DoNotStoreTime = 0        'Arguments: Time
Const StoreTime      = 1        'Instructions: Minimum, Maximum

'Declare Public Variables
Public maintenance_flag As Boolean
Public maintenance_count As Long
Public reset_flag As Long
Public PTemp, DL1_volt
Units DL1_volt  = V
Units PTemp = oC        'logger internal temperature

' Pluvio2  Variables
Public Group1(3)
Public Group2(3)
Public Group3(3)
Public Group4(3)
Public HeaterSwitch As String
Public SensorInfo As String * 25
Public SN As Long

Alias Group1(1) = Intensity
Alias Group1(2)= AccumRTNRT
Alias Group1(3)= AccumNRT
Alias Group2(1)= AccumTotalNRT
Alias Group2(2)= BucketRT
Alias Group2(3)= BucketNRT
Alias Group3(1)= LoadCellTemp
Alias Group3(2)= HeaterStatus
Alias Group3(3)= PluvioStatus
```

```
Alias Group4(1)= ElecUnitTemp
Alias Group4(2)= SupplyVoltage
Alias Group4(3)= OrificeTemp


Units Intensity= mm/min
Units AccumRTNRT= mm
Units AccumNRT = mm
Units AccumTotalNRT = mm
Units BucketRT = mm
Units BucketNRT = mm
Units LoadCellTemp = Deg C
Units HeaterStatus = count
Units PluvioStatus = count
Units ElecUnitTemp = Deg C
Units SupplyVoltage = V
Units OrificeTemp = Deg C
Units SN = count
'Units HeaterSwitch = count



'Define Data Tables
DataTable (DL2,True,AllRemainingMemory)
   DataInterval (RecordTimeInto,RecordInterval,RecordUnit,Lapses)
   Minimum (1,DL1_volt,FP2,0,False)
   Average (1,PTemp,FP2,0)
   Sample (1,Intensity,FP2)
   Sample (1,AccumRTNRT,FP2)
   Sample (1,AccumNRT,FP2)
   Sample (1,AccumTotalNRT,FP2)
   Sample (1,BucketRT,FP2)
   Sample (1,BucketNRT,FP2)
   Sample (1,LoadCellTemp,FP2)
```

```
    Sample (1,HeaterStatus,Long)
    Sample (1,PluvioStatus,Long)
    Sample (1,ElecUnitTemp,FP2)
    Sample (1,SupplyVoltage,FP2)
    Sample (1,OrificeTemp,FP2)
            Totalize (1,maintenance_flag,Long,0)
            Sample (1,reset_flag,Long)
            Sample (1,SN,Long)
EndTable



'Define Subroutines
'Sub
      'EnterSub instructions here
'EndSub

'Main Program
BeginProg
  'Initialization

    'Control port configurations
    PortsConfig (heartbeat_mask,    heartbeat_cfg)
    PortsConfig (maintenance_mask,  maintenance_cfg)


    PortSet (maintenance_port, False)


    maintenance_flag = False
    maintenance_count = 0

   ' Main Pluvio2 data collection
```

```
Scan (1,Min,0,0)                'fastest polling is every 3 seconds


'Logger Instructions
PanelTemp (PTemp,250)
Battery (DL1_volt)
                'Toggle hearbeat LED
                PortSet (heartbeat_port, Not CheckPort (heartbeat_port))


'Pluvio2 Instructions
SDI12Recorder (Group1(),3,"0","M!",1,0)
SDI12Recorder (Group2(),3,"0","D1!",1,0)
SDI12Recorder (Group3(),3,"0","D2!",1,0)
SDI12Recorder (Group4(),3,"0","M1!",1,0)
SDI12Recorder (SensorInfo,3,"0","I!",1,0)
SN = Mid(SensorInfo,20,7)


'Call Output Tables
CallTable (DL2)


'---Maintenance logic---


'Has maintenance been activated from Connect > Monitor > Ports & Flags window?
maintenance_flag = CheckPort (maintenance_port)


'Reset accumulaton and increment maintenance_count when emptying bucket
If maintenance_flag
   maintenance_count = maintenance_count + 1
   SDI12Recorder(reset_flag,3,"0","OMR!",1,0)
Else
  maintenance_count = 0
```

```
    reset_flag = 0
  Endif

  'Maintenance flag times out after 20 minutes (20 scans actually)
  'should one forget to reset in port window
  If (maintenance_count > 20)
        maintenance_flag = False
    PortSet (maintenance_port, False)
  Endif

  NextScan

  'heater switch instructions
  SlowSequence
  Scan (1,day,0,0)
    SDI12Recorder (HeaterSwitch,3,"0","0CH1!",1,0) ' 0CH1! = on 0CH0! = off
  NextScan

EndProg
```

www.arm.gov

U.S. DEPARTMENT OF
ENERGY

Office of Science