Seasonal frost and soil temperature data, Western Cape Mountains, South Africa, Version 1

USER GUIDE

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National Snow and Ice Data Center

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1 DETAILED DATA DESCRIPTION

Details of Data Compiler

1.1 Coverage of data set:

Air and Ground microclimate (Temperature, Precipitation, Relative Soil Moisture)

Study Location: Waaihoek mountains, Western Cape, South Africa

1.2 Geographic extent:

Northwest latitude: 33.417 S

Northwest longitude: 19.25 E

Southeast latitude: 33.533 S

Southeast longitude: 19.5 E

1.3 Period of investigation:

February 1990 - December 1996 (ongoing)

1.4 Summary

1.4.1 OBJECTIVES

Micro-climatic monitoring of air and ground was started in 1990 to evaluate climatic controls on the present-day diurnal soil frost environment in the Western Cape mountains of South Africa. To this effect two data logger stations were established in the summit region of the Waaihoek mountains. Two sites were established at Waaihoek Peak and Mount Superior, respectively. The general characteristics of these two sites and their instrumentation are described here.

1.4.2 SITE CHARACTERISTIC

Two micro-climatic monitoring stations have been in operation. The first is position at Waaihoek Peak, the second at Mount Superior. Both sites are described separately below and includes a description of data collection methods. This is followed by a technical description of the instrumentation.

1.4.3 Waaihoek Peak

The Waaihoek Peak monitoring site is positioned on the southeast extension of a small summit plateau at 1900m elevation where it changes into a southeast trending ridge flanked by two small valleys. The station stands on a 4-5o slope with an aspect of 140o and is underlain by steeply dipping quartzitic sandstone of the Peninsula Formation. A shallow sandy soil here reaches a thickness of 0.35m and supports a sparse vegetation cover of Restio (Cape reeds) species up to 0.2m high with a total cover of around 30%.

Locally manufactured MCS data loggers were used for this project. The first data logger was installed on 7-1-1990. This logger stored data on tape and used batteries which supplied power for up to 8 weeks. The system proved highly unreliable, producing the broken data record for 1990 and 1991. Acquisition of an updated model, using data storage on IC modules and power supply from a solar panel, improved continuity in records since 29-11-1991. A gap in the 1992 record occurred due to the physical collapse of the solar panel as a result of high windspeeds, while in 1993 one memory module was damaged resulting in a loss of data. The system still proved sensitive to moisture under cold conditions and has resulted in a less than optimal record. Further technical details regarding the instrumentation is provided below.

The physical structure of the stations and the type and position of sensors maintained between 1990 and 1994 are described in (Boelhouwers, 1997). Soil and air temperature sensors produce an output voltage proportional to temperature between -20oC and +70 oC with an accuracy of 0.2oC. All sensors were calibrated according to manufacturers instructions (Mike Cotton Systems, Cape Town). Soil moisture was monitored by nylon resistance blocks consisting of an inner mesh electrode wrapped in nylon material, and an outer mesh electrode enclosing the sensor (Bouyoucos, 1949). This sensor is calibrated by setting the sensor value at 0 when it is air dry. A value of 100 is assigned to a sensor in fully saturated condition. The sensors thus record relative soil moisture levels on a linear scale between air dry soil and complete saturation. Tipping bucket raingauges with a bucket capacity of 0.2mm were used to record precipitation.

Initially both daily and hourly records were kept which necessitated frequent visits to replace the data storage tapes. As from 29-11-1992 only daily records were kept, including maximum and minimum temperature and 24hr precipitation totals. Average daily soil moisture levels were recorded only as the range between daily maximum and minium values proved to be minimal.

1.4.4 Mount Superior

Field observations established the presence of active soil frost features near Mount Superior during December 1991. A second data logger site was consequently established by 1-5-1993 to provide microclimatic data from a site with a different substrate and currently active soil-frost processes.

The Mount Superior station is positioned 5km SSE of the Waaihoek Peak site on a flat summit plateau of Cedarberg shale at 1860m elevation. The surface cover is comprised of fractured bedrock and bare shallow soil with tussocks of Restio spp. up to 0.5m high. The instrumentation set-up is described below and in (Boelhouwers 1997) and was similar as used for the Waaihoek Peak site. The soil temperature and moisture sensors were placed in a bare sediment of 0.15m depth. Daily maximum and minimum temperature were recorded for each sensor as well as daily average relative soil moisture levels and daily precipitation totals.

1.5 INSTRUMENTATION USED FOR THE MICRO-CLIMATIC MONITORING

1.5.1 Data loggers

Model 120-02EX data loggers manufactured by Mike Cotton Systems, Cape Town, were used for the project from 29-11-1991. The simpler model MCS 101, used in 1990-1991, has essentially similar specifications. The following specifications of the 120-02-EX are as supplied by the manufacturer.

1.5.2 Specifications

Real time clock: Better than 5 seconds/month.
Analog channels: 12, at 3 optional DC ranges to accommodate input spans of ?20mV, 200mV and ?2000mV signals.

Two AC ranges are provided to accommodate continuous AC signals or sampled AC signals.

Digital channels: 4, CMOS compatible, maximum frequency 1000Hz.
Digital accuracy: 0 to 8000 counts per log period.
Scan period: Analog channels are scanned once per minute, digital channels accumulated over scan period
Log period: Two independent log periods may be selected from 1 minute to 24 hours. All sensors are logged in parallel, that is simultaneously, at log time.
Output programs: Instantaneous, totalled, average, maximum and minimum, time of max/min, 360 wind direction algorithm.
Internal storage: 2000 data points FIFO buffer.
Output device: Built-in solid state memory module recorder,
Power: 12 V 50milli-amp solar cell panel, charging a gel cell battery.

1.5.3 Temperature sensors

Temperature transducers models MCS 151 and 153 were used throughout the monitoring programme. These have the following specifications:

Specifications

MCS 151: This sensor has a thermal inertia approximately equal to a large mercury thermometer. The sensor is mounted in a 75mm long, thick walled aluminium tube.

Size: 8mm diameter x 75mm.
Response time: Other specifications as for MCS 153 sensor.

MCS 153: This sensor has a low thermal inertia allowing rapid temperature changes. The sensor is mounted in a 25mm long, thin walled, plated brass tube.

Size: 4mm diameter x 25mm.
Response time:
Weight: 50mg
Measuring range: -200 to +70oC
Accuracy: ?0.20C at 250C
Resolution: ?0.10C
Output signal: Analog output voltage proportional to temperature. Power requirements: 4.8 to 6.5V at 300 micro-amps.

Calibration

Before installation in the field all sensors were calibrated to improve linearity and comparison between the sensors, using the two point auto-calibration facility of the logger. This was done by connecting all sensors to the logger. All sensors were then inserted in a beaker with ice and water and stirred continuously until all sensors were stable. At this stage a low end value of 0.20C was entered for all temperature channels. A high end value was established by inserting the sensors in a beaker of water with a temperature of 340C (determined with a mercury thermometer).

Installation

MCS 151 sensors were used for air and soil temperature measurement. Sensors placed in the air were shielded from direct incoming solar radiation by reflective aluminium, placed 4cm above and on the sides of the sensor. No shielding from indirect radiation from the ground surface was put in place.

MCS 153 sensors were used for all rock temperature measurements.

Maintenance

The sensing elements are sealed solid state devices and the calibration elements inserted by MC Systems are stable and therefore do not require periodic calibration. Long term stability is better than 0.030C per month under normal use.

1.5.4 Soil moisture sensors

The application of nylon soil moisture sensors, also known as Bouyoucous blocks, is based on the changes in electrical resistivity of the sensor due to changes in relative moisture content. They consist of an inner mesh electrode wrapped in nylon material and an outer mesh electrode enclosing the sensor. The sensor is excited by a AC reference signal to prevent a polarizing effect from the electrodes formed by the chemical composition of the soil. The moisture content of the nylon material equilibrates with the soil moisture where the drier the nylon material the greater the resistance between the two electrode meshes.

Specifications

Measuring range: 0 - 100% moisture content
Operating temperature: -100 to +500C
Accuracy: Soil dependent
Response time: 5 - 20 minutes, depending on soil type
Active area: 25cm2
Size: 70 x 18 x 4mm

Calibration

The nylon soil moisture sensors were calibrated using the auto-calibration facility on the logger as part of the installation process. To use this method, the sensors must be placed at a low and high known soil moisture content. The logger learns these values and calculates the correct offset and multiplier for each sensor.

All moisture sensors were connected to the logger at the monitoring site. A low end value of 0 was assigned to the air dry sensors. Next, soil from the hole where the sensors were to be installed was placed in a tray and over saturated with water. The sensors were placed in the tray, making sure that each had good contact with the slurry by rubbing the sensor with the material. Once all sensors had stabilised a value of 100 was assigned to the sensors in this state. The loggers thus record a series of values from 0 to 100 between air dry state and a state of saturation.

The soil moisture sensors at -5cm at Waaihoek Peak and Mount Superior were more accurately calibrated during January 1995 to allow an estimation of moisture content by percentage weight, as required for a comparison with the data of Meentemeyer and Zippin (1981) (see section 4.4.2.).

The sensor was placed in a tray with soil from the site and saturated with water. The soil and sensor were left to dry. Periodically, small samples were taken from the tray to establish the soil moisture content by gravimetric method with simultaneous reading of the logger-recorded values. Due to the slow drying of the soil and the short duration of the field visit, only upper values are available.

	Soil moisture content (weight wet sample - dry weight / dry weight x 100%)	
Logger value	Waaihoek Pk	Mt. Superior
100	21.5	44.0
99	21.4	44.0
95	20.6	42.8
90	19.3	39.6

1.5.5 Tipping bucket raingauges

MCS 160 Tipping Bucket Raingauges (TBR) were used to monitor precipitation. They adhere to the following specifications as supplied by the manufacturer.

Specifications

Orifice: 203.0?0.2mm diameter brass rim.
Funnel: 125mm deep throat copper funnel.
Outer housing: White epoxy sprayed aluminium.
Base: White epoxy sprayed die cast aluminium, integral bubble level.
Filters: Fine stainless mesh steel on all openings.
Bucket capacity: 0.2mm
Bearings: Stainless steel.
Outlets: 2x15mm OD waste or check gauge.
Sensor: Switch with electronically stretched 120mS pulse duration.
Calibration: Individual bucket adjustment using nylon stop screws.
Accuracy: ?1% at 1-100mm per hour.
Size: 230mm diameter x 430mm height.
Mounting: Adjustable stainless steel 3 leg arrangement with 3 holes for permanent fixture.

Installation

The tipping bucket raingauges were placed directly on the ground and fixed with steel pens. Adjustments were made to achieve a horizontal position of the TBR using the bubble level at the base.

Calibration

After installation TBR magnet position was checked for correct distance between it and the sensor, that is allowing free bucket movement and confirmed detection of this movement on the data logger.

Calibration of measurement was done by applying a known amount of water to the system and calculating the volume of water used per tip. The latter should be set to measure a volume to the equivalent of 0.2mm. This volume is known by multiplying the area of funnel x 0.2mm. This is 32365.5mm2 x 0.2mm = 6.47mm3.

One tip is 6.47cc. Using a measuring glass 100cc were poured into the system and the number of tips read from the logger. The bucket tip volume is derived from

Bucket tip = Volume used / Number of tips

With the use of the adjustment screws at the end stop of the bucket the volume at which tipping takes place can be increased or decreased. No need for adjustment was found after initial installation. No further calibration was done to the TBRs.

2 REFERENCES AND RELATED PUBLICATIONS

The following publications provide further information on the data records and their analysis:

Boelhouwers, J. 1995b. Present-day soil frost activity at Mt. Superior, Hexriver Mountains, South Africa. Zeitschrift fÆr Geomorphologie 39(2): 237-248.

Boelhouwers, J.C. 1996. The present-day frost action environment and its geomorphological significance in the Western Cape Mountains, South Africa. Unpublished PhD thesis, Department of Earth Sciences, University of the Western Cape.

Boelhouwers, J. 1997a. Sediment movement by frost in the Hex River Mountains, South Africa. South African Geographical Journal 97(2): 129-135.

Boelhouwers, J. 1997b. Environmental controls on diurnal soil frost activity in the Hex River Mountains, South Africa. Earth Surface Processes and Landforms 23: 211-221.

3 CONTACTS AND ACKNOWLEDGMENTS

Name: Dr Jan Boelhouwers

Organization: University of the Western Cape

Mailing Address: Department of Earth Sciences Private Bag X17, Bellville 7535, South Africa

Tel: +27 21 9592135

Fax: +27 21 9592438

E-mail: janboel@artso.uwc.ac.za

4 DOCUMENT INFORMATION

Usage of data:

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Boelhouwers, J. 1998. Seasonal frost and soil temperature data, Western Cape Mountains, South Africa. In: International Permafrost Association, Data and Information Working Group, comp. Circumpolar Active-Layer Permafrost System (CAPS), version 1.0. CD-ROM available from National Snow and Ice Data Center, nsidc@kryos.colorado.edu. Boulder, Colorado: NSIDC, University of Colorado at Boulder.

4.1 Publication Date

1998

4.2 Date Last Updated

2021