Vital Signs Protocol

Weather Stations

Version 1.0

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1. INTRODUCTION

Weather data, and the climate data that results from the analysis of long time-series of weather data, is among the most fundamental of environmental information.

It is needed by most parts of Vital Signs (VS) as well as by many users outside VS. Yet reliable weather and climate data is often hard to get for large parts of the world. The VS contribution to help fill this gap is small, nowhere near the measurement density needed for recommended levels of coverage at regional scale. VS expects that national weather services have that responsibility, and VS simply aims to supplement the coverage in places critical to VS needs, namely in the intensively-sampled landscapes.

For regional-scale continuous coverage of weather observations, VS depends on ‘data assimilation products,’ which fuse information from meteorological satellites, ground stations of national networks, and atmospheric physics models similar to those used for weather forecasting. These products, which currently have a resolution as fine as 10 km at regional scale, are reasonably accurate when aggregated to large areas and over a period of weeks to months, but may be quite far off at a particular point and at the daily time scale.

The function of the VS weather stations is to help calibrate and validate these products at regional scale, and stand in for them at local scale and for hourly to daily data within the landscapes.

**Vital Signs specifies two types of automatic recording weather station.** The first type (“**full station**”) records rainfall, temperature, humidity (RH), wind speed, barometric pressure and incoming shortwave radiation. The sensors must conform to World Meteorological Organization (WMO) standards of accuracy and maintenance, and the siting (location) of the station must meet WMO standards for a Class 1 station (Table 1). Since national meteorological services also adhere to these standards, it follows that VS weather data should also satisfy national requirements.

The second type of VS station (“**mini station**”) records only rainfall and temperature. The rainfall and temperature sensors are of the same or only slightly lower accuracy to those used in the full weather stations, and the siting requirements for mini stations conform to those for WMO class 3 stations.
Table 1: the specifications and standards for sensors linked to the VS full weather station. (The sensor specifications for the VS mini station, which records only rainfall and temperature, are similar to those for the full station, but the temperature accuracy is only 0.5°C and the location restrictions can be relaxed to having no obstacles within 4 times their height away from the rain gauge.)

<table>
<thead>
<tr>
<th></th>
<th>Rainfall</th>
<th>Air temperature</th>
<th>Humidity</th>
<th>Atmospheric pressure</th>
<th>Solar radiation</th>
<th>Wind speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Units</td>
<td>mm</td>
<td>°C</td>
<td>% relative humidity</td>
<td>mBar</td>
<td>W/m²</td>
<td>m/s</td>
</tr>
<tr>
<td>Specification</td>
<td>15.4 cm orifice (6&quot;)</td>
<td>-20 to +70 °C</td>
<td>0-100%</td>
<td>660-1070 mBar</td>
<td>0-1280 W/m²</td>
<td>0-45 m/s</td>
</tr>
<tr>
<td>Accuracy (resolution)</td>
<td>2% (0.25 mm)</td>
<td>0.21 (0.02) °C</td>
<td>2.5% (0.1%)</td>
<td>3 (0.1) mBar</td>
<td>10 W/m² ie 5%</td>
<td>1.1 m/s</td>
</tr>
<tr>
<td>(resolution)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(1.25 W/m²)</td>
<td></td>
</tr>
<tr>
<td>Exposure and location of the sensor</td>
<td>No obstacles closer than 10 x their height. Orifice horizontal and at least 30 cm above ground. Preferred height 2 m</td>
<td>In a radiation shield, passively ventilated, at 2 m above ground, away from highly reflective or absorptive surfaces and water bodies</td>
<td>Inside the instrument cabinet which houses the datalogger with free access to outside air.</td>
<td>Horizontal, no objects obscuring the sky to within 5° of the horizon.</td>
<td>3 m or higher above the ground, at least 10 x the height of any obstacles away from them</td>
<td></td>
</tr>
<tr>
<td>VSA recommended model</td>
<td>Onset RGB-M002</td>
<td>Onset S-THB-M002</td>
<td>Onset S-BPA-CM10</td>
<td>Onset S-LIB-M003</td>
<td>Onset S-WDA-M003</td>
<td></td>
</tr>
</tbody>
</table>

The WMO standards do not specify which of the many available types of datalogger should be used. VS has chosen the Onset U30 for its full weather station. The mini-weather stations have a built-in Onset Hobo pendant event and temperature datalogger. The Onset U30-GSM was chosen because it is reliable but affordable, meets the accuracy and capacity requirements, has low power consumption (which means that it can be powered for long periods using a battery alone, eliminating the
need for solar panels), uses the same download software as other data loggers
used in VS and can be communicated with using GSM cell phone technology. Other
makes and models of datalogger can be used in the full weather stations, provided
that they have at least 5 analog input channels and one pulse sensor channel and
12-bit resolution.

Examples of the questions that can be addressed with this protocol include:

• What were the weather drivers of agricultural and ecosystem service yields
observed in the same season?
• What is the climate of a given area, and is it suitable for particular crops?
• Is the climate changing?

1.1 Definitions of Key Technical Terms

**Anemometer:** an instrument to measure wind speed, consisting of three cups
spinning on a vertical axis.

**Automatic Weather Station (AWS):** a combination of a datalogger, weather
sensors, power supply, supporting mast and in some cases communication
equipment, which collects weather data continuously and unattended.

**Datalogger:** the electronic device that reads information from the weather sensors,
stores it and in some cases sends it via cell phone communication to the VS office.

**GSM:** a cellphone communication technology that allows data to be sent from the
weather station to a remote database.

**Landscape:** a 10 km x 10 km area in which Vital Signs develops an understanding
of the spatial and temporal dynamics of agriculture, ecosystems and human well-
being.

**Pyranometer:** an instrument to measure the energy coming from the sun. In the VS
case, this is solar radiation in the wavelengths 300 to 1100 nm (the ‘shortwave’).

**Relative Humidity (RH):** the amount of water vapor in the air relative to the amount
of water vapor it could hold at that temperature. See note on table 2.
1.2 Standard Conventions Used in this Document

The following conventions are used throughout this document:

- The use of **bold** in the text indicates a critical point. Please pay special attention to terms, sentences and paragraphs marked in **bold** as they are key to the understanding of the protocol.

2. ROLES AND RESPONSIBILITIES

The following table introduces the roles and responsibilities of a Vital Signs team:

<table>
<thead>
<tr>
<th>Role</th>
<th>Responsibility</th>
</tr>
</thead>
</table>
| Technicians               | • Install weather stations  
                           | • Visit weather stations every 3 months, or as needed, to maintain them and download data. |
| Technical Manager         | • Supervises teams  
                           | • Ensures equipment is well-managed and team is safe  
                           | • Ensures consistency and quality of measurements  
                           | • Ensures data are checked and uploaded to the VS server  
                           | • Performs monthly and annual data analyses and reporting |
| Country Director          | • Develops and submits sampling schedule for approval  
                           | • Supports team with a complete understanding of the protocol manual  
                           | • Trains technicians, including initially and occasionally later accompanying them in fieldwork |
| Africa Field Director     | • Approves sampling schedule  
                           | • Helps train technicians and ensure consistency of protocol implementation across Vital Signs countries  
                           | • Reviews data when uploaded  
                           | • Approves protocol updates and sends out update notifications to field teams |
| Protocol Manager          | • Receives and archives comments about the protocol  
                           | • Updates and re-circulates the protocol |
3. EQUIPMENT LIST

The following equipment is required to carry out the activities described in this manual. Before traveling to the field to carry out sampling, use this list to ensure you have all the equipment needed for the day.

At the end of each day’s work, equipment should be wiped down and stowed correctly so that the team can start working immediately the next morning. This practice also ensures that all equipment is accounted for and does not go missing.

<table>
<thead>
<tr>
<th>General Supplies (needed for all visits to weather station)</th>
</tr>
</thead>
<tbody>
<tr>
<td>o Maintenance logbook (to note work completed)</td>
</tr>
<tr>
<td>o Clipboards, notebooks and pens</td>
</tr>
<tr>
<td>o Water to drink and to rinse equipment</td>
</tr>
<tr>
<td>o Packs for carrying equipment</td>
</tr>
<tr>
<td>o Hat, Sun Lotion</td>
</tr>
<tr>
<td>o Vital Signs brochures in local languages</td>
</tr>
<tr>
<td>o Identity cards and letters of introduction</td>
</tr>
<tr>
<td>o Basic toolkit that includes a hammer, pliers, side-cutter, small, medium and large screwdrivers (both flat and star types), multimeter, socket wrench to fit bolts on the mast, cable ties, insulation tape, cleaning cloth, tape measure, level</td>
</tr>
<tr>
<td>o Key to the padlock on the full weather station</td>
</tr>
<tr>
<td>o Fully charged 4v 10 Ah lead acid battery for the full weather station, box of lithium batteries for mini stations</td>
</tr>
<tr>
<td>o Tipping bucket calibration bottle (fig 1) and as many pre-weighed bottles containing exactly 373 ml of water as the number of stations that must be calibrated</td>
</tr>
<tr>
<td>o Optic USB cable to connect to mini weather station and USB cable to connect to full weather stations.</td>
</tr>
<tr>
<td>o Laptop with HoboWare pro loaded and preregistered with HoboLink, laptop charger</td>
</tr>
<tr>
<td>o You may need a short ladder, chair or box to stand on to be able to clean and service the sensors on the crossbar</td>
</tr>
</tbody>
</table>

7
In addition to the general supplies, you will need:

For Installing a Mini Weather Station

- 2.5 long vertical steel tube about 50 cm diameter or
  2.2 m long wooden pole 20 cm in diameter
- Spade to dig a hole for the pole, concrete to fill it
- GPS and camera when first installing the station.
- Rain Gauge Onset RG3-M
- Radiation Shield RS1 or M-RSA

For Installing a Full Weather Station

- Spade and machete to level and clear the site
- GPS and camera when first installing the station.
- U30-GSM in its weatherproof box, SIM card fitted
- 4 V 10 Ah battery with cable
- Tipping bucket raingauge RGB-M002
- Smart sensors for temperature and humidity, shortwave radiation, wind speed and barometric pressure
- Mast kit and crossarm, RS3 radiation shield
- Fencing materials if decided it is needed, for a 3m x 3 m fence 1 m high

4. SITE AND SENSOR DESCRIPTION METADATA

When you install the weather stations, collect the following information which describes the station. It will be stored in an electronic file at the Vital Signs office (plus a paper backup) and must be kept updated when changes occur on the station or its surroundings. This form, (see Appendix 1) must contain the following information, and the data files need refer to it as the source of ‘metadata’:

1. Exact GPS location and ground altitude of the station and the name or code that VS gives the station.
2. Make, model and serial numbers of the data logger and all the instruments, noting that the temperature and humidity sensors are in a passively-ventilated radiation shield.

3. Height of each of the sensors above the ground surface.

4. Degree of interference from other instruments or obstacles. One or more photos will show this. If you set up the stations as described, there should be no interference between sensors.

5. The near and far surroundings of the weather station, in particular:
   a. The ground cover within 5 m of the station, nearby (within 25 m) major obstacles (buildings, fences, trees) and their size (a panoramic photo and an annotated sketch map will supply this information).
   b. The degree of horizon obstruction for sunshine and radiation observations (also backed up by the panoramic photo).
   c. Surrounding terrain roughness and the height and cover of vegetation which could influencing the wind.
   d. All medium-distance (200 m) landscape features such as slopes or hills, paved roads, or water surfaces.
   e. Major large-scale features (within 5 km), such as coasts, mountains or urbanization.

5. **FULL WEATHER STATIONS**

   5.1 *Choosing a Location for a Full Weather Station*

   The purposes of Vital Signs Full Weather Stations are to:

   - **Provide the barometric pressure** needed to correct the gauging station water depth sensors;
Start here

Choosing a location for the full weather station

Select the Vital Signs Landscape in which you are going to place the full weather station

Ask the local community in the landscape about possible secure locations for the weather station, explaining the key requirements outlined in the protocol

Use satellite images of the landscape to help assess potential places, again keeping in mind the key requirements outlined in the protocol

When you have identified some candidate locations, negotiate with the people who are responsible for the land to install the weather station

Installing a full weather station

Follow protocol instructions for checks performed before going to the field

Once there, fill in the metadata form for the location and surrounding area of the station

Record the GPS location (to within 0.00001 degrees) and altitude (to the nearest m) of the ground below the rain gauge location

Assemble the tripod and crossbar, then mount and install the U30 instrument box, sensors, rain gauge, and radiation shield

Ensure all connectors and cables are installed and plugged in

Connect a laptop to the U30 via the USB and open the software. Check that the U30 is collecting data correctly, that the logging interval is 1800 seconds (half an hour) and the connection interval is daily.

Disconnect the laptop. Close the door of the U30 with a padlock

Collecting data from a full weather station (every 3 months)

When you arrive at the weather station for the routine visit, check that the mast is secure

Connect the laptop to the U30 USB port, download all data using HoboWare pro, and save the file

Check the battery voltage and sensor cable port

Clear any debris out of the rain gauge funnel

Up-end the bottle with 373 ml of water in the top of the rain gauge so that the water drips out over about 1 hour. The logger should record 98 to 102 tips. Write the # of tips down and record it

Check that equipment and cables are undamaged

Reset and restart the logger to clear the rainfall data you collected, fill in the service log, and lock up the enclosure

Full Weather Stations

Connecting a location for the full weather station

Installing a full weather station

Collecting data from a full weather station (every 3 months)
• **Calculate daily potential evapotranspiration** needed for doing water balance calculations for verifying hydrological models and the water flows measured at the gauging stations; and

• **Provide comprehensive weather records** to run and validate crop models.

Vital Signs therefore locates full weather stations in places that:

1) Don’t already have a full weather station from which the data is available

2) Are in VS landscapes that have VS river gauging stations (this typically amounts to about 2 VS full weather stations per VS region or country).

Automatic weather stations are quite robust and require little maintenance, but they can be subject to theft, tampering and vandalism. Since they are relatively expensive, and the data is valuable, it is best to locate full weather stations in secure places.

It is also desirable to keep them in the same location for many years so that climate data can be accumulated. Locations which are likely to have the same owners or managers in the foreseeable future are desired. The **grounds of government facilities often make good locations**, for example:

• Police Stations
• Schools
• Clinics
• Airports
• Research Stations
• National parks

It helps if the property has a fence to keep out unauthorized people and livestock. The best protection is to have the hosts and community in which the weather station is located feel a sense of ownership and responsibility for the instruments.

Any place within the VS 10 x 10 km landscape is potentially an acceptable location, or even up to 5 km away from its edge. The key requirements are:
• There are no obstacles which might block the wind or sunlight from the wind and solar radiation sensors within a distance of 10 times the height of the obstacle

• The temperature sensor must be well away from large areas that reflect or absorb sunlight (like dark roads, parking lots or shiny roofs)

• The RH sensor must be 100 m away from lakes, large rivers or dams

This means that you are looking for an open grassy, shrubby or cultivated patch, typically about 50 m across; preferably neither at the top of a hill nor the bottom of a valley and reasonably level (<19° slope).

A location within range of cell phone reception is highly desirable but not essential, since you can download the data manually. If there is a possibility to mount the wind sensor much higher than 3 m (the ideal is 10 m) on an existing radio mast or other stable structure, that is an advantage.

Ask within the local community in a landscape about possible secure locations for the weather station, and then look on the satellite images of the landscape whether they might have suitable places for a weather station. Once you have located some candidate locations, negotiate with those who are responsible for the land to install a weather station. Explain to them:

• What is does
• That it does not harm the environment or the people around it
• That the data will be freely available and could help guide local decisions
• That it only requires a physical patch of land about 3m x 3m and an agreement not to change the vegetation or buildings immediately around it without letting you know.

You should note that the weather station will be visited by a technician about once every 3 months to download the data and clean the sensors. Electrical power is not needed.
5.2 Installing a Full Weather Station

Once you have decided on a location and negotiated with the owner for permission to place the full weather station there, record the exact GPS location (to within 0.00001 degrees) and altitude (to the nearest m) of the spot on the ground immediately below the rain gauge location.

A detailed description (with photos) of the steps to install, start and collect data from the U30 is given in the manual for the datalogger and the instructions that come with the mast kit and the sensors. Follow those if you are using the U30, or else the instructions that come with other sorts of dataloggers and sensors you may be using. What follows is a summary, assuming you are using a U30 logger and the standard VS sensor set.

Before you go into the field:

- Register the HoboLink software on your laptop via the internet and link it to the specific U30-GSM dataloggers via the serial number inside the box and the VS station name or number.

- Plug the sensors into the U30 in the order (left to right) raingauge, temperature and humidity, pressure, solar radiation, wind speed. This order is not essential (the datalogger recognizes which sensors are plugged in, and where) but it helps with troubleshooting and consistent database structures to do the same on every weather station.

- Plug in the battery and power up the datalogger.

- Connect your laptop to the U30 USB port and configure and test the sensors using HoboLink or HoboWare.

- For the test, set the logging interval to be 5 seconds and manually tip the tipping bucket raingauge a few times (take off the protective rubber band to do this). Check the device status as reported in the software on your laptop and make a few graphs to verify that sensors are reporting correctly and the U30 station is being read out properly.
• When you are satisfied that everything is working properly, change the Logging Interval to 30 minutes (1800 seconds) and Connection Interval (when data is sent by cellphone to the VS office) to 1 day, at midnight.

• Close the software, switch off the logger, disconnect the battery and sensors and repackage them for transport to the field (put the rubber band back on the raingauge so that it does not rattle while travelling).

It may be desired to fence off the weather station in its own enclosure, 3 m x 3 m in area and 1 m high, with an access gate. This is mostly to keep out animals and people who might want to fiddle with the sensors.

**When you are in the field at your chosen site:**

1. Assemble the parts of the mast or tripod following the instructions that come with the kit. (VS often uses a simple pole mast with a welded crossbar, manufactured in-country, to save shipping costs).

2. Place the crossbar at 2.6 m height. Anchor the tripod or pole to the ground with pegs and guy lines, ensuring that the central pole is vertical.

3. Install the lightning protection grounding cable and peg.

4. Bolt the U30 instrument box onto the upright mast at a convenient height for reading (about 1.5 m from the ground) and connect the ground cable to the ground terminal of the U30.

5. Twist the crossbar to point North-South and tighten the bolts.

6. Mount the solar radiation sensor on the end towards the equator and ensure that it is level.

7. On the other end of the crossbar, install the wind speed sensor, ensuring that its axle is vertical (ie. the anemometer cups rotate in a horizontal plane at 3 ± 0.1 m above the ground).
8. Bolt the rain gauge to the mast near the top of the pole using two 6 cm diameter hose clamps, so that the top of the rain gauge is level, above the crossbar and about 2 m above the ground.

9. Bolt the radiation shield to the main mast between the instrument box and the rain gauge and install the temperature and humidity sensor inside it.

10. Bolt the barometric sensor, in its weatherproof box, immediately below the U30 box.

11. Poke all the cables neatly in through the cable entry ports in the bottom of the instrument box and pull them almost taut. Strap the cables to the crossbar and mast every 10 cm using cable ties, leaving no slack between the box and the sensor.

12. Tighten the cable ports to seal them and tie the excess cable into a roll inside the box.

13. Plug the RS-12 ‘smart connectors’ on the ends to the sensor cables into the sockets on the U30, in the order described above. Install the 10 Ah 4 v sealed lead-acid battery in the instrument box and connect it to the power input of the U30\(^1\). The U30 should recognize the sensors itself.

14. Connect a laptop to the U30 via the USB cable, and open the HoboLink or HoboWare software. Start the station and check that the U30 is collecting data correctly, that the logging interval is 1800 seconds (half an hour) and the connection interval is daily, at midnight.

15. When satisfied, close the software and disconnect the laptop.

16. Close the door of the U30 box and put a padlock on it. Make sure a duplicate key is kept in a safe place in the VS office. If the ‘field key,’ which is signed out to the technician serving the station is lost, make a new duplicate – don’t send the master key to the field.

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\(^1\) Do it in this order. Sensors plugged in once logging has started will not be recognized unless you force a restart using the software. You could also install a 6A 12v solar panel on the mast to charge the battery, if you think that the site is safe from theft.
5.3 Maintaining and Collecting Data from a Full Station

The data should automatically download from the full weather station to the VS office daily, via the cell phone link. Ensure that your HoboLink contract is still working.

Check the data received every day during the week in the VS office, and on Mondays for the data received over the weekend. Add the new data to the data file for that weather station. If a problem is noted (such as data not being received, or the values being unreasonable), send a technician out to the site as soon as possible. Also send a technician as soon as possible if the host of the station tells you that there is a problem.

The full weather station should be routinely visited by a technician once every 3 months.

When you arrive at the weather station for the routine visit:

1. Check that the mast is undamaged and secure, and fix if necessary. Cut down any vegetation near to the sensors.

2. Connect the laptop to the U30 USB port, download all data using HoboWare pro, and save the file. This is a check on the data receive via the cell phone and may cover some gaps in that record. The data on the logger is the ‘master record.’

3. Replace the battery with a freshly-charged one, even if the charge in the old one is above 3.5 V. Check the battery voltage of the installed battery as indicated in HoboWare; it must be above 3.5 V. Return the old battery to the VS office to be charged. This can be done many times.

4. Clear any debris out of the funnel of the tipping bucket rain gauge. Take the funnel off and check inside the tipping bucket for any debris, insect nests etc., and remove if necessary. Put a drop of light machine oil on the bearings of the tipping bucket. Replace the funnel.

5. Take the plastic sealing the bottle with 373 ml of water off (Figure 1), and up-end the bottle in the top of the rain gauge so that the water drips out over
about 1 hour. You should hear the bucket tipping, and the logger should record 98 to 102 tips. Write this number of tips down and record it in the calibration file in the VS office.

Figure 1. A 500 ml plastic soft drink bottle with the screw-on lid modified for calibrating tipping bucket rain gauges. Drill a tiny (<1 mm) hole in the lid to let the water out over a period of an hour, and a second hole fitted with a straw to let air in when the bottle is turned upside down.

6. While waiting for the rain gauge calibration to finish, wipe the top of the solar radiation sensor gently with a damp cloth and check that it is horizontal. Check that the anemometer has all its cups and is spinning freely. If it is broken it cannot be repaired in the field – it must be replaced and if necessary sent back to the supplier for repair.

7. Check that the radiation shield containing the temperature and humidity sensors is not damaged and has not been occupied by wasps or other obstacles. If the RH sensor is giving clearly wrong results, it can be replaced. Check that all the cables are undamaged and firmly secured to the mast.

8. Reset and restart the logger to clear the rainfall data you collected during calibration, fill in the service log, and lock up the enclosure.
6. MINI WEATHER STATIONS

6.1 Choosing a Location for a Mini Weather Station

The purpose of the Vital Signs mini stations is to ensure that the bare minimum of weather data – rainfall and temperature – are available in every VS landscape.

There are typically about 10 landscapes per region (of which two should have full weather stations). VS places a mini weather station in the landscapes that do not already have a reliable and available weather station to supply daily rainfall and maximum and minimum temperature.

The mini weather stations consist of a tipping-bucket rain gauge with a datalogger, which has a built-in temperature sensor. They need to be placed in an open space, with no objects that will block the rain or sunlight within 4 times the height of that obstacle. Usually this means the weather station will be on a grassy patch or field margin, with low vegetation around it.

The mini weather stations are less expensive and less likely to be vandalized or stolen than the full weather station, so they can often be located in the yards or fields of farmers (though schools, clinics and government offices can also be considered). They should be in or within 5 km of the border of a VS landscape. Once you have chosen a few likely spots, go through the same negotiation process as described for finding a host for the full weather station. The mini weather stations occupy less than 0.5 x 0.5 m of space, and can be moved if necessary to another spot if one becomes unsuitable.

6.2 Installing a Mini Weather Station

Before you go into the field, do the following:

• Open the event/temperature datalogger and install one 3v CR2032 lithium battery (+ side up). This should last about a year.

• Take the top (ring and funnel) off the rain gauge. Pass the logger’s black and white cables from the outside through the grommet (a hole filled with a rubber plug) on the side of the rain gauge and connect them to the terminals of the tipping bucket (the order does not matter).
Workflow 2: Mini Weather Stations

Start here

Choosing a location for the mini weather station

Select the Vital Signs Landscape in which you will place the mini weather station

Ask the local community in the landscape about possible secure locations for the weather station, explaining the key requirements outlined in the protocol

Use satellite images of the landscape to help assess potential places, again keeping in mind the key requirements outlined in the protocol

When you have identified some candidate locations, negotiate with the people who are responsible for the land to install the weather station

Installing a mini weather station

Follow protocol instructions for checks performed before going to the field

Once there, fill in the metadata form for the location and surrounding area of the station

Record the GPS location (to within 0.00001 degrees) and altitude (to the nearest m) of the ground below the rain gauge location

Connect the rain gauge to the top of the steel tube/wooden pole and mount the radiation shield just below the rain gauge

Insert the Hobo recorder into the radiation shield and secure the cable to the tube

Connect the event logger to the laptop using a USB and check that it is working using HoboLink. Ensure it is working and that the temperature logging interval is 1800 seconds

Disconnect USB and put the logger back in the radiation screen

Collecting data from a mini weather station (every 3 months)

When you arrive at the weather station for the routine visit, check that the mast is secure

Carefully pull the temperature/event logger out of the radiation shield and insert it into the Optic USB base station, which is connected to the laptop

Use the logger software to read the data and save it to a file

Check the battery voltage and sensor cable port. Check that the desiccant is still bright blue and replace if necessary. Clear any debris out of the rain gauge funnel

Up-end the bottle with 373 ml of water in the top of the rain gauge so that the water drips out over about 1 hour. The logger should record 98 to 102 tips. Write the # of tips down and record it

Make a note of the date and your actions in the maintenance logbook

Perform once a year
• Connect the Optic USB Base station between the event logger and the laptop and use HoboWare to connect to the logger and check that it is working, by taking off the rubber band securing the tipping bucket and tipping it manually a few times. The temperature should be the same as the temperature in the place you are working.

• When you are satisfied, disconnect the Optic USB and re-secure the equipment for transport to the field.

Choose a location for the mini weather station and negotiate access as described above. We suggest that the mini weather station is either mounted on the top of a 2.5 long vertical steel tube about 50 cm diameter (with the bottom 0.5 m buried in a hole in the ground and anchored with concrete), or on the flat and level top of a vertical wooden pole about 20 cm diameter and 2.2 m long (with the bottom 0.5 m buried securely in a hole in the ground). The mini station could also be mounted on top of a structure such as a wall or building.

To install the station:

1. Connect the rain gauge to the top of the steel tube using hose clamps, or to the top of the wooden pole using three screws (in both cases so that the orifice is at about 2 m and level).

2. Remove the rubber band that protects the tipping bucket during transport.

3. Mount a RS1 or MRSA radiation shield just below the rain gauge, with bolts on the tube or wood screws on the pole.

4. Insert the Hobo Event/Temperature recorder into the radiation shield, connected by cable to the tipping bucket terminals (polarity does not matter) via the grommet on the side of the rain gauge.

5. Secure the cable to the tube with cable ties, or to the pole using electrical cable saddles.

6. Connect the event logger to the laptop using an Optic USB and check that it is working using HoboLink. Once you are sure it is working and that the
temperature Logging Interval is 1800 seconds, disconnect the Optic USB and put the logger back inside the radiation screen.

6.3 Maintaining and Collecting Data from a Mini Station

The mini weather station should be visited by a technician once every 3 months. When you are at the mini weather station:

1. Check that the mast is undamaged and secure, and fix if necessary. Cut down any vegetation near to the tipping bucket or radiation shield.

2. Carefully pull the temperature/event logger out of the radiation shield and insert it into the Optic USB base station, which is connected to the laptop.

3. Use the logger software to read the data and save it to a file. This file must be added to the database kept at the VS office.

4. Take a look at the battery voltage – if it is low, take the event logger out of the Optic USB, open it up and replace the battery (+ side up). While the logger is open check that the dessicant bag inside the case is still bright blue. If it is not, replace with a dessicant packet which is bright blue after being dried in a warm place, like an oven set on low, for several hours.

6. Clear any debris out of the funnel of the tipping bucket rain gauge. Take the funnel off and check inside, in the tipping buckets, for any debris, insect nests, etc., and remove if necessary. Put a drop of light machine oil on the bearings of the tipping bucket. Replace the funnel.

7. About once a year, perform a calibration. Take the plastic sealing the bottle with 373 ml of water off, and up-end the bottle in the top of the rain gauge so that the water drips out over about 1 hour. You should hear the bucket tipping, and the logger should record 98 to 102 tips. Write this number of tips down and record it in the calibration file in the VS office.

8. Make a note of the date and your actions in the maintenance logbook.
7. ANALYZING AND REPORTING WEATHER DATA

The data from both types of weather station is measured continuously, but only recorded by the datalogger every half hour. The smart sensors will determine exactly what is recorded – usually it is the average over that period, but sometimes it is the value exactly at the end of the period, or the maximum or minimum or total during the period.

When the data is returned to the Vital Signs office, either over the GSM (cell phone) link or from the files downloaded by the technician, it must be compiled into the database for that weather station, making sure no dates or times are duplicated and, as far as possible, none are missing.

The weather data are then analyzed for daily, monthly and annual periods (this is now ‘climate data’, see Table 2), and these are output into different files.

Note 1. The instrument reports relative humidity (RH as a %). To get the actual water vapour pressure ($e_a$) use this formula:

$$e_a = e^\circ(T) \times \frac{RH}{100}$$

where $e^\circ(T)$ is the saturated vapour pressure at temperature $T$, given by $e^\circ(T) = 0.6108 \exp(17.27 \times T/(T+237.3))$.

Note 2. To get RH from $e_a$ at any time scale, calculate the $e^\circ(T)$ for the average temperature over that period using the formula in note 1, and use the average $e_a$ for the same time period in the following formula $RH = 100 \times e_a / e^\circ(T)$.

The data files with the weather station data in them (raw half-hourly data, daily data, monthly data or annual data) must have the following station metadata associated with them, describing the instruments and their exposure.
Table 2: climate variables which are calculated from the half-hourly weather data.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Daily reporting</th>
<th>Monthly</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air temperature</td>
<td>Daily maximum temperature ($T_{\text{max}}$), daily minimum temperature ($T_{\text{min}}$) and daily average temperature ($T_{\text{ave}}$) over the 48 half-hourly records from 00:30 to 24:00</td>
<td>Mean daily maximum, mean daily minimum and mean daily average temperature over the days of the month.</td>
<td>Mean of the monthly average temperatures, mean minimum temp of coldest month and mean maximum temperature of warmest month.</td>
</tr>
<tr>
<td>Humidity</td>
<td>Maximum RH, minimum RH, average vapour pressure of water ($e_a$), and average RH calculated by expressing the average $e_a$ relative to the saturated vapour pressure at the average temperature for the day(^2).</td>
<td>Mean monthly $e_a$ as the mean of the mean daily $e_a$ for the days of the month, RH as the mean monthly $e_a$ relative to the saturated vapour pressure at the mean daily temperature for the month(^2).</td>
<td>Mean annual $e_a$ as the mean of the mean monthly $e_a$ for the 12 months, mean annual RH as the mean annual $e_a$ relative to the saturated vapour pressure at the mean annual temperature for the year(^2).</td>
</tr>
<tr>
<td>Solar shortwave</td>
<td>Integral of W/m(^2) over the day (=MJ)</td>
<td>Sum of daily MJ over the month</td>
<td>Sum of monthly MJ over the year</td>
</tr>
<tr>
<td>incoming radiation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind speed</td>
<td>Average daily wind speed Maximum gust speed</td>
<td>Average of daily wind speeds over the month</td>
<td>Average of monthly wind speeds over the year</td>
</tr>
<tr>
<td>Rainfall</td>
<td>Daily sum of rainfall</td>
<td>Monthly sum of daily rainfall</td>
<td>Annual sum of monthly rainfall</td>
</tr>
</tbody>
</table>
**Workflow 3: Data Archive and Analyses**

**For the full weather station**

*Every Day*
Each day at the office, check that the data from the full weather station have been received

Incorporate the data into the master database, making sure no dates or times are duplicated and, as far as possible, none are missing

*Every Month*
Once per month, perform the monthly summary analyses

*Every Year*
Once per year, perform the annual summary analyses

**For the mini weather station**

*Every 3 Months*
Every three months, append the recorded data to the master files

*Every Year*
Once per year, perform the annual summary analyses
8. BIBLIOGRAPHY

9. APPENDIX

<table>
<thead>
<tr>
<th>Vital Signs Weather Station Metadata Form</th>
<th>Date</th>
<th>Observer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station Name</td>
<td>Latitude</td>
<td>Longitude</td>
</tr>
<tr>
<td>Terrain description of the area 200 m to 5 km from location</td>
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Name of file with a 360° panoramic photograph

<table>
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<tr>
<th>Equipment/sensor</th>
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<th>Height installed (m)</th>
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<td>Rainguage</td>
<td></td>
<td></td>
<td></td>
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<td>Barometric pressure</td>
<td></td>
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<td></td>
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<tr>
<td>Temperature</td>
<td></td>
<td>in naturally ventilated radiation shield</td>
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</tr>
<tr>
<td>Relative humidity</td>
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</tr>
<tr>
<td>Wind speed</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>SW radiation</td>
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<td>Sketch map of 60 x 60 m surroundings of the location</td>
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<tr>
<td>Form Value</td>
<td>Definition</td>
<td>Data Type</td>
<td>Values List</td>
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<tr>
<td>-----------------------</td>
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<tr>
<td><strong>Month</strong></td>
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<td>The day of the plot survey. (DD)</td>
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<tr>
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</tr>
<tr>
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<td><strong>Pressure</strong></td>
<td>Mean atmospheric pressure during period (Pa)</td>
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## Mini Weather Station Record

**Version:** 1.0

<table>
<thead>
<tr>
<th>Form Value</th>
<th>Definition</th>
<th>Data Type</th>
<th>Values List</th>
<th>Example</th>
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